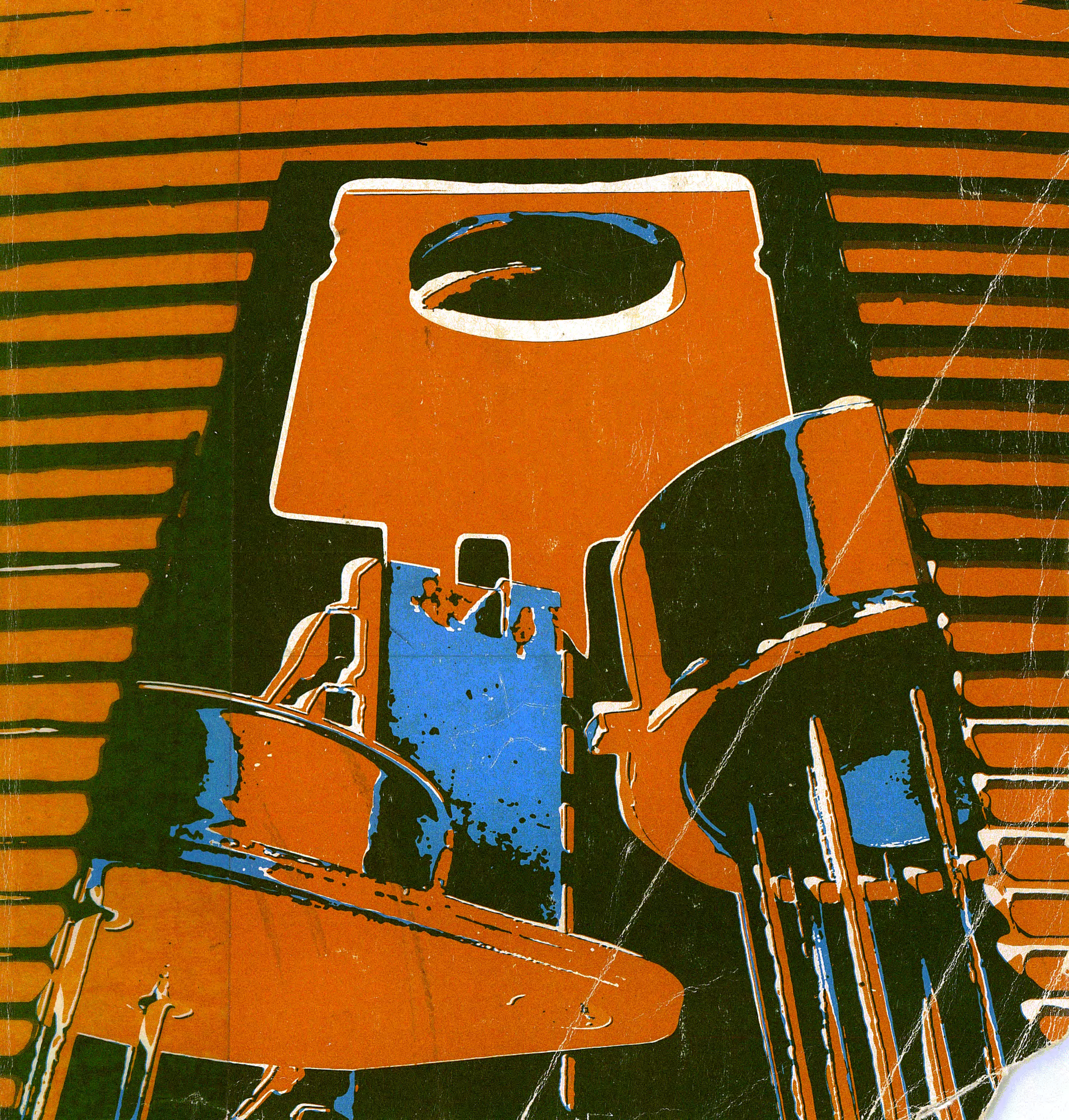
LINEAR
DATA BOOK

National



Edge Index by Function

Introduction

NEW DATA BOOK FORMAT

This edition of National's Linear Data Book has been reformatted to make it more useful. **Several new sections have been added** which reflect National's larger and more diverse Linear product line. Added are Voltage References, Instrumentation Amplifiers, Sample and Hold circuits, and A/D and D/A converters. What was formerly the Consumer section is now Audio, Radio and TV, and the old Functional Blocks is now Industrial/Automotive/Functional Blocks.

Guides pertinent to a particular section are now found at the beginning of that section. Included are section contents, selection guides and/or definition of terms. This now allows the user to find all information concerning any particular product in one section without looking through the entire catalog. Ordering information, table of contents, reliability programs, and any other information common to all sections is located in the front or back of the catalog.

Products new to National's Linear line since the last printing are denoted by asterisks in the Table of Contents and in the Section Contents at the beginning of each section.

For further information, please contact our local representative, distributor, or regional office.

NEW DIRECTIONS IN LINEAR

National's Linear line is moving in new directions, summarized by looking at several developments which have taken place in the past year.

The **Bi-FET process** is a technological breakthrough pioneered by National, integrating implanted JFETs on the same chip with standard bipolar transistors. The dramatic results are order-of-magnitude improvements in input characteristics, slew rates, and noise specifications. Products include LF156 series op amps, LF198 sample and hold, LF152 instrumentation amplifier, and LF11331/LF11201 series quad analog switches.

A family of 15 **D/A and A/D** products are being manufactured including 8, 10 and 12-bit D/A and A/D converters, successive approximation registers, dual slope A/D's for panel meters, and precision voltage references. We have the distinct advantage of using any one of our many processing technologies to optimize the D/A, A/D design.

A low noise, ultra stable **subsurface zener** pioneered at National, is combined with a temperature stabilize… a single chip to make the LM199 series precision voltage references. The LM199 features 1 ppm/°guaranteed drift, 20 ppm long term stability, and 0.5Ω dynamic impedance at highly competi… prices. An LM1?9 series unheated version is also available.

New di…tions in Linear are aimed at development of **building block circuits.** Quad devices such as the L…124, LM139 and LM1900 series are finding wide acceptance as cost-saving alternates to single a… dual devices. The new LM148, LM149 quad 741 family is a versatile addition to this group which …vides class AB outputs and wideband operation. The building block trend also includes timers …1556), audio, radio and TV circuits, and in particular, automotive circuits (LM2907, LM291… equency to voltage converter).

Manufactured u…e or more of the following U.S. patents: 3083262, 3189758, 3231797, 3303356, 3317671, 3323071, 3381071, 3408542, 3421025, 3426423, 3440498, 3518750, 3519897, 3557431, 3560765, 3566218, 357163…609, 3579059, 3593069, 3597640, 3607469, 3617859, 3631312, 3633052, 3638131, 3648071, 3651565, 3693248.

National does n…me any responsibility for use of any circuitry described; no circuit patent licenses are implied; and National reserves the right, at any time without notice, to change said circuitry.

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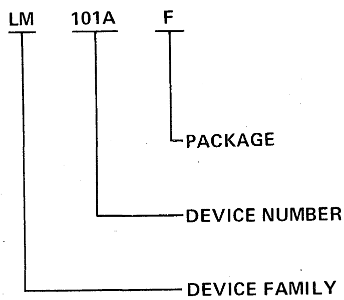
IM-CP90M66/Printed in W.-Germany

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 (Steel)
KC – TO-3 (Aluminum)
N – Plastic Dual-In-Line Package
P – TO-202 (D-40, Durawatt)
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

AD – Analog to Digital
AH – Analog Hybrid
AM – Analog Monolithic
CD – CMOS Digital
DA – Digital to Analog
DM – Digital Monolithic
LF – Linear FET
LH – Linear Hybrid
LM – Linear Monolithic
LX – Transducer
MM – MOS Monolithic
TBA – Linear Monolithic

Devices are listed in the table of contents alpha-numerically by device family (LH, LM, LX, etc.) and then byvice number. **With most of National's proprietary linear circuits, a 1-2-3 numbering system is employed. The 1 denotes a Milit temperature range device (–55°C to +125°C), the 2 denotes an Industrial temperature range device (–25°C to +85°C), ande 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 terature range; some hybrid circuits which employ a "C" suffix to denote the commercial temperature range; and second-ce 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. Ve a separate data sheet exists for a different temperature range, the device will be listed separately, i.e. LM119/LM219 and d separately LM319. Where only one temperature range exists, the part will be listed in its proper order, i.e. LM340.

Table of Contents

*Product added to this Data Book since last printing.

OPERATIONAL AMPLIFIERS/BUFFERS – SECTION 3 (con't)

*Product added to this Data Book since last printing.

OPERATIONAL AMPLIFIERS/BUFFERS – SECTION 3 (con't)

INSTRUMENTATION AMPLIFIERS – SECTION 4

VOLTAGE COMPARATORS – SECTION 5

ANALOG SWITCHES – SECTION 6

*Product added to this Data Book since last printing.

ANALOG SWITCHES – SECTION 6 (con't)

SAMPLE AND HOLD – SECTION 7

A TO D AND D TO A – SECTION 8

INDUSTRIAL/AUTOMOTIVE/FUNCTIONAL BLOCKS – SECTION 9

*Product added to this Data Book since last printing.

INDUSTRIAL/AUTOMOTIVE/FUNCTIONAL BLOCKS – SECTION 9 (con't)

AUDIO, RADIO AND TV CIRCUITS – SECTION 10

*Product added to this Data Book since last printing.

AUDIO, RADIO AND TV CIRCUITS – SECTION 10 (con't)

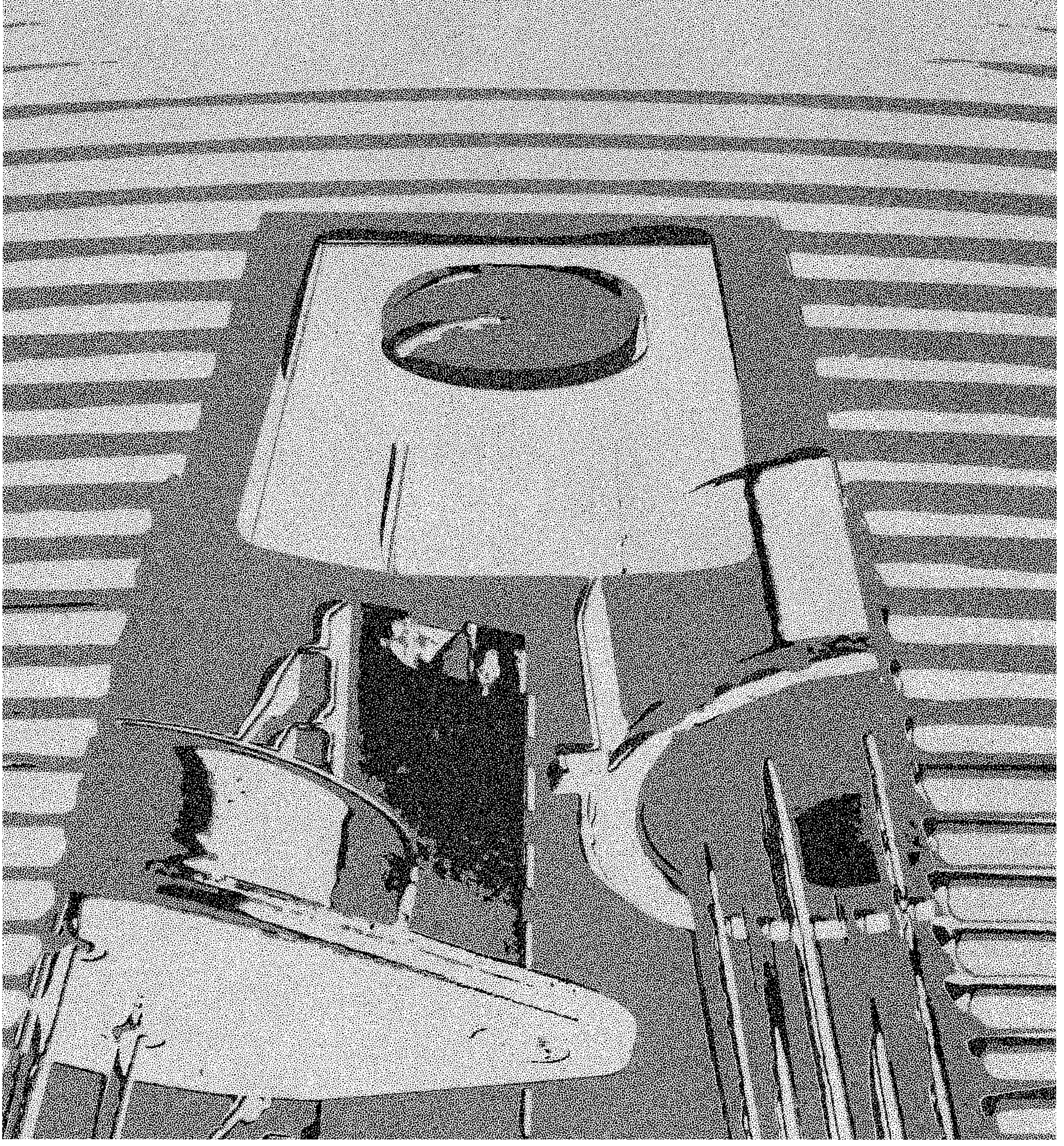
TRANSISTOR ARRAYS – SECTION II

APPENDICES/PHYSICAL DIMENSIONS – SECTION 12

*Product added to this Data Book since last printing.

Alpha-Numerical Index

National Semiconductor
VOLTAGE REGULATORS
Section 1



Voltage Regulators

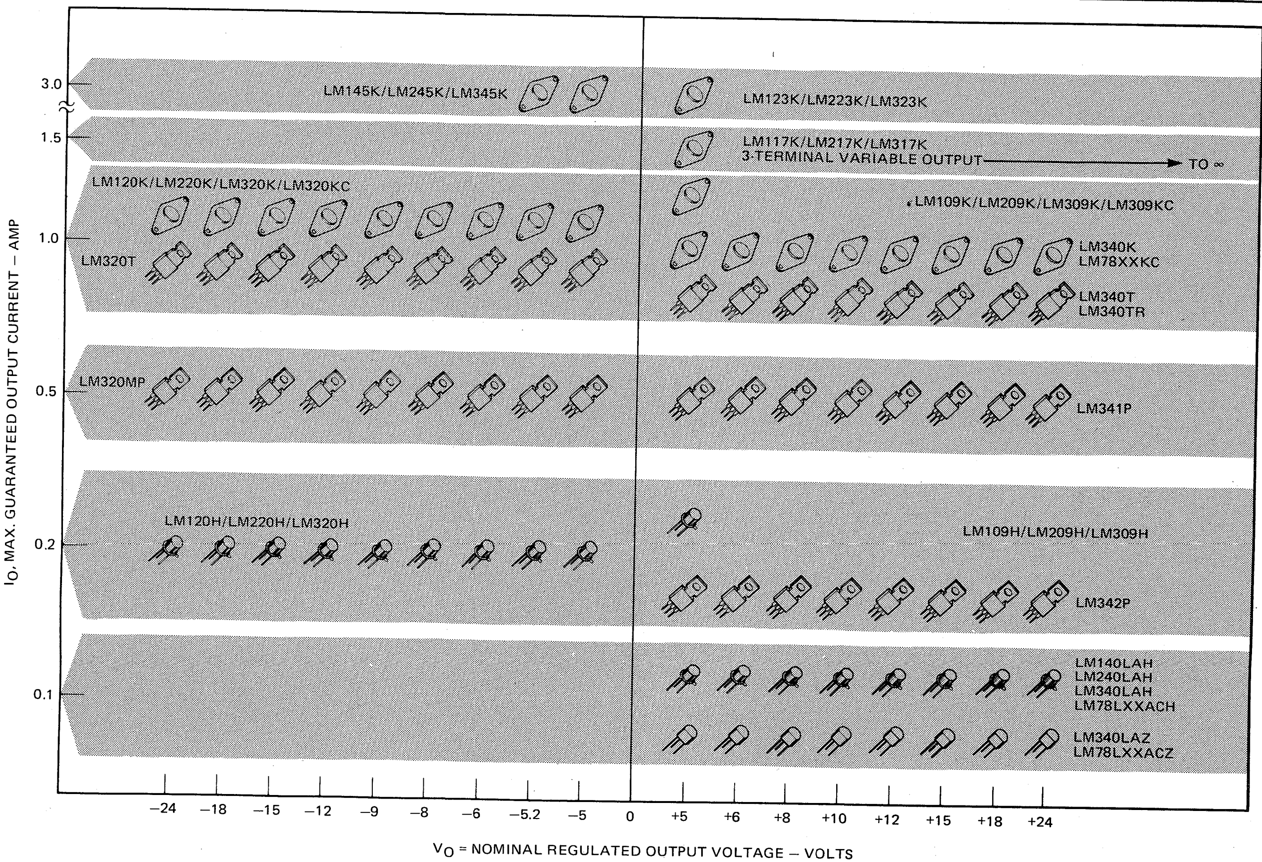
Section Contents

*Product added to this Data Book since last printing.

Voltage Regulator Guide

Device[1, 2]	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 (dB) Typ	Input-Output Differential (V) Min	Input-Output Differential (V) Max	Temperature Stability (%)	Quiescent Current (mA) Typ	Max Output Current[13] (mA)
POSITIVE VARIABLE VOLTAGE REGULATORS													
LM100H, F, LM200H,F[12]	8.5	40	2.0	30	0.1	12	0.5	70	3	30	1.0	1.0	20
LM300H, F	8.5	30	2.0	20	0.1	12	0.5	70	3	20	2.0	1.0	20
LM105H, F, LM205H,F[12]	8.5	50	4.5	40	0.02	12	0.015	86	3	30	1.0	0.8	20
LM305H, F	8.5	40	4.5	30	0.02	12	0.015	86	3	30	1.0	0.8	20
LM305AH	8.5	50	4.5	40	0.02	45	0.015	86	3	30	1.0	0.8	45
LM376N	9.0	40	5.0	37	0.2 max	25	0.03 max	76	3	30	–	2.5 max	25
LM723N, H, D	9.5	40	2.0	37	0.3	50	0.01	74	3	38	0.015%/°C	1.3	150
LM723CN, CH, CD	9.5	40	2.0	37	0.3	50	0.01	74	3	38	0.015%/°C	1.3	150
NEGATIVE VARIABLE VOLTAGE REGULATORS													
LM104H, F, LM204H,F[12]	−50	−8	−40	−15 mV	0.01	20	0.5	76	2	50	1.0	3.6	20
LM304H, F	−40	−8	−30	−15 mV	0.01	20	0.5	76	2	40	1.0	3.6	20
LM723N, H. D	−40	−9.5	−37	−2	0.03	50	0.01	74	3	38	0.015%/°C	1.3	150
LM723CN, CH, CD	−40	−9.5	−37	−2	0.03	50	0.01	74	3	38	0.015%/°C	1.3	150

Device[1, 2]	V_{OUT} Over Temp Range (V)	(±%)	Regulation Line[3] (mV/V)[5]	Regulation Load[4] (mV/V)[5]	Max V_{IN} (V)	Max I_Q (mA)	Typ Ripple (dB)[6]	Typ Dropout Voltage (V)	Device	Pkg. Style	Rated I_{OUT} (A)	Typ θ_{JC} (°C/W)	Typ θ_{JA}	Max P_D (W)
POSITIVE THREE TERMINAL VOLTAGE REGULATORS														
LM109, LM209	5	8	10	20	35	10		1–2	LM109H series	TO-39	0.2	15	150	2
LM309		5	10	20					LM109K series	TO-3	1	3	35	20
LM117K,LM217K, LM317K	Adj. 1.2 to 40V	N/A	2	10	42	N/A	75	2.0	LM117K series	TO-3	1.5	2	35	30
LM123K, LM223K	5	8	5	20	20	20		1.7–2	LM123K series	TO-3	3	2	35	30
LM323K		5												
LM340	5,6,8,12,15,18 24	5[7]	20	20	35	10	74	1.6–2	LM340K	TO-3	1	4	35	18
					40				LM340T	TO-220	1	4	50	18
LM341	5,6,8,12,15,18 24	5	20	20	35	10	74	1.2–1.7	LM341P	TO-202	0.5	12	80	12
					40									
LM342	5,6,8	5	20	20	30	6	74	1.5–2	LM342H	TO-39	0.2	40	140	3
	10,12,15,18				35				LM342P	TO-202	0.2	12	80	10
	24				40									
LM78LXXAC	5	5[8]	20	10	30	6	74	1.5–2	LM78LXXACH	TO-39	0.1	40	140	3
	8,12,15,18				35				LM78LXXACZ	TO-92	0.1	40	180	1
	24				40									
LM340L	5,6,8,10	3			40	4		1.5–2	LM340LAH	TO-39	0.1	40	140	3
	12,15,18,24								LM340LAZ	TO-92	0.1		180	1
NEGATIVE FIXED VOLTAGE REGULATORS														
LM120, LM220, LM320	5,5.2,8	5	10	20	25	4	80	2	LM120H series	TO-39	0.2	15	150	2
	12,15,18				35[9]				LM120K series	TO-3	1[10]	3	35	20
	24				40				LM120T series	TO-220	1[10]	5	50	15
LM320M	← Identical to LM120 series →					4	80	1.6	LM320MP series	TO-202	0.5	12	70	7.5
LM145, LM245, LM345	5,5.2	4	5	20	20	3	65	2	LM145K series	TO-3	3	2	35	25
DUAL TRACKING REGULATORS														
LM125, LM225, LM325	±15	5	1	1	30				LM125, 126, 127H	TO-99	0.1	45	150	2
LM126, LM226, LM326	±12	5	1	1	30	5		1–2.5	LM225, 226, 227H	TO-99	0.1	45	150	2
LM127, LM227, LM327	+5 and −12	5	1	1	30				LM325, 326, 327N	DIP[11]	0.1		150	1
									LM325, 326, 327S	SGS[11]	0.1	12	55	5



NOTES:

1 Operating temperature range
- LM100 series −55 to +125°C
- LM200 series −25 to +85°C
- LM300 series 0 to +70°C

2 Max T_J = 150°C except 125°C for LM309, LM320, LM323, LM345
3 Typ at 50–100% of rated I_{OUT}, 25°C, max V_{IN} change
4 Near zero to max rated I_{OUT}, 25°C pulse test
5 Max mV per volt of out voltage rating

6 Subtract (20 log V_{OUT}) for ripple rejection factor
7 ±10% available as LM340K R and LM430T R
8 ±10% available as LM78LXXCH and LM78LXXCZ
9 V_{IN} = 40V for LM120H-15 and LM120K-15 series

10 1.5A for V_{OUT} = 5 and 5.2V
11 DIP = 14 pin dual-in-line plastic package
SGS = Special DIP with heat sink

12 The maximum power dissipation for the LM100, LM104 and LM105 is 800 mW. In most cases the output current will be limited by the maximum junction temperature. (See Thermal Derating chart).

13 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.

THERMAL DERATING CHART

Package	Thermal Resistance Junction to Air	Thermal Resistance Junction to Case
TO-5	150°C/W	45°C
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

1

Voltage Regulator Guide

Voltage Regulators

Definition of Terms

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.

Voltage Regulators

LM100/LM200/LM300 voltage regulator

general description

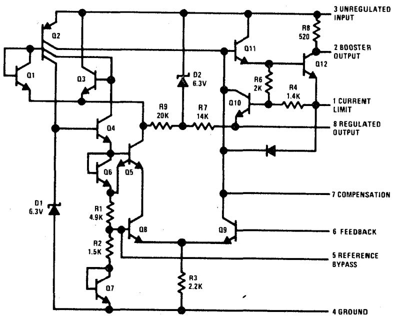
The LM100, LM200 and LM300 are integrated voltage regulators designed for a wide range of applications from digital power supplies to precision regulators for analog circuitry. Built on a single silicon chip, these devices are encapsulated in either an 8-lead, low profile TO-5 header or a 1/4 x 1/4 metal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

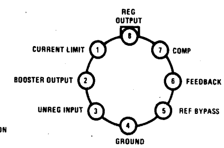
The LM100 is specified for operation over the −55°C to +125°C military temperature range. The LM200 and LM300 are low cost, commercial-industrial versions of the LM100. They are identical to the LM100 except that they are specified for operation from −25°C to 85°C and from 0°C to 70°C respectively.

schematic and connection diagrams



Pin connections shown are for TO-5 package

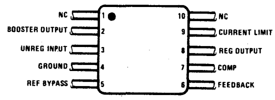
Metal Can Package



Note: Pin 4 connected to case.
TOP VIEW

Order Number LM100H or LM200H or LM300H
See Package 11

Flat Package

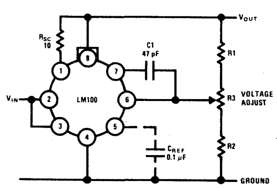


Note: Pin 4 connected to bottom of package.
TOP VIEW

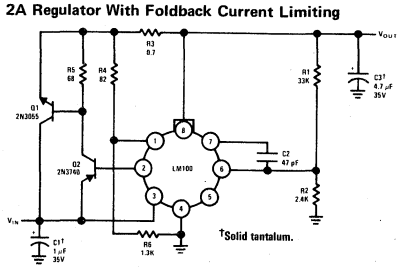
Order Number LM100F or LM200F or LM300F
See Package 3

typical applications

Basic Regulator Circuit

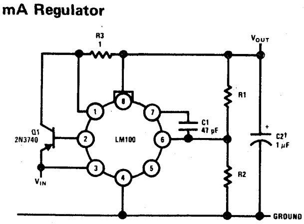


2A Regulator With Foldback Current Limiting



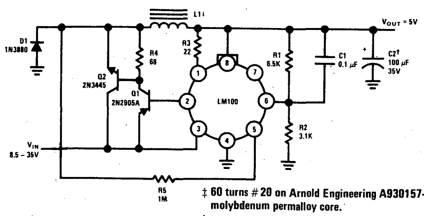
†Solid tantalum.

200 mA Regulator



†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	-55°C to +125°C
LM200	–25°C to +85°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
	$V_{IN} - V_{OUT}$ _ 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	$V_{IN} - V_{OUT} = 20V$				

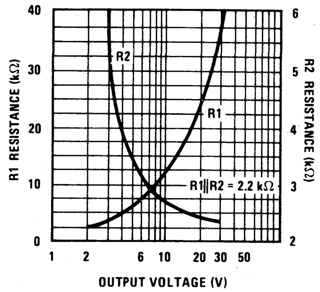
Note 1: The maximum junction temperature of the LM100 is 150°C, while that of the LM200 is 100°C, and the LM300 is 85°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W junction to ambient or 45°C/W, junction to case. For the 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.

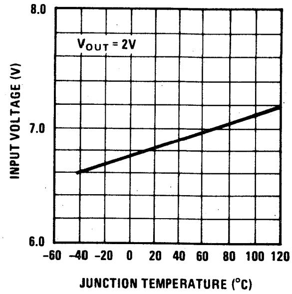
Note 3: The output currents given, as well as the load regulation, can be increased by the addition of external transistors. The improvement factor will be roughly equal to the composite current gain of the added transistors.

typical performance characteristics

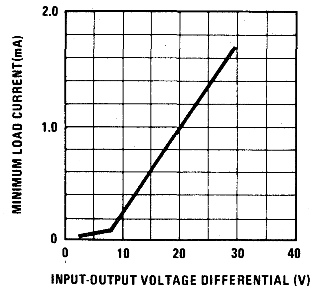
Optimum Divider Resistance Values vs Output Voltage



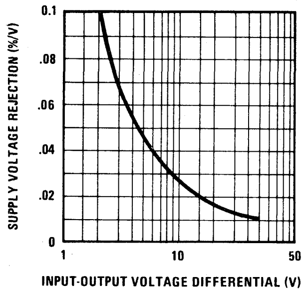
Minimum Input Voltage vs Junction Temperature



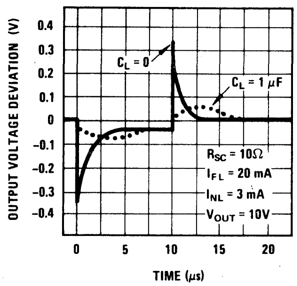
Minimum Load Current vs Input-Output Voltage Differential



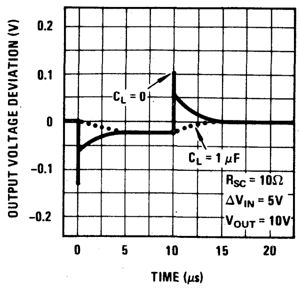
Supply Voltage Rejection vs Input-Output Voltage Differential



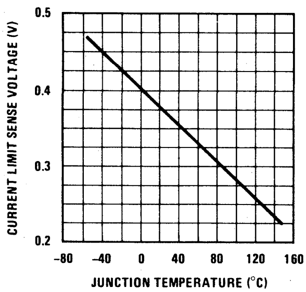
Load Transient Response



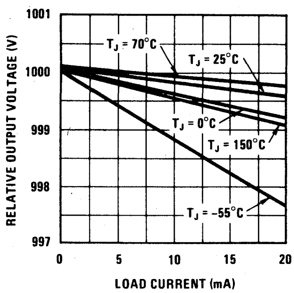
Line Transient Response



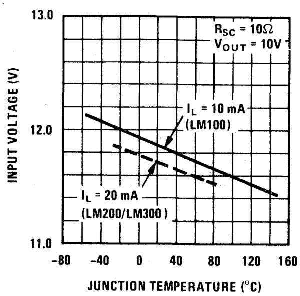
Current Limit Sense Voltage vs Junction Temperature



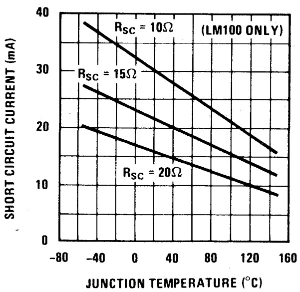
Regulation Characteristics Without Current Limiting



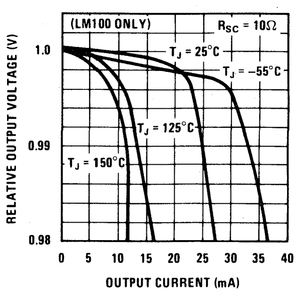
Regulator Dropout Voltage vs Junction Temperature



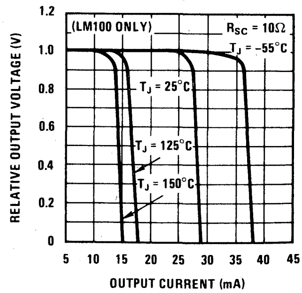
Short Circuit Current vs Junction Temperature



Regulation Characteristics With Current Limiting



Current Limiting Characteristics



Voltage Regulators

LM104/LM204/LM304 negative regulator

general description

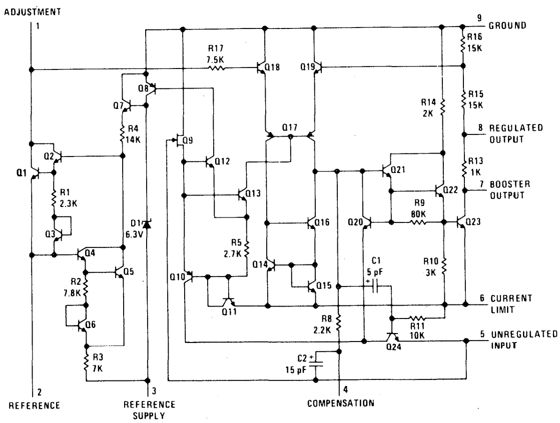
The LM104 series are precision voltage regulators which can be programmed by a single external resistor to supply any voltage from 40V down to zero while operating from a single unregulated supply. They can also provide 0.01-percent regulation in circuits using a separate, floating bias supply, where 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

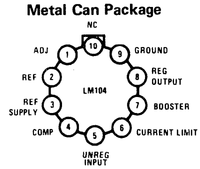
The LM104 series are complements of the LM100 and LM105 positive regulators, intended for systems requiring regulated negative voltages which have a common ground with the unregulated supply. By themselves, they can deliver output currents to 25 mA, but external transistors can be added to get any desired 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. The LM304 is specified for operation from 0°C to +70°C.

schematic and connection diagrams



Metal Can Package

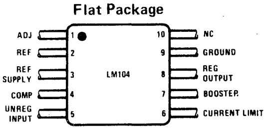


Note: Pin 5 connected to case.

TOP VIEW

Order Number LM104H, LM204H or LM304H
See Package 12

Flat Package



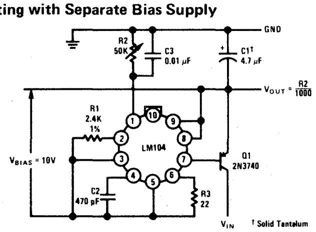
Note: Pin 5 connected to bottom of package.

TOP VIEW

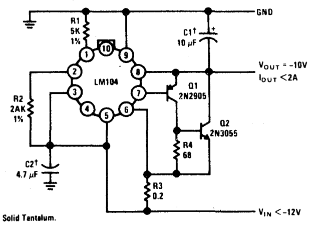
Order Number LM104F, LM204F or LM304F
See Package 3

typical applications

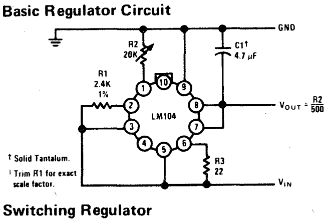
Operating with Separate Bias Supply



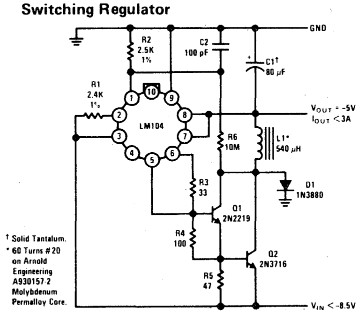
High Current Regulator



Basic Regulator Circuit



Switching Regulator



absolute maximum ratings

	LM104/LM204	LM304
Input Voltage	50V	40V
Input-Output Voltage Differential	50V	40V
Power Dissipation (Note 1)	500 mW	500 mW
Operating Temperature Range		
LM104	-55°C to 125°C	
LM204	-25°C to 85°C	
LM304		0°C to +70°C
Storage Temperature Range	-65°C to 150°C	−65°C to +150°C
Lead Temperature (Soldering, 10 sec)	300°C	300°C

electrical characteristics (Note 2)

PARAMETER	CONDITIONS	LM104/LM204			LM304			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Voltage Range		−50		−8	−40		−8	V
Output Voltage Range		−40		−0.015	−30		−0.035	V
Output-Input Voltage Differential (Note 3)	$I_O = 20$ mA	2.0		50	2.0		40	V
	$I_O = 5$ mA	0.5		50	0.5		40	V
Load Regulation (Note 4)	$0 \leq I_O \leq 20$ mA, $R_{SC} = 15\Omega$		1	5		1	5	mV
Line Regulation (Note 5)	$V_{OUT} \leq -5V$, $\Delta V_{IN} = 0.1\ V_{IN}$		0.056	0.1		0.056	0.1	%
Ripple Rejection	$C_{19} = 10\ \mu F$, f = 120 Hz, $V_{IN} < -15V$		0.2	0.5		0.2	0.5	mV/V
	$-7V \geq V_{IN} \geq -15V$		0.5	1.0		0.5	1.0	mV/V
Output Voltage Scale Factor	$R_{23} = 2.4k$	1.8	2.0	2.2	1.8	2.0	2.2	V/kΩ
Temperature Stability	$V_O \leq -1V$		0.3	1.0		0.3	1.0	%
Output Noise Voltage	$10\ Hz \leq f \leq 10\ kHz$, $V_O \leq -5V$, $C_{19} = 0$		0.007			0.007		%
	$C_{19} = 10\ \mu F$		15			15		μV
Standby Current Drain	$I_L = 5$ mA, $V_O = 0$		1.7	2.5		1.7	2.5	mA
	$V_O = -30V$					3.6	5.0	mA
	$V_O = -40V$		3.6	5.0				mA
Long Term Stability	$V_O \leq -1V$		0.1	1.0		0.1	1.0	%

Note 1: The maximum junction temperature of the LM104 is 150°C, while that of the LM204 is 125°C and LM304 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 0°C to +85°C for the LM304) 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.

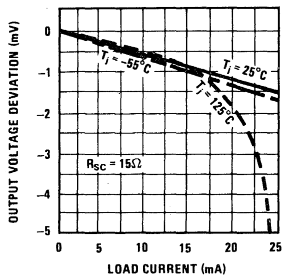
Note 3: When external booster transistors are used, the minimum output-input voltage differential is increased, in the worst case, by approximately 1V.

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.

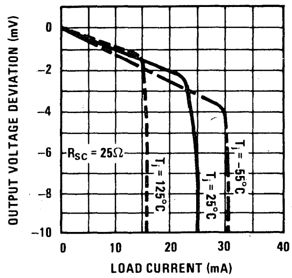
Note 5: With zero output, the dc line regulation is determined from the ripple rejection. Hence, with output voltages between 0V and −5V, a dc output variation, determined from the ripple rejection, must be added to find the worst-case line regulation.

typical performance characteristics

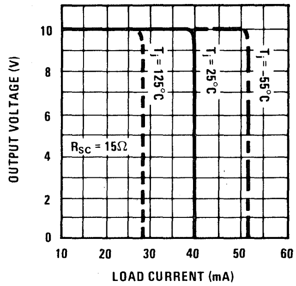
Load Regulation



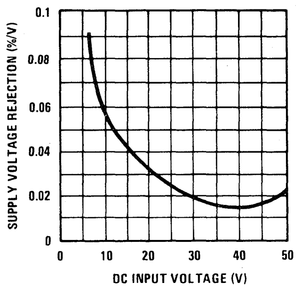
Load Regulation



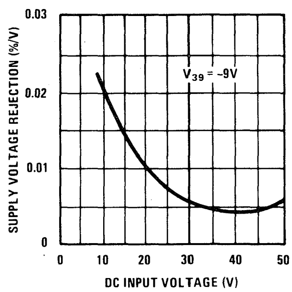
Current Limiting



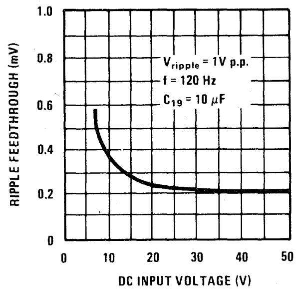
Supply Voltage Rejection



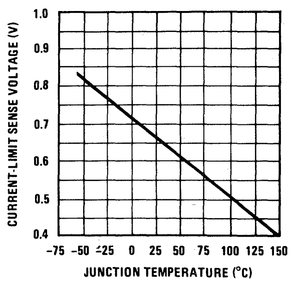
Supply Voltage Rejection With Preregulated Reference Supply



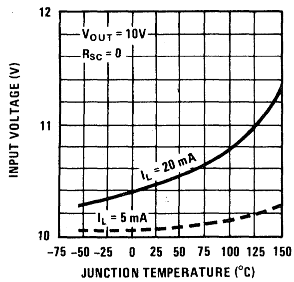
Ripple Rejection



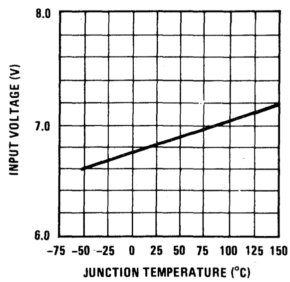
Current Limit Sense Voltage



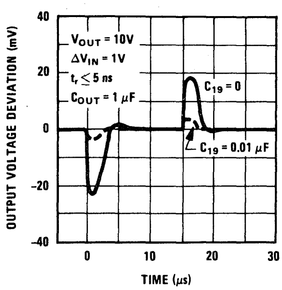
Regulator Dropout Voltage



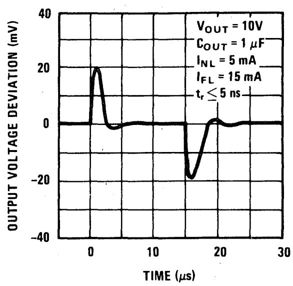
Minimum Input Voltage



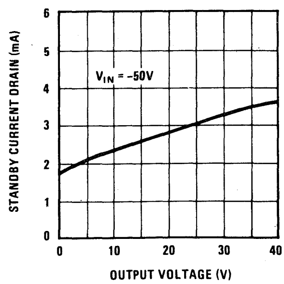
Line Transient Response



Load Transient Response



Standby Current Drain



Voltage Regulators

LM105/LM205/LM305/LM305A, LM376 voltage regulators

general description

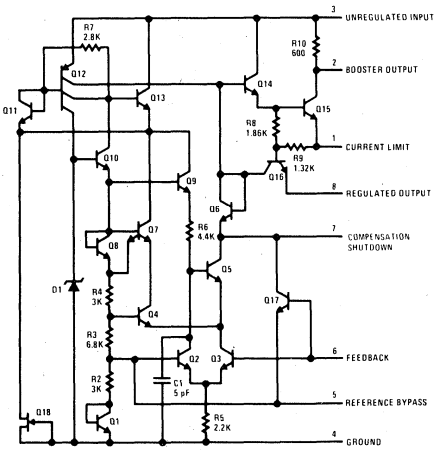
The LM105 series are positive voltage regulators similar to the LM100, except that an extra gain stage has been added for improved regulation. A redesign of the biasing circuitry removes any minimum load current requirement and at the same time reduces standby current drain, permitting higher voltage 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
- 45 mA output current without external pass transistor (LM305A)

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.

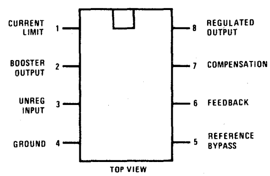
The LM105 is specified for operation for $-55^{\circ}C \le T_A \le +125^{\circ}C$, the LM205 is specified for $-25^{\circ}C \le T_A \le +85^{\circ}C$, and the LM305/LM305A, LM376 is specified for $0^{\circ}C \le T_A \le +70^{\circ}C$.

schematic and connection diagrams



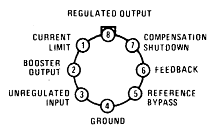
Pin connections shown are for metal can.

Dual-In-Line Package



Order Number LM376N
See Package 20

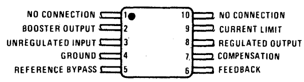
Metal Can Package



Note: Pin 4 connected to case.
TOP VIEW

Order Number LM105H, LM205H, LM305H or LM305AH
See Package 11

Flat Package

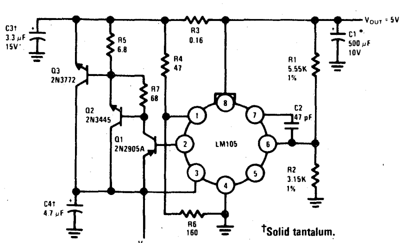


Note: Pin 4 connected to bottom of package.

Order Number LM105F, LM205F or LM305F
See Package 3

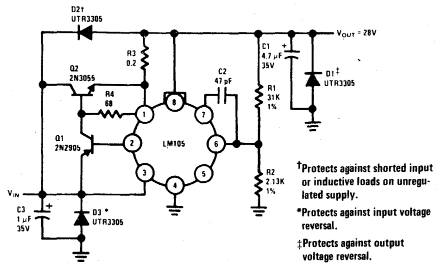
typical applications

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

	LM105	LM205	LM305	LM305A	LM376
Input Voltage	50V	50V	40V	50V	40V
Input-Output Differential	40V	40V	40V	40V	40V
Power Dissipation (Note 1)	800 mW	800 mW	800 mW	800 mW	400 mW
Operating Temperature Range	−55°C to +125°C	−25°C to +85°C	0°C to +70°C	0°C to +70°C	0°C to +70°C
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C	300°C	300°C	300°C	300°C

electrical characteristics (Note 2)

PARAMETER	CONDITIONS	LM105			LM205			LM305			LM305A			LM376			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Voltage Range		8.5		50	8.5		50	8.5		40	8.5		50	9.0		40	V
Output Voltage Range		4.5		40	4.5		40	4.5		30	4.5		40	5.0		37	V
Input-Output Voltage Differential		3.0		30	3.0		30	3.0		30	3.0		30	3.0		30	V
Load Regulation (Note 3)	$R_{SC} = 10\Omega$, $T_A = 25°C$		0.02	0.05		0.02	0.05		0.02	0.05							%
	$R_{SC} = 10\Omega$, $T_A = T_{A(MAX)}$		0.03	0.1		0.03	0.1		0.03	0.1							%
	$R_{SC} = 10\Omega$, $T_A = T_{A(MIN)}$		0.03	0.1		0.03	0.1		0.03	0.1							%
			$0 \le I_O \le 12$ mA			$0 \le I_O \le 12$ mA			$0 \le I_O \le 12$ mA								
	$R_{SC} = 0\Omega$, $T_A = 25°C$											0.02	0.2			0.2	%
	$R_{SC} = 0\Omega$, $T_A = 70°C$											0.03	0.4			0.5	%
	$R_{SC} = 0\Omega$, $T_A = 0°C$											0.03	0.4			0.5	%
												$0 \le I_O \le 45$ mA			$0 \le I_O \le 25$ mA		
Line Regulation	$T_A = 25°C$															0.3	%/V
	$V_{IN} - V_{OUT} \le 5V$		0.025	0.06		0.025	0.06		0.025	0.06		0.025	0.06				%/V
	$V_{IN} - V_{OUT} > 5V$		0.015	0.03		0.015	0.03		0.015	0.03		0.015	0.03				%/V
Temperature Stability	$T_{A(MIN)} \le T_A \le T_{A(MAX)}$		0.3	1.0		0.3	1.0		0.3	1.0		0.3	1.0				%
Reference Voltage		1.63	1.7	1.81	1.63	1.7	1.81	1.63	1.7	1.81	1.55	1.7	1.85	1.60	1.72	1.80	V
Output Noise Voltage	$10\text{ Hz} \le f \le 10\text{ kHz}$																
	$C_{REF} = 0$		0.005			0.005			0.005			0.005					%
	$C_{REF} = 0.1\mu F$		0.002			0.002			0.002			0.002					%
Standby Current Drain	$V_{IN} = 30V$, $T_A = 25°C$															2.5	mA
	$V_{IN} = 40V$								0.8	2.0							mA
	$V_{IN} = 50V$		0.8	2.0		0.8	2.0					0.8	2.0				mA
Current Limit Sense Voltage	$T_A = 25°C$, $R_{SC} = 10\Omega$, $V_{OUT} = 0V$, (Note 4)	225	300	375	225	300	375	225	300	375	225	300	375		300		mV
Long Term Stability			0.1	1.0		0.1	1.0		0.1	1.0		0.1	1.0				%
Ripple Rejection	$C_{REF} = 10\mu F$, $f = 120$ Hz		0.003	0.01		0.003	0.01		0.003	0.01		0.003				0.1	%/V

Note 1: The maximum junction temperature of the LM105 and LM305A is 150°C, the LM205 and LM376 is 100°C, and the LM305 is 85°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. For the epoxy dual-in-line package, derating is based on a thermal resistance of 187°C/W junction to ambient. 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.

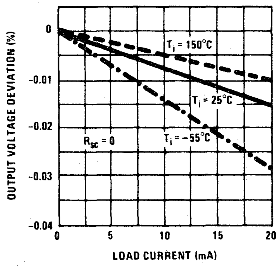
Note 2: Unless otherwise specified, these specifications apply for temperatures within the operating temperature range, for input and output voltages within the range given, and for a divider impedance seen by the feedback terminal of 2 kΩ. Load and line regulation specifications are for a constant junction 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.

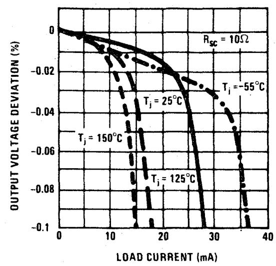
Note 4: With no external pass transistor.

typical performance characteristics LM105/LM205/LM305/LM305A

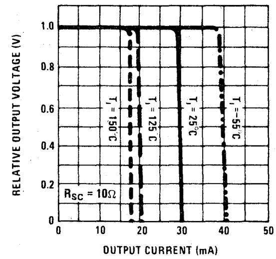
Load Regulation



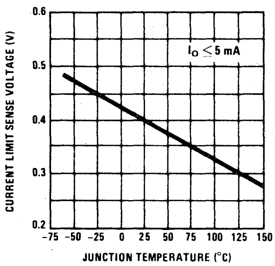
Load Regulation



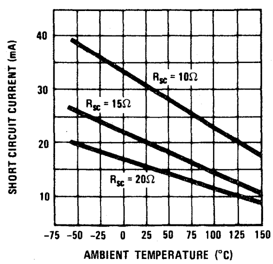
Current Limiting Characteristics



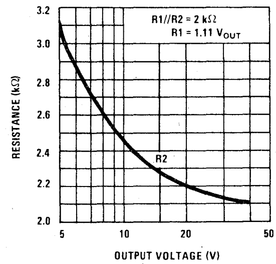
Current Limit Sense Voltage



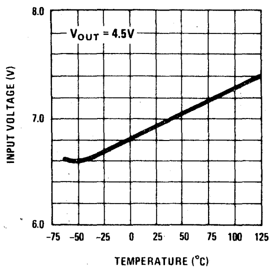
Short Circuit Current



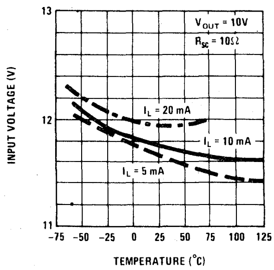
Optimum Divider Resistance Values



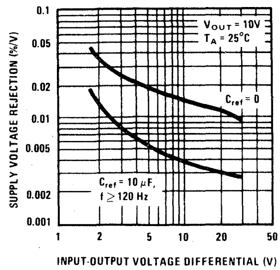
Minimum Input Voltage



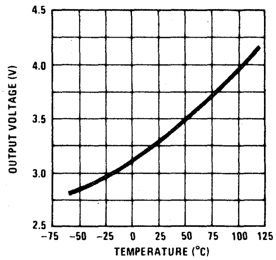
Regulator Dropout Voltage



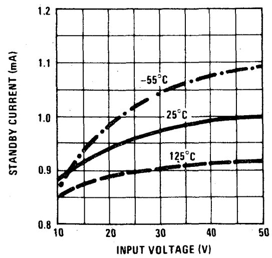
Supply Voltage Rejection



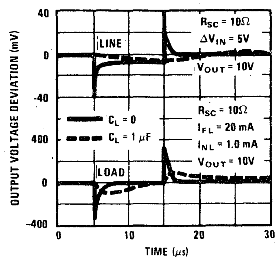
Minimum Output Voltage



Standby Current Drain

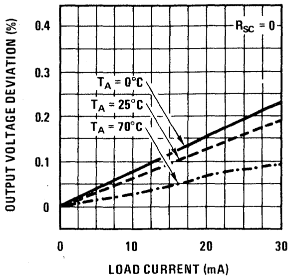


Transient Response

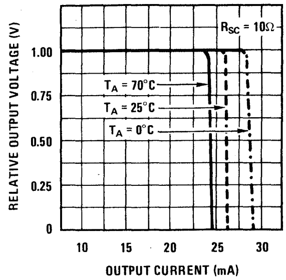


typical performance characteristics LM376

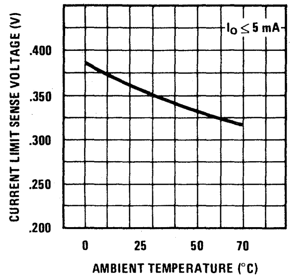
Load Regulation



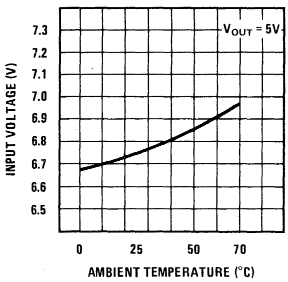
Current Limiting Characteristics



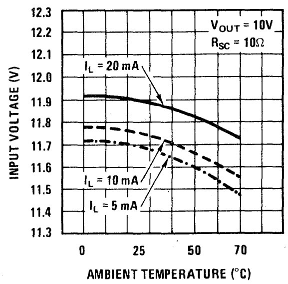
Current Limit Sense Voltage



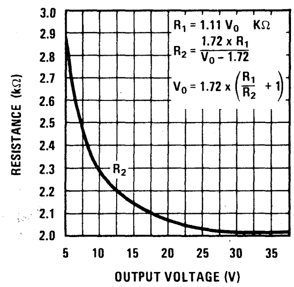
Minimum Input Voltage



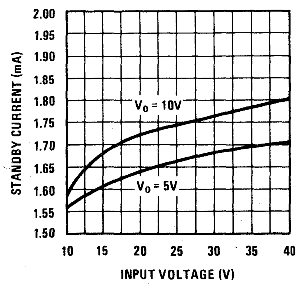
Regulator Dropout Voltage



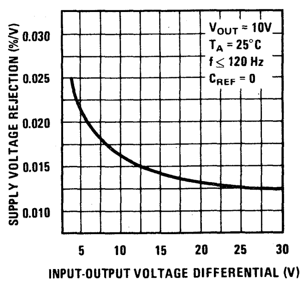
Optimum Divider Resistance



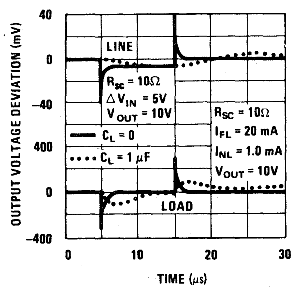
Standby Current Drain
$T_A = 25°C$



Supply Voltage Rejection

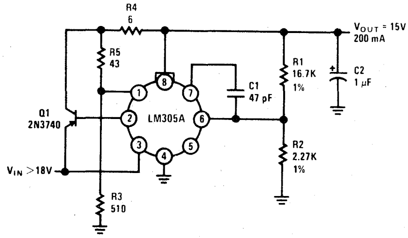


Transient Response

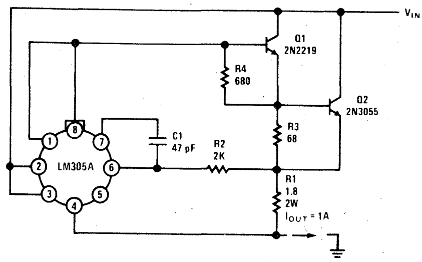


typical applications (con't)

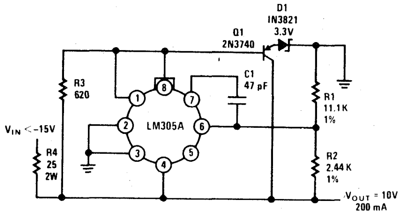
Linear Regulator with Foldback Current Limiting



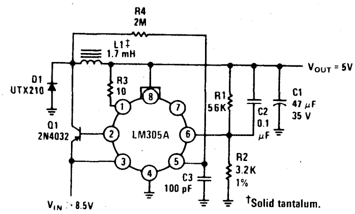
Current Regulator



Shunt Regulator



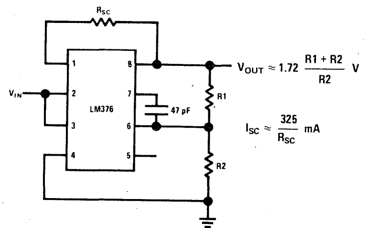
Switching Regulator



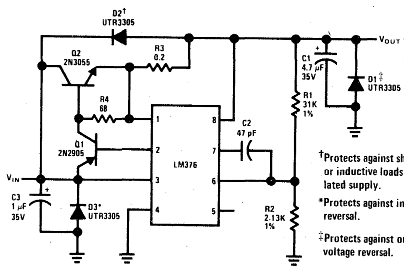
†Solid tantalum.

‡125 turns =22 on Arnold Engineering A262123-2 molybdenum permally core.

Basic Positive Regulator with Current Limiting



1.0A Regulator with Protective Diodes

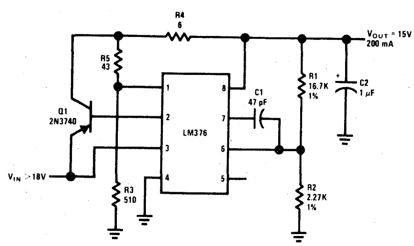


†Protects against shorted input or inductive loads on unregulated supply.

*Protects against input voltage reversal.

‡Protects against output voltage reversal.

Linear Regulator with Foldback Current Limiting



Voltage Regulators

LM109/LM209/LM309 5-volt regulator

general description

The LM109 series 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.

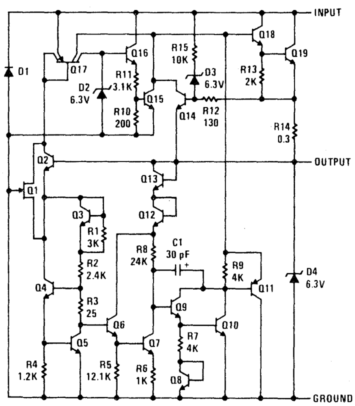
Considerable effort was expended to make these devices easy to use and minimize the number of external components. It is not necessary to bypass the output, although this does improve transient response somewhat. Input bypassing is needed, however, if the regulator is located very far from the filter 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 series 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:

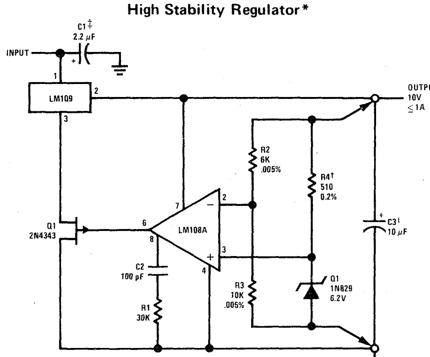
- Specified to be complete, worst case, with TTL and DTL
- Output current in excess of 1A
- Internal thermal overload protection
- No external components required

schematic diagram



typical applications

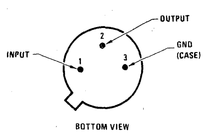
High Stability Regulator*



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

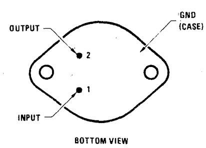
connection diagrams

Metal Can Package



Order Number LM109H, LM209H or LM309H
See Package 9

Metal Can Package



Order Number LM109K, LM209K LM309K (Steel) or LM309KC (Aluminum)
See Package 18

absolute maximum ratings

Input Voltage	35V
Power Dissipation	Internally Limited
Operating Junction Temperature Range	
LM109	−55°C to +150°C
LM209	−25°C to +150°C
LM309	0°C to +125°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 1)

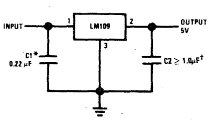
PARAMETER	CONDITIONS	LM109/LM209			LM309			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	$T_j = 25°C$	4.7	5.05	5.3	4.8	5.05	5.2	V
Line Regulation	$T_j = 25°C$, $7V \leq V_{IN} \leq 25V$		4	50		4.0	50	mV
Load Regulation	$T_j = 25°C$							
TO-5 Package	$5\ mA \leq I_{OUT} \leq 0.5A$		20	50		20	50	mV
TO-3 Package	$5\ mA \leq I_{OUT} \leq 1.5A$		50	100		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	4.75		5.25	V
Quiescent Current	$7V \leq V_{IN} \leq 25V$		5.2	10		5.2	10	mA
Quiescent Current Change	$7V \leq V_{IN} \leq 25V$			0.5			0.5	mA
	$5\ mA \leq I_{OUT} \leq I_{MAX}$			0.8			0.8	mA
Output Noise Voltage	$T_A = 25°C$, $10\ Hz \leq f \leq 100\ kHz$		40			40		µV
Long Term Stability				10			20	mV
Thermal Resistance	(Note 2)							
Junction to Case								
TO-5 Package			15			15		°C/W
TO-3 Package			3			3.0		°C/W

Note 1: Unless otherwise specified, these specifications apply for $-55°C \leq T_j \leq +150°C$ for the LM109, $-25°C \leq T_j \leq +150°C$ for the LM209, and $0°C \leq T_j \leq +125°C$ for the LM309, 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)

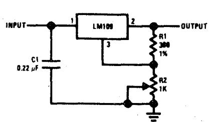
Fixed 5V Regulator



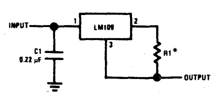
*Required if regulator is located an apprecible distance from power supply filter.

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

Adjustable Output Regulator



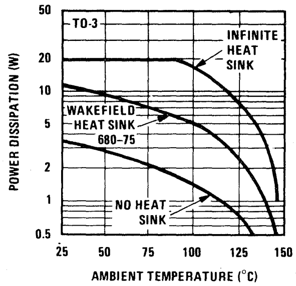
Current Regulator



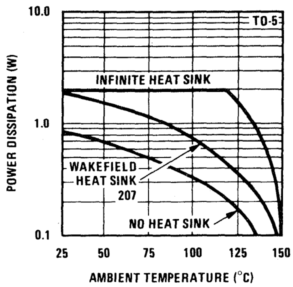
*Determines output current.

typical performance characteristics

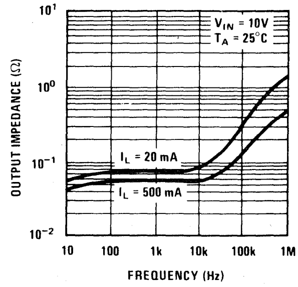
Maximum Average Power Dissipation



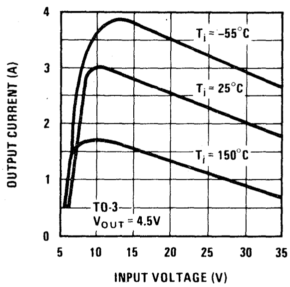
Maximum Average Power Dissipation



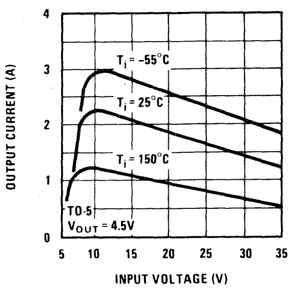
Output Impedance



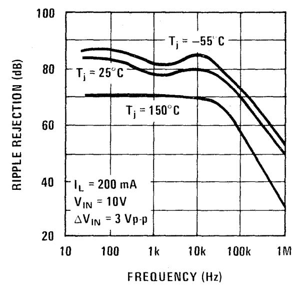
Peak Output Current



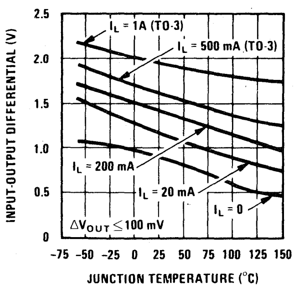
Peak Output Current



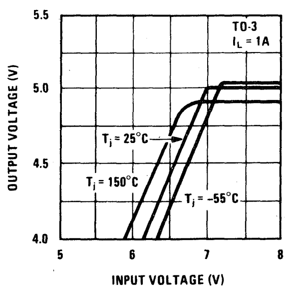
Ripple Rejection



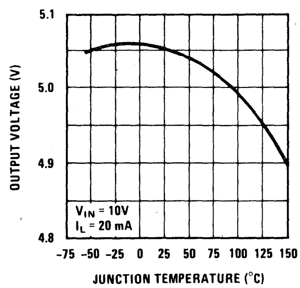
Dropout Voltage



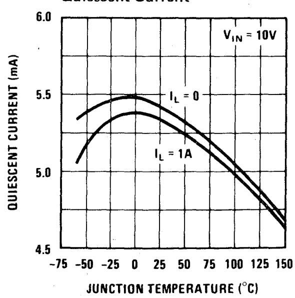
Dropout Characteristic



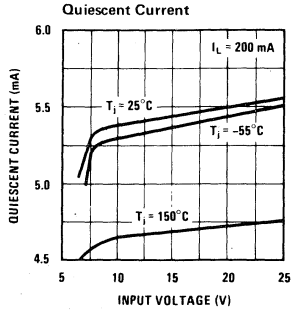
Output Voltage



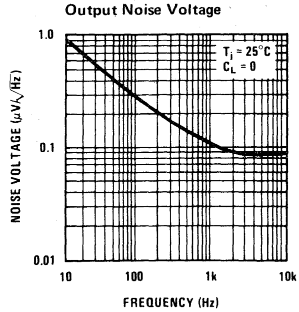
Quiescent Current



Quiescent Current



Output Noise Voltage



Voltage Regulators

LM117/LM217/LM317 3-terminal adjustable regulator

general description

The LM117/LM217/LM317 are adjustable 3-terminal positive voltage regulators capable of supplying in excess of 1.5A over a 1.2V to 37V output range. They are exceptionally easy to use and require only two external resistors to set the output voltage. Further, both line and load regulation are better than standard fixed regulators. Also, the LM117 is packaged in standard transistor packages which are easily mounted and handled.

In addition to higher performance than fixed regulators, the LM117 series offers full overload protection available only in IC's. Included on the chip are current limit, thermal overload protection and safe area protection. All overload protection circuitry remains fully functional even if the adjustment terminal is disconnected.

features

- Adjustable output down to 1.2V
- Guaranteed 1.5A output current
- Line regulation typically 0.01%/V
- Load regulation typically 0.1%
- Current limit constant with temperature
- 100% electrical burn-in
- Eliminates the need to stock many voltages
- Standard 3-lead transistor package
- 80 dB ripple rejection

Normally, no capacitors are needed unless the device is situated far from the input filter capacitors in which case an input bypass is needed. An optional output capacitor can be added to improve transient response. The adjustment terminal can be bypassed to achieve very high ripple rejections ratios which are difficult to achieve with standard 3-terminal regulators.

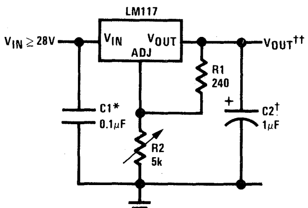
Besides replacing fixed regulators, the LM117 is useful in a wide variety of other applications. Since the regulator is "floating" and sees only the input-to-output differential voltage, supplies of several hundred volts can be regulated as long as the maximum input to output differential is not exceeded.

Also, it makes an especially simple adjustable switching regulator, a programmable output regulator, or by connecting a fixed resistor between the adjustment and output, the LM117 can be used as a precision current regulator. Supplies with electronic shutdown can be achieved by clamping the adjustment terminal to ground which programs the output to 1.2V where most loads draw little current.

The LM117K, LM217K and LM317K are packaged in standard TO-3 transistor packages while the LM117H, LM217H and LM317H are packaged in a solid Kovar base TO-5 transistor package. The LM117 is rated for operation from −55°C to +150°C, the LM217 from −25°C to +150°C and the LM317 from 0°C to +125°C. The LM317T, rated for operation over a 0°C to +125°C range is available in a TO-220 plastic package.

typical applications

1.2V–25V Adjustable Regulator

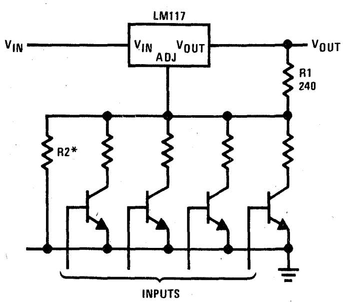


†Optional—improves transient response

*Needed if device is far from filter capacitors

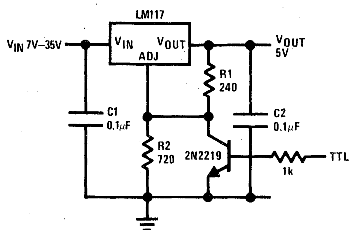
$$^{\dagger\dagger}V_{OUT} = 1.25V\left(1 + \frac{R2}{R1}\right)$$

Digitally Selected Outputs



*Sets maximum V_{OUT}

5V Logic Regulator with Electronic Shutdown*



*Min output ≈ 1.2V

absolute maximum ratings

Power Dissipation	Internally limited
Input–Output Voltage Differential	40V
Operating Junction Temperature Range	
LM117	–55°C to +150°C
LM217	–25°C to +150°C
LM317	0°C to +125°C
Storage Temperature	–65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 1)

PARAMETER	CONDITIONS	LM117/217			LM317			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Line Regulation	$T_A = 25°C$, $3V \leq V_{IN} - V_{OUT} \leq 40V$ (Note 2)		0.01	0.02		0.01	0.04	%/V
Load Regulation	$T_A = 25°C$, $10\ mA \leq I_{OUT} \leq I_{MAX}$							
	$V_{OUT} \leq 5V$, (Note 2)		5	15		5	25	mV
	$V_{OUT} \geq 5V$, (Note 2)		0.1	0.3		0.1	0.5	%
Adjustment Pin Current			50	100		50	100	μA
Adjustment Pin Current Change	$10\ mA \leq I_L \leq I_{MAX}$ $2.5V \leq (V_{IN}-V_{OUT}) \leq 40V$		0.2	5		0.2	5	μA
Reference Voltage	$3 \leq (V_{IN}-V_{OUT}) \leq 40V$, (Note 3) $10\ mA \leq I_{OUT} \leq I_{MAX}$, $P \leq P_{MAX}$	1.20	1.25	1.30	1.20	1.25	1.30	V
Line Regulation	$3V \leq V_{IN} - V_{OUT} \leq 40V$, (Note 2)		0.02	0.05		0.02	0.07	%/V
Load Regulation	$10\ mA \leq I_{OUT} \leq I_{MAX}$, (Note 2)							
	$V_{OUT} \leq 5V$		20	50		20	70	mV
	$V_{OUT} \geq 5V$		0.3	1		0.3	1.5	%
Temperature Stability	$T_{MIN} \leq T_j \leq T_{MAX}$		1			1		%
Minimum Load Current	$V_{IN}-V_{OUT} = 40V$		3.5	5		3.5	10	mA
Current Limit	$V_{IN}-V_{OUT} \leq 15V$							
	K and T Package	1.5	2.2		1.5	2.2		A
	H and P Package	0.5	0.8		0.5	0.8		A
	$V_{IN}-V_{OUT} = 40V$							
	K and T Package		0.4			0.4		A
	H and P Package		0.07			0.07		A
RMS Output Noise, % of V_{OUT}	$T_A = 25°C$, $10\ Hz \leq f \leq 10\ kHz$		0.003			0.003		%
Ripple Rejection Ratio	$V_{OUT} = 10V$, $f = 120\ Hz$		65			65		dB
	$C_{ADJ} = 10\mu F$	66	80		66	80		dB
Long-Term Stability	$T_A = 125°C$		0.3	1		0.3	1	%
Thermal Resistance, Junction to Case	H Package		12	15		12	15	°C/W
	K Package		2.3	3		2.3	3	°C/W
	T Package					5		°C/W
	P Package					12		°C/W

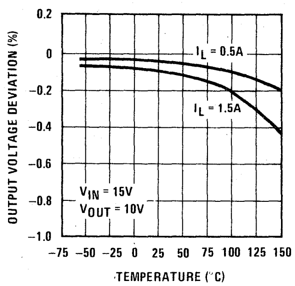
Note 1: Unless other wise specified, these specifications apply $-55°C \leq T_j \leq +150°C$ for the LM117, $-25°C \leq T_j \leq +150°C$ for the LM217 and $0°C \leq T_j \leq +125°C$ for the LM317; $V_{IN}-V_{OUT} = 5V$ and $I_{OUT} = 0.1A$ for the TO-5 package and $I_{OUT} = 0.5A$ for the TO-3 package and TO-220 package. Although power dissipation is internally limited, these specifications are applicable for power dissipations of 2W for the TO-5 and 20W for the TO-3 and TO-220. I_{MAX} is 1.5A for the TO-3 and TO-220 package and 0.5A for the TO-5 package.

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

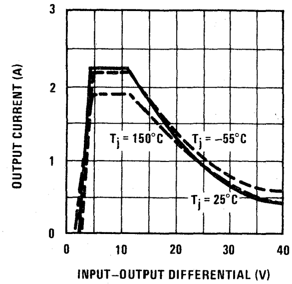
Note 3: Selected devices with tightend tolerance reference voltage available.

typical performance characteristics (K and T Packages)

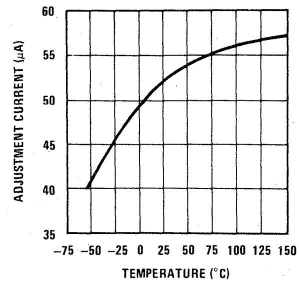
Load Regulation



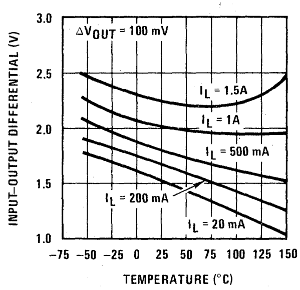
Current Limit



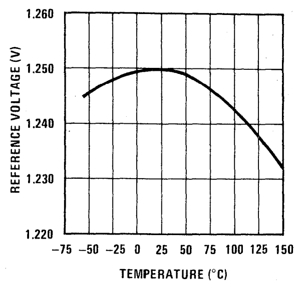
Adjustment Current



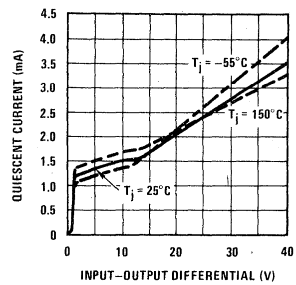
Dropout Voltage



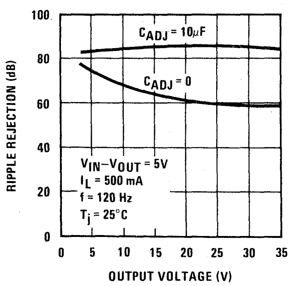
Temperature Stability



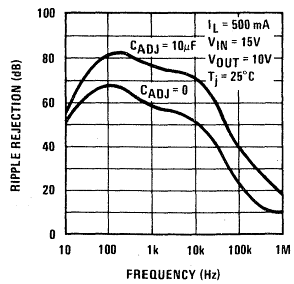
Minimum Operating Current



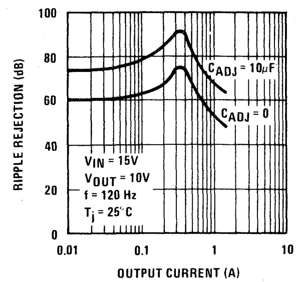
Ripple Rejection



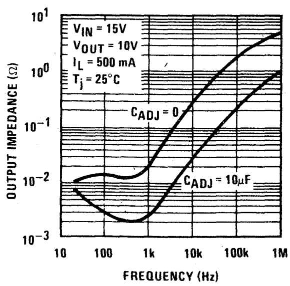
Ripple Rejection



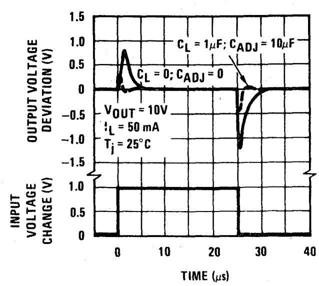
Ripple Rejection



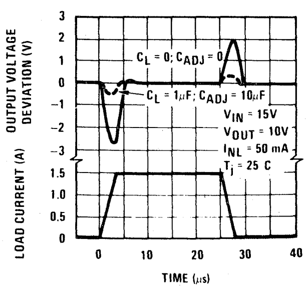
Output Impedance



Line Transient Response



Load Transient Response



application hints

In operation, the LM117 develops a nominal 1.25V reference voltage, V_{REF}, between the output and adjustment terminal. The reference voltage is impressed across program resistor R1 and, since the voltage is constant, a constant current I_1 then flows through the output set resistor R2, giving an output voltage of

$$V_{OUT} = V_{REF} \left(1 + \frac{R2}{R1}\right) + I_{ADJ} R2$$

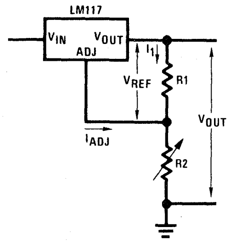


FIGURE 1.

Since the 100μA current from the adjustment terminal represents an error term, the LM117 was designed to minimize I_{ADJ} and make it very constant with line and load changes. To do this, all quiescent operating current is returned to the output establishing a minimum load current requirement. If there is insufficient load on the output, the output will rise.

External Capacitors

An input bypass capacitor is recommended. A 0.1μF disc or 1μF solid tantalum on the input is suitable input bypassing for almost all applications. The device is more sensitive to the absence of input bypassing when adjustment or output capacitors are used but the above values will eliminate the possibility of problems.

The adjustment terminal can be bypassed to ground on the LM117 to improve ripple rejection. This bypass capacitor prevents ripple from being amplified as the output voltage is increased. With a 10μF bypass capacitor 80 dB ripple rejection is obtainable at any output level. Increases over 10μF do not appreciably improve the ripple rejection at frequencies above 120 Hz. If the bypass capacitor is used, it is sometimes necessary to include protection diodes to prevent the capacitor from discharging through internal low current paths and damaging the device.

In general, the best type of capacitors to use are solid tantalum. Solid tantalum capacitors have low impedance even at high frequencies. Depending upon capacitor construction, it takes about 25μF in aluminum electrolytic to equal 1μF solid tantalum at high frequencies. Ceramic capacitors are also good at high frequencies; but some types have a large decrease in capacitance at frequencies around 0.5 MHz. For this reason, 0.01μF disc may seem to work better than a 0.1μF disc as a bypass.

Although the LM117 is stable with no output capacitors, like any feedback circuit, certain values of external capacitance can cause excessive ringing. This occurs with values between 500 pF and 5000 pF. A 1μF solid tantalum (or 25μF aluminum electrolytic) on the output swamps this effect and insures stability.

Load Regulation

The LM117 is capable of providing extremely good load regulation but a few precautions are needed to obtain maximum performance. The current set resistor connected between the adjustment terminal and the output terminal (usually 240Ω) should be tied directly to the output of the regulator rather than near the load. This eliminates line drops from appearing effectvely in series with the reference and degrading regulation. For example, a 15V regulator with 0.05Ω resistance between the regulator and load will have a load regulation due to line resistance of 0.05Ω x I_L. If the set resistor is connected near the load the effective line resistance will be 0.05Ω (1 + R2/R1) or in this case, 11.5 times worse.

Figure 2 shows the effect of resistance between the regulator and 240Ω set resistor.

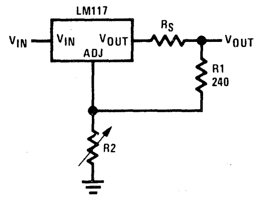


FIGURE 2. Regulator with Line Resistance in Output Lead

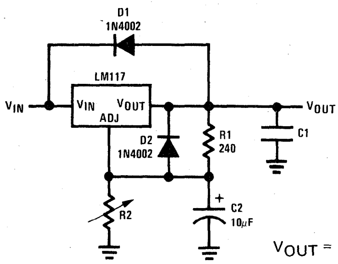
With the TO-3 package, it is easy to minimize the resistance from the case to the set resistor, by using two separate leads to the case. However, with the TO-5 package, care should be taken to minimize the wire length of the output lead. The ground of R2 can be returned near the ground of the load to provide remote ground sensing and improve load regulation.

Protection Diodes

When external capacitors are used with *any* IC regulator it is sometimes necessary to add protection diodes to prevent the capacitors from discharging through low current points into the regulator. Most 10μF capacitors have low enough internal series resistance to deliver 20A spikes when shorted. Although the surge is short, there is enough energy to damage parts of the IC.

When an output capacitor is connected to a regulator and the input is shorted, the output capacitor will discharge into the output of the regulator. The discharge current depends on the value of the capacitor, the output voltage of the regulator, and the rate of decrease of V_{IN}. In the LM117, this discharge path is through a large junction that is able to sustain 15A surge with no problem. This is not true of other types of positive regulators. For output capacitors of 25μF or less, there is no need to use diodes.

The bypass capacitor on the adjustment terminal can discharge through a low current junction. Discharge occurs when *either* the input or output is shorted. Internal to the LM117 is a 50Ω resistor which limits the peak discharge current. No protection is needed for output voltages of 25V or less and 10μF capacitance. *Figure 3* shows an LM117 with protection diodes included for use with outputs greater than 25V and high values of output capacitance.



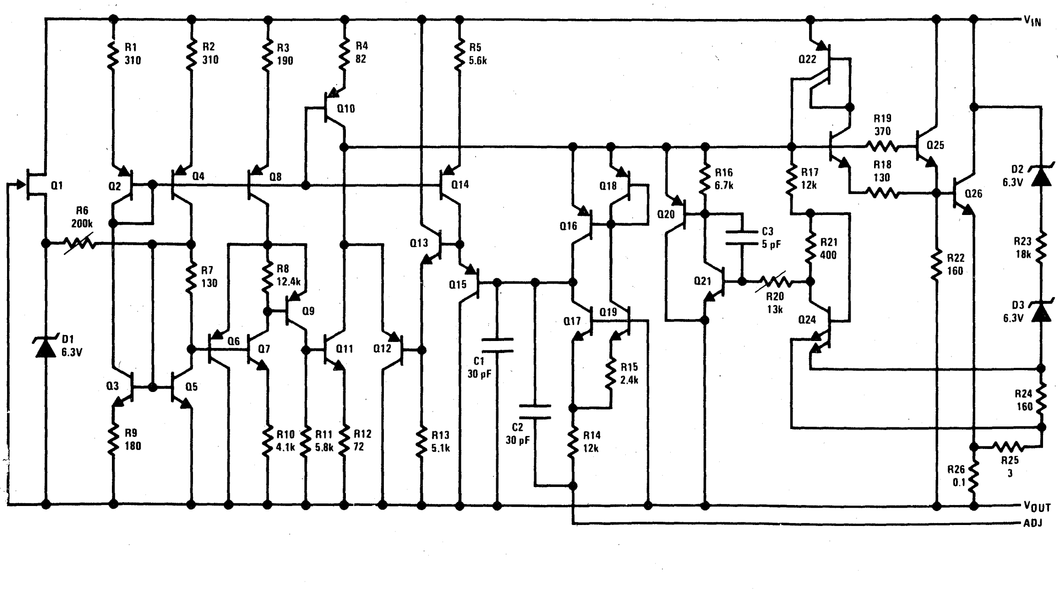
$$V_{OUT} = 1.25V\left(1 + \frac{R2}{R1}\right) + R2 I_{ADJ}$$

D1 protects against C1

D2 protects against C2

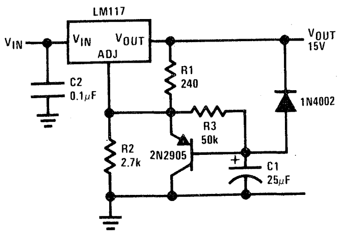
FIGURE 3. Regulator with Protection Diodes

schematic diagram

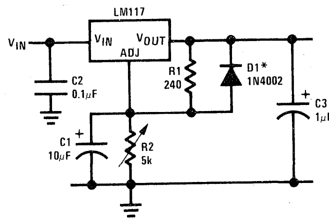


typical applications (con't)

Slow Turn-On 15V Regulator



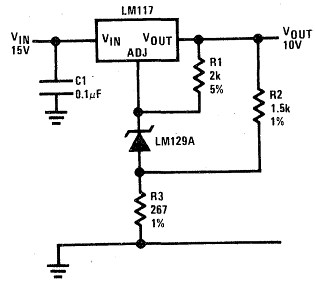
Adjustable Regulator with Improved Ripple Rejection



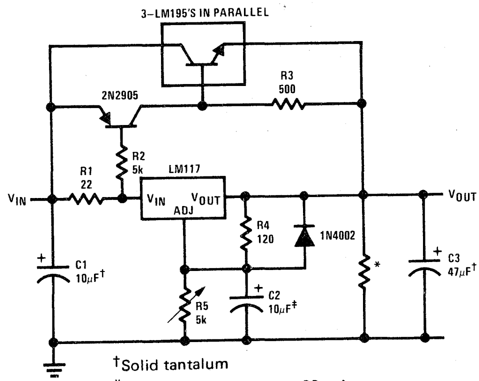
†Solid tantalum

*Discharges C1 if output is shorted to ground

High Stability 10V Regulator



High Current Adjustable Regulator

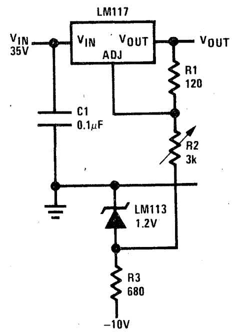


†Solid tantalum

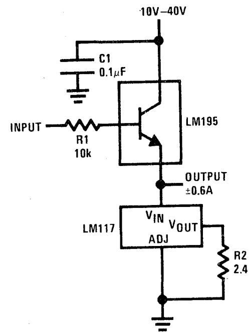
*Minimum load current = 30 mA

‡Optional—improves ripple rejection

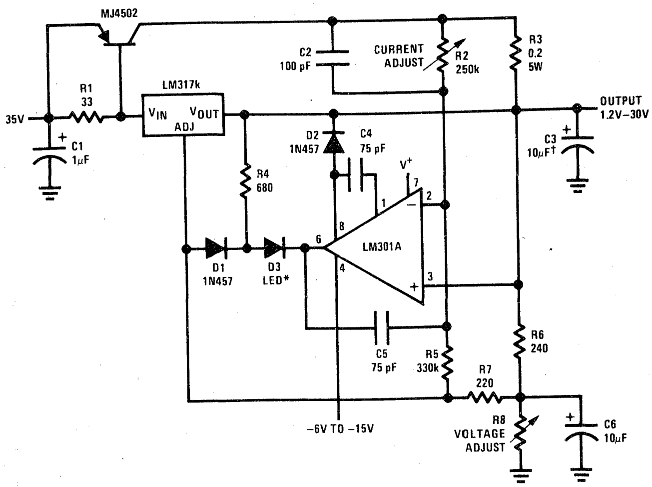
0 to 30V Regulator



Power Follower



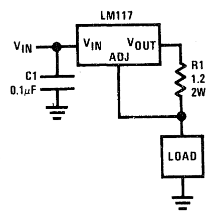
5A Constant Voltage/Constant Current Regulator



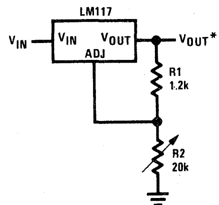
†Solid tantalum

*Lights in constant current mode

1A Current Regulator



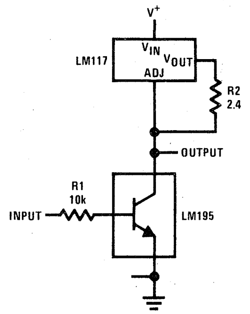
1.2V–20V Regulator with Minimum Program Current



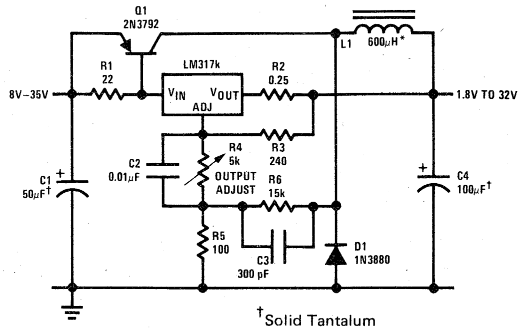
*Minimum load current ≈ 4 mA

typical applications (con't)

High Gain Amplifier

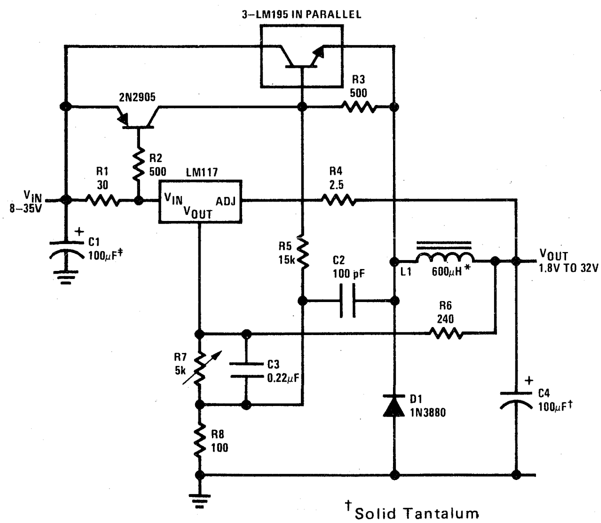


Low Cost 3A Switching Regulator



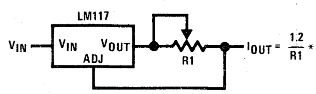
†Solid Tantalum
*Core—Arnold A-254168-2 60 turns

4A Switching Regulator with Overload Protection



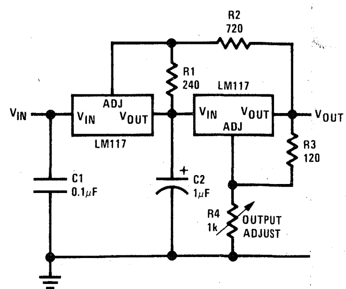
†Solid Tantalum
*Core Arnold A-254168-2 60 turns

Precision Current Limiter

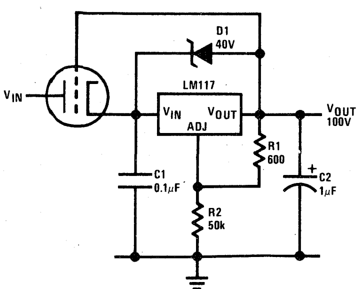


*0.8Ω ≤ R1 ≤ 120Ω

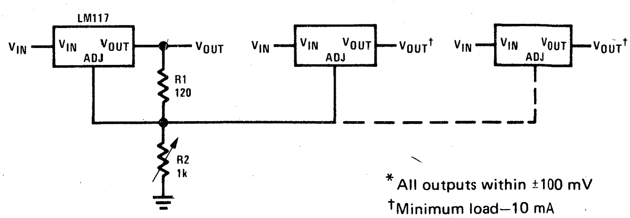
Tracking Preregulator



High Voltage Regulator



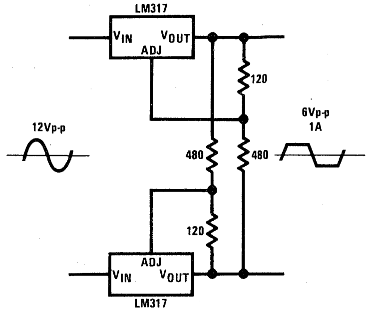
Adjusting Multiple On-Card Regulators with Single Control*



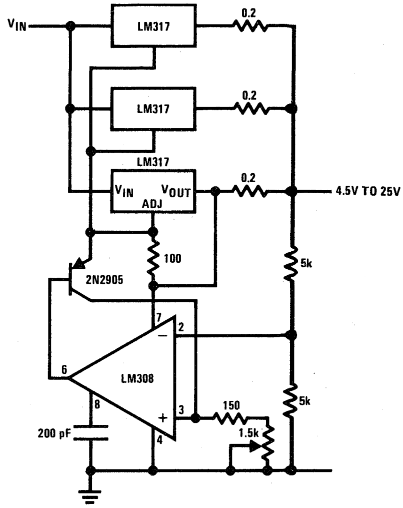
*All outputs within ±100 mV
†Minimum load—10 mA

typical applications (con't)

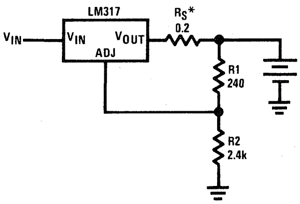
AC Voltage Regulator



Adjustable 4A Regulator

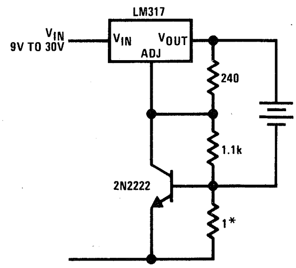


12V Battery Charger



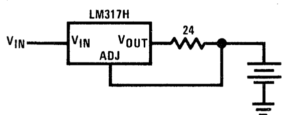
*R_S—sets output ... of charger $Z_{OUT} = R_S\left(1 + \frac{R2}{R1}\right)$
...ng rates with fully

Current Limited 6V Charger



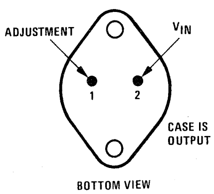
*Sets peak current (0.6A for 1Ω)

Current Battery Charger



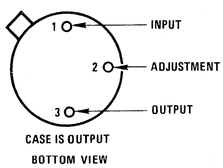
connection diagrams

Metal Can Package



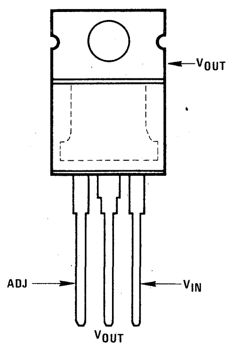
Order Number LM117K, LM217K or LM317K
See Package 18

Metal Can Package



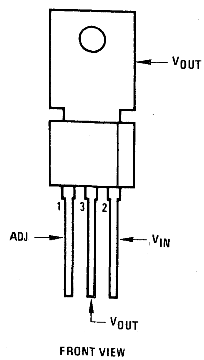
Order Number LM117H, LM217H or LM317H
See Package 9

Plastic Package



Order Number LM317T
See Package 26

Plastic Package



Order Number LM317P
See Package 37

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, −6V, −8V, −9V, −12V, −15V, −18V, and −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 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.

features

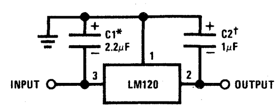
- Preset output voltage error less than ±3%
- Preset current limit
- Internal thermal shutdown
- Operates with input-output voltage differential down to 1V
- Excellent ripple rejection
- Low temperature drift
- Easily adjustable to higher output voltage

120 Series Packages Available

DEVICE	PACKAGE	RATED POWER DISSIPATION	DESIGN LOAD CURRENT
LM120 LM220 LM320	TO-3	20W	1.5A
	TO-5	2W	0.5A
LM320T	TO-220	15W	1.5A
LM320MP	TO-202	7.5W	0.5A

typical applications

Fixed Regulator

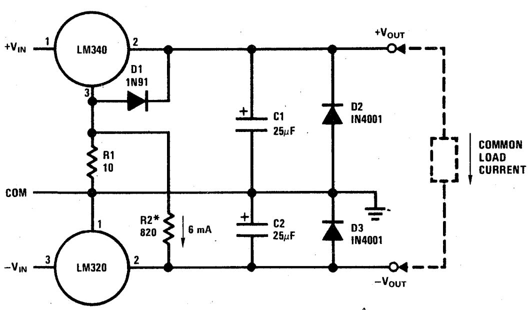


*Required if regulator is separated from filter capacitor by more than 3". For value given, capacitor must be solid tantalum. 25μF aluminum electrolytic may be substituted.

†Required for stability. For value given, capacitor must be solid tantalum. 25μF aluminum electrolytic may 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.

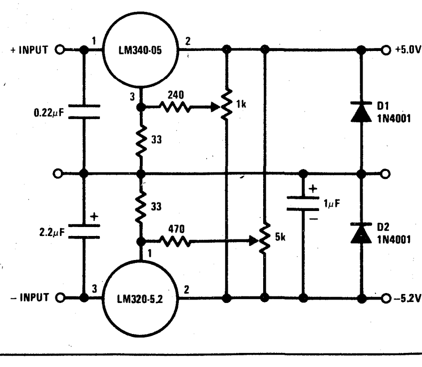
Preventing Positive Regulator Latch-Up



R1 & D1 allow the positive regulator to "start-up" when $^+V_{IN}$ is delayed relative to $^-V_{IN}$ and a heavy load is drawn between the outputs. Without R1 & D1, most three-terminal regulators will not start with heavy (0.1A–1A) load current flowing to the negative regulator, even though the positive output is clamped by D2.

*R2 is optional. Ground pin current from the positive regulator flowing through R1 will increase $+V_{OUT} \approx 60$ mV if R2 is omitted.

Dual Trimmed Supply



–5 VOLT REGULATORS (Note 3)

absolute maximum ratings

Power Dissipation	Internally Limited
Input Voltage	–25V
Input-Output Voltage Differential	25V
Junction Temperatures	See Note 1
Storage Temperature Range	–65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics

		METAL CAN PACKAGE												POWER PLASTIC PACKAGE						
ORDER NUMBERS		LM120K-5.0 LM220K-5.0 (TO-3)			LM320K-5.0 (TO-3)			LM120H-5.0 LM220H-5.0 (TO-5)			LM320H-5.0 (TO-5)			LM320T-5.0 (TO-220)			LM320MP-5.0 (TO-202)			UNITS
DESIGN OUTPUT CURRENT (I_D) DEVICE DISSIPATION (P_D)		1.5A 20W			1.5A 20W			0.5A 2W			0.5A 2W			1.5A 15W			0.5A 7.5W			
PARAMETER	CONDITIONS (NOTE 1)	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	T_J = 25°C, V_{IN} = 10V, I_{LOAD} = 5 mA	–5.1	–5	–4.9	–5.2	–5	–4.8	–5.1	–5.0	–4.9	–5.2	–5.0	–4.8	–5.2	–5.0	–4.8	–5.2	–5.0	–4.8	V
Line Regulation	T_J = 25°C, I_{LOAD} = 5 mA, $V_{MIN} \leq V_{IN} \leq V_{MAX}$		10	25		10	40		10	25		10	40		10	40		10	40	mV
Input Voltage		–25		–7	–25		–7	–25		–7	–25		–7	–25		–7.5	–25		–7.5	V
Ripple Rejection	f = 120 Hz	54	64		54	64		54	64		54	64		54	64		54	64		dB
Load Regulation, (Note 2)	T_J = 25°C, V_{IN} = 10V, 5 mA $\leq I_{LOAD} \leq I_D$		50	75		50	100		30	50		30	50		50	100		40	100	mV
Output Voltage, (Note 1)	–7.5V $\leq V_{IN} \leq V_{MAX}$, 5 mA $\leq I_{LOAD} \leq I_D$, $P \leq P_D$	–5.20		–4.80	–5.25		–4.75	–5.20		–4.80	–5.25		–4.75	–5.25		–4.75	–5.25	–5.0	–4.75	V
Quiescent Current	$V_{MIN} \leq V_{IN} \leq V_{MAX}$		1	2		1	2		1	2		1	2		1	2		1	2	mA
Quiescent Current Change	T_J = 25°C																			
	$V_{MIN} \leq V_{IN} \leq V_{MAX}$		0.1	0.4		0.1	0.4		0.05	0.4		0.05	0.4		0.1	0.4		0.05	0.3	mA
	5 mA $\leq I_{LOAD} \leq I_D$		0.1	0.4		0.1	0.4		0.04	0.4		0.04	0.4		0.1	0.4		0.04	0.25	mA
Output Noise Voltage	T_A = 25°C, C_L = 1μF, I_L = 5 mA, V_{IN} = 10V, 10 Hz $\leq f \leq$ 100 kHz		150			150			150			150			150			150		μV
Long Term Stability			5	50		5	50		5	50		5	50		10			10		mV
Thermal Resistance																				
Junction to Case				3			3			15			15		5			12		°C/W
Junction to Ambient				35			35			150			150		50			70		°C/W

Note 1: Unless otherwise stated, these specifications apply: device dissipation $\leq P_D$, and –55°C $\leq T_J \leq$ +150°C for the LM120, –25°C $\leq T_J \leq$ +150° for the LM220 and 0°C $\leq T_J \leq$ +125°C for the LM320.

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, low duty cycle, pulse testing is used. The LM120/LM320 series does have low thermal feedback, improving line and load regulation. On all other tests, even though power dissipation is internally limited, electrical specifications apply only up to P_D.

Note 3: For –5V 3 amp regulators, see LM145 data sheet.

−5.2 VOLT REGULATORS (Note 3)

absolute maximum ratings

Power Dissipation	Internally Limited
Input Voltage	−25V
Input-Output Voltage Differential	25V
Junction Temperatures	See Note 1
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics

		METAL CAN PACKAGE												POWER PLASTIC PACKAGE						
ORDER NUMBERS		LM120K-5.2 LM220K-5.2 (TO-3)			LM320K-5.2 (TO-3)			LM120H-5.2 LM220H-5 2 (TO-5)			LM320H-5.2 (TO-5)			LM320T-5.2 (TO-220)			LM320MP-5.2 (TO-202)			UNITS
DESIGN OUTPUT CURRENT (I_D) DEVICE DISSIPATION (P_D)		1.5A 20W			1.5A 20W			0.5A 2W			0.5A 2W			1.5A 15W			0.5A 7.5W			
PARAMETER	CONDITIONS (NOTE 1)	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	$T_J = 25°C$, $V_{IN} = 10V$, $I_{LOAD} = 5\ mA$	−5.3	−5.2	−5.1	−5.4	−5.2	−5.0	−5.3	−5.2	−5.1	−5.4	−5.2	−5.0	−5.4	−5.2	−5.0	−5.4	−5.2	−5.0	V
Line Regulation	$T_J = 25°C$, $I_{LOAD} = 5\ mA$, $V_{MIN} \le V_{IN} \le V_{MAX}$		10	25		10	40								10	40		10	40	mV
Input Voltage		−25		−7	−25		−7	−25		−7	−25		−7	−25		−7.5	−25		−7.5	V
Ripple Rejection	f = 120 Hz	54	64		54	64		54	64		54	64		54	64			64		dB
Load Regulation, (Note 2)	$T_J = 25°C$, $V_{IN} = 10V$, $5\ mA \le I_{LOAD} \le I_D$		50	75		50	100		30	50		30	50		50	100		40	100	mV
Output Voltage, (Note 1)	$-7.7V \le V_{IN} \le V_{MAX}$, $5\ mA \le I_{LOAD} \le I_D$, $P \le P_D$	−5.40		−5.00	−5.45		−4.95	−5.40		−5.00	−5.45		−4.95	−5.45		−4.95	−5.45	−5.20	−4.95	V
Quiescent Current	$V_{MIN} \le V_{IN} \le V_{MAX}$		1	2		1	2		1	2		1	2		1	2		1	2	mA
Quiescent Current Change	$T_J = 25°C$																			
	$V_{MIN} \le V_{IN} \le V_{MAX}$		0.1	0.4		0.1	0.4		0.05	0.4		0.05	0.4		0.1	0.4		0.05	0.3	mA
	$5\ mA \le I_{LOAD} \le I_D$		0.1	0.4		0.1	0.4		0.04	0.4		0.04	0.4		0.1	0.4		0.04	0.25	mA
Output Noise Voltage	$T_A = 25°C$, $C_L = 1\mu F$, $I_L = 5\ mA$, $V_{IN} = 10V$, $10\ Hz \le f \le 100\ kHz$		150			150			150			150			150			150		μV
Long Term Stability			5	50		5	50		5	50		5	50		10			10		mV
Thermal Resistance																				
Junction to Case				3			3			15			15		5			12		°C/W
Junction to Ambient				35			35			150			150		50			70		°C/W

Note 1: Unless otherwise stated, these specifications apply: device dissipation $\le P_D$, and $-55°C \le T_J \le +150°C$ for the LM120, $-25°C \le T_J \le +150°$ for the LM220 and $0°C \le T_J \le +125°C$ for the LM320.

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, low duty cycle, pulse testing is used. The LM120/LM320 series does have low thermal feedback, improving line and load regulation. On all other tests, even though power dissipation is internally limited, electrical specifications apply only up to P_D.

Note 3: For −5.2V 3 amp regulators, see LM145 data sheet.

−6 VOLT REGULATORS

absolute maximum ratings

Power Dissipation	Internally Limited
Input Voltage	−25V
Input-Output Voltage Differential	25V
Junction Temperatures	See Note 1
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics

		METAL CAN PACKAGE												POWER PLASTIC PACKAGE						
ORDER NUMBERS		LM120K-6.0 LM220K-6.0 (TO-3)			LM320K-6.0 (TO-3)			LM120H-6.0 LM220H-6.0 (TO-5)			LM320H-6.0 (TO-5)			LM320T-6.0 (TO-220)			LM320MP-6.0 (TO-202)			UNITS
DESIGN OUTPUT CURRENT (I_D) DEVICE DISSIPATION (P_D)		1.5A 20W			1.5A 20W			0.5A 2W			0.5A 2W			1.5A 15W			0.5A 7.5W			
PARAMETER	CONDITIONS (NOTE 1)	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	$T_J = 25°C$, $V_{IN} = 11V$, $I_{LOAD} = 5\ mA$	−6.15	−6	−5.85	−6.25	−6	−5.75	−6.15	−6	−5.85	−6.25	−6	−5.75	−6.25	−6	−5.75	−6.25	−6	−5.75	V
Line Regulation	$T_J = 25°C$, $I_{LOAD} = 5\ mA$, $V_{MIN} \leq V_{IN} \leq V_{MAX}$		10	25		10	40		10	25		10	40		10	40		12	40	mV
Input Voltage		−25		−8	−25		−8	−25		−8	−25		−8	−25		−8.5	−25		−8.5	V
Ripple Rejection	f = 120 Hz	54	64		54	64		54	64		54	64		54	64		54	64		dB
Load Regulation, (Note 2)	$T_J = 25°C$, $V_{IN} = 11V$, $5\ mA \leq I_{LOAD} \leq I_D$		50	75		50	100		30	50		30	50		50	100		40	100	mV
Output Voltage, (Note 1)	$-8.5V \leq V_{IN} \leq V_{MAX}$, $5\ mA \leq I_{LOAD} \leq I_D$, $P \leq P_D$	−6.25		−5.75	−6.30		−5.70	−6.25		−5.75	−6.30		−5.70	−6.3		−5.7	−6.3		−5.7	V
Quiescent Current	$V_{MIN} \leq V_{IN} \leq V_{MAX}$		1	2		1	2		1	2		1	2		1	2		1	2	mA
Quiescent Current Change	$T_J = 25°C$																			
	$V_{MIN} \leq V_{IN} \leq V_{MAX}$		0.1	0.4		0.1	0.4		0.05	0.4		0.05	0.4		0.1	0.4		0.05	0.3	mA
	$5\ mA \leq I_{LOAD} \leq I_D$		0.1	0.4		0.1	0.4		0.04	0.4		0.04	0.4		0.1	0.4		0.04	0.25	mA
Output Noise Voltage	$T_A = 25°C$, $C_L = 1\mu F$, $I_L = 5\ mA$, $V_{IN} = 11V$, $10\ Hz \leq f \leq 100\ kHz$		180			180			180			180			180			180		μV
Long Term Stability			6	60		6	60		6	60		6	60		12			12		mV
Thermal Resistance																				
Junction to Case				3			3			15			15		5			12		°C/W
Junction to Ambient				35			35			150			150		50			70		°C/W

Note 1: Unless otherwise stated, these specifications apply: device dissipation $\leq P_D$, and $-55°C \leq T_J \leq +150°C$ for the LM120, $-25°C \leq T_J \leq +150°$ for the LM220 and $0°C \leq T_J \leq +125°C$ for the LM320.

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, low duty cycle, pulse testing is used. The LM120/LM320 series does have low thermal feedback, improving line and load regulation. On all other tests, even though power dissipation is internally limited, electrical specifications apply only up to P_D.

absolute maximum ratings

Power Dissipation	Internally Limited
Input Voltage	−25V
Input-Output Voltage Differential	25V
Junction Temperatures	See Note 1
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics

		METAL CAN PACKAGE												POWER PLASTIC PACKAGE						
ORDER NUMBERS		LM120K-8.0 LM220K-8.0 (TO-3)			LM320K-8.0 (TO-3)			LM120H-8.0 LM220H-8.0 (TO-5)			LM320H-8.0 (TO-5)			LM320T-8.0 (TO-220)			LM320MP-8.0 (TO-202)			UNITS
DESIGN OUTPUT CURRENT (I_D) DEVICE DISSIPATION (P_D)		1.5A 20W			1.5A 20W			0.5A 2W			0.5A 2W			1.5A 15W			0.5A 7.5W			
PARAMETER	CONDITIONS (NOTE 1)	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	$T_J = 25°C$, $V_{IN} = 13V$, $I_{LOAD} = 5$ mA	−8.2	−8	−7.8	−8.3	−8	−7.7	−8.2	−8	−7.8	−8.3	−8	−7.7	−8.3	−8	−7.7	−8.3	−8.0	−7.7	V
Line Regulation	$T_J = 25°C$, $I_{LOAD} = 5$ mA, $V_{MIN} \leq V_{IN} \leq V_{MAX}$		15	25		15	40		15	25		15	40		15	40		15	40	mV
Input Voltage		−25		−10.5	−25		−10.5	−25		−10.5	−25		−10.5	−25		−10.5	−25		−10.5	V
Ripple Rejection	f = 120 Hz	54	60		54	60		54	60		54	60		54	60		54	60		dB
Load Regulation, (Note 2)	$T_J = 25°C$, $V_{IN} = 13V$, 5 mA $\leq I_{LOAD} \leq I_D$		50	80		50	100		10	25		10	40		50	100		40	100	mV
Output Voltage, (Note 1)	$V_{MIN} \leq V_{IN} \leq V_{MAX}$, 5 mA $\leq I_{LOAD} \leq I_D$, $P \leq P_D$	−8.35		−7.65	−8.4		−7.6	−8.35		−7.65	−8.4		−7.6	−8.4		−7.6	−8.4		−7.6	V
Quiescent Current	$V_{MIN} \leq V_{IN} \leq V_{MAX}$		1	2		1	2		1	2		1	2		1	2		1	2	mA
Quiescent Current Change	$T_J = 25°C$																			
	$V_{MIN} \leq V_{IN} \leq V_{MAX}$		0.1	0.4		0.1	0.4		0.05	0.4		0.05	0.4		0.1	0.4		0.05	0.3	mA
	5 mA $\leq I_{LOAD} \leq I_D$		0.1	0.4		0.1	0.4		0.04	0.4		0.04	0.4		0.1	0.4		0.04	0.25	mA
Output Noise Voltage	$T_A = 25°C$, $C_L = 1\mu F$, $I_L = 5$ mA, $V_{IN} = 13V$, 10 Hz $\leq f \leq$ 100 kHz		250			250			250			250			250			250		µV
Long Term Stability			8	80		8	80		8	80		8	80		16			16		mV
Thermal Resistance																				
Junction to Case				3			3			15			15		5			12		°C/W
Junction to Ambient				35			35			150			150		50			70		°C/W

Note 1: Unless otherwise stated, these specifications apply: device dissipation $\leq P_D$, and $-55°C \leq T_J \leq +150°C$ for the LM120, $-25°C \leq T_J \leq +150°$ for the LM220 and $0°C \leq T_J \leq +125°C$ for the LM320.

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, low duty cycle, pulse testing is used. The LM120/LM320 series does have low thermal feedback, improving line and load regulation. On all other tests, even though power dissipation is internally limited, electrical specifications apply only up to P_D.

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−9 VOLT REGULATORS

absolute maximum ratings

Power Dissipation	Internally Limited
Input Voltage	−35V
Input-Output Voltage Differential	30V
Junction Temperatures	See Note 1
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics

		METAL CAN PACKAGE												POWER PLASTIC PACKAGE						
ORDER NUMBERS		LM120K-9.0 LM220K-9.0 (TO-3)			LM320K-9.0 (TO-3)			LM120H-9.0 LM220H-9.0 (TO-5)			LM320H-9.0 (TO-5)			LM320T-9.0 (TO-220)			LM320MP-9.0 (TO-202)			UNITS
DESIGN OUTPUT CURRENT (I_D) DEVICE DISSIPATION (P_D)		1A 20W			1A 20W			0.2A 2W			0.2A 2W			1A 15W			0.5A 7.5W			
PARAMETER	CONDITIONS (NOTE 1)	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	$T_J = 25°C$, $V_{IN} = 14V$, $I_{LOAD} = 5\ mA$	−9.2	−9	−8.8	−9.35	−9	−8.65	−9.2	−9	−8.8	−9.35	−9	−8.65	−9.35	−9	−8.65	−9.35	−9	−8.65	V
Line Regulation	$T_J = 25°C$, $I_{LOAD} = 5\ mA$, $V_{MIN} \leq V_{IN} \leq V_{MAX}$		4	10		4	20		4	10		4	20		4	20		4	20	mV
Input Voltage		−30		−11.5	−30		−11.5	−30		−11.5	−30		−11.5	−30		−11.5	−30		−11.5	V
Ripple Rejection	f = 120 Hz	56	80		56	80		56	80		56	80		56	80		56	80		dB
Load Regulation, (Note 2)	$T_J = 25°C$, $V_{IN} = 14V$, $5\ mA \leq I_{LOAD} \leq I_D$		30	80		30	80		10	25		10	40		30	80		40	100	mV
Output Voltage, (Note 1)	$-11.5V \leq V_{IN} \leq V_{MAX}$, $5\ mA \leq I_{LOAD} \leq I_D$, $P \leq P_D$	−9.4		−8.6	−9.45		−8.55	−9.4		−8.6	−9.45		−8.55	−9.45		−8.55	−9.45		−8.55	V
Quiescent Current	$V_{MIN} \leq V_{IN} \leq V_{MAX}$		2	4		2	4		2	4		2	4		2	4		2	4	mA
Quiescent Current Change	$T_J = 25°C$																			
	$V_{MIN} \leq V_{IN} \leq V_{MAX}$		0.1	0.4		0.1	0.4		0.05	0.4		0.05	0.4		0.1	0.4		0.05	0.3	mA
	$5\ mA \leq I_{LOAD} \leq I_D$		0.1	0.4		0.1	0.4		0.03	0.4		0.03	0.4		0.1	0.4		0.04	0.25	mA
Output Noise Voltage	$T_A = 25°C$, $C_L = 1\mu F$, $I_L = 5\ mA$, $V_{IN} = 14V$, $10\ Hz \leq f \leq 100\ kHz$		300			300			300			300			300			300		μV
Long Term Stability			9	90		9	90		9	90		9	90		18			18		mV
Thermal Resistance																				
Junction to Case				3			3			15			15		5			12		°C/W
Junction to Ambient				35			35			150			150		50			70		°C/W

Note 1: Unless otherwise stated, these specifications apply: device dissipation $\leq P_D$, and $-55°C \leq T_J \leq +150°C$ for the LM120, $-25°C \leq T_J \leq +150°$ for the LM220 and $0°C \leq T_J \leq +125°C$ for the LM320.

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, low duty cycle, pulse testing is used. The LM120/LM320 series does have low thermal feedback, improving line and load regulation. On all other tests, even though power dissipation is internally limited, electrical specifica-[illegible] only up to P_D.

−12 VOLT REGULATORS

absolute maximum ratings

Power Dissipation	Internally Limited
Input Voltage	−35V
Input-Output Voltage Differential	30V
Junction Temperatures	See Note 1
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics

		METAL CAN PACKAGE												POWER PLASTIC PACKAGE						
ORDER NUMBERS		LM120K-12 LM220K-12 (TO-3)			LM320K-12 (TO-3)			LM120H-12 LM220H-12 (TO-5)			LM320H-12 (TO-5)			LM320T-12 (TO-220)			LM320MP-12 (TO-202)			UNITS
DESIGN OUTPUT CURRENT (I_D)		1A			1A			0.2A			0.2A			1A			0.5A			
DEVICE DISSIPATION (P_D)		20W			20W			2W			2W			15W			7.5W			
PARAMETER	CONDITIONS (NOTE 1)	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	$T_J = 25°C$, $V_{IN} = 17V$, $I_{LOAD} = 5\ mA$	−12.3	−12	−11.7	−12.4	−12	−11.6	−12.3	−12	−11.7	−12.4	−12	−11.6	−12.4	−12	−11.6	−12.5	−12	−11.5	V
Line Regulation	$T_J = 25°C$, $I_{LOAD} = 5\ mA$, $V_{MIN} \leq V_{IN} \leq V_{MAX}$		4	10		4	20		4	10		4	20		4	20		4	24	mV
Input Voltage		−32		−14	−32		−14	−32		−14	−32		−14	−32		−14.5	−32		−14.5	V
Ripple Rejection	f = 120 Hz	56	80		56	80		56	80		56	80		56	80		56	80		dB
Load Regulation, (Note 2)	$T_J = 25°C$, $V_{IN} = 17V$, $5\ mA \leq I_{LOAD} \leq I_D$		30	80		30	80		10	25		10	40		30	80		40	100	mV
Output Voltage, (Note 1)	$14.5V \leq V_{IN} \leq V_{MAX}$, $5\ mA \leq I_{LOAD} \leq I_D$, $P \leq P_D$	−12.5		−11.5	−12.6		−11.4	−12.5		−11.5	−12.6		−11.4	−12.6		−11.4	−12.6		−11.4	V
Quiescent Current	$V_{MIN} \leq V_{IN} \leq V_{MAX}$		2	4		2	4		2	4		2	4		2	4		2	4	mA
Quiescent Current Change	$T_J = 25°C$																			
	$V_{MIN} \leq V_{IN} \leq V_{MAX}$		0.1	0.4		0.1	0.4		0.05	0.4		0.05	0.4		0.1	0.4		0.05	0.3	mA
	$5\ mA \leq I_{LOAD} \leq I_D$		0.1	0.4		0.1	0.4		0.03	0.4		0.03	0.4		0.1	0.4		0.04	0.25	mA
Output Noise Voltage	$T_A = 25°C$, $C_L = 1\mu F$, $I_L = 5\ mA$, $V_{IN} = 17V$, $10\ Hz \leq f \leq 100\ kHz$		400			400			400			400			400			400		µV
Long Term Stability			12	120		12	120		120	120		12	120		24			24		mV
Thermal Resistance																				
Junction to Case				3			3			15			15		5			12		°C/W
Junction to Ambient				35			35			150			150		50			70		°C/W

Note 1: Unless otherwise stated, these specifications apply: device dissipation $\leq P_D$, and $-55°C \leq T_J \leq +150°C$ for the LM120, $-25°C \leq T_J \leq +150°$ for the LM220 and $0°C \leq T_J \leq +125°C$ for the LM320.

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, low duty cycle, pulse testing is used. The LM120/LM320 series does have low thermal feedback, improving line and load regulation. On all other tests, even though power dissipation is internally limited, electrical specifications apply only up to P_D.

–15 VOLT REGULATORS

absolute maximum ratings

Power Dissipation	Internally Limited
Input Voltage	
LM120/LM320	–40V
LM320T/LM320MP	–35V
Input-Output Voltage Differential	30V
Junction Temperatures	See Note 1
Storage Temperature Range	–65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics

		METAL CAN PACKAGE												POWER PLASTIC PACKAGE						
ORDER NUMBERS		LM120K-15 LM220K-15 (TO-3)			LM320K-15 (TO-3)			LM120H-15 LM220H-15 (TO-5)			LM320H-15 (TO-5)			LM320T-15 (TO-220)			LM320MP-15 (TO-202)			UNITS
DESIGN OUTPUT CURRENT (I_D) DEVICE DISSIPATION (P_D)		1A 20W			1A 20W			0.2A 2W			0.2A 2W			1A 15W			0.5A 7.5W			
PARAMETER	CONDITIONS (NOTE 1)	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	$T_J = 25°C$, $V_{IN} = 20V$, $I_{LOAD} = 5$ mA	–15.3	–15	–14.7	–15.4	–15	–14.6	–15.3	–15	–14.7	–15.4	–15	–14.6	–15.5	–15	–14.5	–15.6	–15	–14.4	V
Line Regulation	$T_J = 25°C$, $I_{LOAD} = 5$ mA, $V_{MIN} \leq V_{IN} \leq V_{MAX}$		5	10		5	20		5	10		5	20		5	20		5	30	mV
Input Voltage		–35		–17	–35		–17	–35		–17	–35		–17	–35		–17.5	–35		–17.5	V
Ripple Rejection	f = 120 Hz	56	80		56	80		56	80		56	80		56	80		56	80		dB
Load Regulation, (Note 2)	$T_J = 25°C$, $V_{IN} = 20V$, $5\text{ mA} \leq I_{LOAD} \leq I_D$		30	80		30	80		10	25		10	40		30	80		40	100	mV
Output Voltage, (Note 1)	$17.5V \leq V_{IN} \leq V_{MAX}$, $5\text{ mA} \leq I_{LOAD} \leq I_D$, $P \leq P_D$	–15.5		–14.5	–15.6		–14.4	–15.5		–14.5	–15.6		–14.4	–15.7		–14.3	–15.7		–14.3	V
Quiescent Current	$V_{MIN} \leq V_{IN} \leq V_{MAX}$		2	4		2	4		2	4		2	4		2	4		2	4	mA
Quiescent Current Change	$T_J = 25°C$																			
	$V_{MIN} \leq V_{IN} \leq V_{MAX}$		0.1	0.4		0.1	0.4		0.05	0.4		0.05	0.4		0.1	0.4		0.05	0.3	mA
	$5\text{ mA} \leq I_{LOAD} \leq I_D$		0.1	0.4		0.1	0.4		0.03	0.4		0.03	0.4		0.1	0.4		0.04	0.25	mA
Output Noise Voltage	$T_A = 25°C$, $C_L = 1\mu F$, $I_L = 5$ mA, $V_{IN} = 20V$, $10\text{ Hz} \leq f \leq 100\text{ kHz}$		400			400			400			400			400			400		µV
Long Term Stability			15	150		15	150		15	150		15	150		30			30		mV
Thermal Resistance																				
Junction to Case				3			3			15			15		5			12		°C/W
Junction to Ambient				35			35			150			150		50			70		°C/W

Note 1: Unless otherwise stated, these specifications apply: device dissipation $\leq P_D$, and $-55°C \leq T_J \leq +150°C$ for the LM120, $-25°C \leq T_J \leq +150°$ for the LM220 and $0°C \leq T_J \leq +125°C$ for the LM320.

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, low duty cycle, pulse testing is used. The LM120/LM320 series does have low thermal feedback, improving line and load regulation. On all other tests, even though power dissipation is internally limited, electrical specifications apply only up to P_D.

−18 VOLT REGULATORS

absolute maximum ratings

Power Dissipation	Internally Limited
Input Voltage	
LM120/LM320	−40V
LM320T/LM320MP	−35V
Input-Output Voltage Differential	30V
Junction Temperatures	See Note 1
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics

		METAL CAN PACKAGE												POWER PLASTIC PACKAGE						
ORDER NUMBERS		LM120K-18 LM220K-18 (TO-3)			LM320K-18 (TO-3)			LM120H-18 LM220H-18 (TO-5)			LM320H-18 (TO-5)			LM320T-18 (TO-220)			LM320MP-18 (TO-202)			UNITS
DESIGN OUTPUT CURRENT (I_D)		1A			1A			0.2A			0.2A			1A			0.5A			
DEVICE DISSIPATION (P_D)		20W			20W			2W			2W			15W			7.5W			
PARAMETER	CONDITIONS (NOTE 1)	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	$T_J = 25°C$, $V_{IN} = 23V$, $I_{LOAD} = 5\ mA$	−18.4	−18.0	−17.6	−18.6	−18.0	−17.4	−18.4	−18.0	−17.6	−18.6	−18.0	−17.4	−18.6	−18.0	−17.4	−18.7	−18	−17.3	V
Line Regulation	$T_J = 25°C$, $I_{LOAD} = 5\ mA$, $V_{MIN} \le V_{IN} \le V_{MAX}$		6	12		6	24		6	12		6	24		6	24		6	36	mV
Input Voltage		−35		−20.5	−35		−20.5	−35		−20.5	−35		−20.5	−35		−21	−35		−21	V
Ripple Rejection	f = 120 Hz	54	75			75		54	75			75		54	75		54	75		dB
Load Regulation, (Note 2)	$T_J = 25°C$, $V_{IN} = 23V$, $5\ mA \le I_{LOAD} \le I_D$		30	80		30	80		10	25		10	40		30	80		40	100	mV
Output Voltage, (Note 1)	$21V \le V_{IN} \le V_{MAX}$, $5\ mA \le I_{LOAD} \le I_D$, $P \le P_D$	−18.6		−17.4		−18.9	−17.1	−18.6		−17.4	−18.9		−17.1	−18.9		−17.1	−18.9	–	−17.1	V
Quiescent Current	$V_{MIN} \le V_{IN} \le V_{MAX}$		2	4		2	4		2	4		2	4		2	4		2	4	mA
Quiescent Current Change	$T_J = 25°C$																			
	$V_{MIN} \le V_{IN} \le V_{MAX}$		0.1	0.4		0.1	0.4		0.05	0.4		0.05	0.4		0.1	0.4		0.05	0.3	mA
	$5\ mA \le I_{LOAD} \le I_D$		0.1	0.4		0.1	0.4		0.03	0.4		0.03	0.4		0.1	0.4		0.04	0.25	mA
Output Noise Voltage	$T_A = 25°C$, $C_L = 1 \mu F$, $I_L = 5\ mA$, $V_{IN} = 23V$, $10\ Hz \le f \le 100\ kHz$		500			500			500			500			500					μV
Long Term Stability			18	180		18	180		18	180		18	180		36			36		mV
Thermal Resistance																				
Junction to Case				3			3			15			15		5			12		°C/W
Junction to Ambient				35			35			150			150		50			70		°C/W

Note 1: Unless otherwise stated, these specifications apply: device dissipation $\le P_D$, and $-55°C \le T_J \le +150°C$ for the LM120, $-25°C \le T_J \le +150°$ for the LM220 and $0°C \le T_J \le +125°C$ for the LM320.

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, low duty cycle, pulse testing is used. The LM120/LM320 series does have low thermal feedback, improving line and load regulation. On all other tests, even though power dissipation is internally limited, electrical specifications apply only up to P_D.

−24 VOLT REGULATORS

absolute maximum ratings

Power Dissipation	Internally Limited
Input Voltage	
LM120/LM320	−42V
LM320T/LM320MP	−40V
Input-Output Voltage Differential	35V
Junction Temperatures	See Note 1
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics

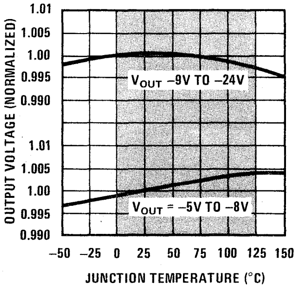
		METAL CAN PACKAGE												POWER PLASTIC PACKAGE						
ORDER NUMBERS		LM120K-24 LM220K-24 (TO-3)			LM320K-24 (TO-3)			LM120H-24 LM220H-24 (TO-5)			LM320H-24 (TO-5)			LM320T-24 (TO-220)			LM320MP-24 (TO-202)			UNITS
DESIGN OUTPUT CURRENT (I_D)		1A			1A			0.2A			0.2A			1A			0.5A			
DEVICE DISSIPATION (P_D)		20W			20W			2W			2W			15W			7.5W			
PARAMETER	CONDITIONS (NOTE 1)	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	T_J = 25°C, V_{IN} = 29V, I_{LOAD} = 5 mA	−24.5	−24	−23.5	−24.8	−24	−23.2	−24.5	−24	−23.5	−24.8	−24	−23.2	−24.8	−24	−23.2	−25	−24	−23	V
Line Regulation	T_J = 25°C, I_{LOAD} = 5 mA, $V_{MIN} \le V_{IN} \le V_{MAX}$		8	20		8	36		8	20		8	36		8	36		8	50	mV
Input Voltage		−40		−27	−40		−27	−40		−27	−40		−27	−40		−27	−40		−27	V
Ripple Rejection	f = 120 Hz	54	70		54	70		54	70		54	70		54	70			70		dB
Load Regulation, (Note 2)	T_J = 25°C, V_{IN} = 29V, 5 mA $\le I_{LOAD} \le I_D$		30	80		30	80		15	25		15	40		30	80		40	100	mV
Output Voltage, (Note 1)	$V_{MIN} \le V_{IN} \le V_{MAX}$, 5 mA $\le I_{LOAD} \le I_D$, $P \le P_D$	−24.8		−23.2	−25.2		−22.8	−24.8		−23.2	−25.2		−22.8	−25.2		−22.8	−25.2		−22.8	V
Quiescent Current	$V_{MIN} \le V_{IN} \le V_{MAX}$		2	4		2	4		2	4		2	4		2	4		2	4	mA
Quiescent Current Change	T_J = 25°C																			
	$V_{MIN} \le V_{IN} \le V_{MAX}$		0.1	0.4		0.1	0.4		0.05	0.4		0.05	0.4		0.1	0.4		0.05	0.3	mA
	5 mA $\le I_{LOAD} \le I_D$		0.1	0.4		0.1	0.4		0.03	0.4		0.03	0.4		0.1	0.4		0.04	0.25	mA
Output Noise Voltage	T_A = 25°C, C_L = 1μF, I_L = 5 mA, V_{IN} = 29V, 10 Hz $\le f \le$ 100 kHz		700			700						700			700					μV
Long Term Stability			24	240		24	240		24	240		24	240		50			50		mV
Thermal Resistance																				
Junction to Case				3			3			15			15		5			12		°C/W
Junction to Ambient				35			35			150			150		50			70		°C/W

Note 1: Unless otherwise stated, these specifications apply: device dissipation $\le P_D$, and $-55°C \le T_J \le +150°C$ for the LM120, $-25°C \le T_J \le +150°$ for the LM220 and $0°C \le T_J \le +125°C$ for the LM320.

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, low duty cycle, pulse testing is used. The LM120/LM320 series does have low thermal feedback, improving line and load regulation. On all other tests, even though power dissipation is internally limited, electrical specifications apply only up to P_D.

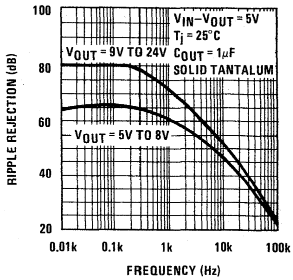
typical performance characteristics

Output Voltage vs Temperature

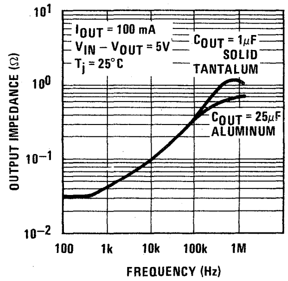


Note: Shaded portion refers to LM320 series regulators.

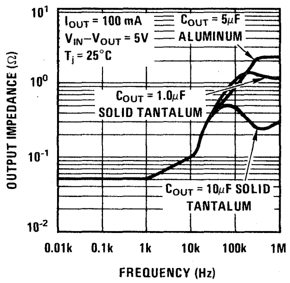
Ripple Rejection (All Types)



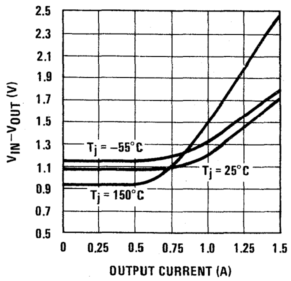
Output Impedance TO-3 and TO-220 Packages



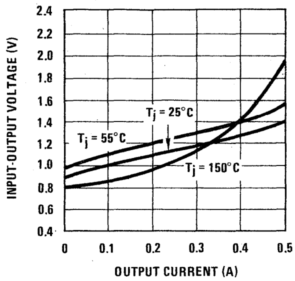
Output Impedance TO-5 and TO-202 Packages



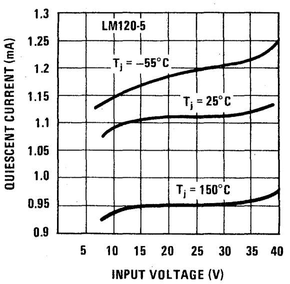
Minimum Input-Output Differential TO-3 and TO-220 Packages



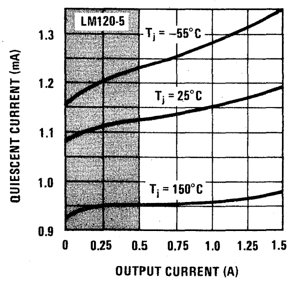
Minimum Input-Output Differential TO-5 and TO-202 Packages



Quiescent Current vs Input Voltage

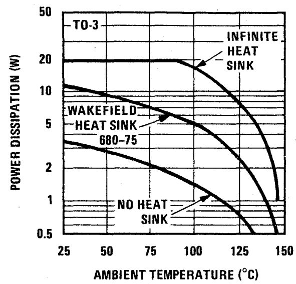


Quiescent Current vs Load Current

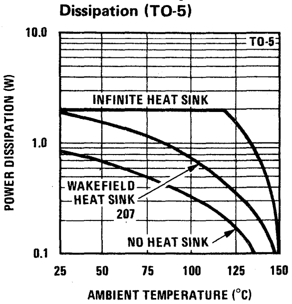


Note: Shaded area shows operating range of TO-5 and TO-202 packages.

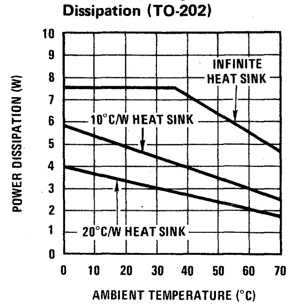
Maximum Average Power Dissipation (TO-3)



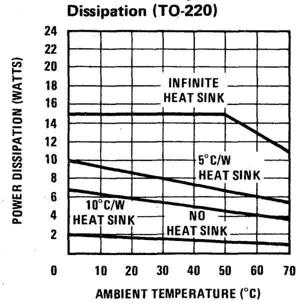
Maximum Average Power Dissipation (TO-5)



Maximum Average Power Dissipation (TO-202)

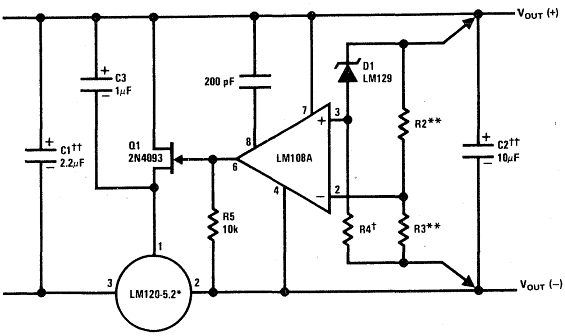


Maximum Average Power Dissipation (TO-220)



typical applications (con't)

High Stability 1 Amp Regulator



Load and line regulation <0.01% temperature stability < 0.2%

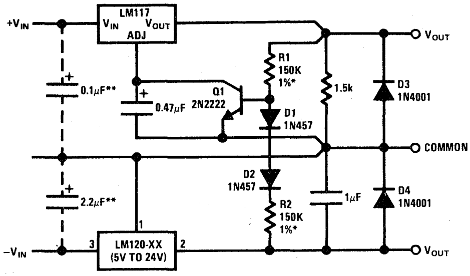
†Determines Zener current.

††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. 2 ppm/°C tracking suggested.

Wide Range Tracking Regulator

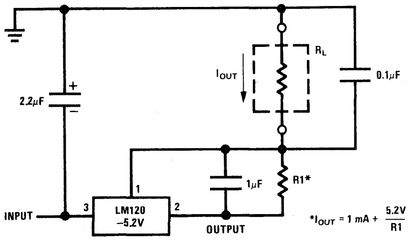


*Resistor tolerance of R1 and R2 determine matching of (+) and (−) inputs.

**Necessary only if raw supply capacitors are more than 3" from regulators

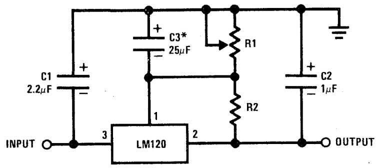
An LM3086N array may substitute for Q1, D1 and D2 for better stability and tracking. In the array diode, transistors Q5 and Q4 (in parallel) make up D2; similarly, Q1 and Q2 become D1 and Q3 replaces the 2N2222.

Current Source



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

Variable Output



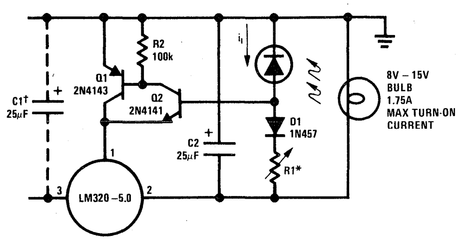
*Optional. Improves transient response and ripple rejection.

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

SELECT R2 AS FOLLOWS

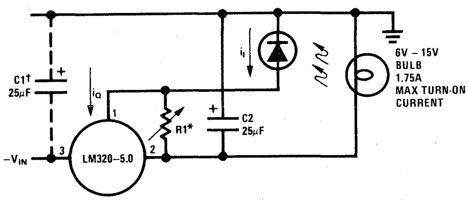
LM120-5/5.2/6	– 300Ω
LM120-8/9	– 470Ω
LM120-12	– 750Ω
LM120-15	– 1K
LM120-18	– 1.2K
LM120-24	– 1.5K

Light Controllers Using Silicon Photo Cells



*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 LM320MP.

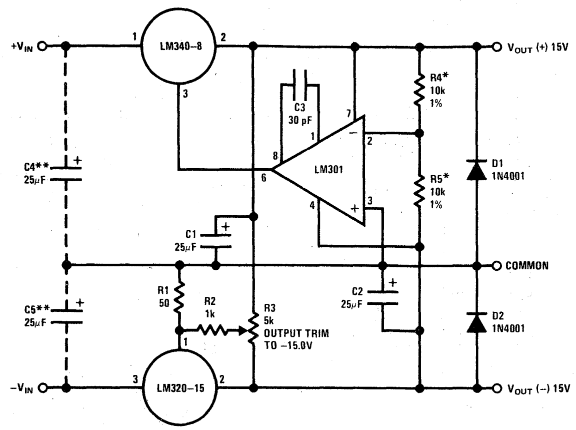


*Lamp brightness increases until $i_l = i_Q$ (≈ 1 mA) + 5V/R1.

†Necessary only if raw supply filter capacitor is more than 2" from LM320.

typical applications (con't)

±15V, 1 Amp Tracking Regulators

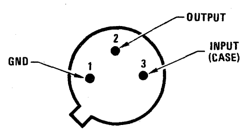


Performance (Typical)

Load Regulation at $\Delta I_L = 1A$	10 mV	1 mV
Output Ripple, $C_{IN} = 3000\mu F$, $I_L = 1A$	100μVrms	100μVrms
Temperature Stability	+50 mV	+50 mV
Output Noise 10 Hz $\leq f \leq$ 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.

connection diagrams

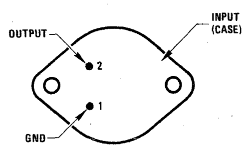


BOTTOM VIEW

Metal Can Package TO-5 (H)
Order Numbers:

LM120H-5.0	LM120H-8.0	LM120H-15
LM220H-5.0	LM220H-8.0	LM220H-15
LM320H-5.0	LM320H-8.0	LM320H-15
LM120H-5.2	LM120H-9.0	LM120H-18
LM220H-5.2	LM220H-9.0	LM220H-18
LM320H-5.2	LM320H-9.0	LM320H-18
LM120H-6.0	LM120H-12	LM120H-24
LM220H-6.0	LM220H-12	LM220H-24
LM320H-6.0	LM320H-12	LM320H-24

See Package 9

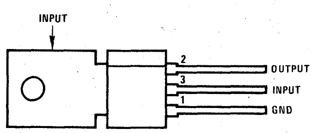


BOTTOM VIEW

Steel Metal Can Package TO-3 (K)
Order Numbers:

LM120K-5.0	LM120K-8.0	LM120K-15
LM220K-5.0	LM220K-8.0	LM220K-15
LM320K-5.0	LM320K-8.0	LM320K-15
LM120K-5.2	LM120K-9.0	LM120K-18
LM220K-5.2	LM220K-9.0	LM220K-18
LM320K-5.2	LM320K-9.0	LM320K-18
LM120K-6.0	LM120K-12	LM120K-24
LM220K-6.0	LM220K-12	LM220K-24
LM320K-6.0	LM320K-12	LM320K-24

For Aluminum TO-3 Package
Order Number LM320KC-XX
See Package 18

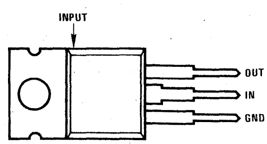


FRONT VIEW

Power Package TO-202 (P)
Order Numbers:

LM320MP–5.0	LM320MP–8.0	LM320MP–15
LM320MP–5.2	LM320MP–9.0	LM320MP–18
LM320MP–6.0	LM320MP–12	LM320MP–24

See Package 37



TOP VIEW

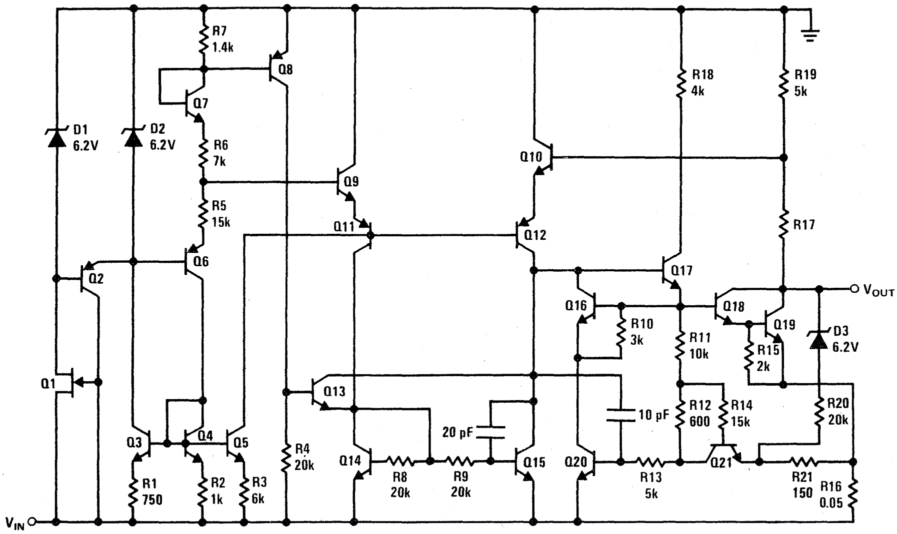
Power Package TO-220 (T)
Order Numbers:

LM320T-5.0	LM320T-12
LM320T-5.2	LM320T-15
LM320T-6.0	LM320T-18
LM320T-8.0	LM320T-24

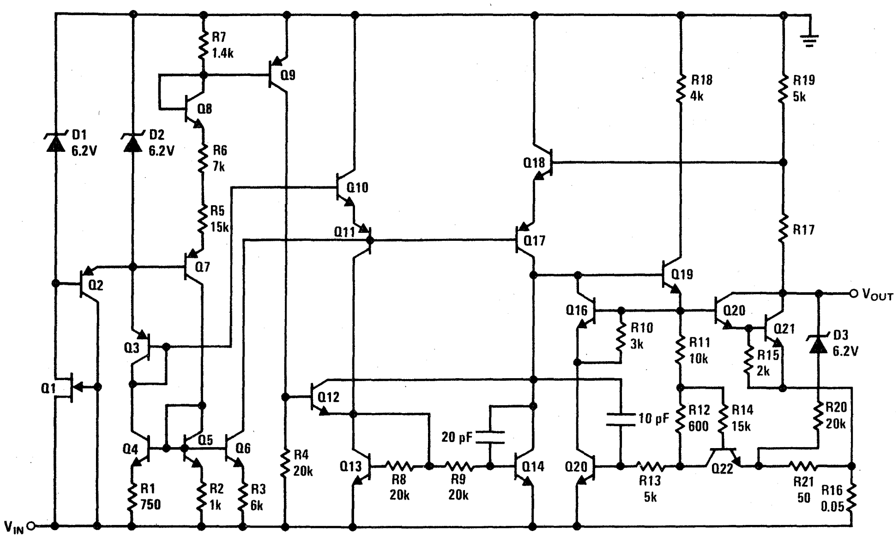
See Package 26

schematic diagrams

–5V through –8V



–9V through –24V



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.

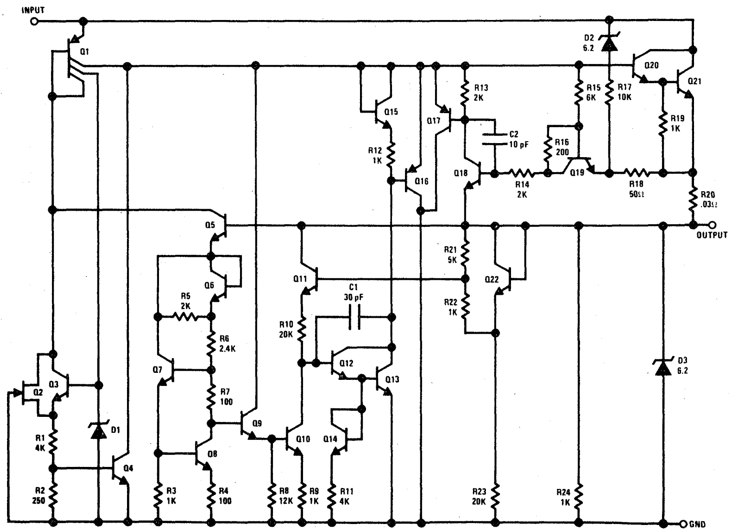
An overall worst case specification for the combined effects of input voltage, load currents, ambient temperature, and power dissipation ensure that the LM123 will perform satisfactorily as a system element.

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

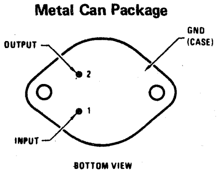
- 3 amp output current
- Internal current and thermal limiting
- 0.01Ω typical output impedance
- 7.5 minimum input voltage
- 30W power dissipation

schematic diagram



connection diagram

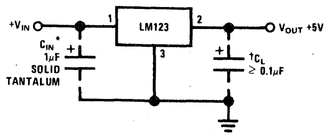
Metal Can Package



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

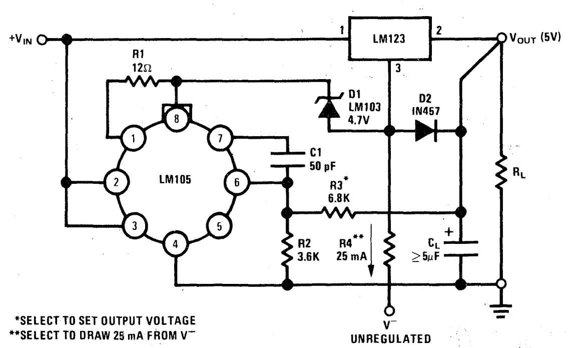
Note 1: Unless otherwise noted, specifications apply for −55°C ≤ T_j ≤ +150°C for the LM123, −25°C ≤ T_j ≤ +150°C for the LM223, and 0°C ≤ T_j ≤ +125°C for the LM323. Although power dissipation is internally limited, specifications apply only for P ≤ 30W.

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%.

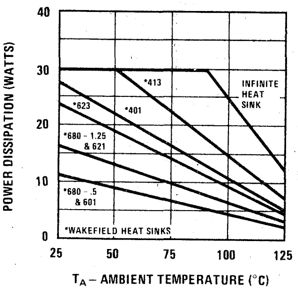
typical applications (con't)

Adjustable Output 5V – 10V 0.1% Regulation

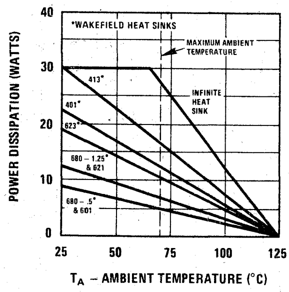


typical performance characteristics

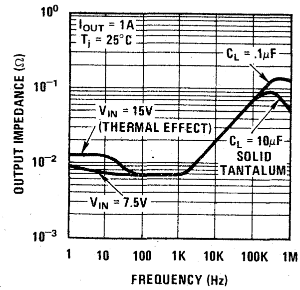
Maximum Average Power Dissipation For LM123; LM223



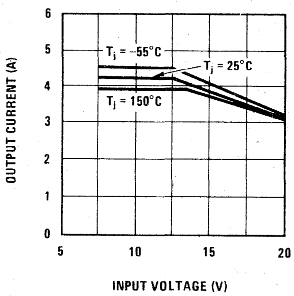
Maximum Average Power Dissipation For LM323



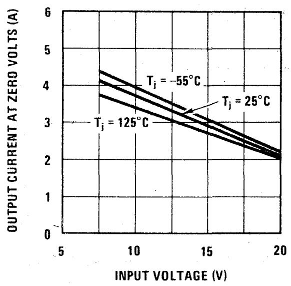
Output Impedance



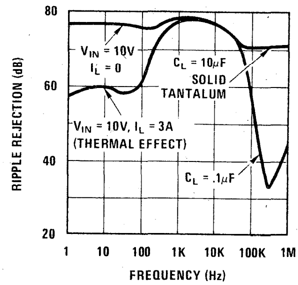
Peak Available Output Current



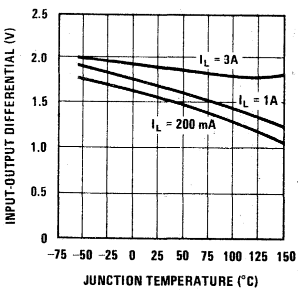
Short Circuit Current



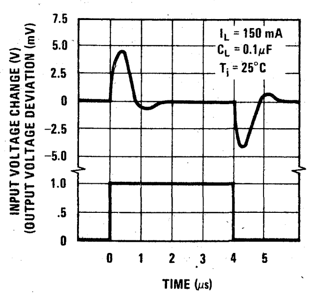
Ripple Rejection



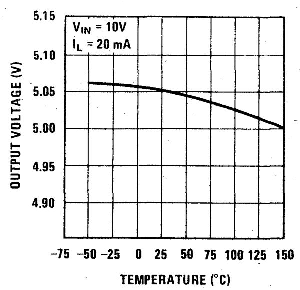
Dropout Voltage



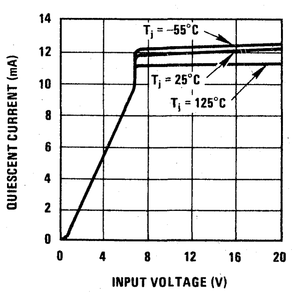
Line Transient Response



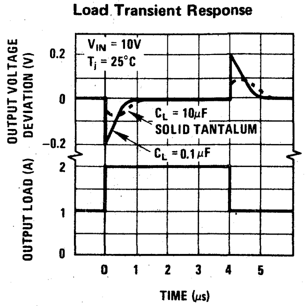
Output Voltage



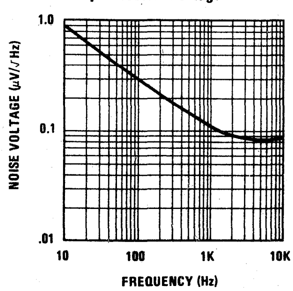
Quiescent Current



Load Transient Response



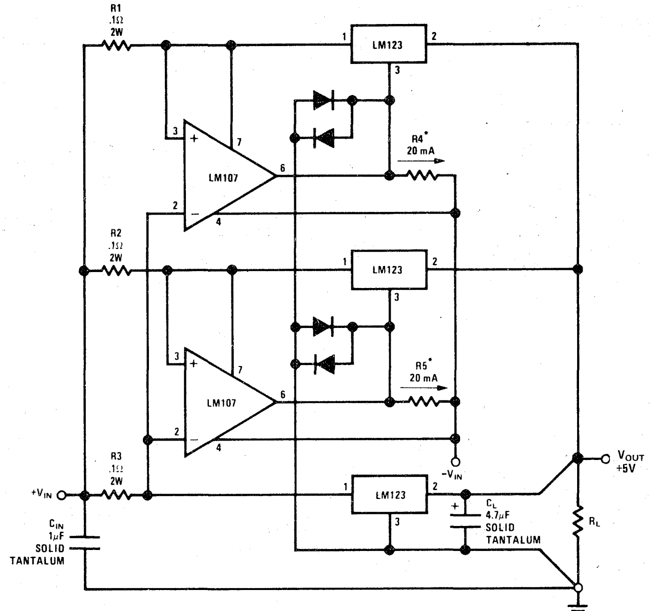
Output Noise Voltage



1

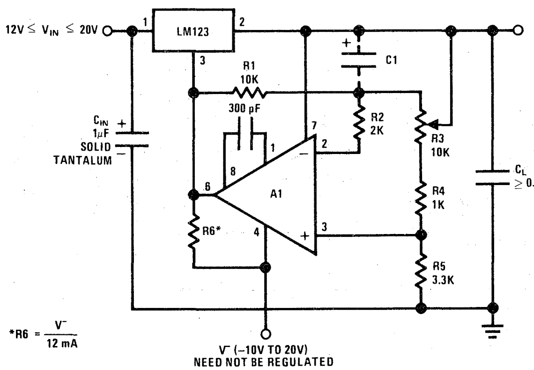
typical applications (con't)

10 Amp Regulator With Complete Overload Protection



*SELECT FOR 20 mA CURRENT FROM UNREGULATED NEGATIVE SUPPLY

Adjustable Regulator 0—10V @ 3A

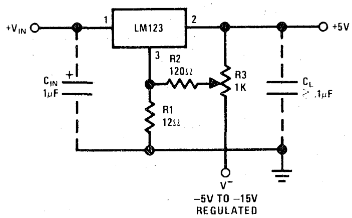


*R6 = $\frac{V^-}{12\text{ mA}}$

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 LM126/LM226/LM326 LM127/LM227/LM327

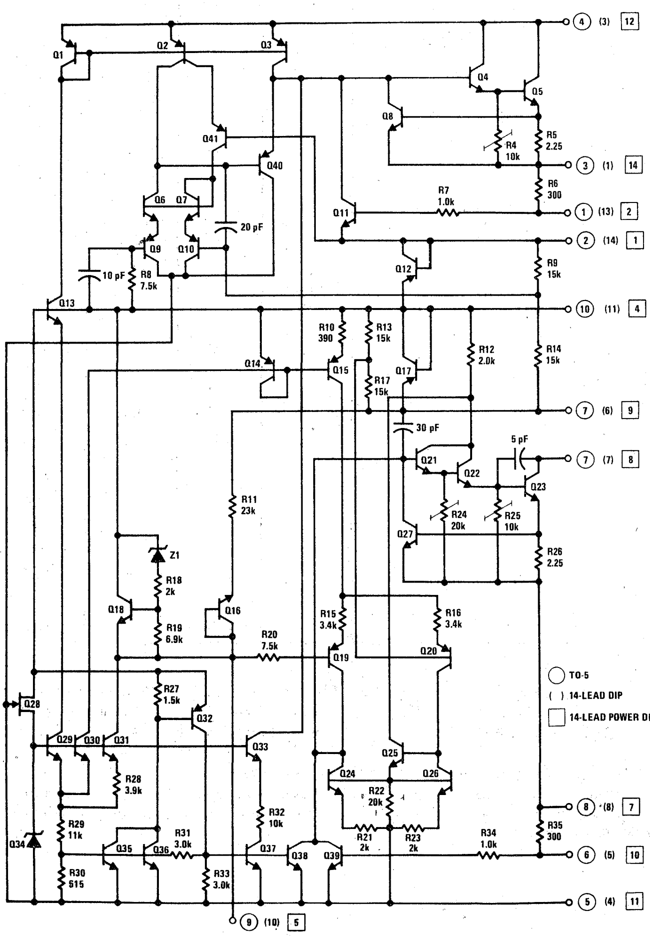
general description

These are dual polarity tracking regulators designed to provide balanced positive and negative output voltages at current up to 100 mA, the devices are set for ±15 V, ±12 V and +5, -12 V outputs respectively. Input voltages up to ±30V can be used and there is provision for adjustable current limiting. These devices are available in three package types to accommodate various power requirements and temperature ranges.

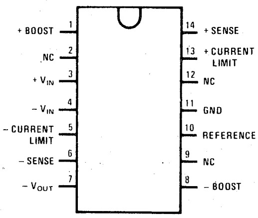
features

- ±15V, ±12V and +5, -12V tracking outputs
- Output currents to 100 mA
- Output voltages balanced to within 1% (LM125, LM126, LM127, 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

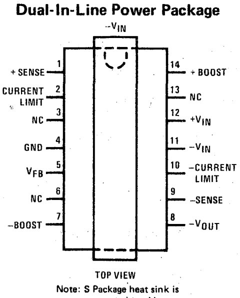


Dual-In-Line Package



Order Number LM325AN, LM325N, LM326N or LM327N
See Package 22

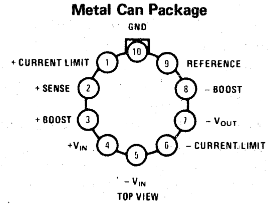
Dual-In-Line Power Package



Note: S Package heat sink is connected to $-V_{IN}$.

Order Number LM325AS, LM325S, LM326S or LM327S
See Package 39

Metal Can Package



Order Number LM125H, LM225H, LM325H, LM126H, LM226H, LM326H, LM127H, LM227H or LM327H
See Package 12

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 LM125/LM225/LM325/LM325A (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, 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				
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 junction to case values specified, depending on the efficiency of the sink.

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 LM126/LM226/LM326 (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, $V_{IN} = \pm30V$, $T_j = 25°C$				
V_O^+			3.0	10	mV
V_O^-			5.0	10	mV
Load Regulation Over Temperature Range	$I_L = 0$ to 50 mA, $V_{IN} = \pm30V$				
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, $15V \leq \lvert V_{IN}\rvert \leq 30V$				
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, $V_{IN} = \pm20V$, $I_L = 0$ 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 junction to case values specified, depending on the efficiency of the sink.

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 LM127/LM227/LM327 (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, $V_{IN} = \pm 30V$, $T_j = 25°C$				
V_O^+			3.0	10	mV
V_O^-			5.0	10	mV
Load Regulation Over Temperature Range	$I_L = 0$ to 50 mA, $V_{IN} = \pm 30V$				
V_O^+			4.0	20	mV
V_O^-			7.0	20	mV
Output Voltage	$P < P_{MAX}$, $0 \leq I_O \leq 50$ mA, $+8.0V \leq V^+_{IN} \leq +30V$, $-30V \leq V^-_{IN} \leq -15V$				
V_O^+		4.75		5.25	V
V_O^-		−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.

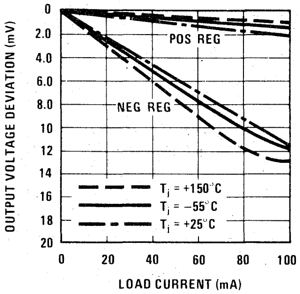
Note 2: Unless otherwise specified, these specifications apply for $T_j = -55°C$ to $+150°C$ on LM127, $T_j = -25°C$ to $+150°C$ on LM227, $T_j = 0°C$ to $+125°C$ on LM327, $V_{IN} = \pm 20V$, $I_L = 0$ mA. $I_{MAX} = 100$ mA, $P_{MAX} = 2.0W$ for the TO-5H Package, $I_{MAX} = 100$ mA, $P_{MAX} = 5.0W$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

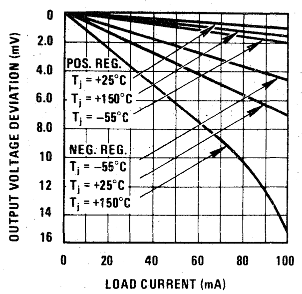
Note 4: Without a heat sink, the thermal resistance junction to ambient of the TO-5 Package is about 150°C/W, while that of the S Package is approximately 55°C/W. With a heat sink, the effective thermal resistance can only approach the junction to case values specified, depending on the efficiency of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

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

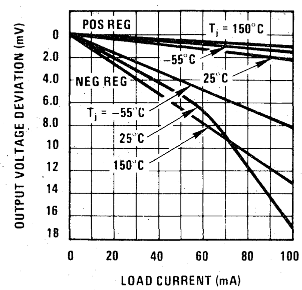
LM125 Load Regulation



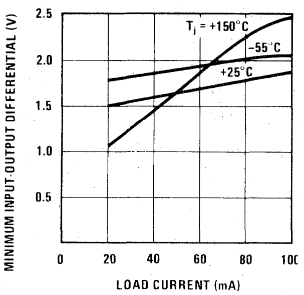
LM126 Load Regulation



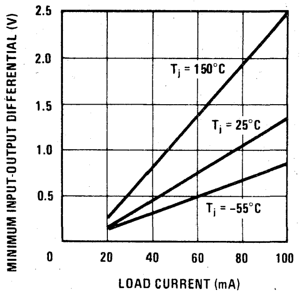
LM127 Load Regulation



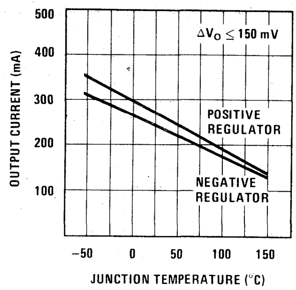
LM125/126/127 Regulator Dropout Voltage for Positive Regulator



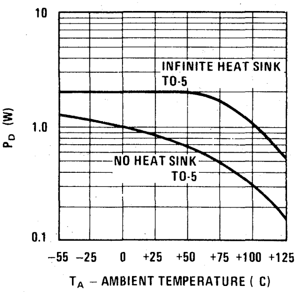
LM125/126/127 Regulator Dropout Voltage for Negative Regulator



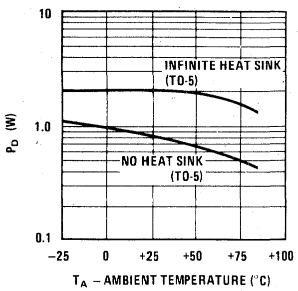
LM125/126/127 Peak Output Current vs Junction Temperature



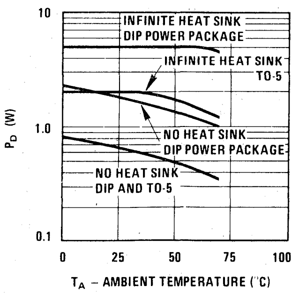
LM125/126/127 Maximum Average Power Dissipation vs Ambient Temperature



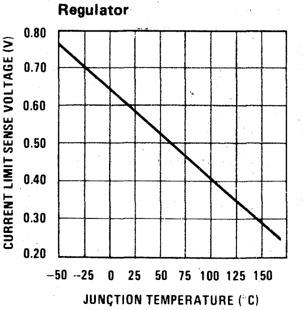
LM225/226/227 Maximum Average Power Dissipation vs Ambient Temperature



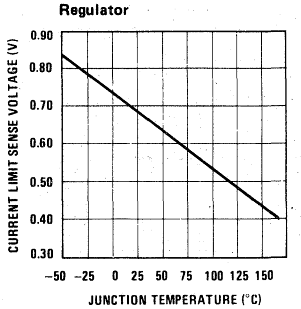
LM325/326/327 Maximum Average Power Dissipation vs Ambient Temperature



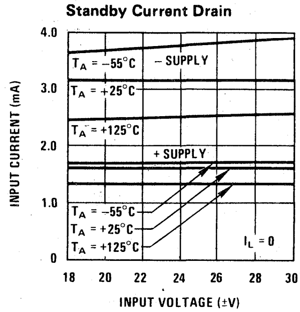
LM125/126/127 Current Limit Sense Voltage vs Temperature for Negative Regulator



LM125/126/127 Current Limit Sense Voltage vs Temperature for Positive Regulator

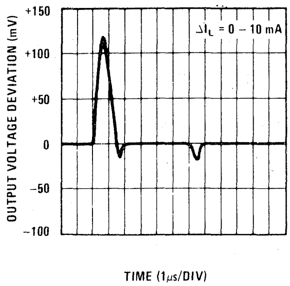


LM125/126/127 Standby Current Drain

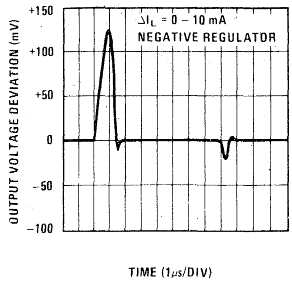


typical performance characteristics (con't)

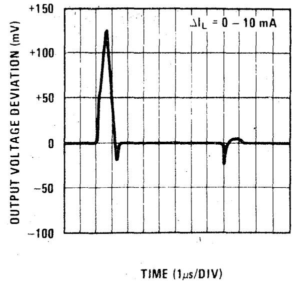
LM125
Load Transient Response for Negative Regulator



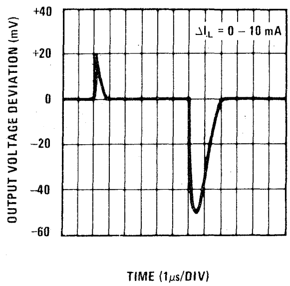
LM126
Load Transient Response



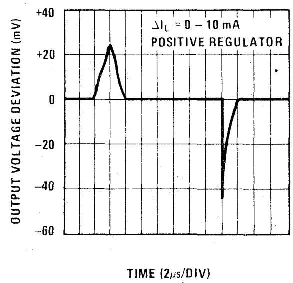
LM127
Load Transient Response for Negative Regulator



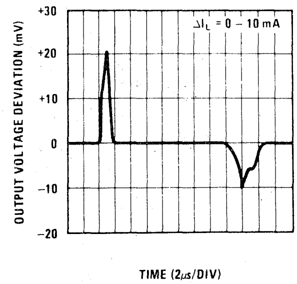
LM125
Load Transient Response for Positive Regulator



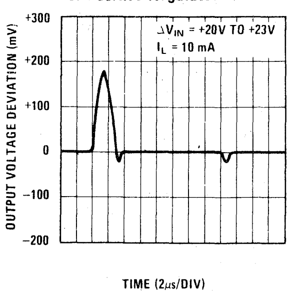
LM126
Load Transient Response



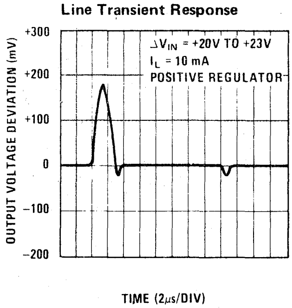
LM127
Load Transient Response for Positive Regulator



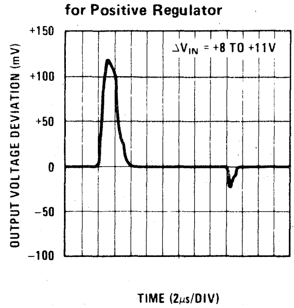
LM125
Line Transient Response for Positive Regulator



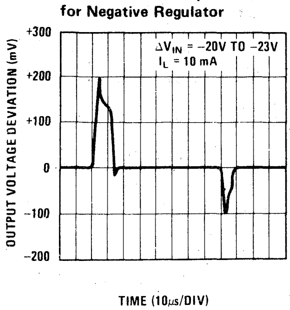
LM126
Line Transient Response



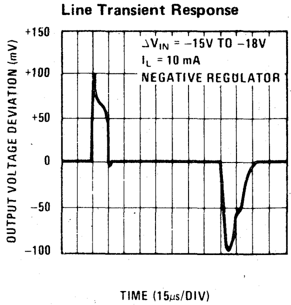
LM127
Line Transient Response for Positive Regulator



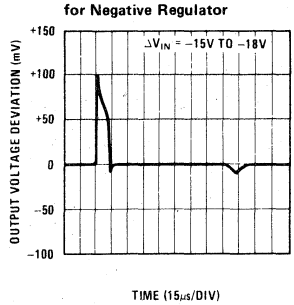
LM125
Line Transient Response for Negative Regulator



LM126
Line Transient Response

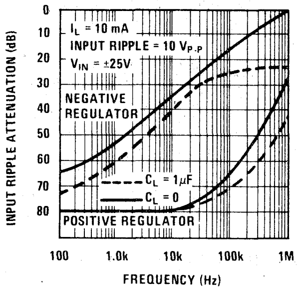


LM127
Line Transient Response for Negative Regulator

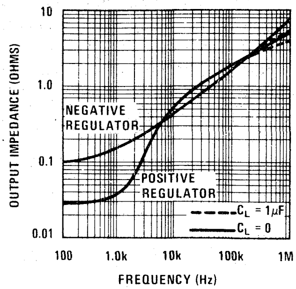


typical performance characteristics (con't)

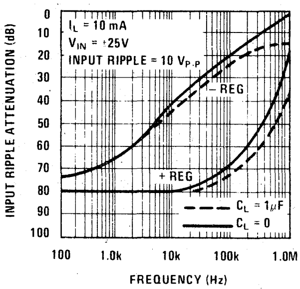
LM125
Ripple Rejection



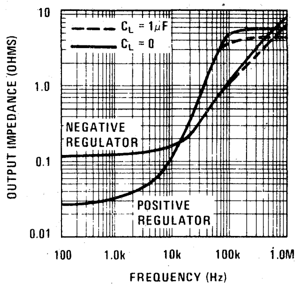
LM125
Output Impedance vs Frequency



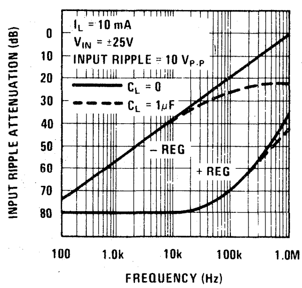
LM126
Ripple Rejection



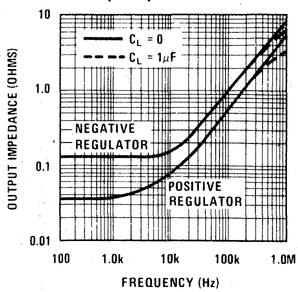
LM126
Output Impedance vs Frequency



LM127
Ripple Rejection



LM127
Output Impedance vs Frequency



Voltage Regulators
Future Products

LM128/LM228/LM328/LM328A voltage regulators

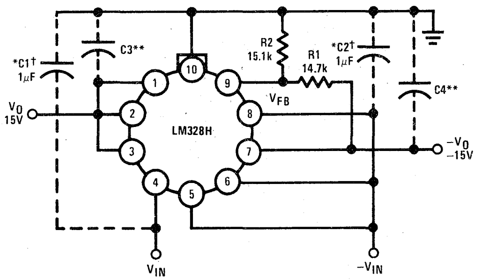
general description

The LM128/LM228/LM328 and LM328A are dual polarity tracking regulators designed to provide balanced positive and negative output voltages from 8V to 27V at output currents up to 100 mA. The output voltages are externally set by two resistors. Input voltages of up to ±30V can be used and there is provision for externally adjusted current limiting. The device is available in three package types to accomodate various power requirements and temperature ranges.

features

- 8V to 27V output voltages
- Output currents to 100 mA
- Output voltages balanced to within 1% (LM128, LM328A)
- Line regulation of 0.006%/V input
- Load regulation of 0.002%/mA
- Internal thermal shutdown
- Output currents easily boosted with external transistors
- Externally adjustable current limit
- Internal current limit

typical application



Note: To prevent damage to regulators in dual-in-line package pin 6 and 7 for DIP(N) and pin 8 and 9 for power DIP(S) must be connected together.

†Solid tantalum.

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

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

Typical Feedback Resistors

V_O	R1 (kΩ)	R2 (kΩ)
V_{FB}	7.5	∞
10	9.79	30.6
12	11.7	20.2
15	14.7	15.1
18	17.8	12.9
27	26.7	10.4

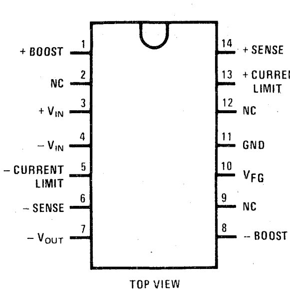
$$R1 = R2\left(\frac{V_O}{V_{FB}} - 1\right)^*$$

$$R2 = 75k\left(\frac{1}{1 - \frac{V_{FB}}{V_O}}\right)^*$$

*Except for $V_O = V_{FB}$

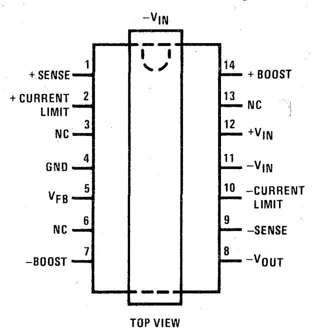
connection diagrams

Dual-In-Line Package



Order Number LM328N or LM328AN
See Package 22

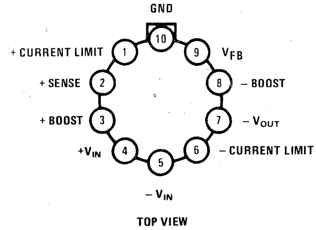
Dual-In-Line Power Package



*Note heat sink is same potential as $-V_{IN}$

Order Number LM328S
See Package 39

Metal Can Package



Note: Pin 5 connected to case.

Order Number LM128H, LM228H or LM328H
See Package 12

Voltage Regulators

LM140L/LM240L/LM340L series 3-terminal positive regulators

general description

The LM140L series of three terminal positive regulators is available with several fixed output voltages making them useful in a wide range of applications. The LM140LA is an improved version of the LM78LXX series with a tighter output voltage tolerance (specified over the full military temperature range), higher ripple rejection, better regulation and lower quiescent current. The LM140LA regulators have ±2% V_{OUT} specification, 0.04%/V line regulation, and 0.01%/mA load regulation. When used as a zener diode/resistor combination replacement, the LM140LA 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 LM140LA to be used in logic systems, instrumentation, Hi-Fi, 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 LM140LA/LM240LA/LM340LA are available in the low profile metal three lead TO-39 (H) and the LM240LA/LM340LA are also available in 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.

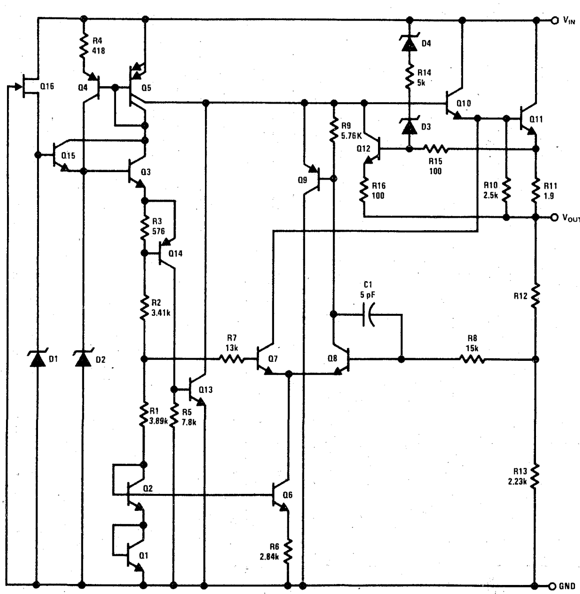
features

- Line regulation of 0.04%/V
- Load regulation of 0.01%/mA
- Output voltage tolerances of ±2% at T_J = 25°C and ±4% over the temperature range (LM140LA/LM240LA)
  ±3% over the temperature range (LM340LA)
- Output current of 100 mA
- Internal thermal overload protection
- Output transistor safe area protection
- Internal short circuit current limit
- Available in metal TO-39 low profile package (LM140LA/LM240LA/LM340LA) and plastic TO-92 (LM240LA/LM340LA)

output voltage options

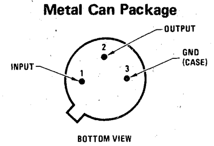
LM140LA-5.0	5V	LM240LA-5.0	5V	LM340LA-5.0	5V
LM140LA-6.0	6V	LM240LA-6.0	6V	LM340LA-6.0	6V
LM140LA-8.0	8V	LM240LA-8.0	8V	LM340LA-8.0	8V
LM140LA-10	10V	LM240LA-10	10V	LM340LA-10	10V
LM140LA-12	12V	LM240LA-12	12V	LM340LA-12	12V
LM140LA-15	15V	LM240LA-15	15V	LM340LA-15	15V
LM140LA-18	18V	LM240LA-18	18V	LM340LA-18	18V
LM140LA-24	24V	LM240LA-24	24V	LM340LA-24	24V

equivalent circuit



connection diagrams

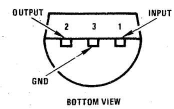
Metal Can Package



LM140LAH-5.0	LM240LAH-5.0	LM340LAH-5.0
LM140LAH-6.0	LM240LAH-6.0	LM340LAH-6.0
LM140LAH-8.0	LM240LAH-8.0	LM340LAH-8.0
LM140LAH-10	LM240LAH-10	LM340LAH-10
LM140LAH-12	LM240LAH-12	LM340LAH-12
LM140LAH-15	LM240LAH-15	LM340LAH-15
LM140LAH-18	LM240LAH-18	LM340LAH-18
LM140LAH-24	LM240LAH-24	LM340LAH-24

See Package 9

Plastic Package



LM240LAZ-5.0	LM340LAZ-5.0
LM240LAZ-6.0	LM340LAZ-6.0
LM240LAZ-8.0	LM340LAZ-8.0
LM240LAZ-10	LM340LAZ-10
LM240LAZ-12	LM340LAZ-12
LM240LAZ-15	LM340LAZ-15
LM240LAZ-18	LM340LAZ-18
LM240LAZ-24	LM340LAZ-24

See Package 38

electrical characteristics (Note 2)

Test conditions unless otherwise specified
T_A = −55°C to +125°C (LM140LA)
T_A = −25°C to +85°C (LM240LA)
T_A = 0°C to +70°C (LM340LA)
I_O = 40 mA
C_{IN} = 0.33μF, C_O = 0.01μF

absolute maximum ratings

Input Voltage	
5.0V through 18V Output Voltage Options	35V
24V Output Voltage Option	40V
Internal Power Dissipation (Note 1)	Internally Limited
Operating Temperature Range	
LM140LA	−55°C to +125°C
LM240LA	−25°C to +85°C
LM340LA	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

OUTPUT VOLTAGE OPTION			5.0V			6.0V			8.0V			10V			12V			15V			18V			24V			UNITS
INPUT VOLTAGE (unless otherwise noted)			10V			11V			14V			16V			19V			23V			27V			33V			
	PARAMETER	CONDITIONS	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
V_O	Output Voltage	T_J = 25°C	4.9	5	5.1	5.88	6	6.12	7.84	8	8.16	9.8	10	10.2	11.75	12	12.25	14.7	15	15.3	17.64	18	18.36	23.5	24	24.5	V
	Output Voltage Over Temp. (Note 4)	LM140LA, LM240LA: I_O = 1-100 mA or	4.8		5.2	5.76		6.24	7.7		8.3	9.6		10.4	11.5		12.5	14.4		15.6	17.3		18.7	23		25	V
		I_O = 1-40 mA and $V_{MIN} \le V_{IN} \le V_{MAX}$		(7.2 - 20)			(8.3 - 21)			(10.3 - 23)			(12.4 - 25)			(14.5 - 27)			(17.6 - 30)			(20.7 - 33)			(27 - 38)		
		LM340LA: I_O = 1-100 mA or	4.85		5.15	5.82		6.18	7.76		8.24	9.7		10.3	11.65		12.35	14.55		15.45	17.46		18.54	23.28		24.72	V
		I_O = 1-40 mA and $V_{MIN} \le V_{IN} \le V_{MAX}$		(7 - 20)			(8.2 - 21)			(10.2 - 23)			(12.2 - 25)			(14.3 - 27)			(17.5 - 30)			(20.5 - 33)			(26.7 - 38)		
ΔV_O	Line Regulation	T_J = 25°C, I_O = 40 mA		18	30		20	35		20	42		25	55		30	65		37	70		45	80		60	100	mV
		$V_{MIN} \le V_{IN} \le V_{MAX}$		(7 - 25)			(8 - 25)			(10.2 - 25)			(12.2 - 30)			(14.2 - 30)			(17.3 - 30)			(20.4 - 33)			(26.5 - 38)		
		I_O = 100 mA		18	30		20	35		20	42		25	55		30	65		37	70		45	80		60	100	mV
		$V_{MIN} \le V_{IN} \le V_{MAX}$		(7.5 - 25)			(8.5 - 25)			(10.5 - 25)			(12.5 - 30)			(14.5 - 30)			(17.5 - 30)			(21 - 33)			(27 - 38)		
	Load Regulation	T_J = 25°C, I_O = 1-40 mA		5	20		6	25		8	30		10	35		10	40		12	50		15	65		20	80	mV
		I_O = 1-100 mA		20	40		22	50		25	60		27	70		30	80		35	100		40	130		50	160	mV
	Long Term Stability			12			14			20			24			24			30			45			66		mV 1000 hrs
I_O	Quiescent Current	T_J = 25°C		3	4.5		3	4.5		3	4.5		3	4.5		3	4.5		3.1	4.5		3.1	4.5		3.1	4.5	mA
		T_J = 125°C			4.2			4.2			4.2			4.2			4.2			4.2			4.2			4.2	mA
ΔI_Q	Quiescent Current Change	ΔLoad I_O = 1-40 mA			0.1			0.1			0.1			0.1			0.1			0.1			0.1			0.1	mA
		T_J = 25°C ΔLine			0.5			0.5			0.5			0.5			0.5			0.5			0.5			0.5	mA
		$V_{MIN} \le V_{IN} \le V_{MAX}$		(7.5 - 25)			(8.2 - 25)			(10.2 - 25)			(12.2 - 30)			(14.3 - 30)			(17.5 - 30)			(20.5 - 33)			(26.7 - 38)		
V_N	Output Noise Voltage	T_J = 25°C (Note 3), f = 10 Hz - 10 kHz		40			50			60			70			80			90			150			200		μV
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple Rejection	f = 120 Hz, $V_{MIN} \le V_{IN} \le V_{MAX}$	55	62		53	60		51	58		50	57		47	54		45	52		44	50		41	48		dB
				(7.5 - 18)			(8.5 - 20)			(10.5 - 23)			(12.5 - 25)			(14.5 - 25)			(17.5 - 28.5)			(21 - 33)			(27 - 35)		
	Input Voltage Required to Maintain Line Regulation	T_J = 25°C, I_O = 40 mA	7			8			10.2			12.2			14.2			17.3			20.4			26.5			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.

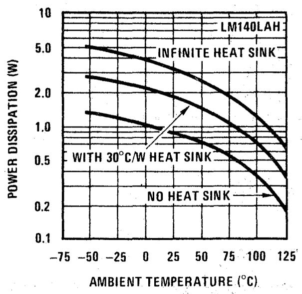
Note 2: The maximum steady state usable output current and input voltage are very dependent on the heat sinking and/or lead length of the package. The data above represent pulse test conditions with junction temperatures as indicated at the initiation of tests.

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

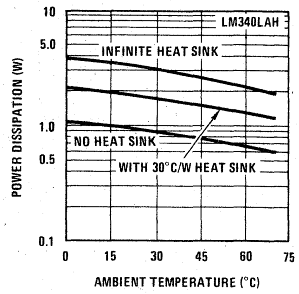
Note 4: The temperature coefficient of V_{OUT} is typically within 0.01%V_O/°C.

typical performance characteristics

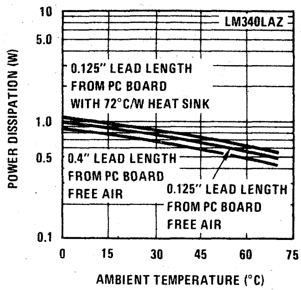
Maximum Average Power Dissipation



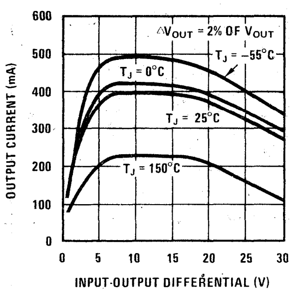
Maximum Average Power Dissipation (Metal Can Package)



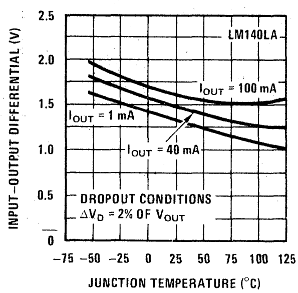
Maximum Average Power Dissipation (Plastic Package)



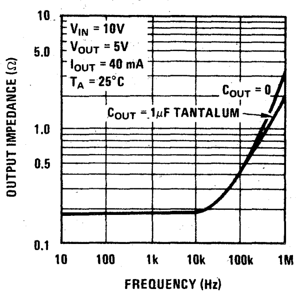
Peak Output Current



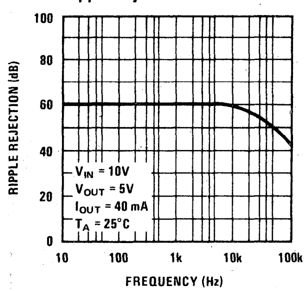
Dropout Voltage



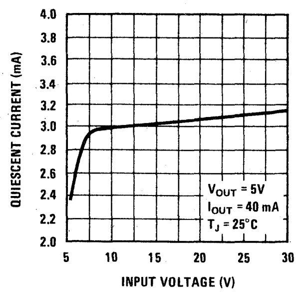
Output Impedance



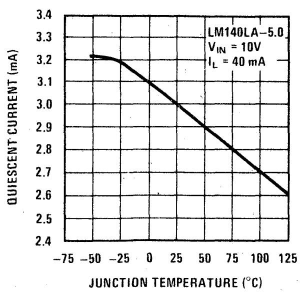
Ripple Rejection



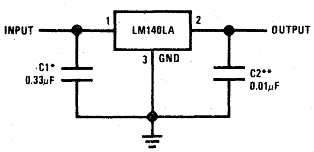
Quiescent Current



Quiescent Current



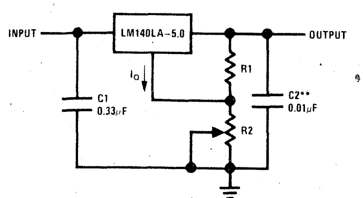
typical applications



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

**See note 3 in the electrical characteristics table.

Fixed Output Regulator

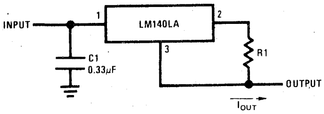


$V_{OUT} = 5V + (5V/R1 + I_Q)\ R2$

$5V/R1 > 3\ I_Q$ load regulation $(L_r) \approx [(R1 + R2)/R1]$ (L_r of LM140LA-5.0)

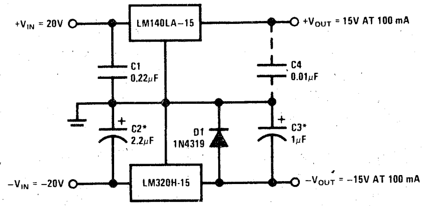
Adjustable Output Regulator

typical applications (con't)



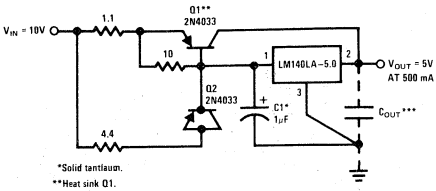
$I_{OUT} = (V_{23}/R1) + I_O$
I_O = 0.5 mA over line and load changes

Current Regulator



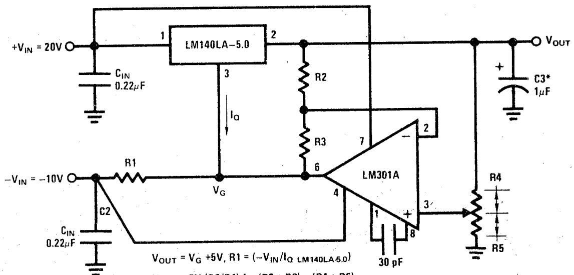
*Solid tantalum.

±15V, 100 mA Dual Power Supply



*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



$V_{OUT} = V_G + 5V$, $R1 = (-V_{IN}/I_{Q\ LM140LA\text{-}5.0})$
$V_{OUT} = 5V\ (R2/R4)$ for $(R2 + R3) = (R4 + R5)$
A 0.5V output will correspond to $(R2/R4) = 0.1$, $(R3/R4) = 0.9$

*Solid tantalum.

Variable Output Regulator 0.5V — 18V

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.

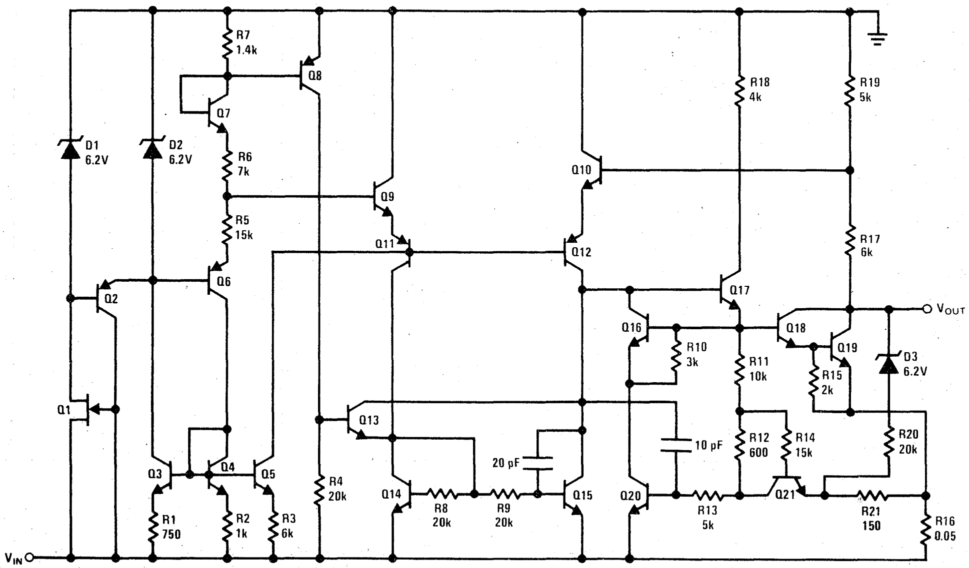
Although primarily intended for fixed output voltage applications, the LM145 may be programmed for higher output voltages with a simple resistive divider. The low quiescent drain current of the device allows this technique to be used with good regulation.

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

features

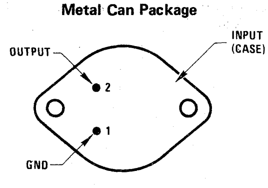
- Output voltage accurate to better than ±2%
- Current limit constant with temperature
- Internal thermal shutdown protection
- Operates with input-output voltage differential of 2.8V at full rated load over full temperature range
- Regulation guaranteed with 25W power dissipation
- 3A output current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

schematic diagram



connection diagram

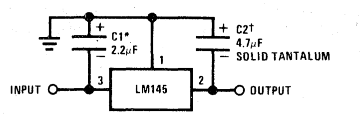
Metal Can Package



BOTTOM VIEW

Order Number LM145K, LM245K or LM345K
See Package 18

typical applications



†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

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)

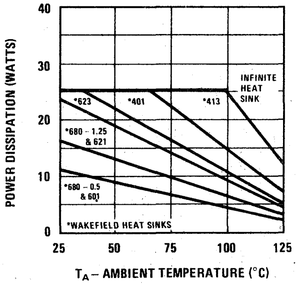
PARAMETER	CONDITIONS	LIMITS						UNITS
		LM145/LM245			LM345			
		MIN	TYP	MAX	MIN	TYP	MAX	
Output Voltage	T_j = 25°C, I_{OUT} = 5 mA, V_{IN} = −7.5							
5.0V		−5.1	−5.0	−4.9	−5.2	−5.0	−4.8	V
5.2V		−5.3	−5.2	−5.1	−5.4	−5.2	−5.0	V
Line Regulation (Note 2)	T_j = 25°C, $-20V \leq V_{IN} \leq -7.5V$		5	15		5	25	mV
Load Regulation (Note 2)	T_j = 25°C, V_{IN} = −7.5V, 5 mA $\leq I_{OUT} \leq$ 3A		30	75		30	100	mV
Output Voltage	$-20V \leq V_{IN} \leq -7.8V$, 5 mA $\leq I_{OUT} \leq$ 3A, $P \leq 25W$, $T_{MIN} \leq T_j \leq T_{MAX}$							
5.0V		−5.20		−4.80	−5.25		−4.75	V
5.2V		−5.40		−5.00	−5.45		−4.95	V
Quiescent Current	$-20V \leq V_{IN} \leq -7.5V$, 5 mA $\leq I_{OUT} \leq$ 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 $\leq f \leq$ 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: $-55°C \leq T_j \leq +150°C$ for the LM145; $-25°C \leq T_j \leq +150°C$ for the LM245 and $0°C \leq T_j \leq +125°C$ 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.

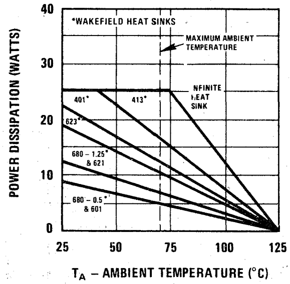
Note 2: Regulation is measured at constant junction temperature. Changes in output voltage due to heating effects must be taken into account separately. To ensure constant junction temperature, pulse testing with a low duty cycle is used.

typical performance characteristics

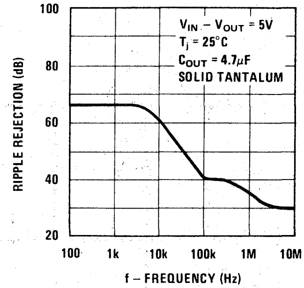
Maximum Average Power Dissipation for LM145, LM245



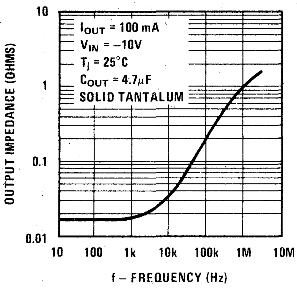
Maximum Average Power Dissipation for LM345



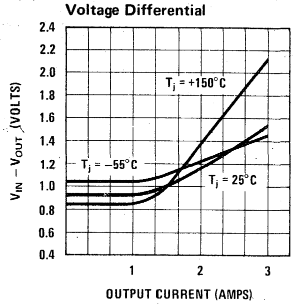
Ripple Rejection



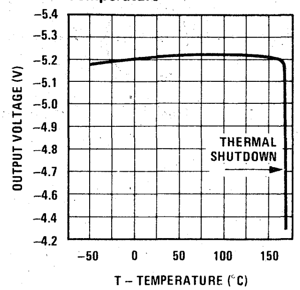
Output Impedance



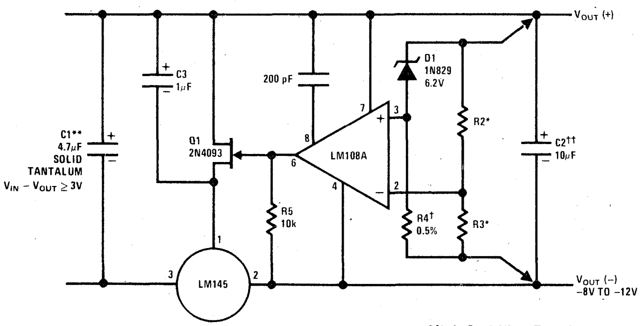
Minimum Input-Output Voltage Differential



Output Voltage vs Temperature



typical applications (con't)



*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.

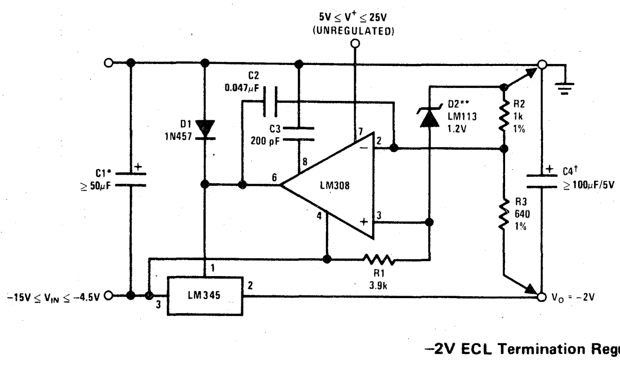
†Determines zener current. May be adjusted to minimize temperature drift.

††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.

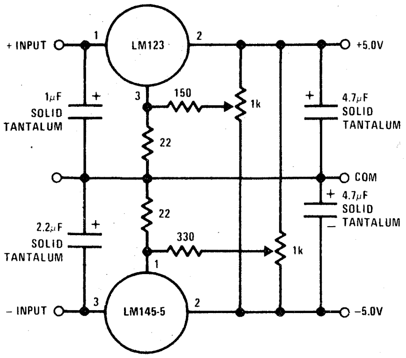
†Keep C4 within 2″ of LM345. There is no upper limit on C4 and unlimited capacitance can be added at extended distances from the regulator.

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

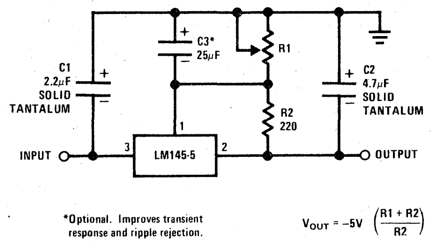
–2V ECL Termination Regulator

1

typical applications (con't)



Dual 3 Amp Trimmed Supply



Variable Output (-5.0V to -15V)

Voltage Regulators

Future Product

LM320L series 3-terminal negative regulators

general description

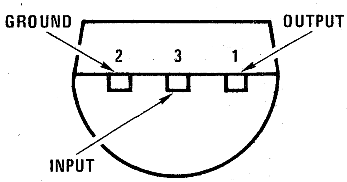
The LM320L-XX series of 3-terminal negative voltage regulators features several selected fixed output voltages from -5V to -24V with load current capabilities to 100 mA. Internal protective circuitry includes safe operating area for the output transistor, short circuit current limit, and thermal shutdown. The LM320L-XX will be available in the 3-lead TO-92 package.

features

- Preset output voltage error less than ±5% over temperature
- 100 mA output current capability
- Internal thermal overload protection
- Input-output voltage differential down to 2V
- Internal current limit
- Maximum load regulation — 0.015%/mA
- Maximum line regulation — 0.1%/V
- Output transistor safe area protection
- Available in the TO-92 package

connection diagram

Plastic Package



BOTTOM VIEW

Order Number LM320L
See Package 38

Voltage Regulators

LM340 series voltage 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.

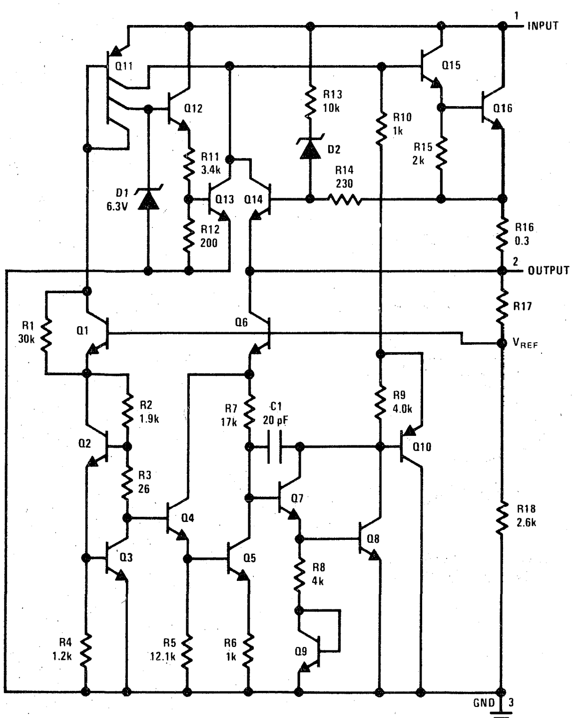
The LM340-XX series is available in two power packages. Both the plastic TO-220 and metal TO-3 packages allow these regulators to deliver over 1.5A if adequate heat sinking is provided. Current limiting is included to limit the peak output current to a safe value. Safe area protection for the output 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.

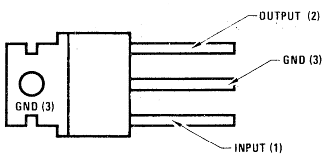
features

- Output current in excess of 1.5A
- 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

schematic and connection diagrams



Plastic Package



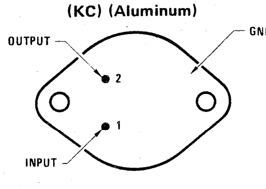
TOP VIEW

Order Numbers

LM340T-5.0	LM340T-12
LM340T-6.0	LM340T-15
LM340T-8.0	LM340T-18
LM340T-10	LM340T-24

See Package 26

Metal Can Package
(K) (Steel)
(KC) (Aluminum)



BOTTOM VIEW

Order Numbers

LM340K-5	LM340KC-5.0
LM340K-6	LM340KC-6.0
LM340K-8	LM340KC-8.0
LM340K-10	LM340KC-10
LM340K-12	LM340KC-12
LM340K-15	LM340KC-15
LM340K-18	LM340KC-18
LM340K-24	LM340KC-24

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

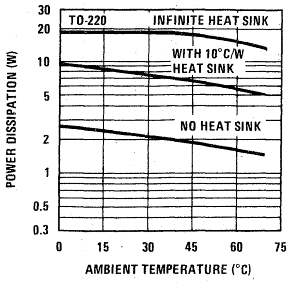
T_A = 0°c to 70°C, I_O = 500 mA, unless otherwise noted.

OUTPUT VOLTAGE			5V			6V			8V			10V			12V			15V			18V			24V			UNITS
INPUT VOLTAGE (unless otherwise noted)			10V			11V			14V			17V			19V			23V			27V			33V			
PARAMETER		CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_O	Output Voltage	T_J = 25°C	4.8	5	5.2	5.75	6	6.25	7.7	8	8.3	9.6	10	10.4	11.5	12	12.5	14.4	15	15.6	17.3	18	18.7	23	24	25	V
		$P_D \le 15W$, 5 mA $\le I_O \le$ 1000 mA	4.75		5.25	5.7		6.3	7.6		8.4	9.5		10.5	11.4		12.6	14.25		15.75	17.1		18.9	22.8		25.2	V
		and $V_{MIN} \le V_{IN} \le V_{MAX}$		$(7 \le V_{IN} \le 20)$			$(8 \le V_{IN} \le 21)$			$(10.5 \le V_{IN} \le 23)$			$(12.5 \le V_{IN} \le 25)$			$(14.5 \le V_{IN} \le 27)$			$(17.5 \le V_{IN} \le 30)$			$(21 \le V_{IN} \le 33)$			$(27 \le V_{IN} \le 38)$		V
ΔV_O	Line Regulation	T_J = 25°C, I_O = 100 mA			50			60			80			100			120			150			180			240	mV
		T_J = 25°C, I_O = 500 mA			100			120			160			200			240			300			360			480	mV
				$(7 \le V_{IN} \le 25)$			$(8 \le V_{IN} \le 25)$			$(10.5 \le V_{IN} \le 25)$			$(12.5 \le V_{IN} \le 25)$			$(14.5 \le V_{IN} \le 30)$			$(17.5 \le V_{IN} \le 30)$			$(21 \le V_{IN} \le 33)$			$(27 \le V_{IN} \le 38)$		V
ΔV_O	Load Regulation	T_J = 25°C			100			120			160			200			240			300			360			480	mV
				$(5 \le I_O \le 1500)$			$(5 \le I_O \le 1500)$			$(5 \le I_O \le 1500)$			$(5 \le I_O \le 1500)$			$(5 \le I_O \le 1500)$			$(5 \le I_O \le 1500)$			$(5 \le I_O \le 1000)$			$(5 \le I_O \le 1000)$		mA
ΔV_O	Long Term Stability				20			24			32			40			48			60			72			96	mV/1000 hrs
I_Q	Quiescent Current	T_J = 25°C		7	10		7	10		7	10		7	10		7	10		7	10		7	10		7	10	mA
ΔI_Q	Quiescent Current Change	$I_{MIN} \le I_O \le I_{MAX}$			0.5			0.5			0.5			0.5			0.5			0.5			0.5			0.5	mA
				$(5 \le I_O \le 1500)$			$(5 \le I_O \le 1500)$			$(5 \le I_O \le 1500)$			$(5 \le I_O \le 1500)$			$(5 \le I_O \le 1500)$			$(5 \le I_O \le 1500)$			$(5 \le I_O \le 1000)$			$(5 \le I_O \le 1000)$		mA
		$V_{MIN} \le V_O \le V_{MAX}$			1.3			1.3			1.0			1.0			1.0			1.0			1.0			1.0	mA
				$(7 \le V_{IN} \le 25)$			$(8 \le V_{IN} \le 25)$			$(10.5 \le V_{IN} \le 25)$			$(12.5 \le V_{IN} \le 25)$			$(14.5 \le V_{IN} \le 30)$			$(17.5 \le V_{IN} \le 30)$			$(21 \le V_{IN} \le 33)$			$(27 \le V_{IN} \le 38)$		V
V_n	Output Noise Voltage	T_J = 25°C, f = 10 Hz – 100 kHz		40			45			52			70			75			90			110			170		µV
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple Rejection	f = 120 Hz		60			57			55			54			62			50			48			44		dB
	Input Voltage Required to Maintain Line Regulation	T_J = 25°C	7			8			10.5			12.5			14.5			17.5			21			27			V

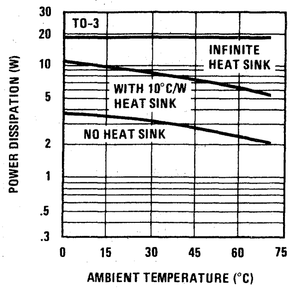
Note 1: Thermal resistance without a heat sink for junction to case temperature is 4°C/W for the TO-3 package and 4°C/W for the TO-220 package. Thermal resistance for case to ambient temperature is 35°C/W for the TO-3 package and 50°C/W for the TO-220 package.

typical performance characteristics

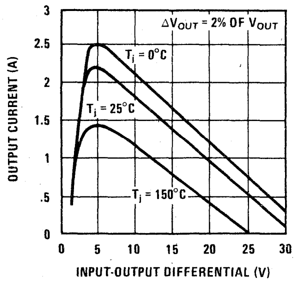
Maximum Average Power Dissipation



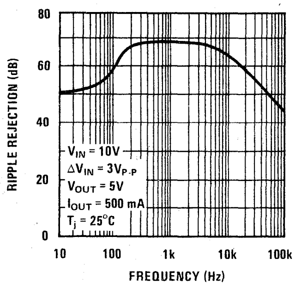
Maximum Average Power Dissipation



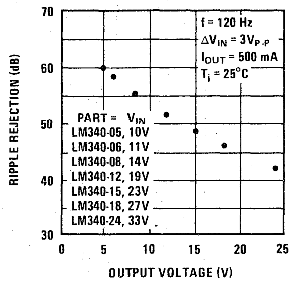
Peak Output Current



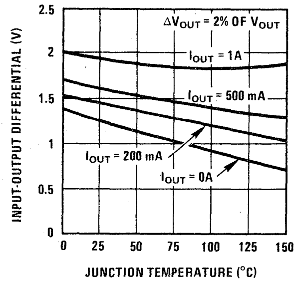
Ripple Rejection



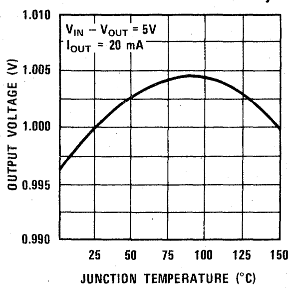
Ripple Rejection



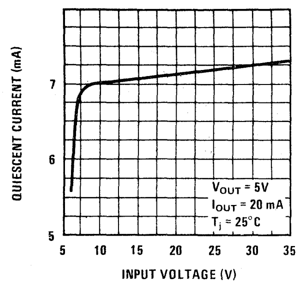
Dropout Voltage



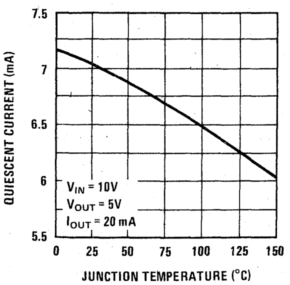
Output Voltage (Normalized to 1V at 25°C T_j)



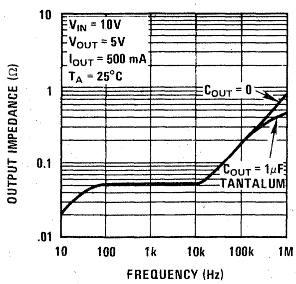
Quiescent Current



Quiescent Current



Output Impedance



Voltage Regulators

LM341 series 3-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.

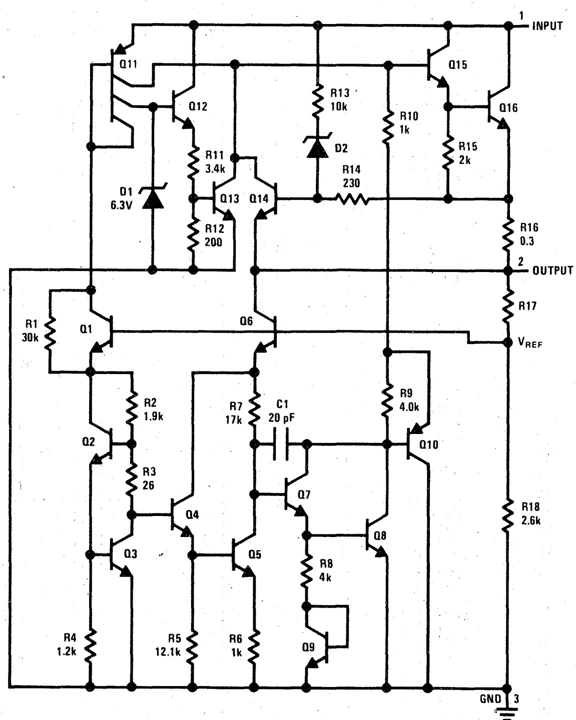
The LM341-XX series is available in the plastic TO-202 package. This package allows these regulators to deliver over 0.5A if adequate heat sinking is provided. Current limiting is included to limit the peak output current to a safe value. Safe area protection for the output transistor is provided to 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.

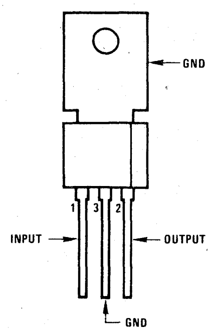
features

- 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

schematic and connection diagrams



Plastic Package



FRONT VIEW

Order Numbers

LM341P-5.0	LM341P-12
LM341P-6.0	LM341P-15
LM341P-8.0	LM341P-18
LM341P-10	LM341P-24

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

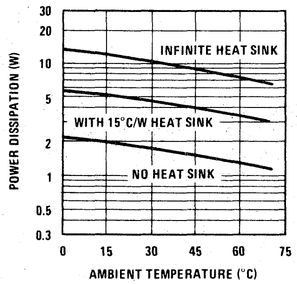
T_A = 0°C to 70°C, I_O = 500 mA, unless otherwise noted.

OUTPUT VOLTAGE			5V			6V			8V			10V			12V			15V			18V			24V			UNITS
INPUT VOLTAGE (unless otherwise noted)			10V			11V			14V			17V			19V			23V			27V			33V			
PARAMETER		CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_O	Output Voltage	T_J = 25°C	4.8	5	5.2	5.75	6	6.25	7.7	8	8.3	9.6	10	10.4	11.5	12	12.5	14.4	15	15.6	17.3	18	18.7	23	24	25	V
		$P_D \leq 7.5W$, 5 mA $\leq I_O \leq$ 500 mA	4.75		5.25	5.7		6.3	7.6		8.4	9.5		10.5	11.4		12.6	14.25		15.75	17.1		18.9	22.8		25.2	V
		and $V_{MIN} \leq V_{IN} \leq V_{MAX}$	$(7.5 \leq V_{IN} \leq 20)$			$(8.6 \leq V_{IN} \leq 21)$			$(10.6 \leq V_{IN} \leq 23)$			$(12.7 \leq V_{IN} \leq 25)$			$(14.8 \leq V_{IN} \leq 27)$			$(18 \leq V_{IN} \leq 30)$			$(21 \leq V_{IN} \leq 33)$			$(27.3 \leq V_{IN} \leq 38)$			V
ΔV_O	Line Regulation	T_J = 25°C, I_O = 100 mA			50			60			80			100			120			150			180			240	mV
		T_J = 25°C, I_O = 500 mA			100			120			160			200			240			300			360			480	mV
			$(7.2 \leq V_{IN} \leq 25)$			$(8.3 \leq V_{IN} \leq 25)$			$(10.3 \leq V_{IN} \leq 25)$			$(12.4 \leq V_{IN} \leq 25)$			$(14.5 \leq V_{IN} \leq 30)$			$(17.6 \leq V_{IN} \leq 30)$			$(20.7 \leq V_{IN} \leq 33)$			$(27 \leq V_{IN} \leq 38)$			mV
ΔV_O	Load Regulation	T_J=25°C, 5 mA $\leq I_O \leq$ 500 mA			100			120			160			200			240			300			360			480	mV
ΔV_O	Long Term Stability				20			24			32			40			48			60			72			96	mV/1000 hrs
I_Q	Quiescent Current	T_J = 25°C		7	10		7	10		7	10		7	10		7	10		7	10		7	10		7	10	mA
ΔI_Q	Quiescent Current Change	T_J = 25°C, 5 mA $\leq I_O \leq$ 500 mA			0.5			0.5			0.5			0.5			0.5			0.5			0.5			0.5	mA
		T_J = 25°C			1			1			1			1			1			1			1			1	mA
		$V_{MIN} \leq V_{IN} \leq V_{MAX}$	$(7.5 \leq V_{IN} \leq 25)$			$(8.6 \leq V_{IN} \leq 25)$			$(10.6 \leq V_{IN} \leq 25)$			$(12.7 \leq V_{IN} \leq 25)$			$(14.8 \leq V_{IN} \leq 30)$			$(18 \leq V_{IN} \leq 30)$			$(21 \leq V_{IN} \leq 33)$			$(27.3 \leq V_{IN} \leq 38)$			mA
V_n	Output Noise Voltage	T_J = 25°C, f = 10 Hz – 100 kHz		40			45			52			65			75			90			110			170		µV
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple Rejection	f = 120 Hz		60			57			55			53			62			50			48			44		dB
	Input Voltage Required to Maintain Line Regulation	T_J = 25°C, I_O = 500 mA	7.2			8.3			10.3			12.4			14.5			17.6			20.7			27			V

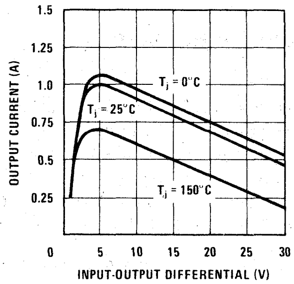
Note 1: Thermal resistance without a heat sink for junction to case temperature is 12°C/W for the TO-202 package. Thermal resistance for case to ambient temperature is 70°C/W for the TO-202 package.

typical performance characteristics

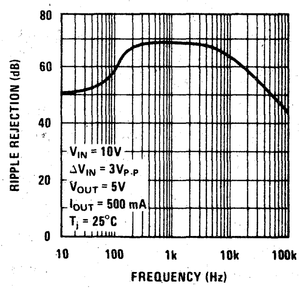
Maximum Average Power Dissipation



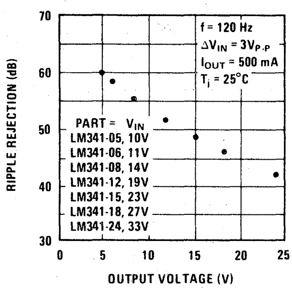
Peak Output Current



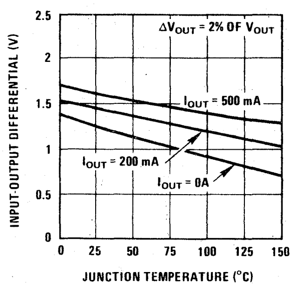
Ripple Rejection



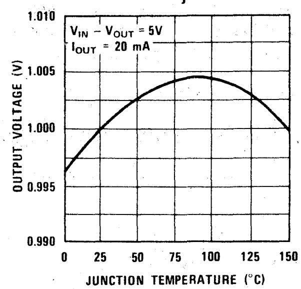
Ripple Rejection



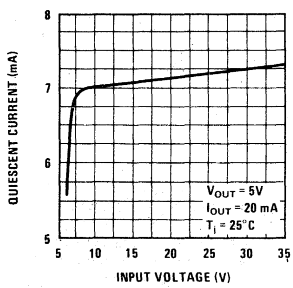
Dropout Voltage



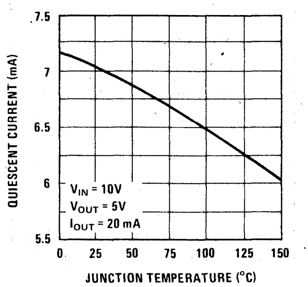
Output Voltage (Normalized to 1V at 25°C T_j)



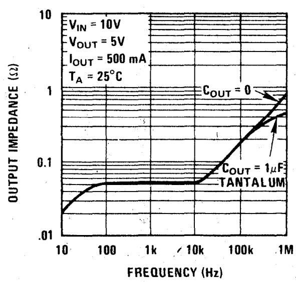
Quiescent Current



Quiescent Current



Output Impedance



Voltage Regulators

LM342 series 3-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 0.25A 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 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.

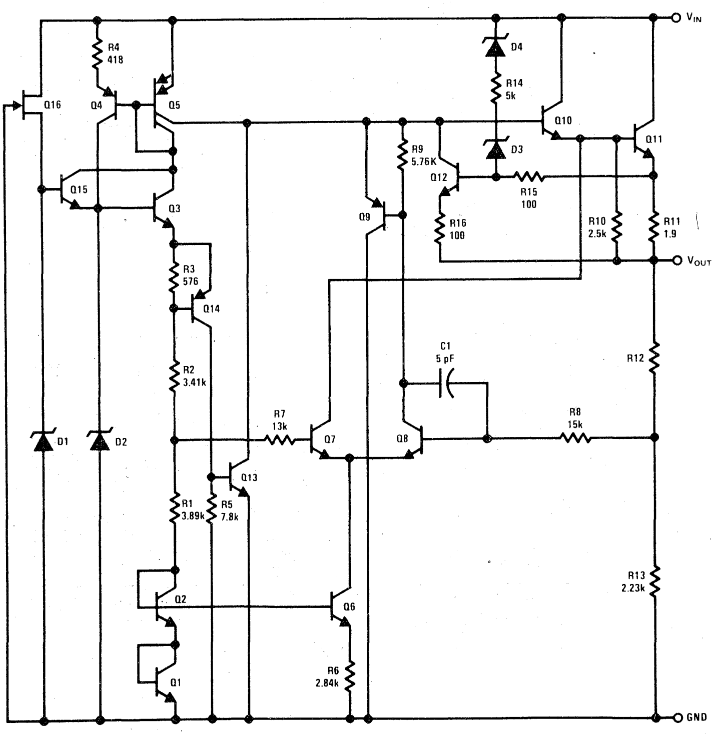
features

- Output current in excess of 0.25A
- Internal thermal overload protection
- No external components required
- Output transistor safe area protection
- Internal short circuit current limit
- Available in plastic TO-202 package

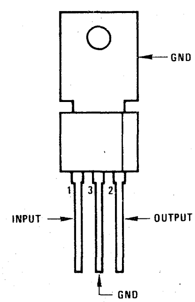
voltage range

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



Plastic Package



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	−55°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics

T_A = 0°C to +70°C, I_O = 250 mA (Note 2) unless noted.

OUTPUT VOLTAGE			5V			6V			8V			10V			12V			15V			18V			24V			UNITS
INPUT VOLTAGE (unless otherwise noted)			10V			11V			14V			16V			19V			23V			27V			33V			
PARAMETER		CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_O	Output Voltage (Note 3)	T_j = 25°C	4.8	5	5.2	5.75	6	6.25	7.7	8	8.3	9.6	10	10.4	11.5	12	12.5	14.4	15	15.6	17.3	18	18.7	23	24	25	V
		1 mA ≤ I_O ≤ 250 mA and	4.75		5.25	5.7		6.3	7.6		8.4	9.5		10.5	11.4		12.6	14.25		15.75	17.1		18.9	22.8		25.2	V
		$V_{MIN} \le V_{IN} \le V_{MAX}$		$(8 \le V_{IN} \le 20)$			$(9 \le V_{IN} \le 21)$			$(11 \le V_{IN} \le 23)$			$(13 \le V_{IN} \le 25)$			$(15 \le V_{IN} \le 27)$			$(18 \le V_{IN} \le 30)$			$(21 \le V_{IN} \le 33)$			$(27 \le V_{IN} \le 38)$		V
ΔV_O	Line Regulation	T_J = 25°C, I_O = 250 mA			55			55			60			65			100			100			115			140	mV
				$(7.3 \le V_{IN} \le 25)$			$(8.4 \le V_{IN} \le 25)$			$(10.4 \le V_{IN} \le 25)$			$(12.5 \le V_{IN} \le 25)$			$(14.6 \le V_{IN} \le 30)$			$(17.7 \le V_{IN} \le 30)$			$(20.8 \le V_{IN} \le 33)$			$(27.1 \le V_{IN} \le 38)$		V
ΔV_O	Load Regulation	T_J = 25°C, 1 mA ≤ I_O ≤ 250 mA			50			60			80			100			120			150			180			240	mV
ΔV_O	Long Term Stability			20			24			32			40			48			60			72			96		mV/1000 hrs
I_Q	Quiescent Current	T_J = 25°C			6			6			6			6			6			6			6			6	mA
ΔI_Q	Quiescent Current Change	T_J = 25°C, 1 mA ≤ I_O ≤ 250 mA			0.5			0.5			0.5			0.5			0.5			0.5			0.5			0.5	mA
		T_J = 25°C, $V_{MIN} \le V_{IN} \le V_{MAX}$			1.5			1.5			1.5			1.5			1.5			1.5			1.5			1.5	mA
				$(7.3 \le V_{IN} \le 25)$			$(8.4 \le V_{IN} \le 25)$			$(10.4 \le V_{IN} \le 25)$			$(12.5 \le V_{IN} \le 25)$			$(14.6 \le V_{IN} \le 30)$			$(17.7 \le V_{IN} \le 30)$			$(20.8 \le V_{IN} \le 33)$			$(27.1 \le V_{IN} \le 38)$		V
V_n	Output Noise Voltage	T_J = 25°C, f = 10 Hz–10 kHz		40			48			64			80			96			120			150			190		µV
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple Rejection	f = 120 Hz	50	64		50	64		48	62		46	60		44	58		42	56		40	54		39	53		dB
	Input Voltage Required to Maintain Line Regulation	T_J = 25°C, I_O = 250 mA	7.3			8.4			10.4			12.5			14.6			17.7			20.8			27.1			V

Note 1: 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.

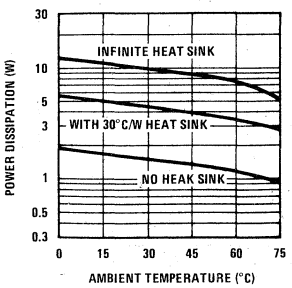
Note 2: The electrical characteristics data represent pulse test conditions with junction temperatures as shown at the initiation of tests.

Note 3: The temperature coefficient of V_{OUT} is typically within 0.01% V_O/°C.

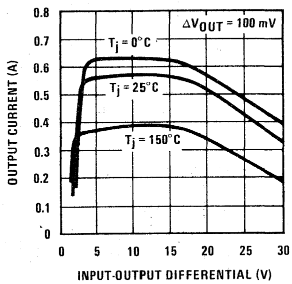
1

typical performance characteristics

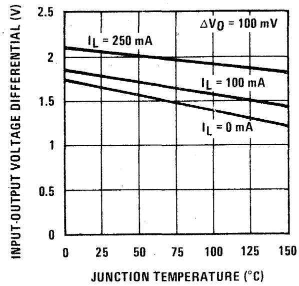
Maximum Average Power Dissipation (TO-202 Package)



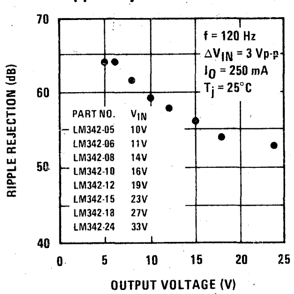
Peak Output Current



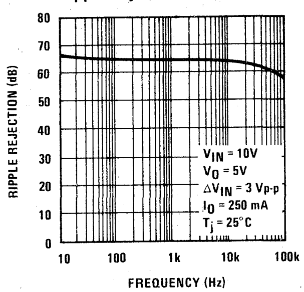
Dropout Voltage



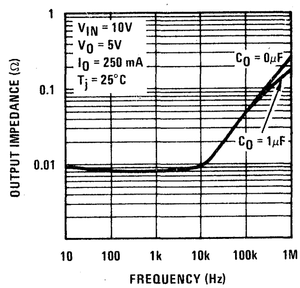
Ripple Rejection



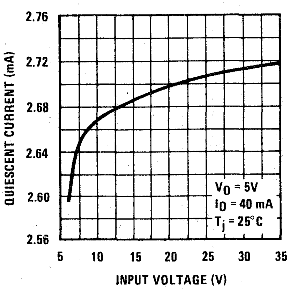
Ripple Rejection



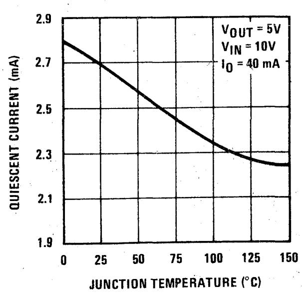
Output Impedance



Quiescent Current

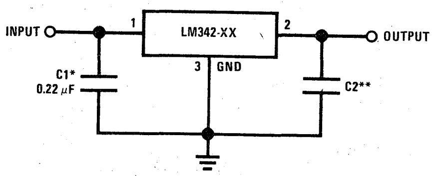


Quiescent Current



typical applications

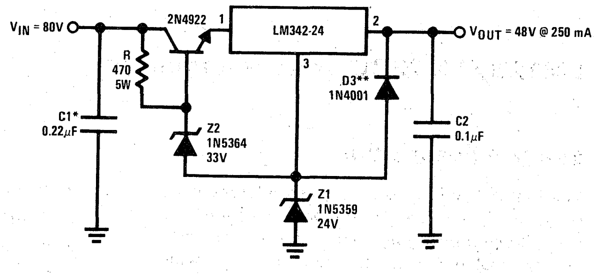
Fixed Output Regulator



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

**Although not required, C2 does improve transient response. (If needed, use 0.1μF ceramic disc.)

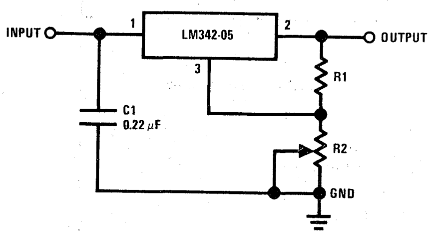
High Output Voltage Regulator



*Necessary if regulator is located far from the power supply filter

**D3 aids in full load start-up and protects the regulator during short circuits from high input to output voltage differentials

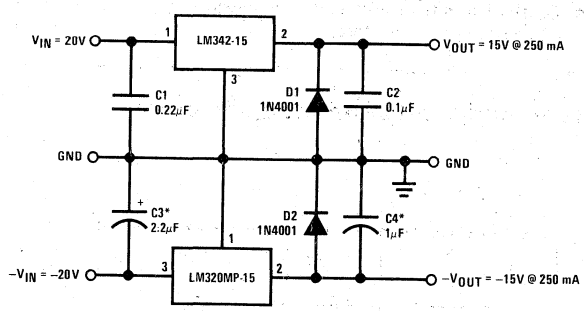
Adjustable Output Regulator



$V_O = 5V + (5V/R1 + I_Q)\ R2$

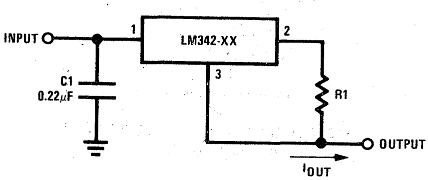
$5V/R1 > 3I_Q$, Load Regulation $(L_R) = [(R1 + R2)/R1] \cdot (L_r$ of LM342-05)

±15V, 250 mA Dual Power Supply



*Solid tantalum

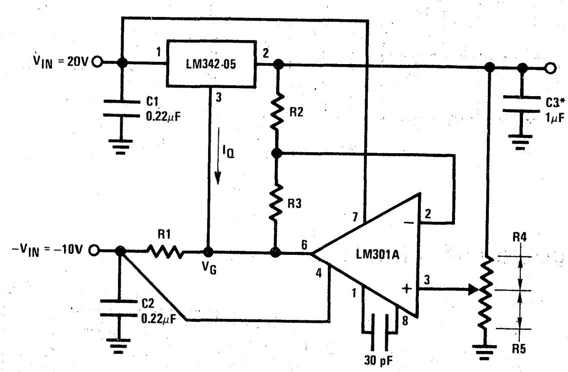
Current Regulator



$I_{OUT} = V^{2-3}/R1 + I_Q$

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

Variable Output Regulator 0.5V – 18V



$V_{OUT} = V_G + 5V$, $R1 = (-V_{IN}/I_Q$ LM342)

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

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

*Solid tantalum

Voltage Regulators

LM723/LM723C voltage regulator

general description

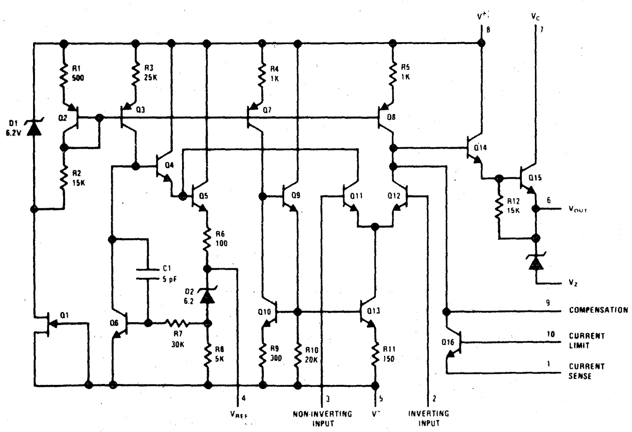
The LM723/LM723C is a voltage regulator designed primarily for series regulator applications. By itself, it will supply output currents up to 150 mA; but external transistors can be added to provide any desired load current. The circuit features extremely low standby current drain, and provision is made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

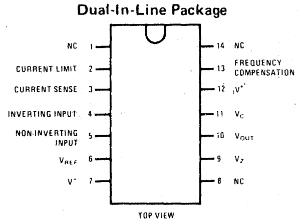
The LM723/LM723C is also useful in a wide range of other applications such as a shunt regulator, a current regulator or a temperature controller.

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

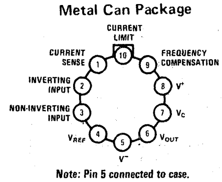


Order Number LM723D or LM723CD
See Package 2B

Order Number LM723N or LM723CN
See Package 22

Order Number LM723J or LM723CJ
See Package 16

Metal Can Package

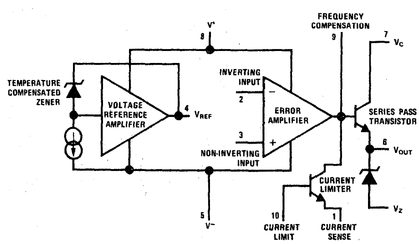


Note: Pin 5 connected to case.

TOP VIEW

Order Number LM723H or LM723CH
See Package 12

equivalent circuit*



*Pin numbers refer to metal can package.

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}
	$-55°C \leq T_A \leq +125°C$			0.3				% V_{OUT}
	$0°C \leq T_A \leq +70°C$						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}
	$-55°C \leq T_A \leq +125°C$			0.6				%V_{OUT}
	$0°C \leq T_A \leq = +70°C$						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	$-55°C \leq T_A \leq +125°C$		.002	.015				%/°C
	$0°C \leq T_A \leq +70°C$					.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.

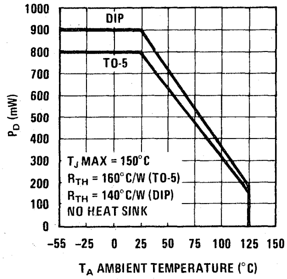
Note 6: V^+ must be connected to a +3V or greater supply.

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

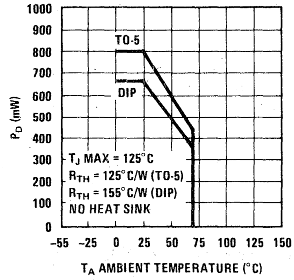
LM723

Power Dissipation vs Ambient Temperature



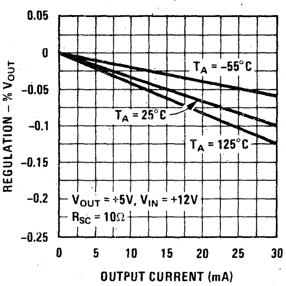
LM723C

Power Dissipation vs Ambient Temperature

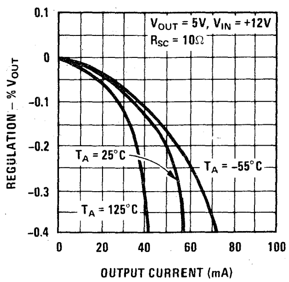


typical performance characteristics

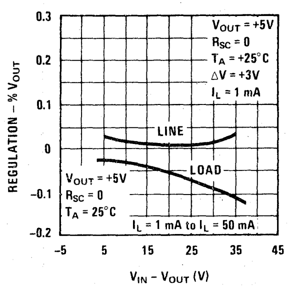
Load Regulation Characteristics with Current Limiting



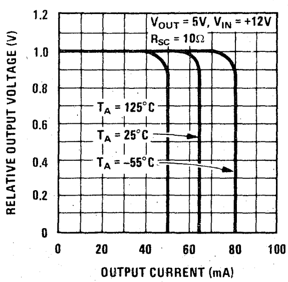
Load Regulation Characteristics with Current Limiting



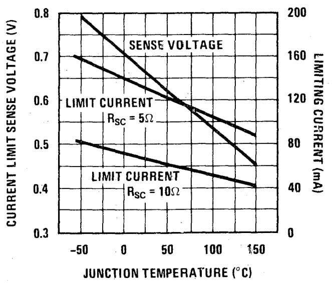
Load & Line Regulation vs Input-Output Voltage Differential



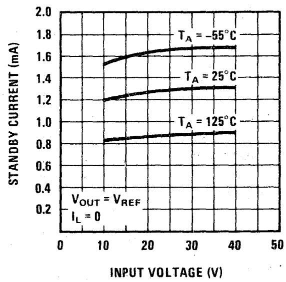
Current Limiting Characteristics



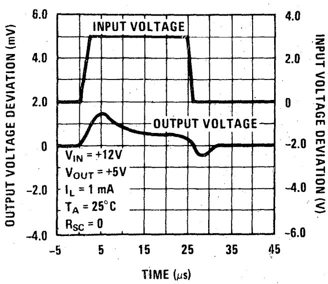
Current Limiting Characteristics vs Junction Temperature



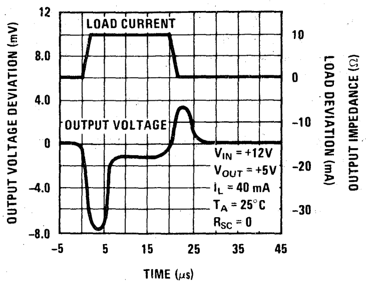
Standby Current Drain vs Input Voltage



Line Transient Response



Load Transient Response



Output Impedance vs Frequency

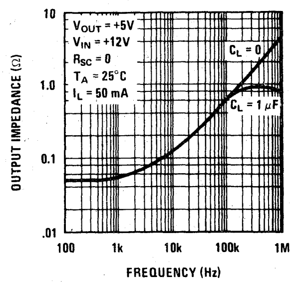


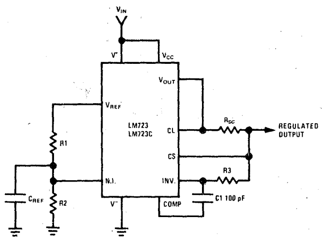
TABLE I RESISTOR VALUES (kΩ) FOR STANDARD OUTPUT VOLTAGE

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

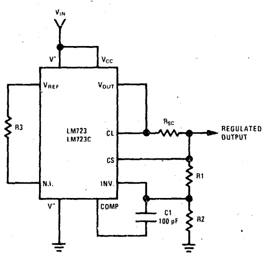
typical applications



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)

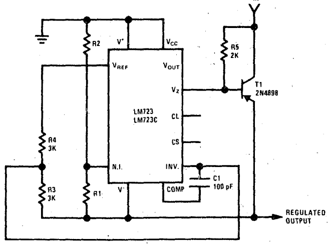


Note: $R3 = \frac{R1\,R2}{R1 + R2}$ for minimum temperature drift.

R3 may be eliminated for minimum component count.

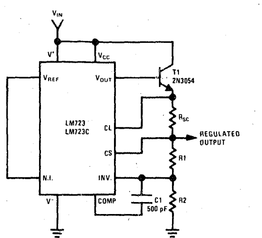
TYPICAL PERFORMANCE	
Regulated Output Voltage	15V
Line Regulation (ΔV_{IN} = 3V)	1.5 mV
Load Regulation (ΔI_L = 50 mA)	4.5 mV

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

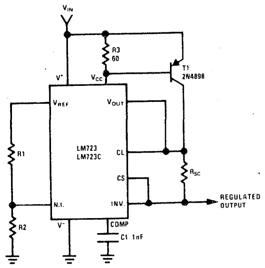
FIGURE 3. Negative Voltage Regulator



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)

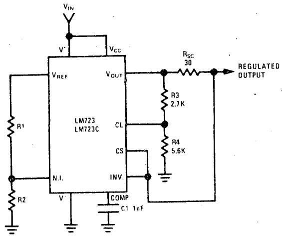
typical applications(con't.)



TYPICAL PERFORMANCE

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

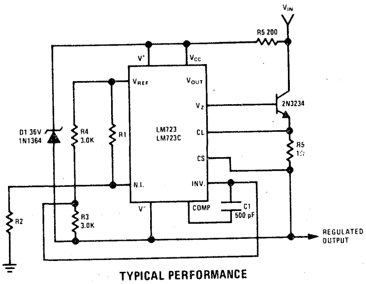
FIGURE 5. Positive Voltage Regulator (External PNP Pass Transistor)



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

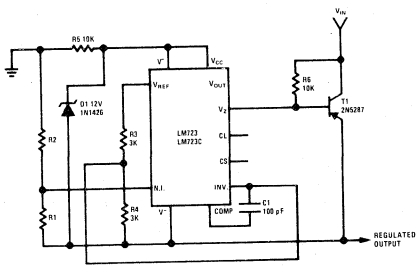
FIGURE 6. Foldback Current Limiting



TYPICAL PERFORMANCE

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

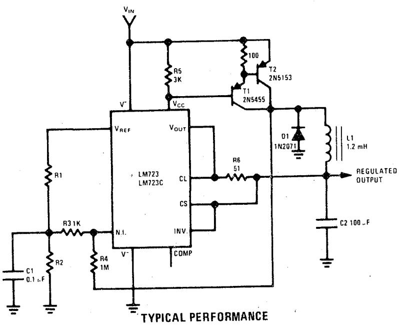
FIGURE 7. Positive Floating Regulator



TYPICAL PERFORMANCE

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

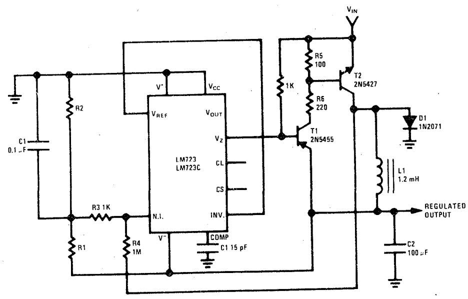
FIGURE 8. Negative Floating Regulator



TYPICAL PERFORMANCE

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

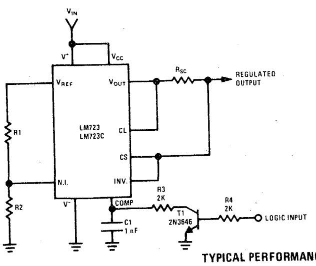
FIGURE 9. Positive Switching Regulator



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

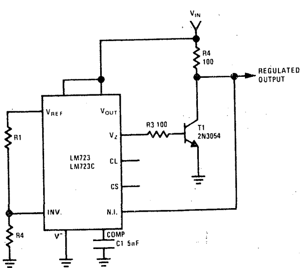


Note: Current limit transistor may be used for shutdown if current limiting is not required.

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

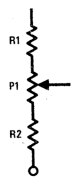


FIGURE 13. Output Voltage Adjust (See Note 5)

Voltage Regulators

LM78XX series voltage regulators

general description

The LM78XX 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 LM78XX series is available in an aluminum TO-3 package which will allow over 1.5A load current 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 LM78XX 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.

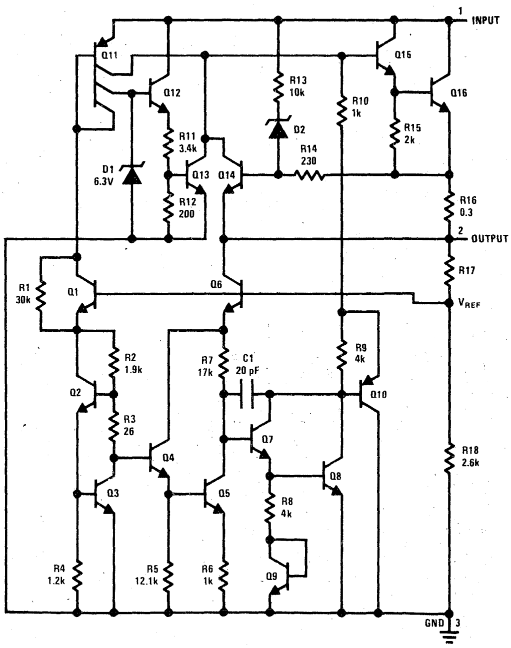
features

- Output current in excess of 1.5A
- Internal thermal overload protection
- No external components required
- Output transistor safe area protection
- Internal short circuit current limit
- Available in the aluminum TO-3 package

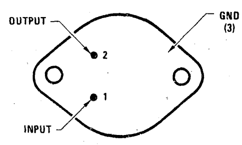
voltage range

LM7805	5V	LM7812	12V
LM7806	6V	LM7815	15V
LM7808	8V	LM7818	18V
LM7810	10V	LM7824	24V

schematic and connection diagrams



Metal Can Package
Aluminum TO-3 (KC)



BOTTOM VIEW

Order Numbers:

LM7805KC	**LM7812KC**
LM7806KC	**LM7815KC**
LM7808KC	**LM7818KC**
LM7810KC	**LM7824KC**

See Package 18

1

absolute maximum ratings

Input Voltage	
(Output Voltage Options 5V through 18V)	35V
(Output Voltage Option 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)	300°C

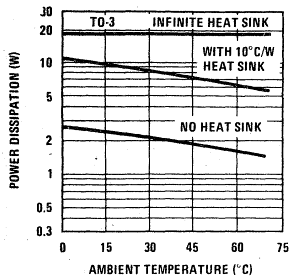
electrical characteristics $T_A = 0°C$ to $+70°C$, $I_O = 500$ mA (unless noted)

OUTPUT VOLTAGE			5V			6V			8V			10V			12V			15V			18V			24V			UNITS
INPUT VOLTAGE (unless otherwise noted)			10V			11V			14V			17V			19V			23V			27V			33V			
PARAMETER		CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_O	Output Voltage	$T_J = 25°C$	4.8	5	5.2	5.75	6	6.25	7.7	8	8.3	9.6	10	10.4	11.5	12	12.5	14.4	15	15.6	17.3	18	18.7	23	24	25	V
		$P_D = 15W$, 5 mA $\leq I_O \leq$ 1000 mA	4.75		5.25	5.7		6.3	7.6		8.4	9.5		10.5	11.4		12.6	14.25		15.75	17.1		18.9	22.8		25.2	V
		and $V_{MIN} \leq V_{IN} \leq V_{MAX}$		$(7 \leq V_{IN} \leq 20)$			$(8 \leq V_{IN} \leq 21)$			$(10.5 \leq V_{IN} \leq 23)$			$(12.5 \leq V_{IN} \leq 25)$			$(14.5 \leq V_{IN} \leq 27)$			$(17.5 \leq V_{IN} \leq 30)$			$(21 \leq V_{IN} \leq 33)$			$(27 \leq V_{IN} \leq 38)$		V
ΔV_O	Line Regulation	$T_J = 25°C$, $I_O = 100$ mA			50			60			80			100			120			150			180			240	mV
		$T_J = 25°C$, $I_O = 500$ mA			100			120			160			200			240			300			360			480	mV
				$(7 \leq V_{IN} \leq 25)$			$(8 \leq V_{IN} \leq 25)$			$(10.5 \leq V_{IN} \leq 25)$			$(12.5 \leq V_{IN} \leq 25)$			$(14.5 \leq V_{IN} \leq 30)$			$(17.5 \leq V_{IN} \leq 30)$			$(21 \leq V_{IN} \leq 33)$			$(21 \leq V_{IN} \leq 33)$		V
ΔV_O	Load Regulation	$T_J = 25°C$ 5 mA $\leq I_O \leq$ 1500 mA			100			120			160			200			240			300			360			480	mV
ΔV_O	Long Term Stability				20			24			32			40			48			60			72			96	mV/1000 hrs
I_Q	Quiescent Current	$T_J = 25°C$		7	10		7	10		7	10		7	10		7	10		7	10		7	10		7	10	mA
ΔI_Q	Quiescent Current Change	$I_{MIN} \leq I_O \leq I_{MAX}$			0.5			0.5			0.5			0.5			0.5			0.5			0.5			0.5	mA
				$(5 \leq I_O \leq 1500)$			$(5 \leq I_O \leq 1500)$			$(5 \leq I_O \leq 1500)$			$(5 \leq I_O \leq 1500)$			$(5 \leq I_O \leq 1500)$			$(5 \leq I_O \leq 1500)$			$(5 \leq I_O \leq 1000)$			$(5 \leq I_O \leq 1000)$		mA
		$V_{MIN} \leq V_{IN} \leq V_{MAX}$			1.3			1.3			1			1			1			1			1			1	mA
				$(7 \leq V_{IN} \leq 25)$			$(8 \leq V_{IN} \leq 25)$			$(10.5 \leq V_{IN} \leq 25)$			$(12.5 \leq V_{IN} \leq 25)$			$(14.5 \leq V_{IN} \leq 30)$			$(17.5 \leq V_{IN} \leq 30)$			$(21 \leq V_{IN} \leq 33)$			$(27 \leq V_{IN} \leq 38)$		V
V_n	Output Noise Voltage	$T_J = 25°C$, f = 10 Hz–100 kHz		40			45			52			70			75			90			110			170		μV
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple Rejection	f = 120 Hz		60			57			55			53			52			50			48			44		dB
Min $V_{IN} - V_{OUT}$	Dropout Voltage	$T_J = 25°C$, $I_O = 1A$		2			2			2			2			2			2			2			2		V

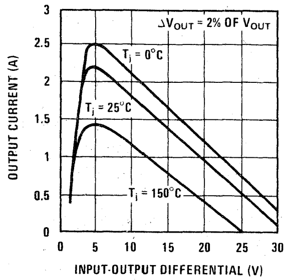
Note 1: Thermal resistance for the aluminum TO-3 is 4°C/W junction to case and 35°C/W case to ambient without a heat sink.

typical performance characteristics

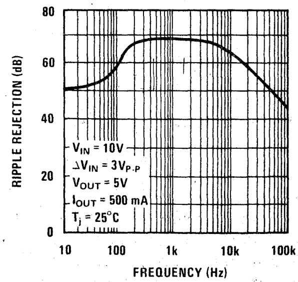
Maximum Average Power Dissipation



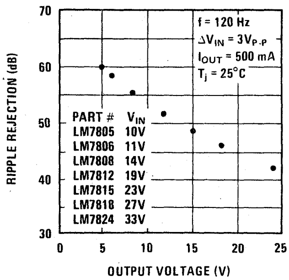
Peak Output Current



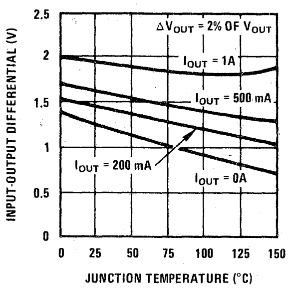
Ripple Rejection



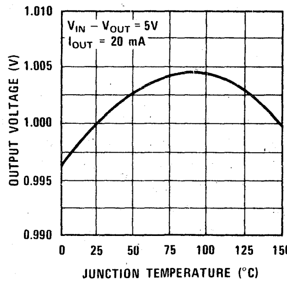
Ripple Rejection



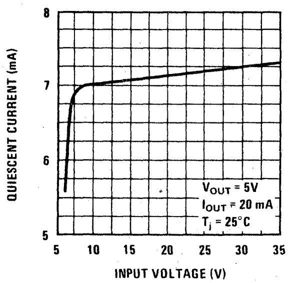
Dropout Voltage



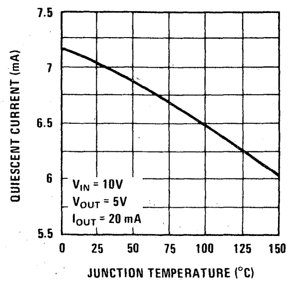
Output Voltage (Normalized to 1V at 25°C T_j)



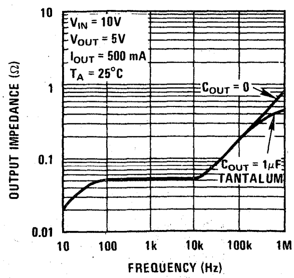
Quiescent Current



Quiescent Current



Output Impedance



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

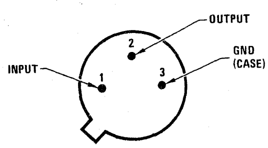
- Output voltage tolerances of ±5% (LM78LXXAC) and ±10% (LM78LXXC) over the temperature range
- Output current of 100 mA
- Internal thermal overload protection
- Output transistor safe area protection
- Internal short circuit current limit
- Available in plastic TO-92 and metal TO-39 low profile packages

voltage range

LM78L05	5V	LM78L12	12V
LM78L06	6V	LM78L15	15V
LM78L08	8V	LM78L18	18V
LM78L10	10V	LM78L24	24V

connection diagrams

Metal Can Package



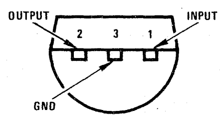
BOTTOM VIEW

Order Numbers:

LM78L05ACH	LM78L05CH
LM78L06ACH	LM78L06CH
LM78L08ACH	LM78L08CH
LM78L10ACH	LM78L10CH
LM78L12ACH	LM78L12CH
LM78L15ACH	LM78L15CH
LM78L18ACH	LM78L18CH
LM78L24ACH	LM78L24CH

See Package 9

Plastic Package



BOTTOM VIEW

Order Numbers:

LM78L05ACZ	LM78L05CZ
LM78L06ACZ	LM78L06CZ
LM78L08ACZ	LM78L08CZ
LM78L10ACZ	LM78L10CZ
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) T_J = 0°C to +125°C, I_O = 40 mA, C_{IN} = 0.33μF, C_O = 0.1μF (unless noted)

LM78LXXAC OUTPUT VOLTAGE			5V			6V			8V			10V			12V			15V			18V			24V			UNITS
INPUT VOLTAGE (unless otherwise noted)			10V			11V			14V			17V			19V			23V			27V			33V			
	PARAMETER	CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_O	Output Voltage (Note 4)	T_J = 25°C	4.8	5	5.2	5.75	6	6.25	7.7	8	8.3	9.6	10	10.4	11.5	12	12.5	14.4	15	15.6	17.3	18	18.7	23	24	25	V
		1 mA ≤ I_O ≤ 70 mA	4.75		5.25	5.7		6.3	7.6		8.4	9.5		10.5	11.4		12.6	14.25		15.75	17.2		18.9	22.8		25.2	V
		1 mA ≤ I_O ≤ 40 mA and	4.75		5.25	5.7		6.3	7.6		8.4	9.5		10.5	11.4		12.6	14.25		15.75	17.2		18.9	22.8		25.2	V
		$V_{MIN} \le V_{IN} \le V_{MAX}$	(7 ≤ V_{IN} ≤ 20)			(8.3 ≤ V_{IN} ≤ 21)			(10.5 ≤ V_{IN} ≤ 23)			(12.5 ≤ V_{IN} ≤ 25)			(14.5 ≤ V_{IN} ≤ 27)			(17.5 ≤ V_{IN} ≤ 30)			(20.7 ≤ V_{IN} ≤ 33)			(27 ≤ V_{IN} ≤ 38)			V
ΔV_O	Line Regulation	T_J = 25°C		10	54		10	68		12	85		16	105		20	110		25	140		35	190		50	200	mV
			(8 ≤ V_{IN} ≤ 20)			(9 ≤ V_{IN} ≤ 21)			(11 ≤ V_{IN} ≤ 23)			(13 ≤ V_{IN} ≤ 25)			(16 ≤ V_{IN} ≤ 27)			(20 ≤ V_{IN} ≤ 30)			(21 ≤ V_{IN} ≤ 33)			(28 ≤ V_{IN} ≤ 38)			V
				18	75		18	90		20	100		25	140		30	180		37	250		45	275		60	300	mV
			(7 ≤ V_{IN} ≤ 20)			(8.3 ≤ V_{IN} ≤ 21)			(10.5 ≤ V_{IN} ≤ 23)			(12.5 ≤ V_{IN} ≤ 25)			(14.5 ≤ V_{IN} ≤ 27)			(17.5 ≤ V_{IN} ≤ 30)			(20.7 ≤ V_{IN} ≤ 33)			(27 ≤ V_{IN} ≤ 38)			V
ΔV_O	Load Regulation	T_J = 25°C, 1 mA ≤ I_O ≤ 40 mA		5	30		6	35		8	40		9	45		10	50		12	75		15	85		20	100	mV
		T_J = 25°C, 1 mA ≤ I_O ≤ 100 mA		20	60		22	70		25	80		27	90		30	100		35	150		40	170		50	200	mV
ΔV_O	Long Term Stability			12			15			20			22			24			30			45			56		mV/1000 hrs
I_Q	Quiescent Current	T_J = 25°C		3	5		3	5		3	5		3	5		3	5		3.1	5		3.1	5		3.1	5	mA
		T_J = 125°C			4.7			4.7			4.7			4.7			4.7			4.7			4.7			4.7	
ΔI_Q	Quiescent Current Change	1 mA ≤ I_O ≤ 40 mA			0.1			0.1			0.1			0.1			0.1			0.1			0.1			0.1	mA
		$V_{MIN} \le V_{IN} \le V_{MAX}$			1.0			1.0			1.0			1.0			1.0			1.0			1.0			1.0	mA
			(8 ≤ V_{IN} ≤ 20)			(9 ≤ V_{IN} ≤ 21)			(11 ≤ V_{IN} ≤ 23)			(13 ≤ V_{IN} ≤ 25)			(16 ≤ V_{IN} ≤ 27)			(20 ≤ V_{IN} ≤ 30)			(21 ≤ V_{IN} ≤ 33)			(28 ≤ V_{IN} ≤ 38)			V
V_n	Output Noise Voltage	T_J = 25°C, (Note 3) f = 10 Hz – 10 kHz		40			50			60			70			80			90			150			200		μV
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple Rejection	f = 120 Hz	47	62		45	60		43	57		41	55		40	54		37	51		36	48		34	45		dB
			(8 ≤ V_{IN} ≤ 16)			(9 ≤ V_{IN} ≤ 18)			(12 ≤ V_{IN} ≤ 23)			(13 ≤ V_{IN} ≤ 25)			(15 ≤ V_{IN} ≤ 25)			(18.5 ≤ V_{IN} ≤ 28.5)			(23 ≤ V_{IN} ≤ 33)			(29 ≤ V_{IN} ≤ 35)			V
	Input Voltage Required to Maintain Line Regulation	T_J = 25°C	7			8.3			10.5			12.5			14.5			17.5			20.7			27			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" leads from a PC board and 160°C/W junction to ambient with 0.125" 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 test.

Note 3: Recommended minimum load capacitance of 0.01μF to limit high frequency noise bandwidth.

Note 4: The temperature coefficient of V_{OUT} is typically within ±0.01% V_O/°C.

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) T_J = 0°C to +125°C, I_O = 40 mA, C_{IN} = 0.33μF, C_O = 0.1μF (unless noted)

LM78LXXC OUTPUT VOLTAGE			5V			6V			8V			10V			12V			15V			18V			24V			UNITS
INPUT VOLTAGE (unless otherwise noted)			10V			11V			14V			17V			19V			23V			27V			33V			
PARAMETER		CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_O	Output Voltage	T_J = 25°C	4.6	5	5.4	5.5	6	6.5	7.36	8	8.64	9.2	10	10.8	11.1	12	12.9	13.8	15	16.2	16.6	18	19.4	22.1	24	25.9	V
	(Note 4)	1 mA ≤ I_O ≤ 70 mA or	4.5		5.5	5.4		6.6	7.2		8.8	9.0		11	10.8		13.2	13.5		16.5	16.2		19.8	21.4		26.4	V
		1 mA ≤ I_O ≤ 40 mA and ΔV_{IN}	$(7 \le V_{IN} \le 20)$			$(8.5 \le V_{IN} \le 21)$			$(10.5 \le V_{IN} \le 23)$			$(13 \le V_{IN} \le 25)$			$(14.5 \le V_{IN} \le 27)$			$(18 \le V_{IN} \le 30)$			$(21.4 \le V_{IN} \le 33)$			$(28 \le V_{IN} \le 38)$			V
ΔV_O	Line Regulation	T_J = 25°C		10	150		10	150		12	150		16	175		20	200		25	250		27	275		30	300	mV
			$(8 \le V_{IN} \le 20)$			$(9 \le V_{IN} \le 21)$			$(11 \le V_{IN} \le 23)$			$(14 \le V_{IN} \le 25)$			$(16 \le V_{IN} \le 27)$			$(20 \le V_{IN} \le 30)$			$(22 \le V_{IN} \le 33)$			$(28 \le V_{IN} \le 38)$			V
				18	200		18	200		20	200		25	225		30	250		30	300		32	325		35	350	mV
			$(7 \le V_{IN} \le 20)$			$(8.5 \le V_{IN} \le 21)$			$(10.5 \le V_{IN} \le 23)$			$(13 \le V_{IN} \le 25)$			$(14.5 \le V_{IN} \le 27)$			$(18 \le V_{IN} \le 30)$			$(21.4 \le V_{IN} \le 33)$			$(27.5 \le V_{IN} \le 38)$			V
ΔV_O	Load Regulation	T_J = 25°C, 1 mA ≤ I_O ≤ 40 mA		5	30		6	35		8	40		9	45		10	50		12	75		15	85		20	100	mV
		T_J = 25°C, 1 mA ≤ I_O ≤ 100 mA		20	60		22	70		25	80		27	90		30	100		35	150		40	170		40	200	mV
ΔV_O	Long Term Stability			12			15			20			22			24			30			45			56		mV/1000 hrs
I_Q	Quiescent Current	T_J = 25°C		3	6		3	6		3	6		3	6		3	6.5		3.1	6.5		3.1	6.5		3.1	6.5	mA
		T_J = 125°C			5.5			5.5			5.5			5.5			6			6			6			6	
ΔI_Q	Quiescent Current	T_J = 25°C, 1 mA ≤ I_O ≤ 40 mA			0.2			0.2			0.2			0.2			0.2			0.2			0.2			0.2	mA
					1.5			1.5			1.5			1.5			1.5			1.5			1.5			1.5	mA
	Change	T_J = 25°C	$(8 \le V_{IN} \le 20)$			$(9 \le V_{IN} \le 21)$			$(11 \le V_{IN} \le 23)$			$(14 \le V_{IN} \le 25)$			$(16 \le V_{IN} \le 27)$			$(20 \le V_{IN} \le 30)$			$(22 \le V_{IN} \le 33)$			$(28 \le V_{IN} \le 38)$			V
V_n	Output Noise Voltage	T_J = 25°C, (Note 3) f = 10 Hz – 10 kHz		40			50			60			70			80			90			150			200		μV
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple Rejection	f = 125 Hz	40	60		38	58		36	55		36	53		36	52		33	49		32	46		30	43		dB
			$(8 \le V_{IN} \le 18)$			$(9 \le V_{IN} \le 19)$			$(12 \le V_{IN} \le 23)$			$(14 \le V_{IN} \le 25)$			$(15 \le V_{IN} \le 25)$			$(18.5 \le V_{IN} \le 28.5)$			$(23 \le V_{IN} \le 33)$			$(29 \le V_{IN} \le 35)$			V
	Input Voltage Required to Maintain Line Regulation	T_J = 25°C		7			8.3			10.5			13			14.5			18			21.4			27.5		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″ leads from a PC board and 160°C/W junction to ambient with 0.125″ lead length to a PC board.

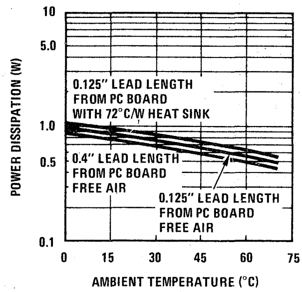
Note 2: The maximum steady state usable output current and input voltage are very dependent on the heat sinking and/or lead length of the package. The data above represent pulse test conditions with junction temperatures as indicated at the initiation of test.

Note 3: Recommended minimum load capacitance of 0.01μF to limit high frequency noise bandwidth.

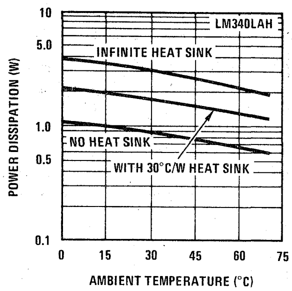
Note 4: The temperature coefficient of V_{OUT} is typically within ±0.01% V_O/°C.

typical performance characteristics

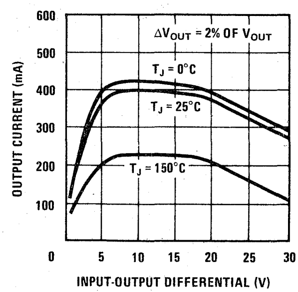
Maximum Average Power Dissipation (Plastic Package)



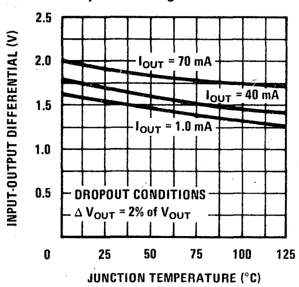
Maximum Average Power Dissipation (Metal Can Package)



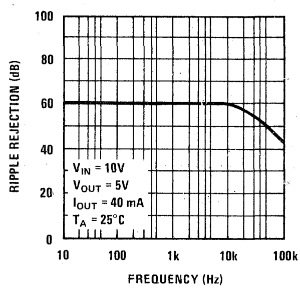
Peak Output Current



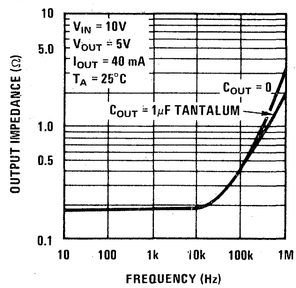
Dropout Voltage



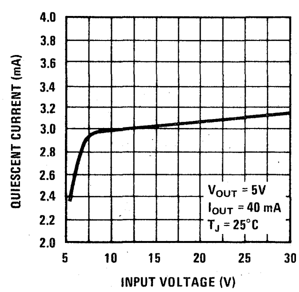
Ripple Rejection



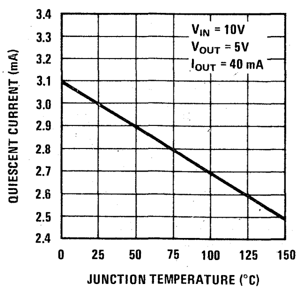
Output Impedance



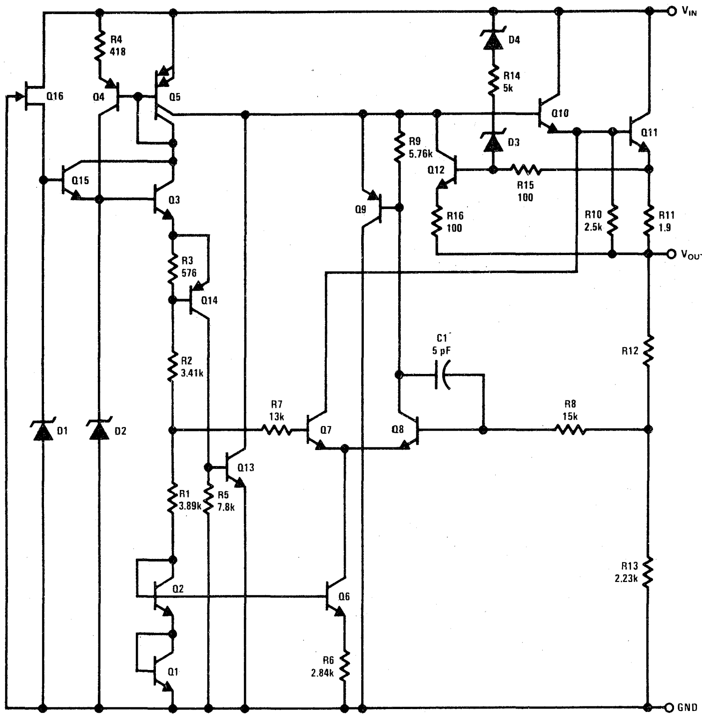
Quiescent Current



Quiescent Current

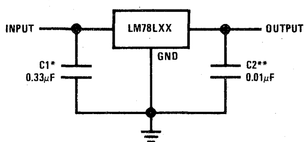


equivalent circuit



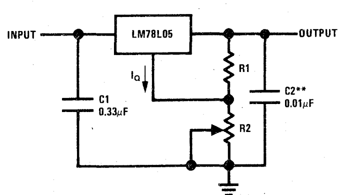
LM78LXX

typical applications



*Required if the regulator is located far from the power supply filter.
**See Note 3 in the electrical characteristics table.

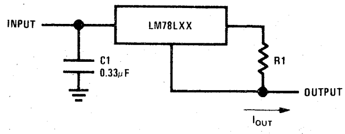
Fixed Output Regulator



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

Adjustable Output Regulator

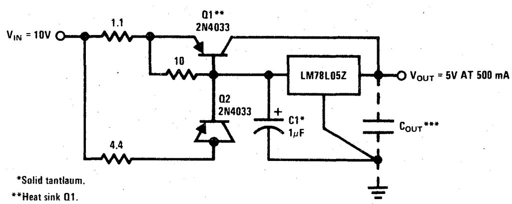
typical applications (con't)



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

ΔI_Q = 1.5 mA over line and load changes

Current Regulator



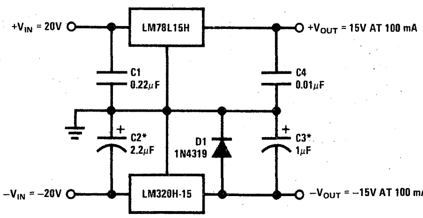
*Solid tantlaum.

**Heat sink Q1.

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

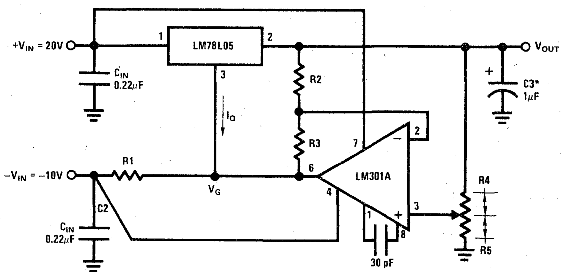
Load Regulation: 0.6% $0 \leq I_L \leq 250$ mA pulsed with t_{ON} = 50 ms.

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

Voltage Regulators

LM7900T series 3-terminal negative regulators

general description

The LM7900T series of 3-terminal regulators is available with fixed output voltages of −5V, −5.2V, −6V, −8V, −9V, −12V, −15V, −18V and −24V. These devices need only one external component – a compensation capacitor at the output. The LM7900T series is packaged in the TO-220 power package and is capable of supplying 1.5A of output current.

These regulators employ internal current limiting safe area protection and thermal shutdown for protection against virtually all overload conditions.

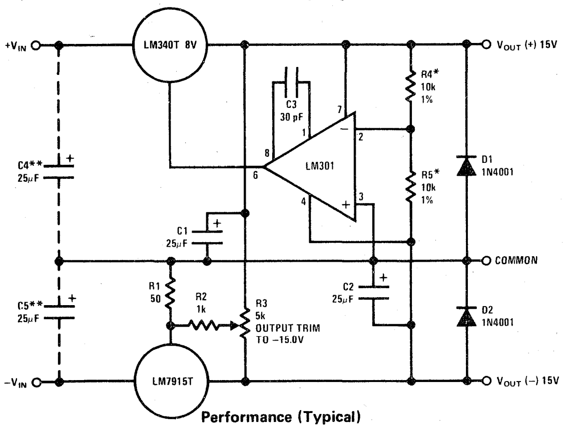
Low ground pin current of the LM7900T series allows output voltage to be easily boosted above the preset value with a resistor divider. The low quiescent current drain of these devices with a specified maximum change with line and load ensures good regulation in the voltage boosted mode.

features

- Thermal, short circuit and safe area protection
- High ripple rejection
- 1.5A output current
- 4% preset output voltage

typical applications

±15V, 1 Amp Tracking Regulators



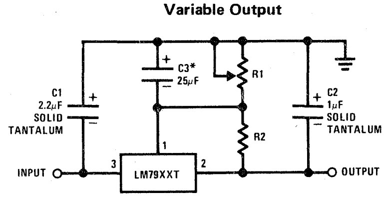
Performance (Typical)

	(−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 $\leq f \leq$ 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 3" from regulators

Variable Output



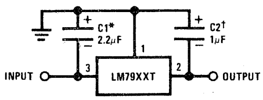
*Improves transient response and ripple rejection. Do not increase beyond 50µF.

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

Select R2 as follows

LM7905T	300Ω
LM7905.2T	300Ω
LM7906T	300Ω
LM7908T	470Ω
LM7909T	470Ω
LM7912T	750Ω
LM7915T	1k
LM7918T	1.2k
LM7924T	2.5k

Fixed Regulator

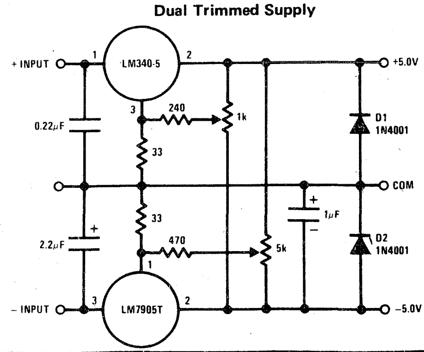


*Required if regulator is separated from filter capacitor by more than 3". For value given, capacitor must be solid tantalum. 25µF aluminum electrolytic may be substituted.

†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.

Dual Trimmed Supply



absolute maximum ratings

Input Voltage		Power Dissipation	Internally Limited
(V_O = 5V to 18V)	−35V	Operating Junction Temperature Range	0°C to +125°C
(V_O = 24V)	−40V	Storage Temperature Range	−65°C to +150°C
Input-Output Differential		Lead Temperature (Soldering, 10 seconds)	230°C
(V_O = 5V to 8V)	25V		
(V_O = 9V to 18V)	30V		
(V_O = 24V)	35V		

electrical characteristics

Conditions unless otherwise noted: I_{OUT} = 500 mA, C_{IN} = 2.2μF, C_{OUT} = 1μF, 0°C ≤ T_J ≤ +125°C, Power Dissipation ≤ 15W.

PART NUMBER			LM7905T			LM7905.2T			LM7906T			LM7908T			LM7909T			UNITS
OUTPUT VOLTAGE			−5V			−5.2V			−6V			−8V			−9V			
INPUT VOLTAGE (unless otherwise specified)			−10V			−10V			−11V			−14V			−15V			
PARAMETER		CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_O	Output Voltage	T_J = 25°C	−4.8	−5.0	−5.2	−5.0	−5.2	−5.4	−5.75	−6.0	−6.25	−7.7	−8.0	−8.3	−8.65	−9	−9.35	V
		5 mA ≤ I_{OUT} ≤ 1A,	−4.75		−5.25	−4.95		−5.45	−5.7		−6.3	−7.6		−8.4	−8.55		−9.45	V
		P ≤ 15W		(−20 ≤ V_{IN} ≤ −7)			(−20.5 ≤ V_{IN} ≤ −7.5)			(−21 ≤ V_{IN} ≤ −8)			(−23 ≤ V_{IN} ≤ −10.5)			(−24 ≤ V_{IN} ≤ −11.5)		V
ΔV_O	Line Regulation	T_J = 25°C, (Note 2)		8	50		7	50		5	60		6	80		6	80	mV
				(−25 ≤ V_{IN} ≤ −7)			(−25 ≤ V_{IN} ≤ −7.5)			(−25 ≤ V_{IN} ≤ −8)			(−25 ≤ V_{IN} ≤ −10.5)			(−26 ≤ V_{IN} ≤ 11.5)		V
				2	15		2	15		2	20		2	30		3	30	mV
				(−12 ≤ V_{IN} ≤ −8)			(−12.5 ≤ V_{IN} ≤ −8.5)			(−13 ≤ V_{IN} ≤ −9)			(−17 ≤ V_{IN} ≤ −11)			(−18 ≤ V_{IN} ≤ −12)		V
ΔV_O	Load Regulation	T_J = 25°C, (Note 2)																mV
		5 mA ≤ I_{OUT} ≤ 1.5A		15	100		15	100		15	120		15	160		15	170	mV
		250 mA ≤ I_{OUT} ≤ 750 mA		5	50		5	50		5	60		5	80		5	80	mV
I_Q	Quiescent Current	T_J = 25°C		1	2		1	2		1	2		1	2		1.5	3	mA
ΔI_Q	Quiescent Current Change	With Line			0.5			0.5			0.5			0.5			0.5	mA
				(−25 ≤ V_{IN} ≤ −7)			(−25 ≤ V_{IN} ≤ −7.5)			(−25 ≤ V_{IN} ≤ −8)			(−25 ≤ V_{IN} ≤ −10.5)			(−25 ≤ V_{IN} ≤ 11.5)		V
		With Load, 5 mA ≤ I_{OUT} ≤ 1A			0.5			0.5			0.5			0.5			0.5	mA
V_n	Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 100 Hz		125			130			150			200			225		μV
	Ripple Rejection	f = 120 Hz	54	66		54	66		54	66		54	66		54	66		dB
				(−18 ≤ V_{IN} ≤ −8)			(−18.5 ≤ V_{IN} ≤ −8.5)			(−19 ≤ V_{IN} ≤ −9)			(−21.5 ≤ V_{IN} ≤ −11.5)			(−22.5 ≤ V_{IN} ≤ −12.5)		V
	Dropout Voltage	T_J = 25°C, I_{OUT} = 1A		1.1			1.1			1.1			1.1			1.1		V
I_{OMAX}	Peak Output Current	T_J = 25°C		2.2			2.2			2.2			2.2			2.2		A
	Average Temperature Coefficient of Output Voltage	I_{OUT} = 5 mA, 0°C ≤ T_J ≤ 100°C		0.4			0.4			0.4			−0.4			−0.6		mV/°C

1

electrical characteristics (con't)

Conditions unless otherwise noted: I_{OUT} = 500 mA, C_{IN} = 2.2μF, C_{OUT} = 1μF, 0°C ≤ T_J ≤ +125°C, Power Dissipation = 1.5W.

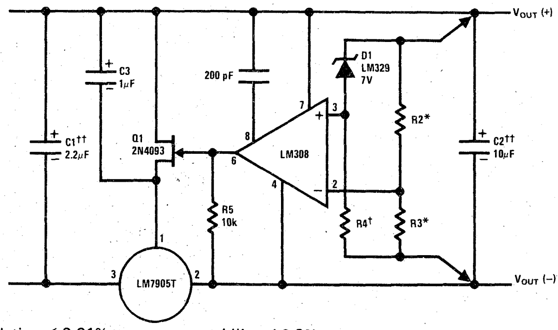
PART NUMBER			LM7912T			LM7915T			LM7918T			LM7924T			UNITS
OUTPUT VOLTAGE			−12V			−15V			−18V			−24V			
INPUT VOLTAGE (unless otherwise specified)			−19V			−23V			−27V			−33V			
	PARAMETER	CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_O	Output Voltage	T_J = 25°C	−11.5	−12.0	−12.5	−14.4	−15.0	−15.6	−17.3	−18.0	−18.7	−23	−24	−25	V
		5 mA ≤ I_{OUT} ≤ 1A,	−11.4		−12.6	−14.25		−15.75	−17.1		−18.9	−22.8	−25.2	–	V
		P ≤ 15W		(−27 ≤ V_{IN} ≤ −14.5)			(−30 ≤ V_{IN} ≤ −17.5)			(−33 ≤ V_{IN} ≤ −21)			(−38 ≤ V_{IN} ≤ −27)		V
ΔV_O	Line Regulation	T_J = 25°C, (Note 2)		5	80		5	100		5	100		5	150	mV
				(−30 ≤ V_{IN} ≤ −14.5)			(−30 ≤ V_{IN} ≤ −17.5)			(−33 ≤ V_{IN} ≤ −21)			(−38 ≤ V_{IN} ≤ −27)		V
				3	30		3	50		5	50		6	75	mV
				(−22 ≤ V_{IN} ≤ −16)			(−26 ≤ V_{IN} ≤ −20)			(−30 ≤ V_{IN} ≤ −24)			(−36 ≤ V_{IN} ≤ −30)		V
ΔV_O	Load Regulation	T_J = 25°C, (Note 2)		15	200		15	200		15	240		15	240	mV
		5 mA ≤ I_{OUT} ≤ 1.5A		15	200		15	200		15	240		15	240	mV
		250 mA ≤ I_{OUT} ≤ 750 mA		5	75		5	75		5	100		5	100	mV
I_Q	Quiescent Current	T_J = 25°C		1.5	3		1.5	3		1.5	3		1.5	3	mA
ΔI_Q	Quiescent Current Change	With Line			0.5			0.5			0.5			0.5	mA
				(−30 ≤ V_{IN} ≤ −14.5)			(−30 ≤ V_{IN} ≤ −17.5)			(−33 ≤ V_{IN} ≤ −21)			(−38 ≤ V_{IN} ≤ −27)		V
		With Load, 5 mA ≤ I_{OUT} ≤ 1A			0.5			0.5			0.5			0.5	mA
V_n	Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 100 Hz		300			375			450			600		μV
	Ripple Rejection	f = 120 Hz	54	70		54	70		54	70		54	66		dB
				(−25 ≤ V_{IN} ≤ −15)			(−30 ≤ V_{IN} ≤ −17.5)			(−32 ≤ V_{IN} ≤ −22)			(−38 ≤ V_{IN} ≤ −28)		V
	Dropout Voltage	T_J = 25°C, I_{OUT} = 1A		1.1			1.1			1.1			1.1		V
I_{OMAX}	Peak Output Current	T_J = 25°C		2.2			2.2			2.2			2.2		A
	Average Temperature Coefficient of Output Voltage	I_{OUT} = 5 mA, 0°C ≤ T_J ≤ 100°C		−0.8			−1.0			−1.0			−1.0		mV/°C

Note 1: For calculations of junction temperature rise due to power dissipation, thermal resistance junction to ambient (θ_{JA}) is 50°C/W (no heat sink) and 5°C/W (infinite heat sink).

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

typical applications (con't)

High Stability 1 Amp Regulator



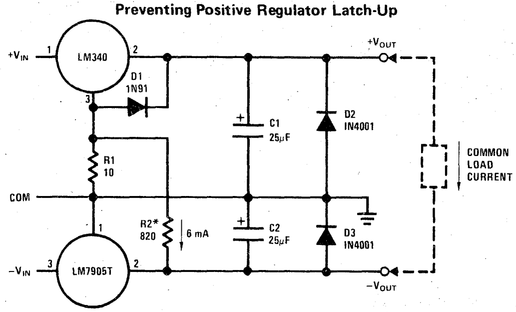
Load and line regulation < 0.01% temperature stability ≤ 0.2%

† Determines Zener current

†† Solid tantalum

*Select resistors to set output voltage. 2 ppm/°C tracking suggested

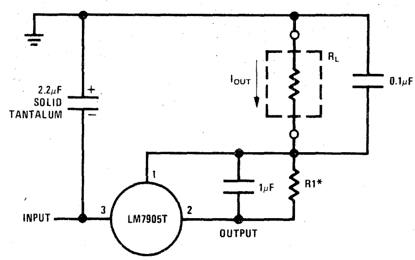
Preventing Positive Regulator Latch-Up



R1 and D1 allow the positive regulator to "start-up" when $+V_{IN}$ is delayed relative to $-V_{IN}$ and a heavy load is drawn between the outputs. Without R1 and D1, most three-terminal regulators will not start with heavy (0.1A–1A) load current flowing to the negative regulator, even though the positive output is clamped by D2.

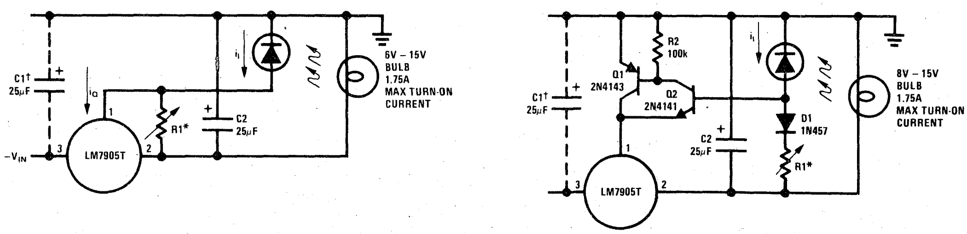
*R2 is optional. Ground pin current from the positive regulator flowing through R1 will increase $+V_{OUT} \approx 60$ mV if R2 is omitted.

Current Source



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

Light Controllers Using Silicon Photo Cells



*Lamp brightness increases until $i_l = i_Q$ (≈ 1 mA) + 5V/R1.

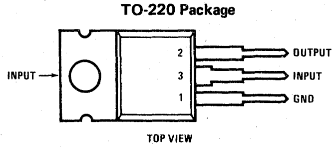
† Necessary only if raw supply filter capacitor is more than 2" from LM7905T

*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 LM7905T

connection diagram

TO-220 Package



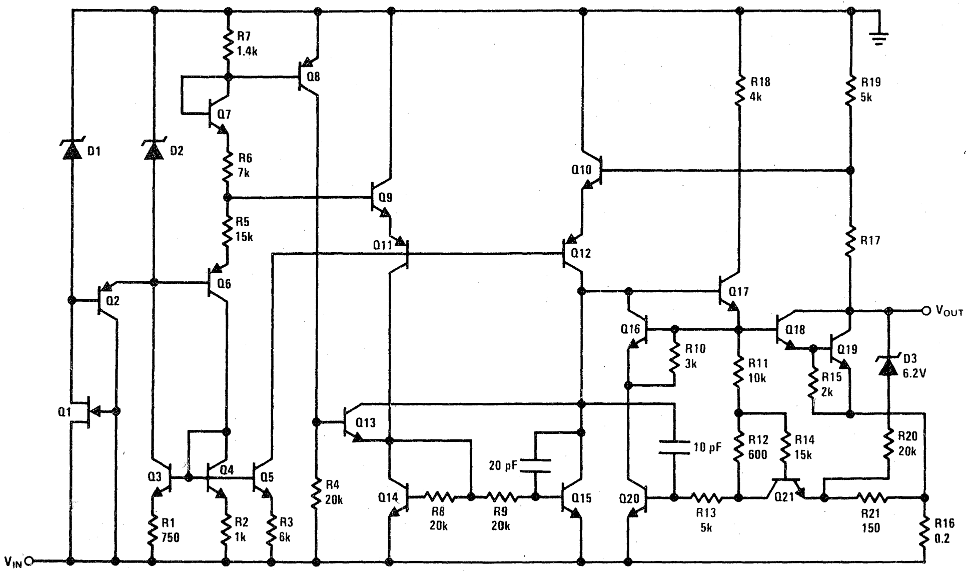
Order Numbers:

LM7905T	**LM7912T**
LM7905.2T	**LM7915T**
LM7906T	**LM7918T**
LM7908T	**LM7924T**
LM7909T	

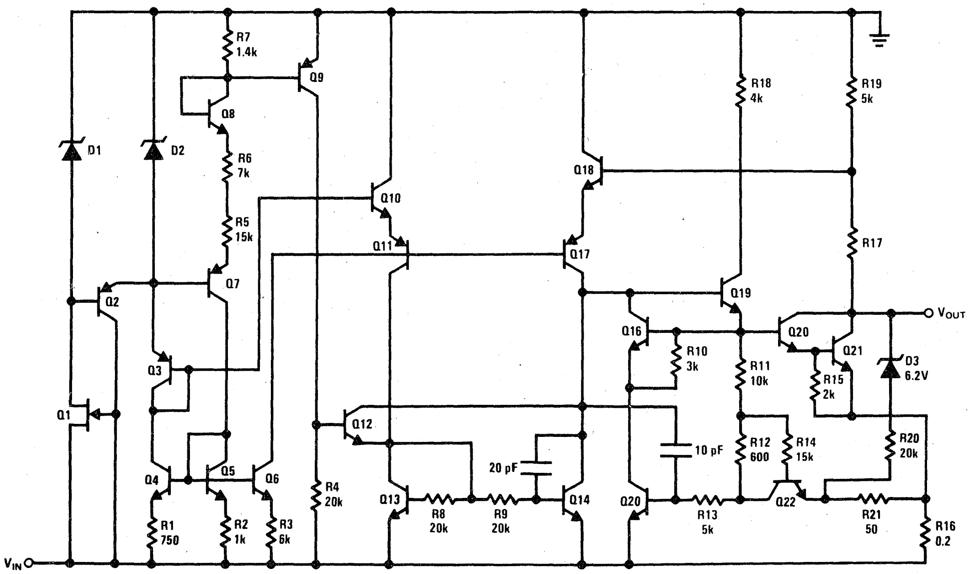
See Package 26

schematic diagrams

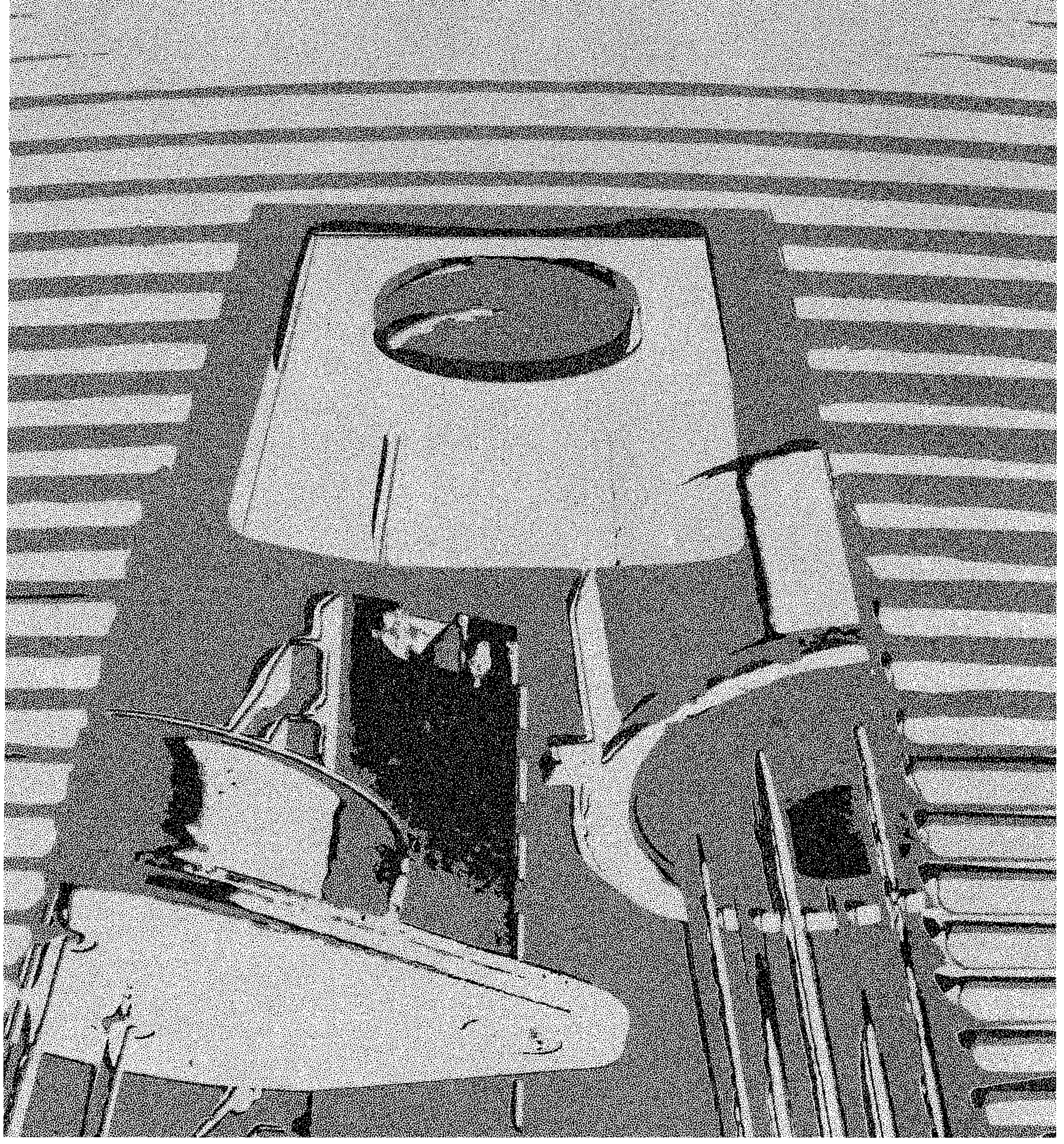
–5V, –5.2V, –6V, –8V



–9V, –12V, –15V, –18V, –24V



National Semiconductor
VOLTAGE REFERENCES
Section 2



Voltage References

Section Contents

*Product added to this Data Book since last printing.

2

Voltage References

Voltage Reference Guide

VOLTAGE	DEVICE	CURRENT RANGE	DYNAMIC IMPEDANCE
1.22	LM113	500μA to 20 mA	0.3Ω
1.8 2.0 2.2 2.4 2.7 3.0 3.3 3.6 3.9 4.3 4.7 5.1 5.6	LM103	10μA to 10 mA	15Ω
6.95	LM199/LM299/LM399 LM129/LM329 LM3999	0.5 mA to 10 mA	0.5Ω
10.00	LH0070	Quiescent Current = 3 mA	0.2Ω
10.24	LH0071		

Voltage References

LH0070 series precision BCD buffered reference
LH0071 series precision binary buffered reference

general description

The LH0070 and LH0071 are precision, three terminal, voltage references consisting of a temperature compensated zener diode driven by a current regulator and a buffer amplifier. The devices provide an accurate reference that is virtually independent of input voltage, load current, temperature and time. The LH0070 has a 10.000V nominal output to provide equal step sizes in BCD applications. The LH0071 has a 10.240V nominal output to provide equal step sizes in binary applications.

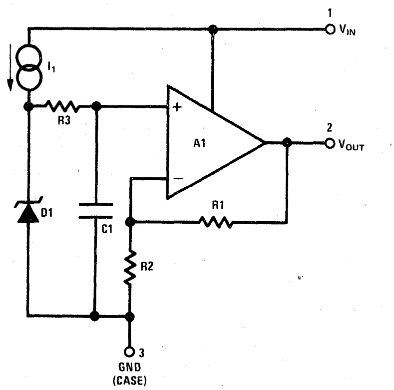
The output voltage is established by trimming ultra-stable, low temperature drift, thin film resistors under actual operating circuit conditions. The devices are short-circuit proof in both the current sourcing and sinking directions.

The LH0070 and LH0071 series combine excellent long term stability, ease of application, and low cost, making them ideal choices as reference voltages in precision D to A and A to D systems.

features

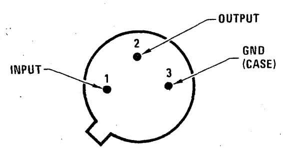
- Accurate output voltage
  - LH0070 — 10V ±0.01%
  - LH0071 — 10.24V ±0.01%
- Single supply operation — 12.5V to 40V
- Low output impedance — 0.1Ω
- Excellent line regulation — 0.1 mV/V
- Low zener noise — 100μVp-p
- 3-lead TO-5 (pin compatible with the LM109)
- Short circuit proof
- Low standby current — 3 mA

equivalent schematic



connection diagram

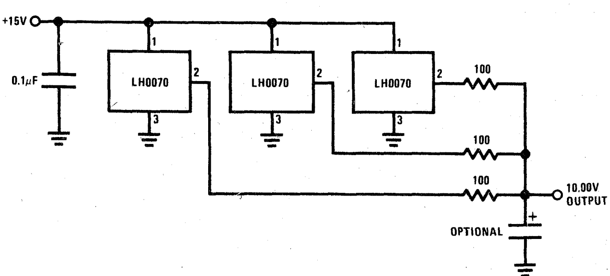
Metal Can Package



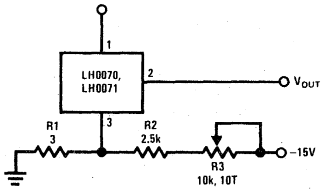
BOTTOM VIEW

Order Number LH0070-1H, LH0070-2H, LH0071-1H or LH0071-2H
See Package 9

typical applications



Statistical Voltage Standard



*Note: The output of the LH0070 and LH0071 may be adjusted to a precise voltage by using the above circuit since the supply current of the devices is relatively small and constant with temperature and input voltage. For the circuit shown, supply sensitivities are degraded slightly to 0.01%/V change in V_{OUT} for changes in V_{IN} and V^-.

An additional temperature drift of 0.0001%/°C is added due to the variation of supply current with temperature of the LH0070 and LH0071. Sensitivity to the value of R1, R2 and R3 is less than 0.001%/%.

***Output Voltage Fine Adjustment**

absolute maximum ratings

Supply Voltage	40V
Power Dissipation (See Curve)	600 mW
Short Circuit Duration	Continuous
Output Current	±20 mA
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 (Note 1)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Output Voltage	T_A = 25°C				
LH0070			10.000		V
LH0071			10.240		V
Output Accuracy	T_A = 25°C				
−1			±0.03	±0.1	%
−2			±0.02	±0.05	%
Output Accuracy					
−1				±0.3	%
−2				±0.2	%
Output Voltage Change With Temperature	(Note 2)				
−1			±0.02	±0.1	%
−2			±0.01	±0.04	%
Line Regulation	13V ≤ V_{IN} ≤ 33V, T_C = 25°C				
−1			0.02	0.1	%
−2			0.01	0.03	%
Input Voltage Range		12.5		40	V
Load Regulation	0 mA ≤ I_{OUT} ≤ 5 mA		0.01	0.03	%
Quiescent Current	13V ≤ V_{IN} ≤ 33V, I_{OUT} = 0 mA	2	3	5	mA
Change In Quiescent Current	ΔV_{IN} = 20V From 13V To 33V		0.75	1.5	mA
Output Noise Voltage	BW = 0.1 Hz to 10 Hz, T_A = 25°C		100		μVp-p
Ripple Rejection	f = 120 Hz		0.01		%/Vp-p
Output Resistance			0.2	1	Ω
Long Term Stability	T_A = 25°C (Note 3)				
−1				±0.2	%/yr.
−2				±0.05	%/yr.

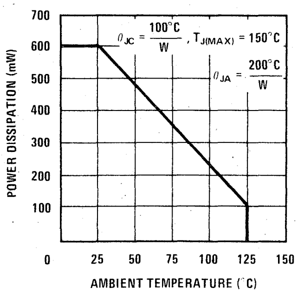
Note 1: Unless otherwise specified, these specifications apply for V_{IN} = 15.0V, R_L = 10 kΩ, and over the temperature range of −55°C ≤ T_A ≤ +125°C.

Note 2: This specification is the difference in output voltage measured at T_A = +85°C and at T_A = −25°C with readings taken after oven and device-under-test stabilization at temperature using a suitable precision voltmeter.

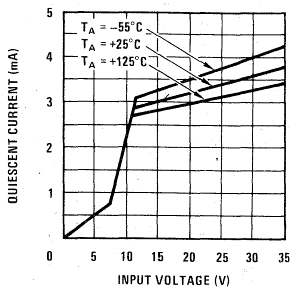
Note 3: This parameter is guaranteed by design and not tested.

typical performance characteristics

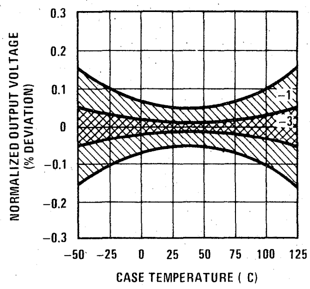
Maximum Power Dissipation



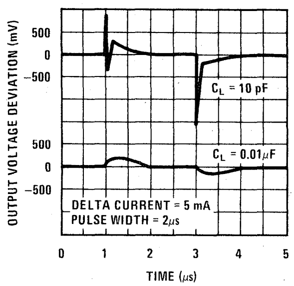
Quiescent Current vs Input Voltage



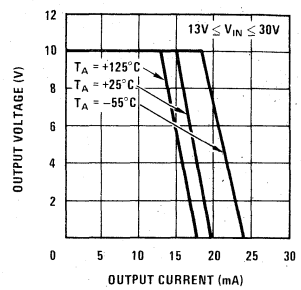
Normalized Output Voltage vs Temperature



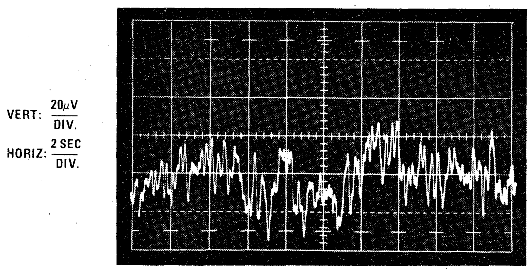
Step Load Response



Output Short Circuit Characteristics

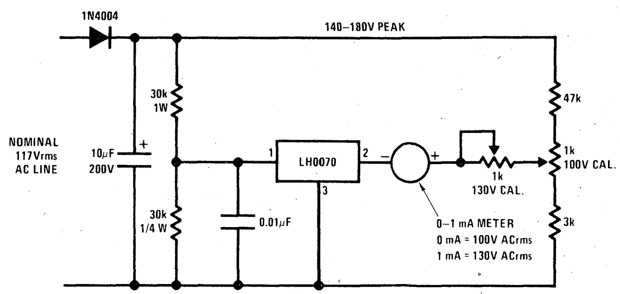


Noise Voltage



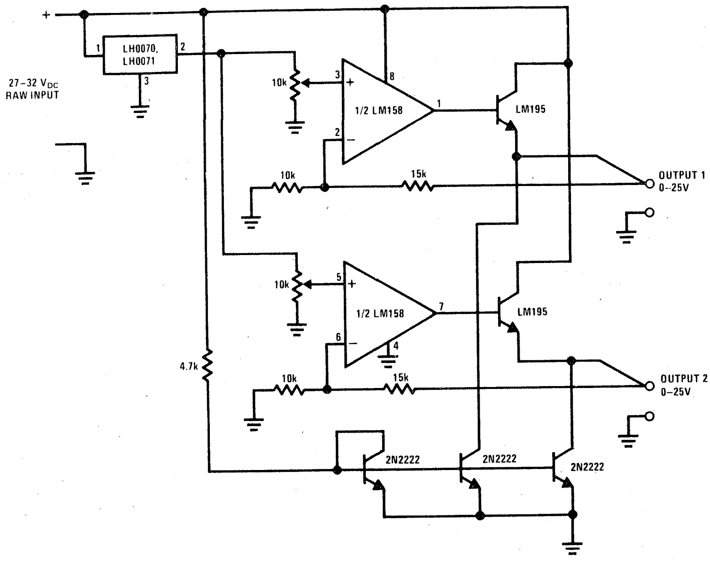
BW = 0.1 Hz TO 10 Hz

typical applications (con't)

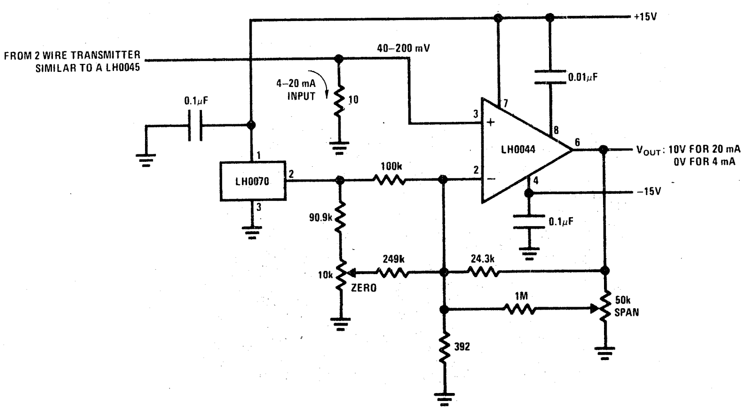


Expanded Scale ac Voltmeter

typical applications (con't)



Dual Output Bench Power Supply



Precision Process Control Interface

Voltage References

LM103 reference diode**

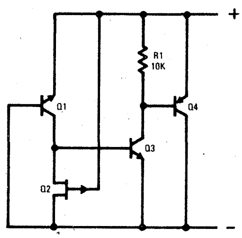
general description

The LM103 is a two-terminal monolithic reference 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:

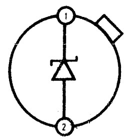
- Exceptionally sharp breakdown
- Low dynamic impedance from 10 μA to 10 mA
- Performance guaranteed over full military temperature range
- Planar, passivated junctions for stable operation
- Low capacitance.

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



Metal Can Package

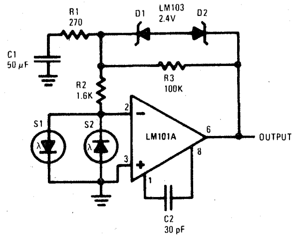


Note: Pin 2 connected to case.
TOP VIEW

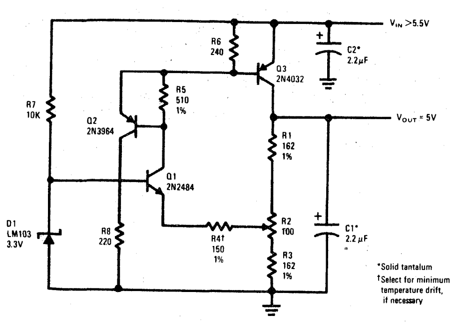
Order Number LM103H
See Package 8

typical applications

Saturating Servo Preamplifier with Rate Feedback



200 mA Positive Regulator



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

absolute maximum ratings

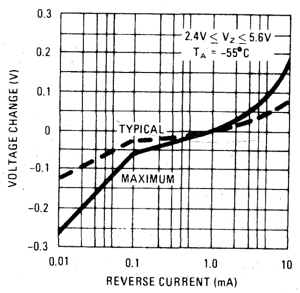
Power Dissipation (note 1)	250 mW
Reverse Current	20 mA
Forward Current	100 mA
Operating Temperature Range	−55°C to 125°C
Storage Temperature Range	−65°C to 150°C
Lead Temperature (soldering, 60 sec)	300°C

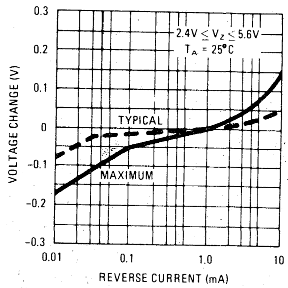
electrical characteristics (Note 2)

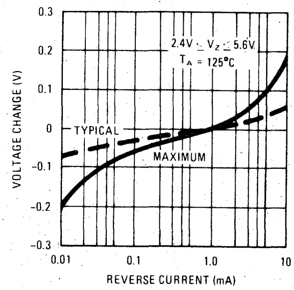
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
Reverse Breakdown Voltage Change	$10\ \mu A \leq I_R \leq 100\ \mu A$		60	120	mV
	$100\ \mu A \leq I_R \leq 1$ mA		15	50	mV
	1 mA $\leq I_R \leq 10$ mA		50	150	mV
Reverse Dynamic Impedance (Note 3)	$I_R = 3$ mA		5	25	Ω
	$I_R = 0.3$ mA		15	60	Ω
Reverse Leakage Current	$V_R = V_Z - 0.2V$		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

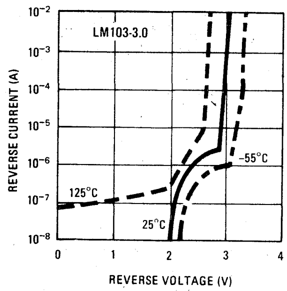




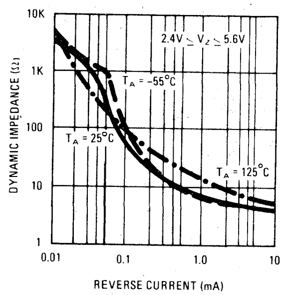


typical performance characteristics

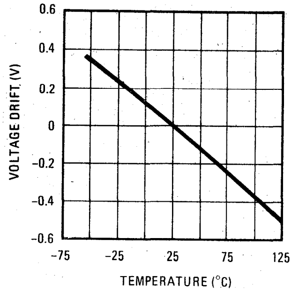
Reverse Characteristics



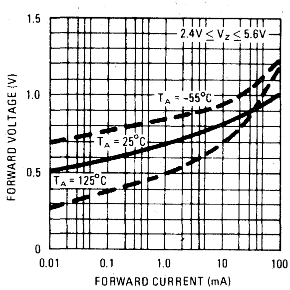
Reverse Dynamic Impedance



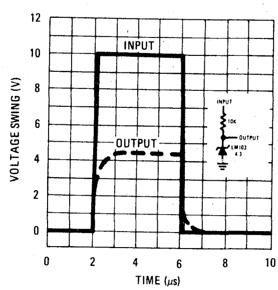
Temperature Drift



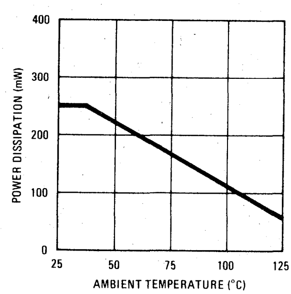
Forward Characteristics



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 References

LM113 reference diode

general description

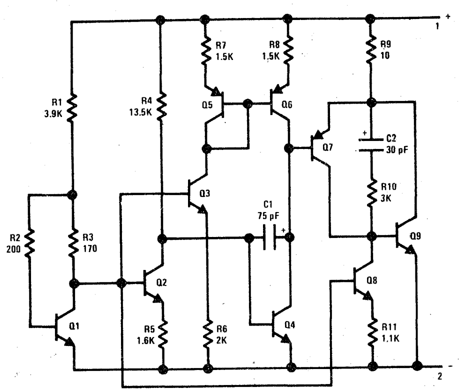
The LM113 is a temperature-compensated, low-voltage reference diode. It features extremely-tight regulation over a wide range of operating currents in addition to an unusually-low breakdown voltage and good temperature stability.

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:

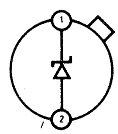
- Low breakdown voltage: 1.220V
- Dynamic impedance of 0.3Ω from 500 μA to 20 mA
- Temperature stability typically 1% over −55°C to 125°C range
- Tight tolerance: ±5% standard, ±2% and ±1% on special order.

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



Metal Can Package

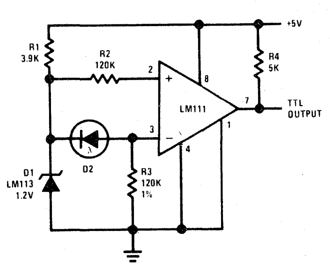


Note: Pin 2 connected to case.
TOP VIEW

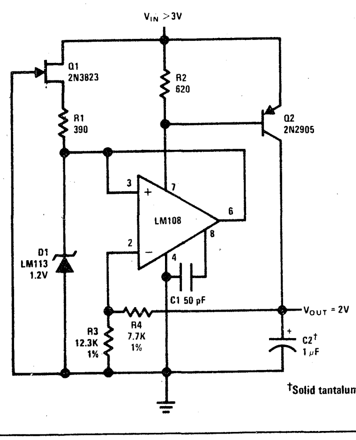
Order Number LM113H
See Package 8

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)

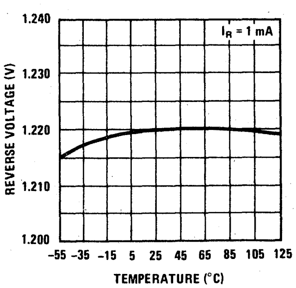
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Reverse Breakdown Voltage	I_R = 1 mA	1.160	1.220	1.280	V
Reverse Breakdown Voltage Change	0.5 mA $\leq I_R \leq$ 20 mA		6.0	15	mV
Reverse Dynamic Impedance	I_R = 1 mA I_R = 10 mA		0.2 0.25	1.0 0.8	Ω Ω
Forward Voltage Drop	I_F = 1.0 mA		0.67	1.0	V
RMS Noise Voltage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

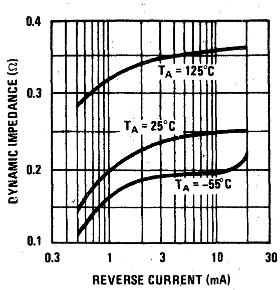
Note 2: These specifications apply for T_A = 25°C, unless stated otherwise. At high currents, breakdown voltage should be measured with lead lengths less than 1/4 inch. Kelvin contact sockets are also recommended. The diode should not be operated with shunt capacitances between 200 pF and 0.1 μF, unless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

typical performance characteristics

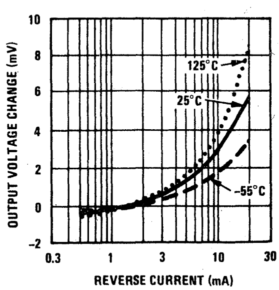
Temperature Drift



Reverse Dynamic Impedance

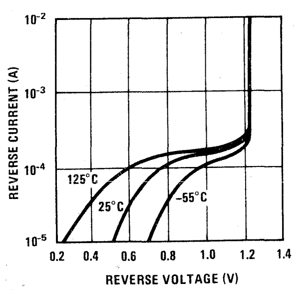


Reverse Characteristics

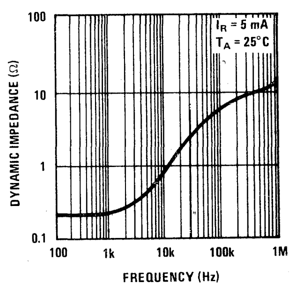


typical performance characteristics (con't)

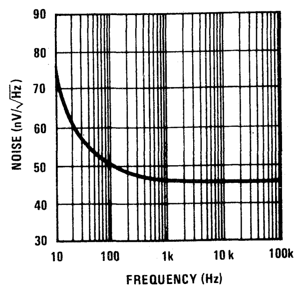
Reverse Characteristics



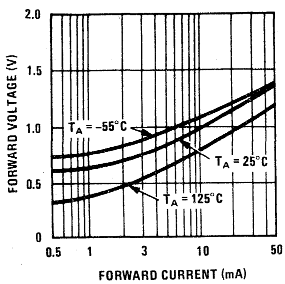
Reverse Dynamic Impedance



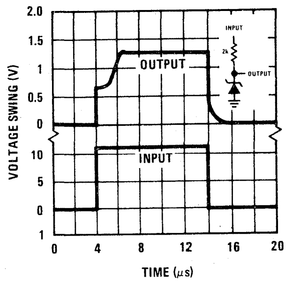
Noise Voltage



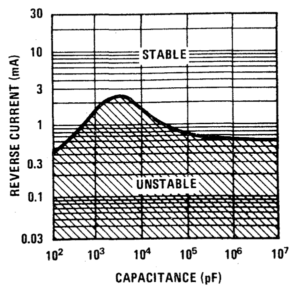
Forward Characteristics



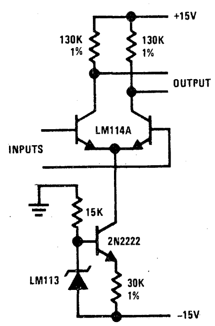
Response Time



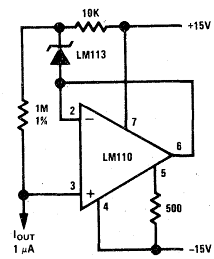
Maximum Shunt Capacitance



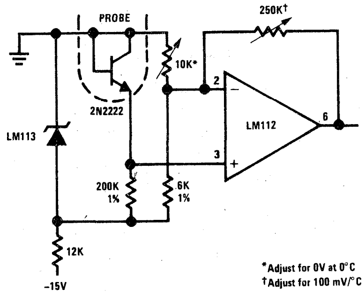
typical applications (con't)



Amplifier Biasing for Constant Gain with Temperature



Constant Current Source



Thermometer

LM129, LM329 precision reference

general description

The LM129 and LM329 family are precision multi-current temperature compensated 6.9V zener references with dynamic impedances a factor of 10 to 100 less than discrete diodes. Constructed in a single silicon chip, the LM129 uses active circuitry to buffer the internal zener allowing the device to operate over a 0.5 mA to 15 mA range with virtually no change in performance. The LM129 and LM329 are available with selected temperature coefficients of 0.001, 0.002, 0.005 and 0.01%/°C. These new references also have excellent long term stability and low noise.

A new subsurface breakdown zener used in the LM129 gives lower noise and better long term stability than conventional IC zeners. Further the zener and temperature compensating transistor are made by a planar process so they are immune to problems that plague ordinary zeners. For example, there is virtually no voltage shifts in zener voltage due to temperature cycling and the device is insensitive to stress on the leads.

The LM129 can be used in place of conventional zeners with improved performance. The low dynamic impedance simplifies biasing and the wide operating current allows the replacement of many zener types.

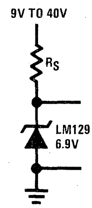
The LM129 is packaged in a 2-lead TO-46 package and is rated for operation over a −55°C to +125°C temperature range. The LM329 for operation over 0–70°C is available in both a hermetic TO-46 package and a TO-92 epoxy package.

features

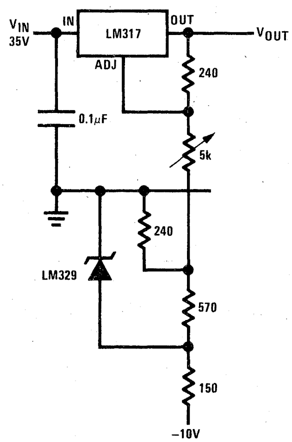
- 0.6 mA to 15 mA operating current
- 0.6Ω dynamic impedance at any current
- Available with temperature coefficients of 0.001%/°C
- 7μV wideband noise
- 5% initial tolerance
- 0.002% long term stability
- Low cost

typical applications

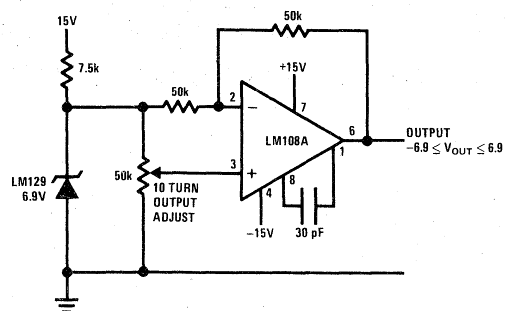
Simple Reference



Low Cost 0–25V Regulator



Adjustable Bipolar Output Reference



2

absolute maximum ratings

Reverse Breakdown Current	30 mA
Forward Current	2 mA
Operating Temperature Range	
LM129	−55°C to +125°C
LM329	0°C to +70°C
Storage Temperature Range	−55°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

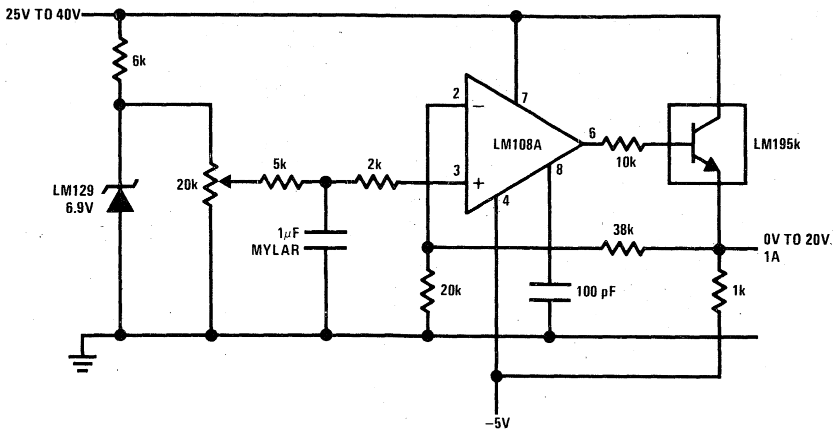
electrical characteristics (Note 1)

PARAMETER	CONDITIONS	LM129A, B, C			LM329B, C, D			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Reverse Breakdown Voltage	T_A = 25°C, 0.6 mA $\leq I_R \leq$ 15 mA	6.7	6.9	7.2	6.55	6.9	7.25	V
Reverse Breakdown Change with Current	T_A = 25°C, 0.6 mA $\leq I_R \leq$ 15 mA		9	14		9	20	mV
Reverse Dynamic Impedance	T_A = 25°C, I_R = 1 mA		0.6	1		0.8	2	Ω
RMS Noise	T_A = 25°C, 10 Hz $\leq F \leq$ 10 kHz		7	20		7	100	μV
Long Term Stability	T_A = 45°C ±0.1°C, I_R = 1 mA ±0.3%		20			20		ppm
Temperature Coefficient	I_R = 1 mA							
LM129A			6	10				ppm/°C
LM129B, LM329B			15	20		15	20	ppm/°C
LM129C, LM329C			30	50		30	50	ppm/°C
LM329D						50	100	ppm/°C
Change In Reverse Breakdown Temperature Coefficient	1 mA $\leq I_R \leq$ 15 mA		1			1		ppm/°C
Reverse Breakdown Change with Current	1 mA $\leq I_R \leq$ 15 mA		12			12		mV
Reverse Dynamic Impedance	1 mA $\leq I_R \leq$ 15 mA		0.8			1		Ω

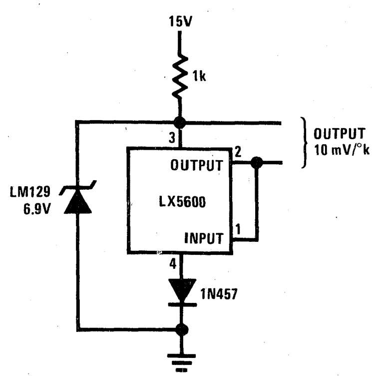
Note 1: These specifications apply for −55°C $\leq T_A \leq$ +125°C for the LM129 and 0°C $\leq T_A \leq$ +70°C for the LM329 unless otherwise specified.

typical applications (con't)

0V to 20V Power Reference

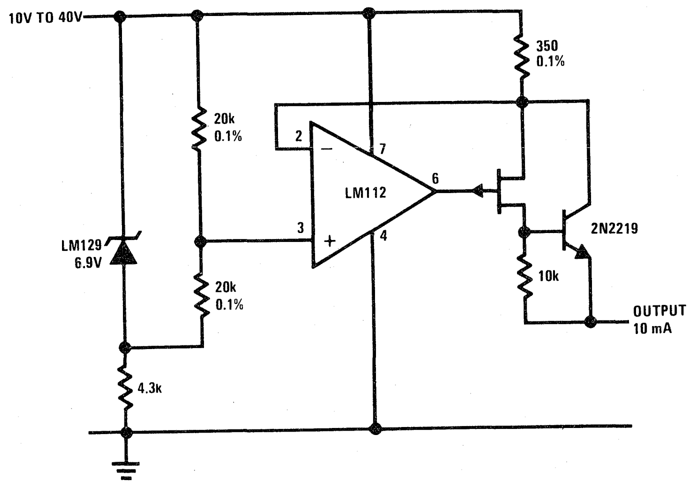


External Reference for Temperature Transducer

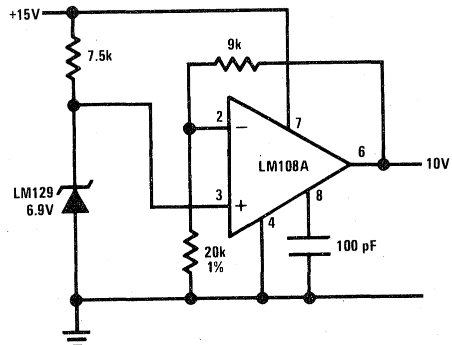


typical applications (con't)

Positive Current Source

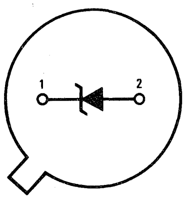


Buffered Reference with Single Supply



connection diagrams

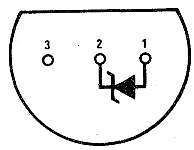
Metal Can Package



BOTTOM VIEW

Order Number LM129AH, LM129BH LM129CH, LM329BH, LM329CH or LM329DH
See Package 8

Plastic Package

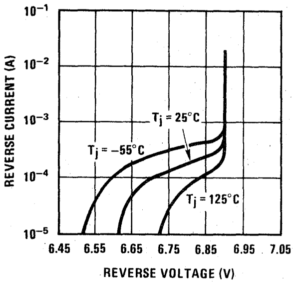


BOTTOM VIEW

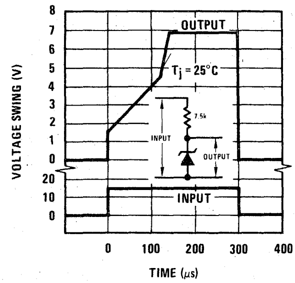
Order Number LM329BZ, LM329CZ or LM329DZ
See Package 38

typical performance characteristics

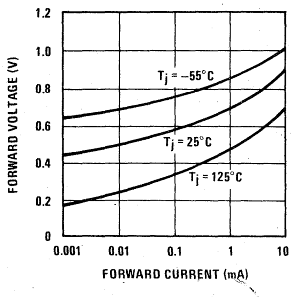
Reverse Characteristics



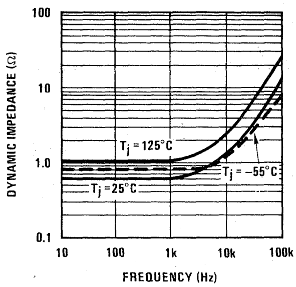
Response Time



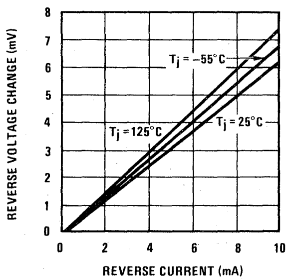
Forward Characteristics



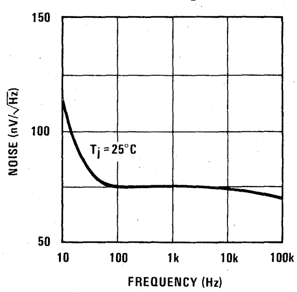
Dynamic Impedance



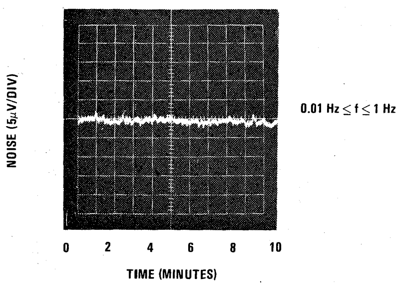
Reverse Voltage Change



Zener Noise Voltage



Low Frequency Noise Voltage



Voltage References

LM199/LM299/LM399 precision reference

general description

The LM199/LM299/LM399 are precision, temperature-stabilized monolithic zeners offering temperature coefficients a factor of ten better than high quality reference zeners. Constructed on a single monolithic chip is a temperature stabilizer circuit and an active reference zener. The active circuitry reduces the dynamic impedance of the zener to about 0.5Ω and allows the zener to operate over 0.5 mA to 10 mA current range with essentially no change in voltage or temperature coefficient. Further, a new subsurface zener structure gives low noise and excellent long term stability compared to ordinary monolithic zeners. The package is supplied with a thermal shield to minimize heater power and improve temperature regulation.

The LM199 series references are exceptionally easy to use and free of the problems that are often experienced with ordinary zeners. There is virtually no hysteresis in reference voltage with temperature cycling. Also, the LM199 is free of voltage shifts due to stress on the leads. Finally, since the unit is temperature stabilized, warm up time is fast.

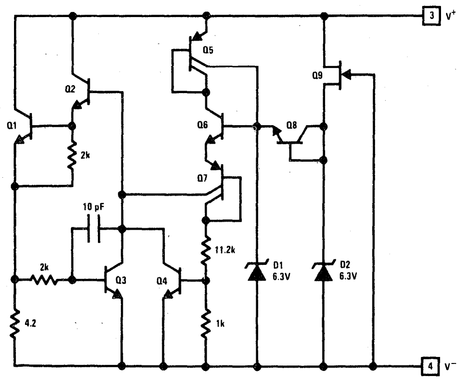
The LM199 can be used in almost any application in place of ordinary zeners with improved performance. Some ideal applications are analog to digital converters, calibration standards, precision voltage or current sources or precision power supplies. Further in many cases the LM199 can replace references in existing equipment with a minimum of wiring changes.

The LM199 series devices are packaged in a standard hermetic TO-46 package inside a thermal shield. The LM199 is rated for operation from −55°C to +125°C while the LM299 is rated for operation from −25°C to +85°C and the LM399 is rated from 0°C to +70°C.

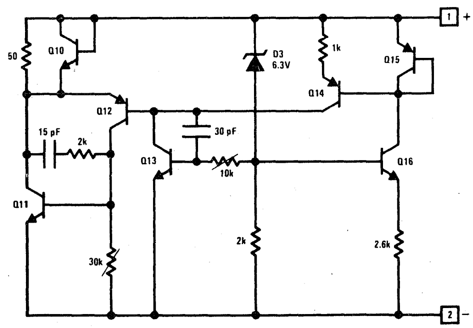
features

- Guaranteed 0.0001%/°C temperature coefficient
- Low dynamic impedance – 0.5Ω
- Initial tolerance on breakdown voltage – 2%
- Sharp breakdown at 400μA
- Wide operating current – 500μA to 10 mA
- Wide supply range for temperature stabilizer
- Guaranteed low noise
- Low power for stabilization – 300 mW at 25°C
- Long term stability – 20 ppm

schematic diagrams



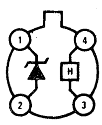
Temperature Stabilizer



Reference

connection diagram

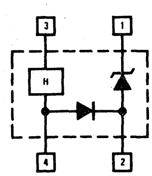
Metal Can Package



TOP VIEW

Order Number LM199H, LM299H or LM399H See Package 9C

functional block diagram



absolute maximum ratings

Temperature Stabilizer Voltage	40V
Reverse Breakdown Current	20 mA
Forward Current	1 mA
Reference to Substrate Voltage $V_{(RS)}$ (Note 1)	40V
	−0.1V
Operating Temperature Range	
LM199	−55°C to +125°C
LM299	−25°C to +85°C
LM399	0°C to +70°C
Storage Temperature Range	−55°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 2)

PARAMETER	CONDITIONS		LM199/LM299			LM399			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Reverse Breakdown Voltage	$0.5\ mA \leq I_R \leq 10\ mA$		6.8	6.95	7.1	6.6	6.95	7.3	V
Reverse Breakdown Voltage Change With Current	$0.5\ mA \leq I \leq 10\ mA$			6	9		6	12	mV
Reverse Dynamic Impedance	$I_R = 1\ mA$			0.5	1		0.5	1.5	Ω
Reverse Breakdown Temperature Coefficient	$-55°C \leq T_A \leq 85°C$	LM199		0.00003	0.0001				%/°C
	$85°C \leq T_A \leq 125°C$	LM199		0.0005	0.0015				%/°C
	$-25°C \leq T_A \leq 85°C$	LM299		0.00003	0.0001				%/°C
	$0°C \leq T_A \leq 70°C$	LM399					0.00003	0.0002	%/°C
RMS Noise	$10\ Hz \leq f \leq 10\ kHz$			7	20		7	50	μV
Long Term Stability	Stabilized, $22°C \leq T_A \leq 28°C$, 1000 Hours, $I_R = 1\ mA \pm 0.1\%$			20			20		ppm
Temperature Stabilizer Supply Current	$T_A = 25°C$, Still Air, $V_S = 30V$			8.5	14		8.5	15	mA
	$T_A = -55°C$			22	28				mA
Temperature Stabilizer Supply Voltage (Note 3)			9		40	9		40	V
Warm-Up Time to 0.05%	$V_S = 30V$, $T_A = 25°C$			3			3		Seconds
Initial Turn-on Current	$9 \leq V_S \leq 40$, $T_A = 25°C$			140	200		140	200	mA

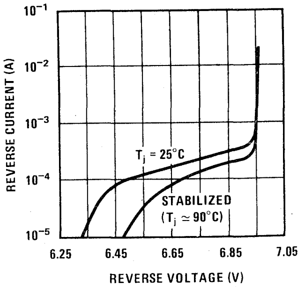
Note 1: The substrate is electrically connected to the negative terminal of the temperature stabilizer. The voltage that can be applied to either terminal of the reference is 40V more positive or 0.1V more negative than the substrate.

Note 2: These specifications apply for 30V applied to the temperature stabilizer and $-55°C \leq T_A \leq +125°C$ for the LM199; $-25°C \leq T_A \leq +85°C$ for the LM299 and $0°C \leq T_A \leq +70°C$ for the LM399.

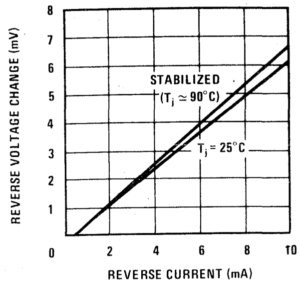
Note 3: CAUTION. If the device is operated for more than 60 seconds with heater supply voltage between 2V and 9V the heater temperature control circuitry is not properly biased and the device can rise to approximately +150°C.

typical performance characteristics

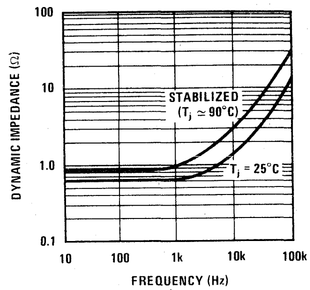
Reverse Characteristics



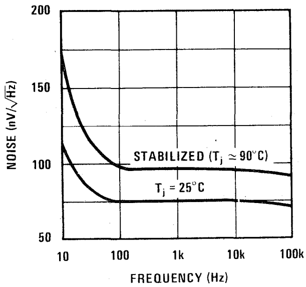
Reverse Voltage Change



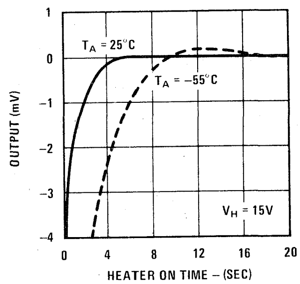
Dynamic Impedance



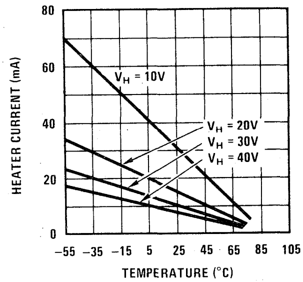
Zener Noise Voltage



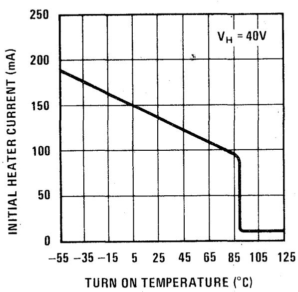
Stabilization Time



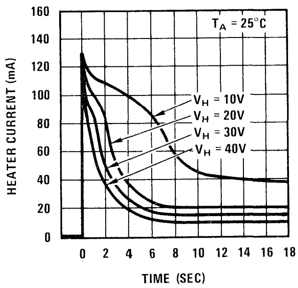
Heater Current



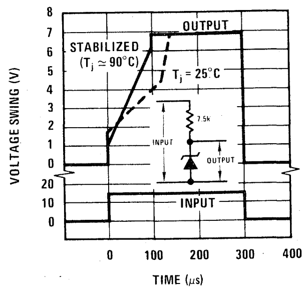
Initial Heater Current



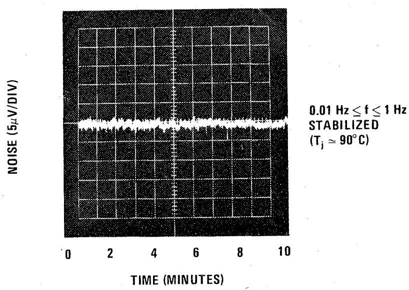
Heater Current



Response Time

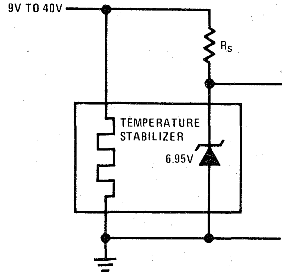


Low Frequency Noise Voltage

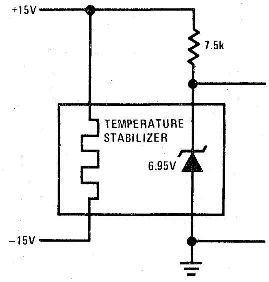


typical applications

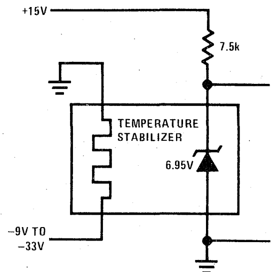
Single Supply Operation



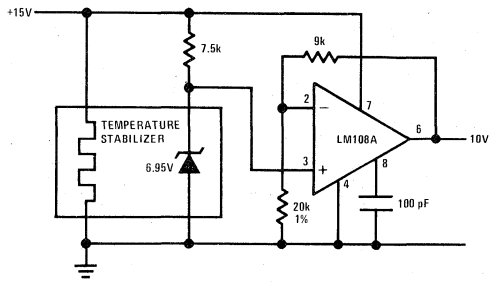
Split Supply Operation



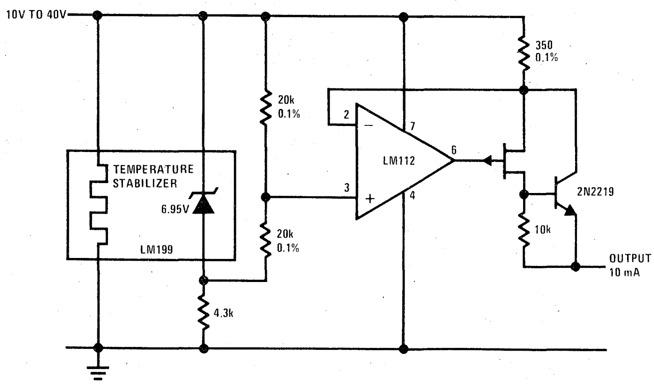
Negative Heater Supply with Positive Reference



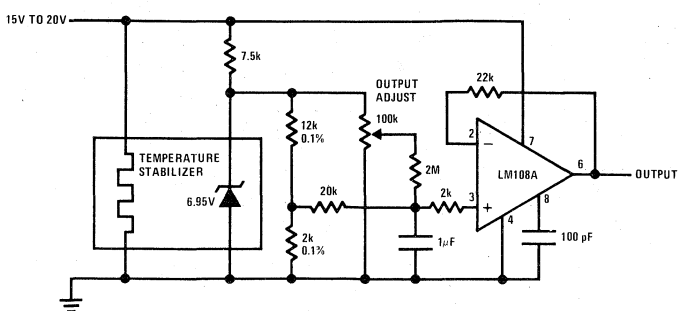
Buffered Reference With Single Supply



Positive Current Source

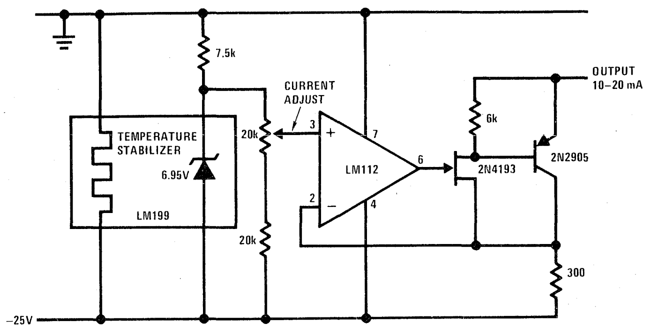


Standard Cell Replacement

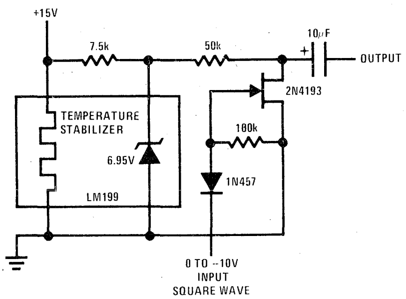


typical applications (con't)

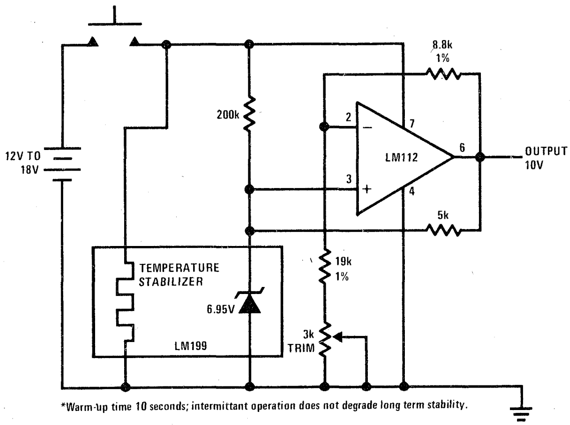
Negative Current Source



Square Wave Voltage Reference

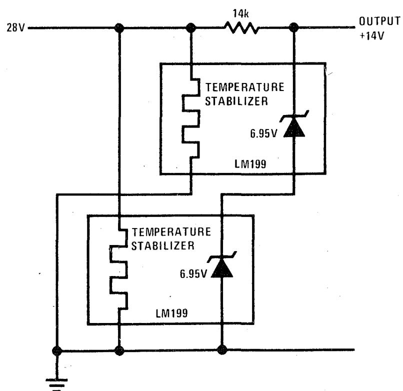


Portable Calibrator*

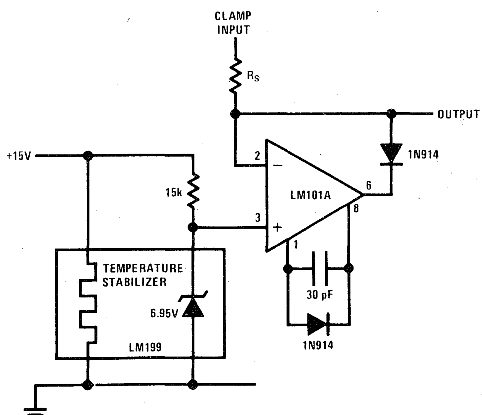


*Warm-up time 10 seconds; intermittant operation does not degrade long term stability.

14V Reference



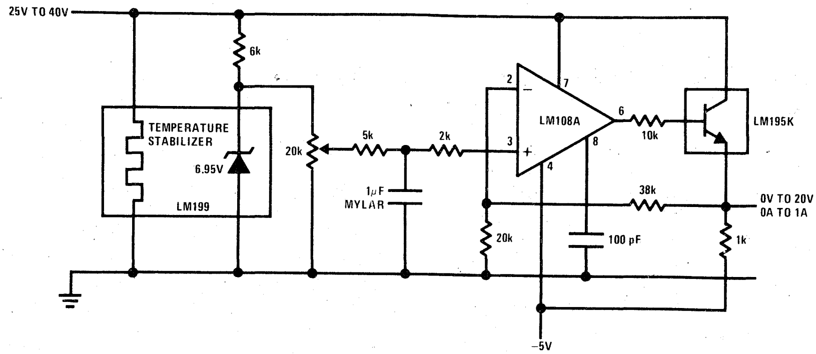
Precision Clamp*



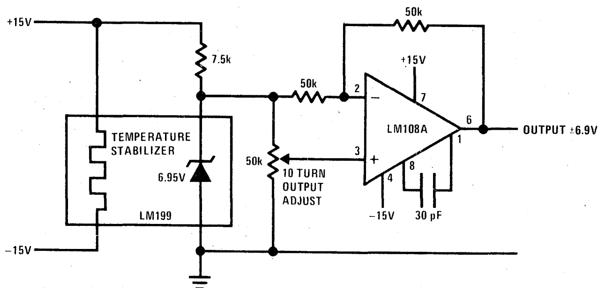
*Clamp will sink 5 mA when input goes more positive than reference.

typical applications (con't)

0V to 20V Power Reference



Bipolar Output Reference



Voltage References

LM199A/LM299A/LM399A precision reference

general description

The LM199A/LM299A/LM399A are precision, temperature-stabilized monolithic zeners offering temperature coefficients a factor of ten better than high quality reference zeners. Constructed on a single monolithic chip is a temperature stabilizer circuit and an active reference zener. The active circuitry reduces the dynamic impedance of the zener to about 0.5Ω and allows the zener to operate over 0.5 mA to 10 mA current range with essentially no change in voltage or temperature coefficient. Further, a new subsurface zener structure gives low noise and excellent long term stability compared to ordinary monolithic zeners. The package is supplied with a thermal shield to minimize heater power and improve temperature regulation.

The LM199A series references are exceptionally easy to use and free of the problems that are often experienced with ordinary zeners. There is virtually no hysteresis in reference voltage with temperature cycling. Also, the LM199A is free of voltage shifts due to stress on the leads. Finally, since the unit is temperature stabilized, warm up time is fast.

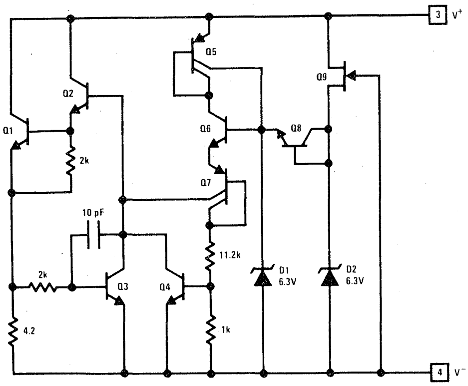
The LM199A can be used in almost any application in place of ordinary zeners with improved performance. Some ideal applications are analog to digital converters, calibration standards, precision voltage or current sources or precision power supplies. Further in many cases the LM199A can replace references in existing equipment with a minimum of wiring changes.

The LM199A series devices are packaged in a standard hermetic TO-46 package inside a thermal shield. The LM199 is rated for operation from −55°C to +125°C while the LM299A is rated for operation from −25°C to +85°C and the LM399A is rated from 0°C to +70°C.

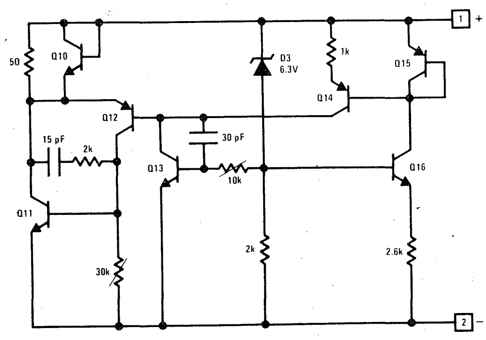
features

- Guaranteed 0.00005%/°C temperature coefficient
- Low dynamic impedance – 0.5Ω
- Initial tolerance on breakdown voltage – 2%
- Sharp breakdown at 400μA
- Wide operating current – 500μA to 10 mA
- Wide supply range for temperature stabilizer
- Guaranteed low noise
- Low power for stabilization – 300 mW at 25°C
- Long term stability – 20 ppm

schematic diagrams



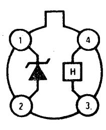
Temperature Stabilizer



Reference

connection diagram

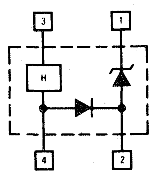
Metal Can Package



TOP VIEW

Order Number LM199AH, LM299AH or LM399AH
See Package 9C

functional block diagram



absolute maximum ratings

Temperature Stabilizer Voltage	40V
Reverse Breakdown Current	20 mA
Forward Current	1 mA
Reference to Substrate Voltage $V_{(RS)}$ (Note 1)	+40V
	−0.1V
Operating Temperature Range	
LM199A	−55°C to +125°C
LM299A	−25°C to +85°C
LM399A	0°C to +70°C
Storage Temperature Range	−55°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 2)

PARAMETER	CONDITIONS		LM199A, LM299A			LM399A			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Reverse Breakdown Voltage	$0.5\ mA \le I_R \le 10\ mA$		6.8	6.95	7.1	6.6	6.95	7.3	V
Reverse Breakdown Voltage Change With Current	$0.5\ mA \le I_R \le 10\ mA$			6	9		6	12	mV
Reverse Dynamic Impedance	$I_R = 1\ mA$			0.5	1		0.5	1.5	Ω
Reverse Breakdown Temperature Coefficient	$-55°C \le T_A \le 85°C$	LM199A		0.00002	0.00005				%/°C
	$85°C \le T_A \le 125°C$	LM199A		0.0005	0.0010				%/°C
	$-25°C \le T_A \le 85°C$	LM299A		0.00002	0.00005				%/°C
	$0°C \le T_A \le 70°C$	LM399A					0.00003	0.0001	%/°C
RMS Noise	$10\ Hz \le f \le 10\ kHz$			7	20		7	50	μV
Long Term Stability	Stabilized, $22°C \le T_A \le 28°C$, 1000 Hours, $I_R = 1\ mA \pm 0.1\%$			20			20		ppm
Temperature Stabilizer Supply Current	$T_A = 25°C$, Still Air, $V_S = 30V$			8.5	14		8.5	15	mA
	$T_A = -55°C$			22	28				mA
Temperature Stabilizer Supply Voltage (Note 3)			9		40	9		40	V
Warm-Up Time to 0.05%	$V_S = 30V$, $T_A = 25°C$			3			3		Seconds
Initial Turn-on Current	$9 \le V_S \le 40$, $T_A = 25°C$			140	200		140	200	mA

Note 1: The substrate is electrically connected to the negative terminal of the temperature stabilizer. The voltage that can be applied to either terminal of the reference is 40V more positive or 0.1V more negative than the substrate.

Note 2: These specifications apply for 30V applied to the temperature stabilizer and 55°C $\le T_A \le$ +125°C for the LM199A; −25°C $\le T_A \le$ +85°C for the LM299A and 0°C $\le T_A \le$ +70°C for the LM399A.

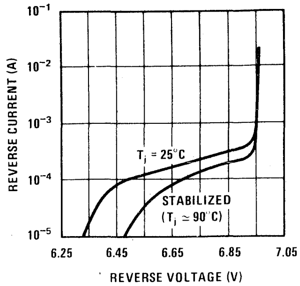
Note 3: CAUTION. If the device is operated for more than 60 seconds with heater supply voltage between 2V and 9V the heater temperature control circuitry is not properly biased and the device can rise to approximately +150°C.

typical applications

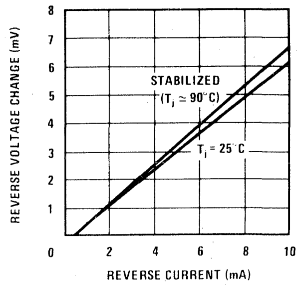
For typical applications, see LM199 data sheet on preceding pages.

typical performance characteristics

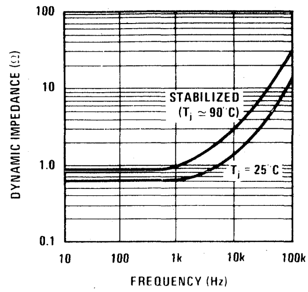
Reverse Characteristics



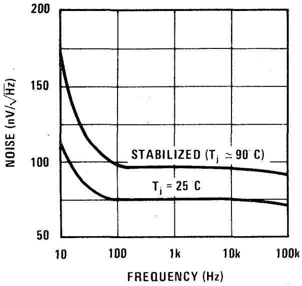
Reverse Voltage Change



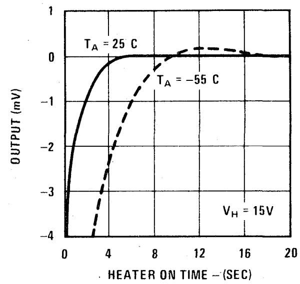
Dynamic Impedance



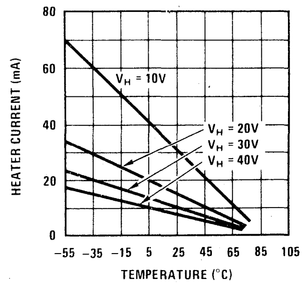
Zener Noise Voltage



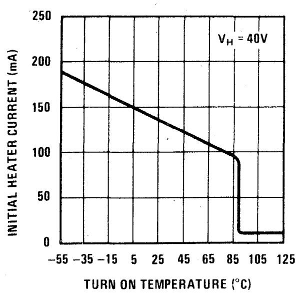
Stabilization Time



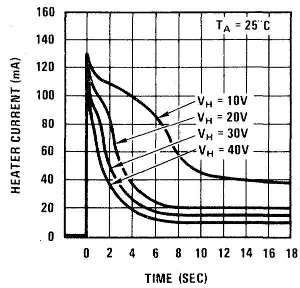
Heater Current



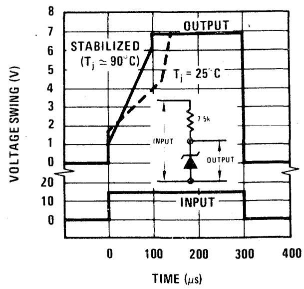
Initial Heater Current



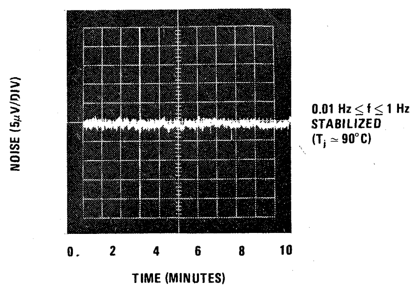
Heater Current



Response Time



Low Frequency Noise Voltage



Voltage References

LM3999 precision reference

general description

The LM3999 is a precision, temperature-stabilized monolithic zener offering temperature coefficients a factor of ten better than high quality reference zeners. Constructed on a single monolithic chip is a temperature stabilizer circuit and an active reference zener. The active circuitry reduces the dynamic impedance of the zener to about 0.5Ω and allows the zener to operate over 0.5 mA to 10 mA current range with essentially no change in voltage or temperature coefficient. Further, a new subsurface zener structure gives low noise and excellent long term stability compared to ordinary monolithic zeners.

The LM3999 reference is exceptionally easy to use and free of the problems that are often experienced with ordinary zeners. There is virtually no hysteresis in reference voltage with temperature cycling. Also, the LM3999 is free of voltage shifts due to stress on the leads. Finally, since the unit is temperature stabilized, warm up time is fast.

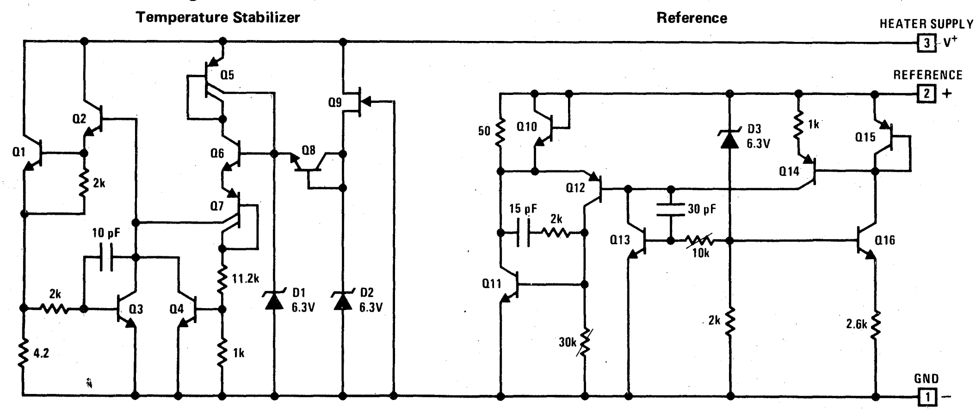
The LM3999 can be used in almost any application in place of ordinary zeners with improved performance. Some ideal applications are analog to digital converters, precision voltage or current sources or precision power supplies. Further, in many cases, the LM3999 can replace references in existing equipment with a minimum of wiring changes.

The LM3999 is packaged in a standard TO-92 package and is rated from 0°C to +70°C.

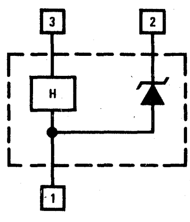
features

- Guaranteed 0.0005%/°C temperature coefficient
- Low dynamic impedance – 0.5Ω
- Initial tolerance on breakdown voltage – 5%
- Sharp breakdown at 400μA
- Wide operating current – 500μA to 10 mA
- Wide supply range for temperature stabilizer
- Low power for stabilization – 400 mW at 25°C
- Long term stability – 20 ppm

schematic diagram

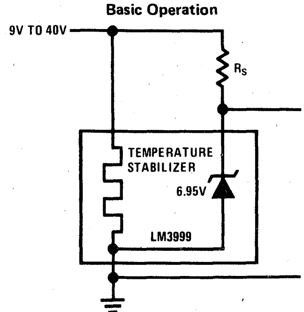


functional block diagram



typical applications

Basic Operation



absolute maximum ratings

Temperature Stabilizer Voltage	36V
Reverse Breakdown Current	20 mA
Forward Current	0.1 mA
Operating Temperature Range	0°C to +70°C
Storage Temperature Range	−55°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

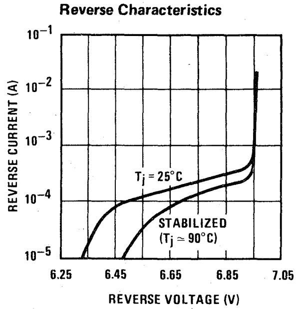
electrical characteristics (Note 1)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Reverse Breakdown Voltage	$0.6\ mA \leq I_R \leq 10\ mA$	6.6	6.95	7.3	V
Reverse Breakdown Voltage Change With Current	$0.6\ mA \leq I \leq 10\ mA$		6	20	mV
Reverse Dynamic Impedance	$I_R = 1\ mA$		0.6	2.2	Ω
Reverse Breakdown Temperature Coefficient	$0°C \leq T_A \leq 70°C$		0.0002	0.0005	%/°C
RMS Noise	$10\ Hz \leq f \leq 10\ kHz$		7		μV
Long Term Stability	Stabilized, $22°C \leq T_A \leq 28°C$, 1000 Hours, $I_R = 1\ mA \pm 0.1\%$		20		ppm
Temperature Stabilizer	$T_A = 25°C$, Still Air, $V_S = 30V$		12	18	mA
Temperature Stabilizer Supply Voltage				36	V
Warm-Up Time to 0.05%	$V_S = 30V$, $T_A = 25°C$		5		Seconds
Initial Turn-on Current	$9 \leq V_S \leq 40$, $T_A = 25°C$		140	200	mA

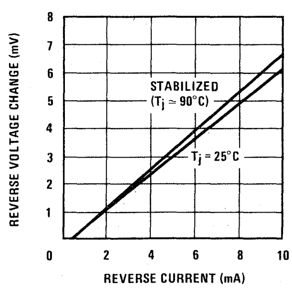
Note 1: These specifications apply for 30V applied to the temperature stabilizer and $0°C \leq T_A \leq +70°C$.

typical performance characteristics

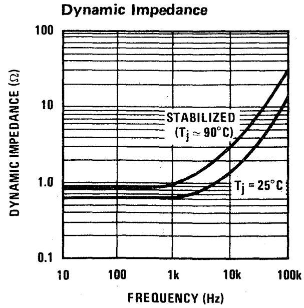
Reverse Characteristics



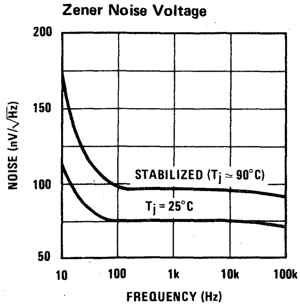
Reverse Voltage Change



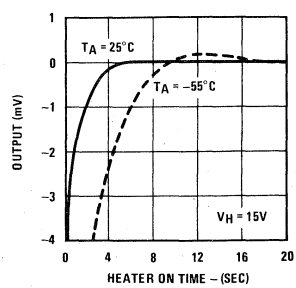
Dynamic Impedance



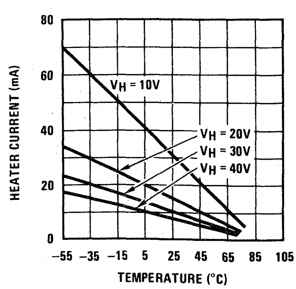
Zener Noise Voltage



Stabilization Time

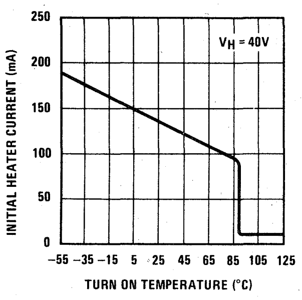


Heater Current

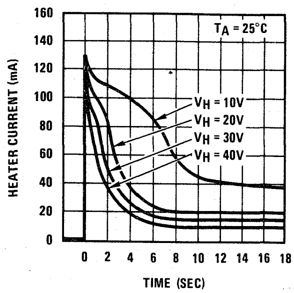


typical performance characteristics (con't)

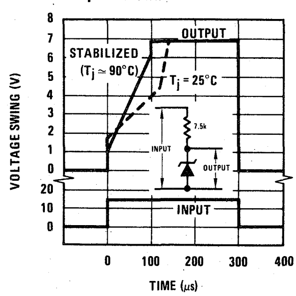
Initial Heater Current



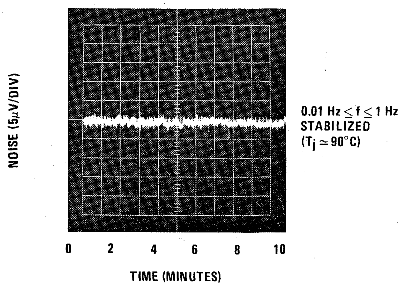
Heater Current



Response Time

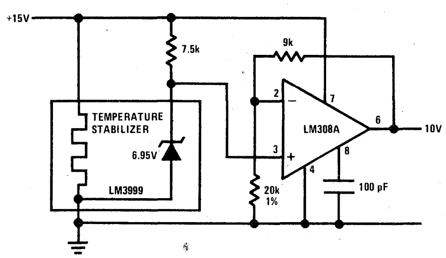


Low Frequency Noise Voltage

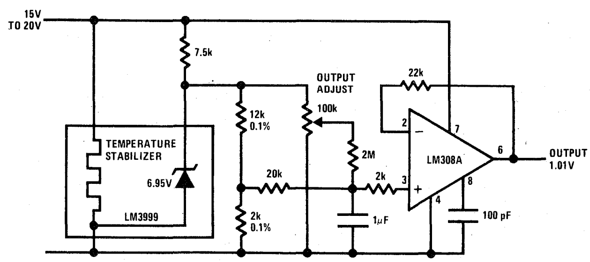


typical applications (con't)

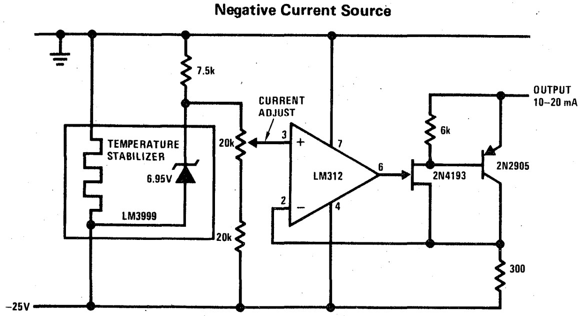
Buffered Reference With Single Supply



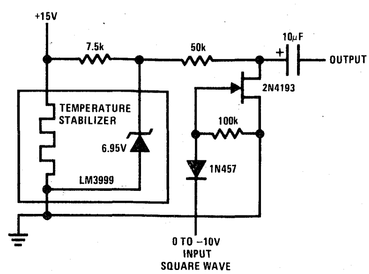
Voltage Reference



Negative Current Source



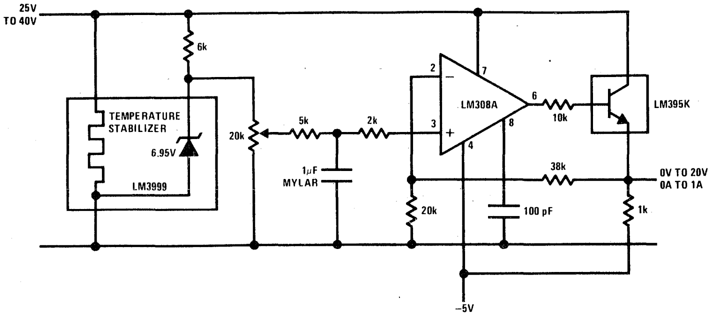
Square Wave Voltage Reference



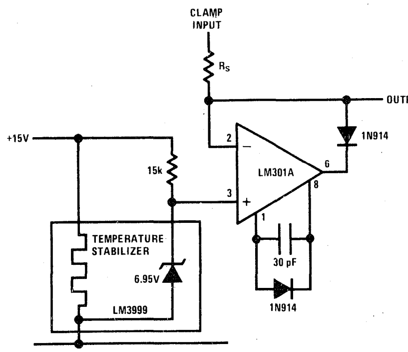
2

typical applications (con't)

0V to 20V Power Reference

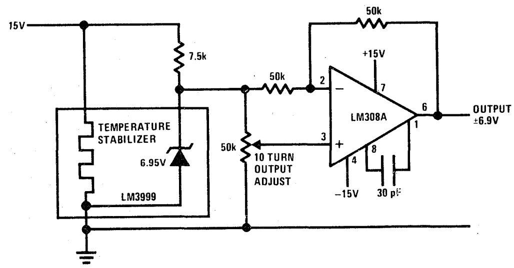


Precision Clamp*

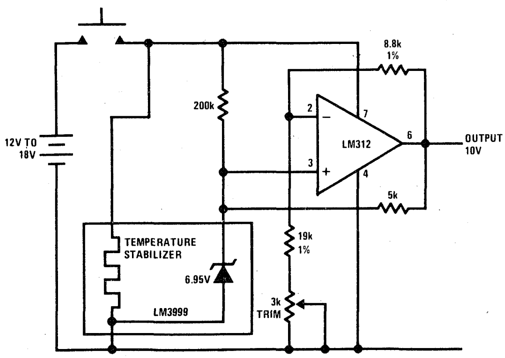


*Clamp will sink 5 mA when input goes more positive than reference.

Bipolar Output Reference



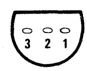
Portable Calibrator*



*Warm-up time 10 seconds; intermittant operation does not degrade long term stability.

connection diagram

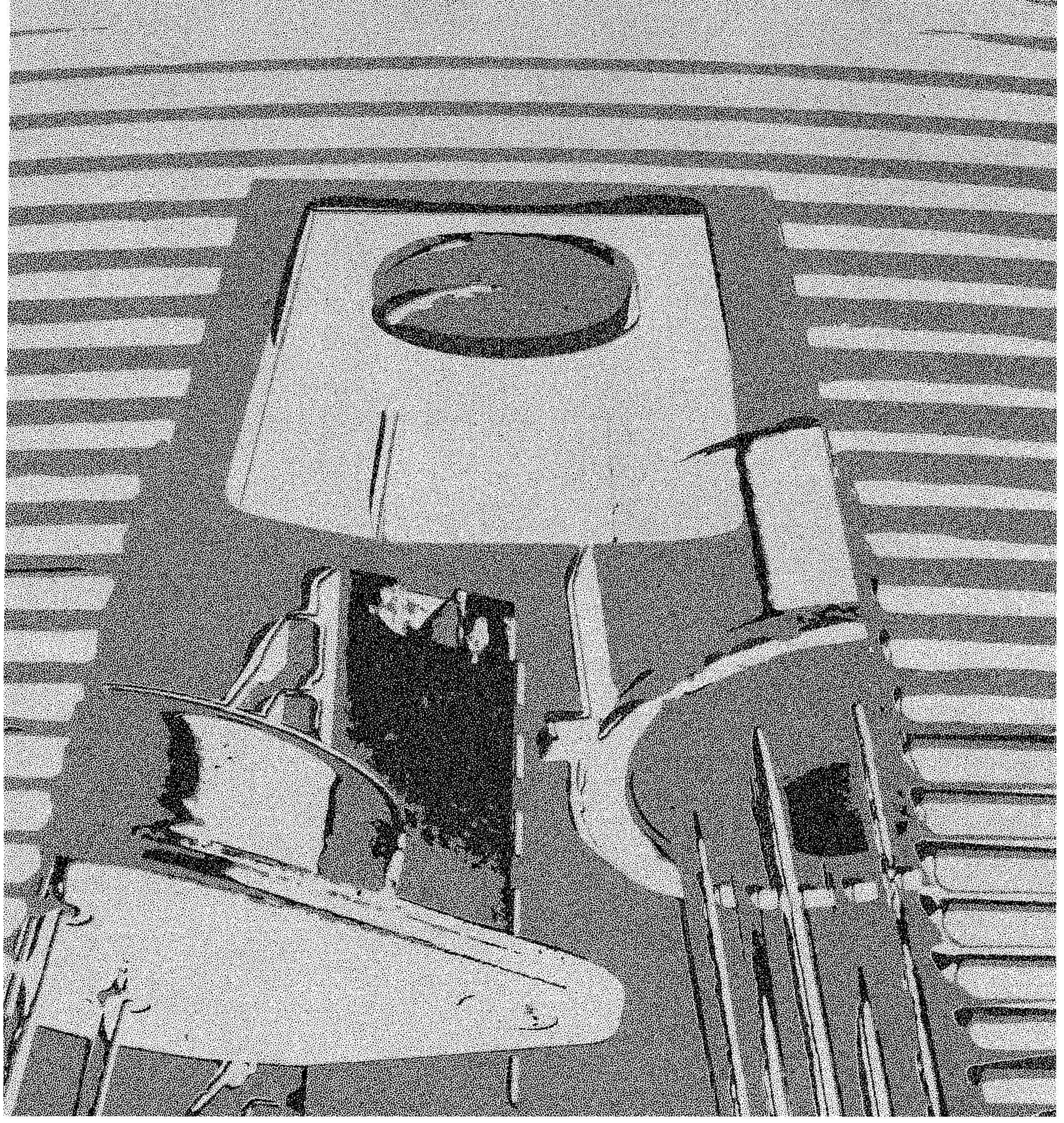
Plastic Package



BOTTOM VIEW

Order Number LM3999Z
See Packagee 38

National Semiconductor
OPERATIONAL AMPLIFIERS/ BUFFERS
Section 3



Operational Amplifiers/Buffers

Section Contents

*Product added to this Data Book since last printing.

Section Contents (con't)

*Product added to this Data Book since last printing.

Section Contents (con't)

*Product added to this Data Book since last printing.

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 Min (Volts/V)	Bandwidth $A_V = 1$ Typ (MHz)	Slew Rate $A_V = 1$ Typ (V/μs)	Output Current Min @ $R_L = 2k$ (mA)	Supply Voltage Min (V)	Supply Voltage Max (V)	Common Mode Range (V)	Differential Input Voltage (V)	Supply Current $T_A = 25^{\circ}C$ Max (mA)	Compensation Components Per Amplifier	Package Types
SINGLE OP AMPS															
LH101	6	6 typ	500	1500	25k	1	0.5	5	±3	±22	±12	±30	3	0	TO-5 F.P.
LM101A	3	15	20	100	25k	1	0.5	5	±3	±22	±12	±30	3	1	TO-5 DIP F.P.
LM101	6	6 typ	500	1500	25k	1	0.5	5	±3	±22	±12	±30	3	1	TO-5 F.P.
LM102	7.5	6 typ	*	100	0.999	10	10	1 ($R_L = 8\ k\Omega$)	±12	±18	±10	*	5.5	1	TO-5
LM107	3	15	20	100	25k	1	0.5	7.5	±3	±22	±12	±30	3	0	TO-5 DIP F.P.
LM108A	1	5	0.4	3	40k	1	0.3	1	±2	±20	±14	(Note 1)	0.6	1	TO-5 DIP F.P.
LM108	3	15	0.4	3	25k	1	0.3	1	±2	±20	±14	(Note 1)	0.6	1	TO-5 DIP F.P.
LM110	6	12	*	10	0.999	20	30	1 ($R_L = 8\ k\Omega$)	±5	±18	±10	*	5.5	0	TO-5 DIP
LM112	3	15	0.4	3	25k	1	0.2	1.3 ($R_L = 10\ k\Omega$)	±2	±20	±14	(Note 1)	0.6	0	TO-5 DIP F.P.
LM118	4	*	50	250	20k	15	50 min	6	±5	±18	±11.5	(Note 1)	8	0	TO-5 DIP F.P.
LM121A (R_{SET}=70k)	0.65	0.2	1	30	16k	0.5	*	*	±5	±20	±15	±15	1.5	1	TO-5 DIP F.P.
LM121 (R_{SET}=70k)	1	1	3	30	16k	0.5	*	*	±5	±20	±15	±15	1.5	1	TO-5 DIP F.P.
LM143	6	*	7	35	50k	1	2.5	4.4 ($R_L \geq 5k$)	±4	±40	±38	±40	4	0	TO-5 DIP F.P.
LM144	6	*	7	35	50k	2	30 ($A_V > 10$)	4.4 ($R_L \geq 5k$)	±4	±40	±38	±40	4	1	TO-5 DIP F.P.
LF155A	**2**	**5**	**0.01**	**0.05**	**25k**	**2.5**	**5**	**5**	**±5**	**±22**	**±20**	**±40**	**4**	**0**	**TO-5**
LF155	**5**	**5 typ**	**0.02**	**0.1**	**25k**	**2.5**	**5**	**5**	**±5**	**±22**	**±20**	**±40**	**4**	**0**	**TO-5**
LF156A	**2**	**5**	**0.01**	**0.05**	**25k**	**5**	**15**	**5**	**±5**	**±22**	**±20**	**±40**	**7**	**0**	**TO-5**
LF156	**5**	**5 typ**	**0.02**	**0.1**	**25k**	**5**	**15**	**5**	**±5**	**±22**	**±20**	**±40**	**7**	**0**	**TO-5**
LF157A ($A_V \geq 5$)	**2**	**5**	**0.01**	**0.05**	**25k**	**25**	**75**	**5**	**±5**	**±22**	**±20**	**±40**	**10**	**0**	**TO-5**
LF157 ($A_V \geq 5$)	**5**	**5 typ**	**0.02**	**0.1**	**25k**	**25**	**75**	**5**	**±5**	**±22**	**±20**	**±40**	**10**	**0**	**TO-5**
LM709A	3	15	250	600	25k	1	0.3	5	±5	±22	±20	±40	3.6	3	TO-5
LM709	6	6 typ	500	1500	25k	1	0.3	5	±9	±18	±8	±5	5.5	3	TO-5 DIP
LM725A	0.7	2	18	180	1000	0.5	0.005	5	±3	±22	±13.5	±5	3.5	4	TO-5 DIP
LM725	1.5	5	40	200	1000	0.5	0.005	5	±3	±22	±13.5	±5	3.5	4	TO-5 F.P.
LM741A	4	15	70	210	32k	1	0.5	7.5	±3	±22	±12	±30	4.0	0	TO-5 DIP F.P.
LM741	6	15 typ	500	1500	25k	1	0.5	5	±3	±22	±12	±30	2.8	0	TO-5 DIP F.P.
LM747A	4	15	70	210	32k	1	0.5	7.5	±3	±22	±12	±30	5.6	0	DIP F.P.
LM747	6	*	500	1500	25k	1	0.5	5	±3	±22	±12	±30	5.6	0	TO-5 DIP F.P.
LM748	6	*	500	1500	25k	1	0.5	5	±3	±22	±12	±30	2.8	1	TO-5
LM4250 (V_S = ±15V)	4	*	3	7.5	50k	0.1	0.03	0.12 ($R_L \geq 100k$)	±1	±18	±12	±15	0.011 set	0	TO-5 DIP

Note 1: Inputs have shunt-diode protection; current must be limited. *Not specified

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 ($\mu V/^{\circ}C$)	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 ($V/\mu s$)	Output Current Min @ R_L = 2k (mA)	Supply Voltage Min (V)	Supply Voltage Max (V)	Common Mode Range (V)	Differential Input Voltage (V)	Supply Current $T_A = 25^{\circ}C$ Max (mA)	Compensation Components Per Amplifier	Package Types
DUAL OP AMPS															
LM158	5	*	30	150	25k	1	*	0.8	±1.5	±16	$V^+-1.5$	V^+	1.2	0	TO-5 DIP
LM1558	6	*	500	1500	25k	1	0.5	5	±3	±22	±12	±30	5.8	0	TO-5
LH2101A	3	15	20	100	25k	1	0.5	7.5	±3	±22	±12	±30	6	1	TO-5 DIP F.P.
LH2108A	1	5	0.4	3	40k	1	0.3	1	±2	±20	±14	(Note 1)	1.2	1	TO-5 DIP F.P.
LH2108	3	15	0.4	3	25k	1	0.3	1	±2	±20	±14	(Note 1)	1.2	1	TO-5 DIP F.P.
LH2110	6	12	*	10	0.999	20	30	1	±2	±20	±14	(Note 1)	0.6	1	TO-5 DIP F.P.
LH24250 (V_S = ±15V)	4	*	3	7.5	50k	0.1	0.03	0.12 ($R_L \geq 100k$)	±1	±18	±12	±15	0.022 (set)	0	DIP F.P.
QUAD OP AMPS															
LM124	7	7 typ	100	300	25k	1	*	10 source 5 sink	±3 (±1.5)	±32 (±16)	$V^+-1.5$	32	2	0	DIP F.P.
LM148	6	15 typ	75	325	25k	1	0.6	5	±3	±22	±12	±30	3.6	0	DIP F.P.
LM149 ($A_V \geq 5$)	6	15 typ	75	325	25k	4	3	5	±3	±22	±12	±30	3.6	0	DIP F.P.
LM1900	*	*	*	150	0.8k	2.5	*	10 source 1 sink	±4	±36	*	*	12	0	DIP

INDUSTRIAL TEMPERATURE RANGE: $-25^\circ C \le T_A \le +85^\circ C$

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 Min (Volts/V)	Bandwidth $A_V = 1$ Typ (MHz)	Slew Rate $A_V = 1$ Typ (V/μs)	Output Current Min @ $R_L = 2\ k\Omega$ (mA)	Supply Voltage Min (V)	Supply Voltage Max (V)	Common Mode Range (V)	Differential Input Voltage (V)	Supply Current $T_A = 25^\circ C$ Max (mA)	Compensation Components Per Amplifier	Package Types
SINGLE OP AMPS															
LM201A	3	15	20	100	25k	1	0.5	5	±3	±22	±12	±30	3	1	TO-5 DIP F.P.
LM202	10	15 typ	*	15	0.999	10	10	1	±12	±18	±10	*	5.5	0	TO-5
LM207	2	20	20	100	25k	1	0.5	5	±3	±22	±12	±30	3	0	TO-5 DIP F.P.
LM208A	1.0	5	0.4	3	40k	1	0.3	1	±2	±20	±14	(Note 1)	0.4	1	TO-5 DIP F.P.
LM208	3	15	0.4	3	25k	1	0.3	1	±2	±20	±14	(Note 1)	0.4	1	TO-5 DIP F.P.
LM210	4	*	*	3	0.999	20	30	1	±5	±18	±10	*	5.5	0	TO-5 DIP F.P.
LM212	2	15	0.2	2	25k	1	0.3	1	±2	±20	±14	(Note 1)	0.6	0	TO-5 DIP F.P.
LM216A	3	*	0.015	0.05	20k	1	0.3	1	±5	±20	±13	(Note 1)	0.6	0	TO-5 DIP F.P.
LM216	10	*	0.05	0.15	10k	1	0.3	1	±5	±20	±13	(Note 1)	0.8	0	TO-5 DIP F.P.
LM218	4	*	50	500	25k	15	50 min	5	±5	±18	±11.5	(Note 1)	8	0	TO-5 DIP F.P.
LM221A (R_{SET} = 70k)	0.65	0.2	1	30	16k	0.5	*	*	±5	±20	±15	±15	1.5	1	TO-5 DIP F.P.
LM221 (R_{SET} = 70k)	1	1	3	30	16k	0.5	*	*	±5	±20	±15	±15	1.5	1	TO-5 DIP F.P.
LF255	**6.5**	**5 typ**	**20**	**50**	**25k**	**2.5**	**5**	**5**	**±5**	**±22**	**±20**	**±40**	**4**	**0**	**TO-5**
LF256	**6.5**	**5 typ**	**20**	**50**	**25k**	**5**	**15**	**5**	**±5**	**±22**	**±20**	**±40**	**7**	**0**	**TO-5**
LF257 ($A_V \ge 5$)	**6.5**	**5 typ**	**20**	**50**	**25k**	**25**	**75**	**5**	**±5**	**±22**	**±20**	**±40**	**7**	**0**	**TO-5**
DUAL OP AMPS															
LM258	7.5	7 typ	150	500	15k	1	0.5	10–source 5–sink	3 (±1.5)	32 (±16)	V^+ −1.5	32	1.2	0	TO-5 DIP
LH2201A	2	15	20	75	25k	1	0.5	5	±3	±22	±12	±30	3	1	DIP F.P.
LH2208A	1.0	5	0.4	3	40k	1	0.3	1 (R_L = 10 kΩ)	±2	±20	±14	(Note 1)	0.4	1	DIP F.P.
LH2208	3.0	15	0.4	3	25k	1	0.3	1 (R_L = 10 kΩ)	±2	±20	±14	(Note 1)	0.4	1	DIP F.P.
LH2210	4	*	*	3	0.999	20	30	1	±5	±18	±10	*	5.5	0	DIP F.P.
QUAD OP AMPS															
LM224	9	7 typ	150	500	15	1	*	10	3	32	V^+−1.5	32	2	0	DIP F.P.
LM248	7.5	15 typ	125	500	15	1	0.5	5	±5	±18	±18	±36	3.6	0	DIP
LM249	7.5	15 typ	125	500	15k	4	2	5	±5	±18	±18	±36	3.6	0	DIP
LM2900	*	*	*	200	1.2k	2.5	*	3–source 0.5–sink	+4	+36	*	*	10	0	DIP
LM2902	10 (T_A=25°)	*	±50 (T_A=25°C)	500 (T_A=25°C)	100k typ	1	*	20–source 8–sink	3.0 single ±1.5 dual	26 single ±13 dual	−0.3 V_{DC} to +26 V_{DC}	26 V_{DC}	2	0	DIP

Note 1: Inputs have shunt-diode protection; current must be limited. *Not specified

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

Device	Input Offset Voltage Max (mV)	Input Offset Voltage Drift Max ($\mu V/^\circ C$)	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 Min $R_L = 2\ k\Omega$ (mA)	Supply Voltage Min (V)	Supply Voltage Max (V)	Common Mode Range (V)	Differential Input Voltage (V)	Supply Current $T_A = 25^\circ C$ Max (mA)	Compensation Components	Package Types
SINGLE OP AMPS															
LH201	10	10 typ	750	2000	15k	1	0.5	5	±3	±22	±12	±30	3	0	TO-5 F.P.
LM201	10	10 typ	750	200	15k	1	0.5	5	±3	±22	±12	±30	3	1	TO-5 F.P.
LM301A	10	30	70	300	15k	1	0.5	5	±3	±18	±12	±30	3	1	TO-5 DIP
LM302	20	20 typ	*	30	0.9985	10	10	1	±12	±18	±10	*	5.5	0	TO-5
LM307	10	30	50	250	15k	1	0.5	5	±3	±18	±12	±30	3	0	TO-5 DIP F.P.
LM308A	0.73	5	1.5	10	60k	1	0.3	1	±2	±20	±14	(Note 1)	0.8	1	TO-5 DIP F.P.
LM308	10	30	1.5	10	15k	1	0.3	1	±2	±18	±14	(Note 1)	0.8	1	TO-5 DIP F.P.
LM310	10	10 typ	*	10	0.999	20	30	1	±5	±18	±10	*	5.5	0	TO-5 DIP F.P.
LM312	10	30	1.5	10	15k	1	0.3	1	±2	±18	±14	(Note 1)	0.8	0	TO-5 DIP F.P.
LM316A	6	*	0.03	0.1	30k	1	0.3	1	±5	±20	±13	(Note 1)	0.6	0	TO-5 DIP F.P.
LM316	15	*	0.1	0.25	15k	1	0.3	1	±5	±20	±13	(Note 1)	0.8	0	TO-5 DIP F.P.
LM318	15	*	300	750	20k	15	50	5	±5	±18	±11.5	(Note 1)	10	0	TO-5 DIP
LM321A (R_{SET}=70k)	0.65	0.2	1	25	12k	0.5	*	*	±5	±20	±15	±15	3.5	1	TO-5 DIP F.P.
LM321 (R_{SET}=70k)	2.5	1	4	28	12k	0.5	*	*	±5	±20	±15	±15	3.5	1	TO-5 DIP F.P.
LM343	10	*	14	55	50k	1	2.5	4 ($R_L \geq 5k$)	±4	±34	±34	±34	5.0	0	TO-5 DIP F.P.
LM344	10	*	14	55	50k	2	30 ($A_V > 10$)	4 ($R_L \geq 5k$)	±4	±34	±34	±34	5.0	1	TO-5 DIP F.P.
LF355A	**2.3**	**5**	**1**	**5**	**25k**	**2.5**	**5**	**5**	**±5**	**±22**	**±20**	**±40**	**4**	**0**	**TO-5**
LF355	**13**	**5 typ**	**2**	**8**	**15k**	**2.5**	**5**	**5**	**±5**	**±18**	**±16**	**±30**	**4**	**0**	**TO-5**
LF356A	**2.3**	**5**	**1**	**5**	**25k**	**5**	**15**	**5**	**±5**	**±22**	**±20**	**±40**	**10**	**0**	**TO-5**
LF356	**13**	**5 typ**	**2**	**8**	**15k**	**5**	**15**	**5**	**±5**	**±18**	**±16**	**±30**	**10**	**0**	**TO-5**
LF357A ($A_V \geq 5$)	**2.3**	**5**	**1**	**5**	**25k**	**25**	**75**	**5**	**±5**	**±22**	**±20**	**±40**	**10**	**0**	**TO-5**
LF357 ($A_V \geq 5$)	**13**	**5 typ**	**2**	**8**	**15k**	**25**	**75**	**5**	**±5**	**±18**	**±16**	**±30**	**10**	**0**	**TO-5**
LM709C	10	12 typ	500	1500	15k	1	0.3	5	±9	±18	±8	±5	6.6	3	TO-5 DIP
LM725C	3.5	2 typ	50	250	125k	0.5	0.005	5	±3	±22	±13.5	±5	5	4	TO-5 DIP
LM741C	7.5	15 typ	300	800	15k	1	0.5	5	±3	±18	±12	±30	2.8	0	TO-5 DIP F.P.
LM741E	4	15	70	210	32k	1	0.5	7.5	±3	±18	±12	±30	3.75	0	TO-5 DIP F.P.
LM747C	6	*	300	800	15k	1	0.5	5	±3	±18	±12	±30	5.6	0	TO-5 DIP F.P.
LM747E	4	15	70	210	32k	1	0.5	7.5	±3	±18	±12	±30	5.6	0	TO-5 DIP F.P.
LM748C	6	6	0.5	1.5	25k	1	0.5	5	±3	±18	±12	±30	2.8	1	TO-5 DIP
LM4250C	6	*	8	10	50k	0.1	0.03	0.12 ($R_L \geq 100k$)	±1	±18	±12	±15	0.011 (Set)	0	TO-5 DIP

Note 1: Inputs have shunt-diode protection; current must be limited. *Not specified

COMMERCIAL TEMPERATURE RANGE: $0^{\circ}C \leq T_A \leq +70^{\circ}C$

Device	Input Offset Voltage Max (mV)	Input Offset Voltage Drift Max ($\mu V/^{\circ}C$)	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 Min $R_L = 2\ k\Omega$ (mA)	Supply Voltage Min (V)	Supply Voltage Max (V)	Common Mode Range (V)	Differential Input Voltage (V)	Supply Current $T_A = 25^{\circ}C$ Max (mA)	Compensation Components	Package Types
DUAL OP AMPS															
LM358	7.5	7 typ	150	500	15k	1	*	8	±1.5	±15	$V^+-1.5$	V^+	1.2	0	TO-5 DIP
LM1458	6	*	300	800	15k	1	0.2	5	±3	±18	±15	±30	5.6	0	TO-5 DIP
LH2301A	10	30	70	300	15k	1	0.5	5	±3	±18	±12	±30	3	1	TO-5 DIP
LH2308A	0.73	5	1.5	10	60k	1	0.3	1	±2	±20	±14	(Note 1)	0.08	1	TO-5 DIP F.P.
LH2308	10	30	1.5	10	15k	1	0.3	1	±2	±18	±14	(Note 1)	0.8	1	TO-5 DIP F.P.
LH2310	10	10 typ	*	10	0.999	20	30	1	±5	±18	±10	*	5.5	0	TO-5 DIP F.P.
LH24250	6	*	8	10	50k	0.1	0.03	0.12 ($R_L \geq 100k$)	±1	±18	±12	±15	0.022 (Set)	0	TO-5 DIP
QUAD OP AMPS															
LM324	9	7 typ	150	500	15k	1	*	10–source 5–sink	3 (±1.5)	32 (±16)	$V^+-1.5$	32	2	0	DIP F.P.
LM348	7.5	15 typ	100	400	15k	1	*	5	±5	±18	±18	±36	4.5	0	DIP F.P.
LM349 ($A_V \geq 5$)	7.5	15 typ	100	400	15k	4	3	5	±5	±18	±18	±36	4.5	0	DIP F.P.
LM3900	*	*	*	200	2.8k	2.5	20	10	4 (±2)	36 (±18)	*	*	10	0	DIP

Definition of Terms

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.

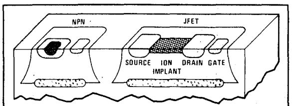
Strobe "OFF" Voltage: The minimum voltage on the strobe terminal that will guarantee that it does not interfere with the operation of the comparator.

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.

Operational Amplifiers/Buffers



BI-FET Technology

LF155, LF156, LF157 monolithic JFET input operational amplifiers

LF155, LF155A, LF255, LF355, LF355A low supply current
LF156, LF156A, LF256, LF356, LF356A wide band
LF157, LF157A, LF257, LF357, LF357A wide band decompensated ($A_{V_{MIN}} = 5$)

general description

These are the first monolithic JFET input operational amplifiers to incorporate well matched, high voltage JFETs on the same chip with standard bipolar transistors (BI-FET Technology). These amplifiers feature 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 devices are also designed for high slew rate, wide bandwidth, extremely fast settling time, low voltage and current noise and a low 1/f noise corner.

advantages

- Replace expensive hybrid and module FET op amps
- Rugged JFETs allow blow-out free handling compared with MOSFET input devices
- Excellent for low noise applications using either high or low source impedance—very low 1/f corner
- Offset adjust does not degrade drift or common-mode rejection as in most monolithic amplifiers
- New output stage allows use of large capacitive loads (10,000 pF) without stability problems
- Internal compensation and large differential input voltage capability

applications

- Precision high speed integrators
- Fast D/A and A/D converters
- High impedance buffers
- Wideband, low noise, low drift amplifiers
- Logrithmic amplifiers
- Photocell amplifiers
- Sample and Hold circuits

common features

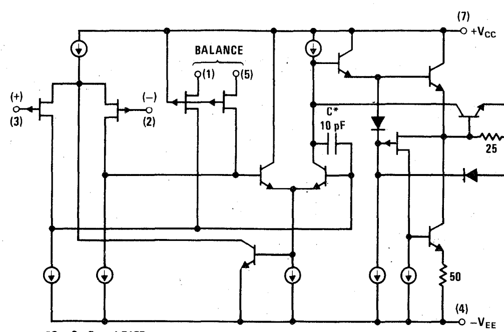
(LF155A, LF156A, LF157A)

■ Low input bias current	30 pA
■ Low Input Offset Current	3 pA
■ High input impedance	$10^{12}\Omega$
■ Low input offset voltage	1 mV
■ Low input offset voltage temperature drift	$3\mu V/^\circ C$
■ Low input noise current	$0.01\ pA/\sqrt{Hz}$
■ High common-mode rejection ratio	100 dB
■ Large dc voltage gain	106 dB

uncommon features

	LF155A	LF156A	LF157A ($A_V = 5$)*	UNITS
■ Extremely fast settling time to 0.01%	4	1.5	1.5	μs
■ Fast slew rate	5	12	50	$V/\mu s$
■ Wide gain bandwidth	2.5	5	20	MHz
■ Low input noise voltage	20	12	12	$nV/\sqrt{Hz}$

simplified schematic



*C = 2 pF on LF157

absolute maximum ratings

	LF155A/6A/7A	LF155/6/7	LF255/6/7	LF355A/6A/7A LF355/6/7
Supply Voltage	±22V	±22V	±22V	±18V
Power Dissipation (Note 1) TO-99 (H package)	670 mW	670 mW	570 mW	500 mW
Operating Temperature Range	−55°C to +125°C	−55°C to +125°C	−25°C to +85°C	0°C to +70°C
$T_{j(MAX)}$	150°C	150°C	115°C	100°C
Differential Input Voltage	±40V	±40V	±40V	±30V
Input Voltage Range (Note 2)	±20V	±20V	±20V	±16V
Output Short Circuit Duration	Continuous	Continuous	Continuous	Continuous
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C	300°C	300°C	300°C

dc electrical characteristics

(Note 3)

SYMBOL	PARAMETER	CONDITIONS	LF155A/6A/7A			LF355A/6A/7A			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{OS}	Input Offset Voltage	$R_S = 50\Omega$, $T_A = 25°C$		1	2		1	2	mV
		Over Temperature			2.5			2.3	mV
$\Delta V_{OS}/\Delta T$	Average TC of Input Offset Voltage	$R_S = 50\Omega$		3	5		3	5	μV/°C
$\Delta TC/\Delta V_{OS}$	Change in Average TC with V_{OS} Adjust	$R_S = 50\Omega$, (Note 4)		0.5			0.5		μV/°C per mV
I_{OS}	Input Offset Current	$T_j = 25°C$, (Notes 3, 5)		3	10		3	10	pA
		$T_j \le T_{HIGH}$			10			1	nA
I_B	Input Bias Current	$T_J = 25°C$, (Notes 3, 5)		30	50		30	50	pA
		$T_J \le T_{HIGH}$			25			5	nA
R_{IN}	Input Resistance	$T_J = 25°C$		10^{12}			10^{12}		Ω
A_{VOL}	Large Signal Voltage Gain	$V_S = \pm15V$, $T_A = 25°C$ $V_O = \pm10V$, $R_L = 2k$	50	200		50	200		V/mV
		Over Temperature	25			25			V/mV
V_O	Output Voltage Swing	$V_S = \pm15V$, $R_L = 10k$	±12	±13		±12	±13		V
		$V_S = \pm15V$, $R_L = 2k$	±10	±12		±10	±12		V
V_{CM}	Input Common-Mode Voltage Range	$V_S = \pm15V$	±11	+15.1 −12		±11	+15.1 −12		V V
CMRR	Common-Mode Rejection Ratio		85	100		85	100		dB
PSRR	Supply Voltage Rejection Ratio	(Note 6)	85	100		85	100		dB

ac electrical characteristics

$T_A = 25°C$, $V_S = \pm15V$

SYMBOL	PARAMETER	CONDITIONS	LF155A/355A			LF156A/356A			LF157A/357A			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew Rate	LF155A/6A: $A_V = 1$,	3	5		10	12					V/μs
		LF157A: $A_V = 5$							40	50		V/μs
GBW	Gain-Bandwidth Product			2.5		4	4.5		15	20		MHz
t_s	Settling Time to 0.01%	(Note 7)		4			1.5			1.5		μs
e_n	Equivalent Input Noise Voltage	$R_S = 100\Omega$										
		f = 100 Hz		25			15			15		$nV/\sqrt{Hz}$
		f = 1000 Hz		20			12			12		$nV/\sqrt{Hz}$
i_n	Equivalent Input Noise Current	f = 100 Hz		0.01			0.01			0.01		$pA/\sqrt{Hz}$
		f = 1000 Hz		0.01			0.01			0.01		$pA/\sqrt{Hz}$
C_{IN}	Input Capacitance			3			3			3		pF

dc electrical characteristics

(Note 3)

SYMBOL	PARAMETER	CONDITIONS	LF155/6/7			LF255/6/7			LF355/6/7			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{OS}	Input Offset Voltage	$R_S = 50\Omega$, $T_A = 25°C$		3	5		3	5		3	10	mV
		Over Temperature			7			6.5			13	mV
$\Delta V_{OS}/\Delta T$	Average TC of Input Offset Voltage	$R_S = 50\Omega$		5			5			5		μV/°C
$\Delta TC/\Delta V_{OS}$	Change in Average TC with V_{OS} Adjust	$R_S = 50\Omega$, (Note 4)		0.5			0.5			0.5		μV/°C per mV
I_{OS}	Input Offset Current	$T_j = 25°C$, (Notes 3, 5)		3	20		3	20		3	50	pA
		$T_j \leq T_{HIGH}$			20			1			2	nA
I_B	Input Bias Current	$T_J = 25°C$, (Notes 3, 5)		30	100		30	100		30	200	pA
		$T_J \leq T_{HIGH}$			50			5			8	nA
R_{IN}	Input Resistance	$T_J = 25°C$		10^{12}			10^{12}			10^{12}		Ω
A_{VOL}	Large Signal Voltage Gain	$V_S = \pm15V$, $T_A = 25°C$ $V_O = \pm10V$, $R_L = 2k$	50	200		50	200		25	200		V/mV
		Over Temperature	25			25			15			V/mV
V_O	Output Voltage Swing	$V_S = \pm15V$, $R_L = 10k$	±12	±13		±12	±13		±12	±13		V
		$V_S = \pm15V$, $R_L = 2k$	±10	±12		±10	±12		±10	±12		V
V_{CM}	Input Common-Mode Voltage Range	$V_S = \pm15V$	±11	+15.1 −12		±11	+15.1 −12		±10	+15.1 −12		V V
CMRR	Common-Mode Rejection Ratio		85	100		85	100		80	100		dB
PSRR	Supply Voltage Rejection Ratio	(Note 6)	85	100		85	100		80	100		dB

dc electrical characteristics

$T_A = 25°C$, $V_S = \pm15V$

PARAMETER	LF155A/355A LF155/255		LF355		LF156A LF156/256		LF356A/LF356		LF157A LF157/257		LF357A/LF357		UNITS
	TYP	MAX	TYP	MAX	TYP	MAX	TYP	MAX	TYP	MAX	TYP	MAX	
Supply Current,	2	4	2	4	5	7	5	10	5	7	5	10	mA

ac electrical characteristics

$T_A = 25°C$, $V_S = \pm15V$

SYMBOL	PARAMETER	CONDITIONS	LF155/LF255/ LF355	LF156/LF256	LF156/LF256/ LF356	LF157/LF257	LF157/LF257/ LF357	UNITS
			TYP	MIN	TYP	MIN	TYP	
SR	Slew Rate	LF155/6: $A_V = 1$,	5	7.5	12			V/μs
		LF157: $A_V = 5$				30	50	V/μs
GBW	Gain-Bandwidth Product		2.5		5		20	MHz
t_s	Settling Time to 0.01%	(Note 7)	4		1.5		1.5	μs
e_n	Equivalent Input Noise Voltage	$R_S = 100\Omega$						
		f = 100 Hz	25		15		15	$nV/\sqrt{Hz}$
		f = 1000 Hz	20		12		12	$nV/\sqrt{Hz}$
i_n	Equivalent Input Current Noise	f = 100 Hz	0.01		0.01		0.01	$pA/\sqrt{Hz}$
		f = 1000 Hz	0.01		0.01		0.01	$pA/\sqrt{Hz}$
C_{IN}	Input Capacitance		3		3		3	pF

notes for electrical characteristics

Note 1: The TO-99 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 package, the device must be derated based on thermal resistance of 175°C/W junction to ambient.

Note 2: Unless otherwise specified the absolute maximum negative input voltage is equal to the negative power supply voltage.

Note 3: These specifications apply for $\pm15V \le V_S \le \pm20V$, $-55°C \le T_A \le +125°C$ and $T_{HIGH} = +125°C$ unless otherwise stated for the LF155A/6A/7A and the LF155/6/7. For the LF255/6/7, these specifications apply for $\pm15V \le V_S \le \pm20V$, $-25°C \le T_A \le +85°C$ and $T_{HIGH} = 85°C$ unless otherwise stated. For the LF355A/6A/7A, these specifications apply for $\pm15V \le V_S \le \pm20V$, $0°C \le T_A \le +70°C$ and $T_{HIGH} = +70°C$, and for the LF355/6/7 these specifications apply for $V_S = \pm15V$ and $0°C \le T_A \le +70°C$. V_{OS}, I_B and I_{OS} are measured at $V_{CM} = 0$.

Note 4: The Temperature Coefficient of the adjusted input offset voltage changes only a small amount (0.5μV/°C typically) for each mV of adjustment from its original unadjusted value. Common-mode rejection and open loop voltage gain are also unaffected by offset adjustment.

Note 5: The input bias currents are junction leakage currents which approximately double for every 10°C increase in the junction temperature, T_J. Due to limited production test time, the input bias currents measured are correlated to junction temperature. In normal operation the junction temperature rises above the ambient temperature as a result of internal power dissipation, Pd. $T_j = T_A + \Theta_{jA}$ Pd where Θ_{jA} is the thermal resistance from junction to ambient. Use of a heat sink is recommended if input bias current is to be kept to a minimum.

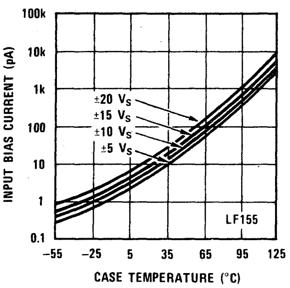
Note 6: Supply Voltage Rejection is measured for both supply magnitudes increasing or decreasing simultaneously, in accordance with common practice.

Note 7: Settling time is defined here, for a unity gain inverter connection using 2 kΩ resistors for the LF155/6. It is the time required for the error voltage (the voltage at the inverting input pin on the amplifier) to settle to within 0.01% of its final value from the time a 10V step input is applied to the inverter. For the LF157, $A_V = -5$, the feedback resistor from output to input is 2 kΩ and the output step is 10V (See Settling Time Test Circuit, page 9).

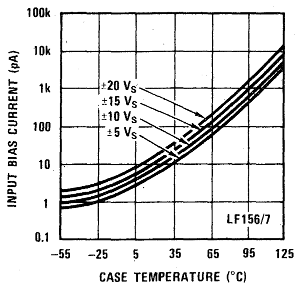
typical dc performance characteristics

Curves are for LF155, LF156 and LF157 unless otherwise specified.

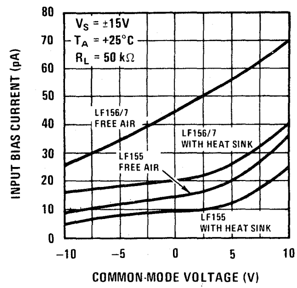
Input Bias Current



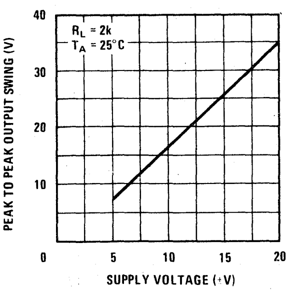
Input Bias Current



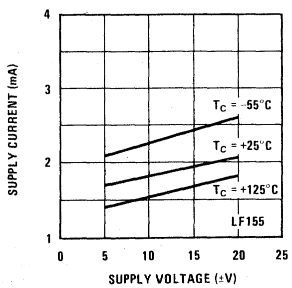
Input Bias Current



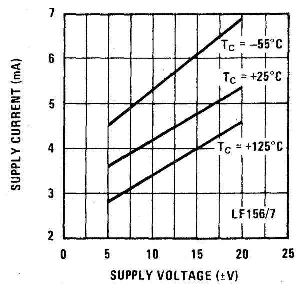
Voltage Swing



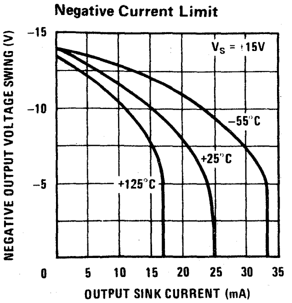
Supply Current



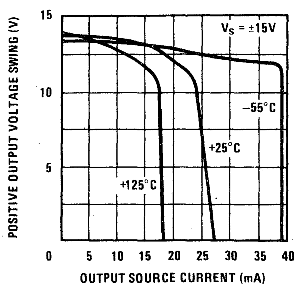
Supply Current



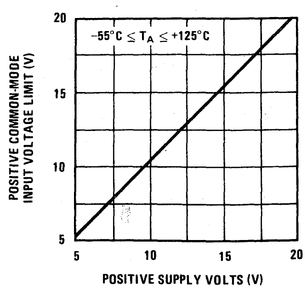
Negative Current Limit



Positive Current Limit

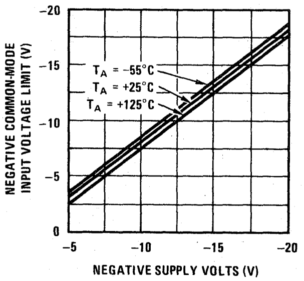


Positive Common-Mode Input Voltage Limit

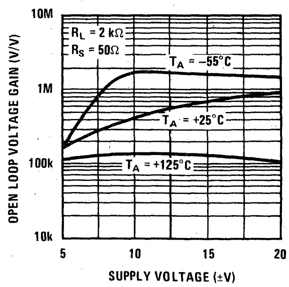


typical dc performance characteristics (con't)

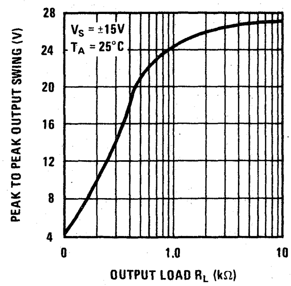
Negative Common-Mode Input Voltage Limit



Open Loop Voltage Gain

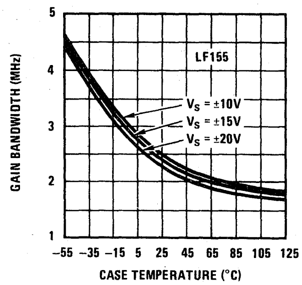


Output Voltage Swing

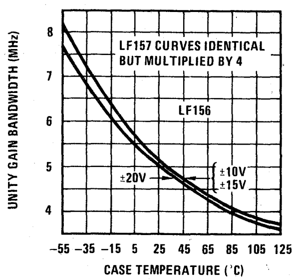


typical ac performance characteristics

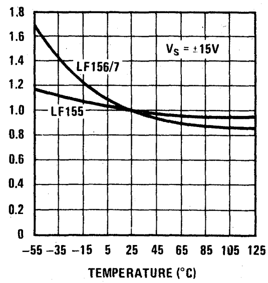
Gain Bandwidth



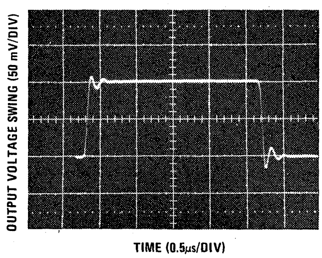
Unity Gain Bandwidth



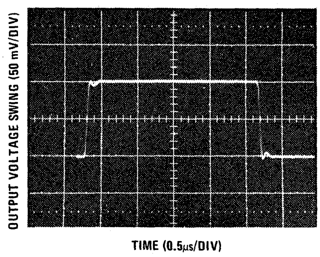
Normalized Slew Rate



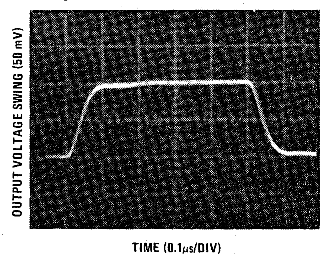
LF155 Small Signal Pulse Response, A_V = +1



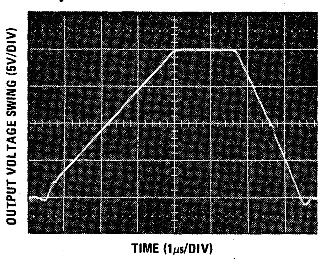
LF156 Small Signal Pulse Response, A_V = +1



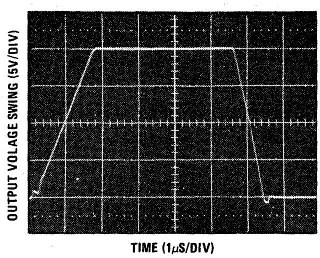
LF157 Small Signal Pulse Response, A_V = +5



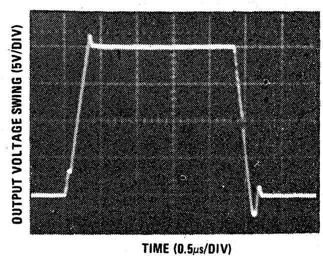
LF155 Large Signal Pulse Response, A_V = +1



LF156 Large Signal Pulse Response, A_V = +1

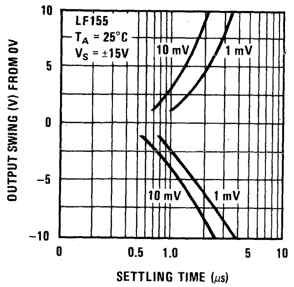


LF157 Large Signal Pulse Response, A_V = +5

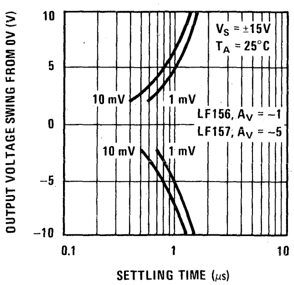


typical ac performance characteristics (con't)

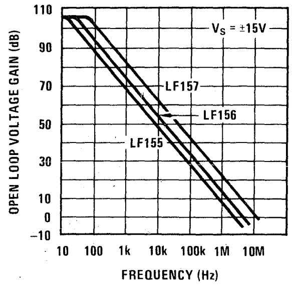
Inverter Settling Time



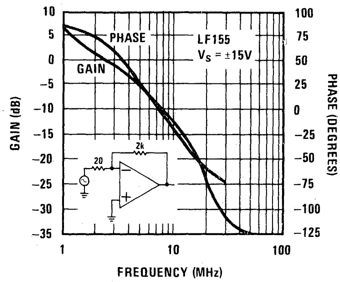
Inverter Settling Time



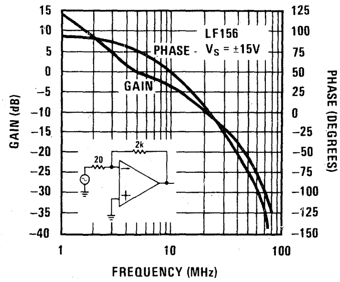
Open Loop Frequency Response



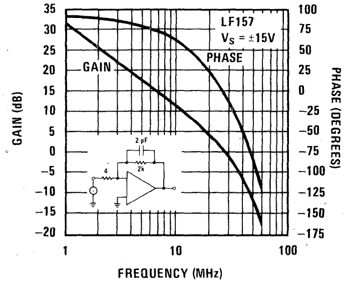
Bode Plot



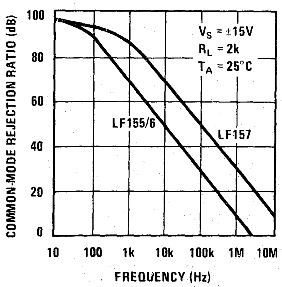
Bode Plot



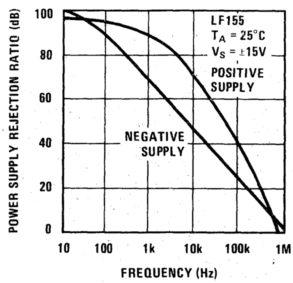
Bode Plot



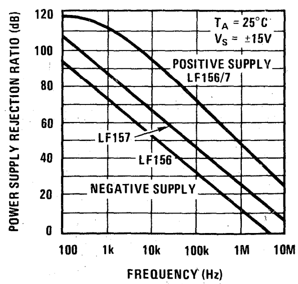
Common-Mode Rejection Ratio



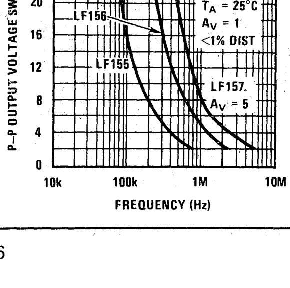
Power Supply Rejection Ratio



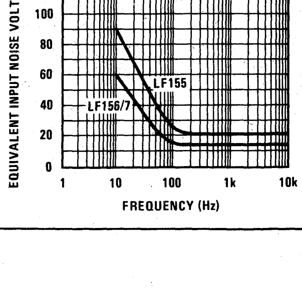
Power Supply Rejection Ratio



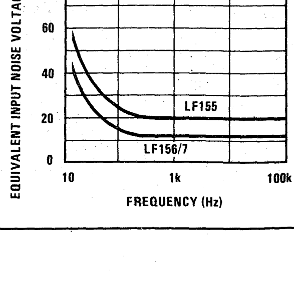
Undistorted Output Voltage Swing



Equivalent Input Noise Voltage

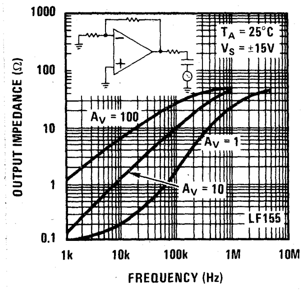


Equivalent Input Noise Voltage (Expanded Scale)

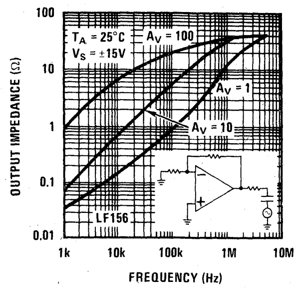


typical ac performance characteristics (con't)

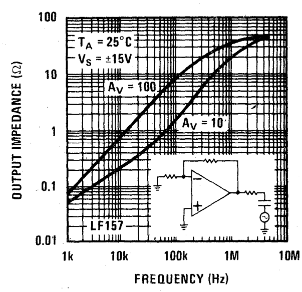
Output Impedance



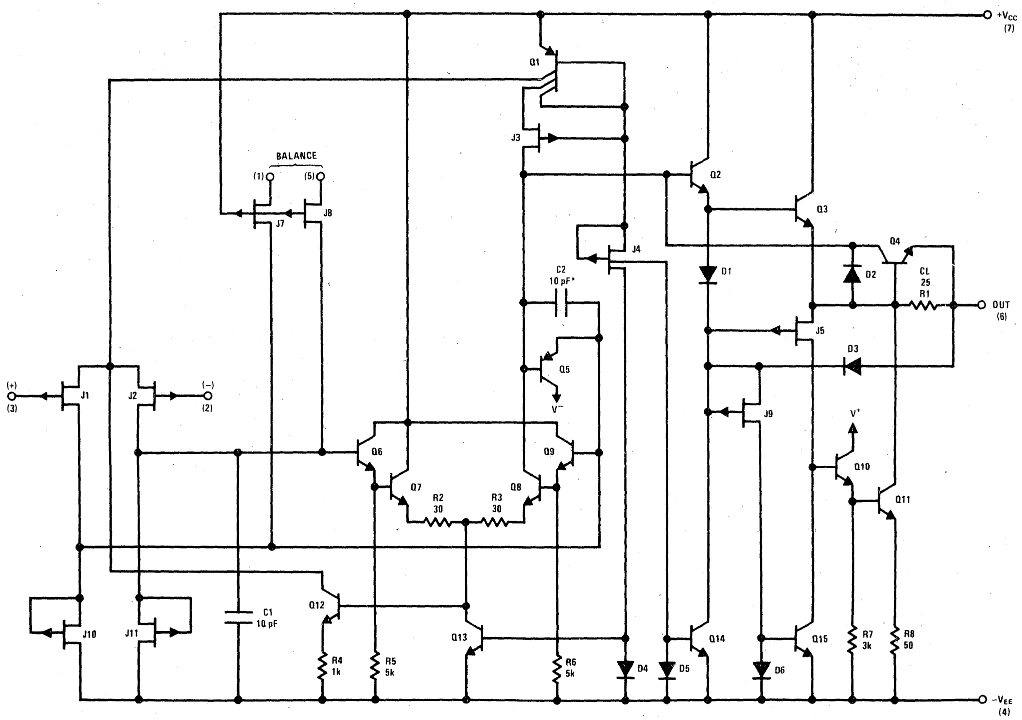
Output Impedance



Output Impedance



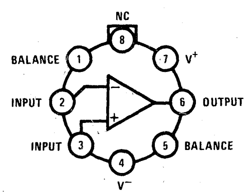
detailed schematic



*C = 2 pF on LF157

connection diagrams

Metal Can Package



Note 4: Pin 4 connected to case.

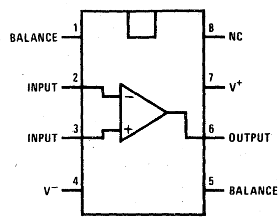
TOP VIEW

Order Number

LF155AH	LF156AH	LF157AH
LF155H	LF156H	LF157H
LF255H	LF256H	LF257H
LF355AH	LF356AH	LF357AH
LF355H	LF356H	LF357H

See Package 11

Dual-In-Line Package



TOP VIEW

Order Number LF355N, LF356N or LF357N

See Package 20

application hints

The LF155/6/7 series are op amps with JFET input devices. These JFETs have large reverse breakdown voltages from gate to source and drain eliminating the need for clamps across the inputs. Therefore large differential input voltages can easily be accomodated without a large increase in input current. The maximum differential input voltage is independent of the supply voltages. However, neither of the input voltages should be allowed to exceed the negative supply as this will cause large currents to flow which can result in a destroyed unit.

Exceeding the negative common-mode limit on either input will cause a reversal of the phase to the output and force the amplifier output to the corresponding high or low state. Exceeding the negative common-mode limit on both inputs will force the amplifier output to a high state. In neither case does a latch occur since raising the input back within the common-mode range again puts the input stage and thus the amplifier in a normal operating mode.

Exceeding the positive common-mode limit on a single input will not change the phase of the output however, if both inputs exceed the limit, the output of the amplifier will be forced to a high state.

These amplifiers will operate with the common-mode input voltage equal to the positive supply. In fact, the common-mode voltage can exceed the positive supply by approximately 100 mV independent of supply voltage and over the full operating temperature range. The positive supply can therefore be used as a reference on an input as, for example, in a supply current monitor and/or limiter.

Precautions should be taken to ensure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a 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.

Because these amplifiers are JFET rather than MOSFET input op amps they do not require special handling.

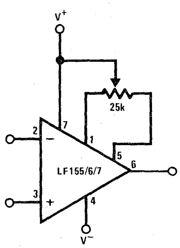
All of the bias currents in these amplifiers are set by FET current sources. The drain currents for the amplifiers are therefore essentially independent of supply voltage.

As with most amplifiers, care should be taken with lead dress, component placement and supply decoupling in order to ensure stability. For example, resistors from the output to an input should be placed with the body close to the input to minimize "pickup" and maximize the frequency of the feedback pole by minimizing the capacitance from the input to ground.

A feedback pole is created when the feedback around any amplifier is resistive. The parallel resistance and capacitance from the input of the device (usually the inverting input) to ac ground set the frequency of the pole. In many instances the frequency of this pole is much greater than the expected 3 dB frequency of the closed loop gain and consequently there is negligible effect on stability margin. However, if the feedback pole is less than approximately six times the expected 3 dB frequency a lead capacitor should be placed from the output to the input of the op amp. The value of the added capacitor should be such that the RC time constant of this capacitor and the resistance it parallels is greater than or equal to the original feedback pole time constant.

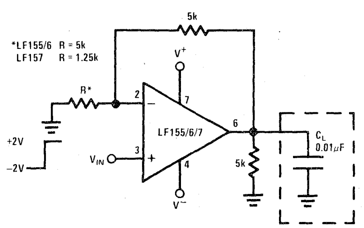
typical circuit connections

V_{OS} Adjustment



- V_{OS} is adjusted with a 25k potentiometer
- The potentiometer wiper is connected to V^+
- For potentiometers with temperature coefficient of 100 ppm/°C or less the additional drift with adjust is ≈ 0.5μV/°C/mV of adjustment
- Typical overall drift: 5μV/°C ± (0.5μV/°C/mV of adj.)

Driving Capacitive Loads

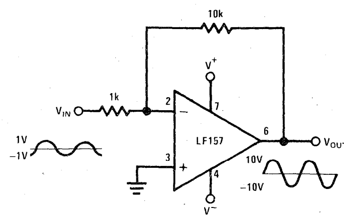


Due to a unique output stage design these amplifiers have the ability to drive large capacitive loads and still maintain stability. $C_{L\,MAX} \cong 0.01\mu F$.

Overshoot ≤ 20%

Settling time (t_s) ≅ 5μs

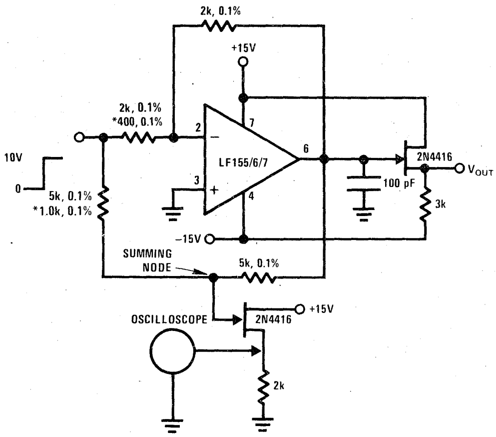
LF157. A Large Power BW Amplifier



For distortion < 1% and a 20 Vp-p V_{OUT} swing, power bandwidth is: 500 kHz.

typical applications

Settling Time Test Circuit



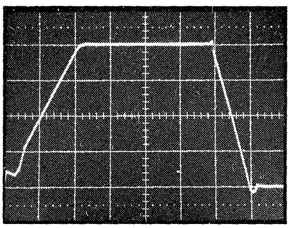
- Settling time is tested with the LF155/6 connected as unity gain inverter and LF157 connected for $A_V = -5$
- FET used to isolate the probe capacitance
- Output = 10V step

$^*A_V = -5$ for LF157

Large Signal Inverter Output, V_{OUT} (from Settling Time Circuit)

LF155

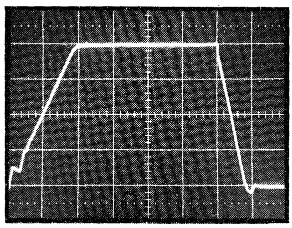
5V/DIV



2µs/DIV

LF156

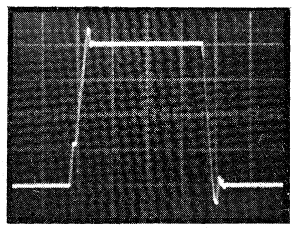
5V/DIV



1µs/DIV

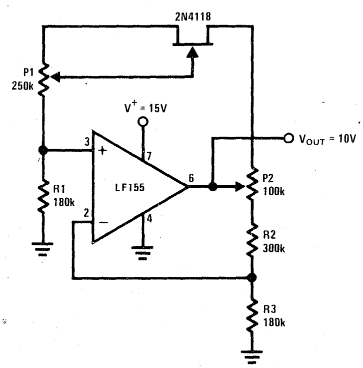
LF157

5V/DIV



1µs/DIV

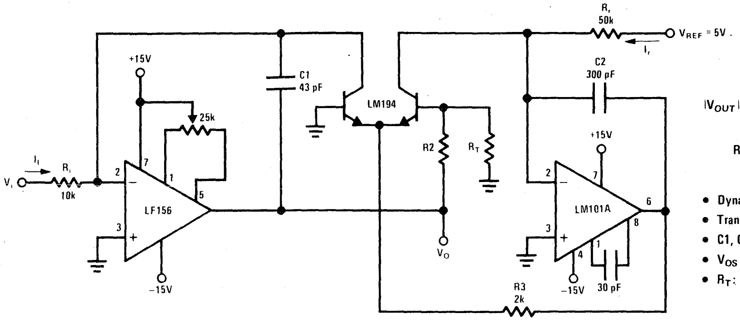
Low Drift Adjustable Voltage Reference



- $\Delta V_{OUT}/\Delta T = \pm 0.002\%/°C$
- All resistors and potentiometers should be wire-wound
- P1: drift adjust
- P2: V_{OUT} adjust
- Use LF155 for
  - ▲ Low I_B
  - ▲ Low drift
  - ▲ Low supply current

typical applications (con't)

Fast Logrithmic Converter

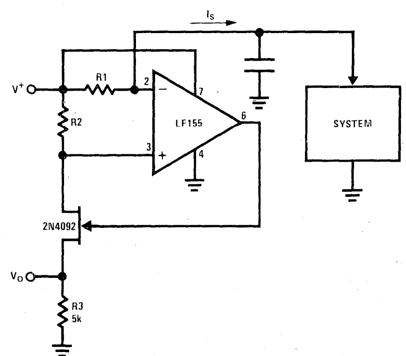


$$|V_{OUT}| = \left[1 + \frac{R2}{R_T}\right] \frac{kT}{q} \ln V_i \left[\frac{R_r}{V_{REF} R_i}\right] = \log V_i \frac{1}{R_i I_r}$$

R2 = 15.7k, R_T = 1k, 0.3%/°C (for temperature compensation)

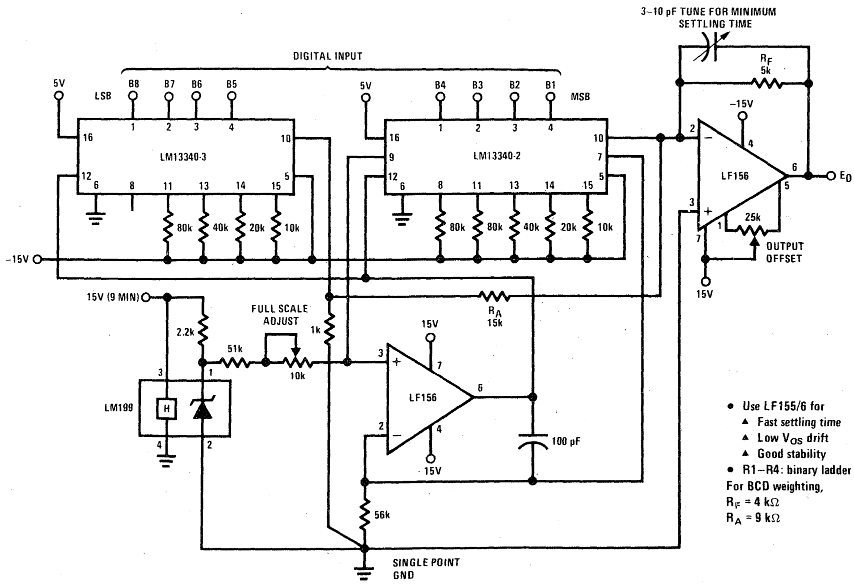
- Dynamic range: $100\mu A \leq I_i \leq 1$ mA (5 decades), $|V_O| = 1V/\text{decade}$
- Transient response: 3μs for $\Delta I_i = 1$ decade
- C1, C2, R2, R3: added dynamic compensation
- V_{OS} adjust the LF156 to minimize quiescent error
- R_T: Tel Labs type Q81 + 0.3%/°C.

Precision Current Monitor



- $V_O = 5 \frac{R1}{R2}$ (V/mA of I_S)
- R1, R2, R3: 0.1% resistors
- Use LF155 for
  - ▲ Common mode range to supply voltage
  - ▲ Low I_B
  - ▲ Low V_{OS}
  - ▲ Low supply current

Temperature Compensated 8-Bit D/A Converter

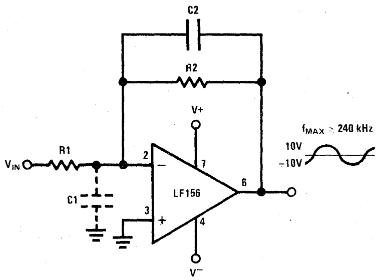


- Use LF155/6 for
  - ▲ Fast settling time
  - ▲ Low V_{OS} drift
  - ▲ Good stability
- R1–R4: binary ladder

For BCD weighting,
R_F = 4 kΩ
R_A = 9 kΩ

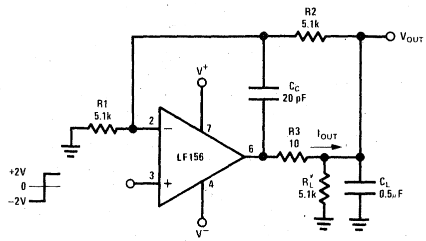
typical applications (con't)

Wide BW Low Noise, Low Drift Amplifier



- Power BW: $f_{MAX} = \frac{S_r}{2\pi V_P} \cong 240$ kHz
- Parasitic input capacitance C1 ≅(3 pF for LF155, LF156, and LF157 plus any additional layout capacitance) interacts with feedback elements and creates undesirable high frequency pole. To compensate add C2 such that: R2C2 ≅ R1C1.

Isolating Large Capacitive Loads

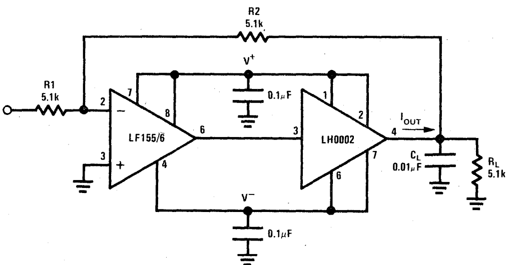


- Overshoot 6%
- t_s 10μs
- When driving large C_L the V_{OUT} slew rate determined by C_L and $I_{OUT\ MAX}$:

$$\frac{\Delta V_{OUT}}{\Delta T} = \frac{I_{OUT}}{C_L} \cong \frac{0.02}{0.5}\ \text{V}/\mu\text{s} = 0.04\ \text{V}/\mu\text{s}$$

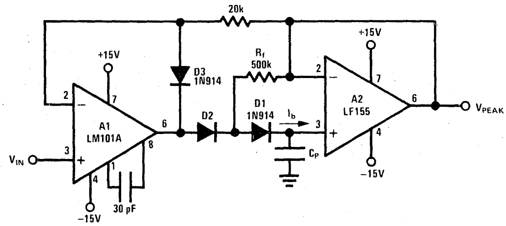
(with C_L shown)

Boosting the LF156 with a Current Amplifier



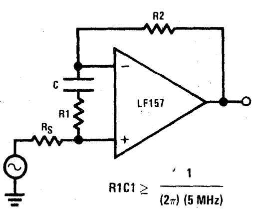
- $I_{OUT\ MAX} \cong 150$ mA (will drive $R_L \geq 100\Omega$)
- $\frac{\Delta V_{OUT}}{\Delta T} = \frac{0.15}{10^{-2}}$ V/μs = 15 V/μs (with C_L shown)
- No additional phase shift added by the current amplifier

Low Drift Peak Detector



- By adding D1 and R_f, $V_{D1} = 0$ during hold mode. Leakage of D2 provided by feedback path through R_f.
- Leakage of circuit is essentially I_b (LF155, LF156) plus capacitor leakage of C_P.
- Diode D3 clamps V_{OUT} (A1) to $V_{IN} - V_{D3}$ to improve speed and to limit reverse bias of D2.
- Maximum input frequency should be << $1/2\pi R_f C_{D2}$ where C_{D2} is the shunt capacitance of D2.

Non-Inverting Unity Gain Operation for LF157

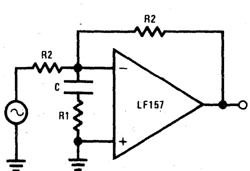


$$R1C1 \geq \frac{1}{(2\pi)(5\ \text{MHz})}$$

$$R1 = \frac{R2 + R5}{4}$$

$A_{V(DC)} = 1$
$f_{-3dB} \approx 5$ MHz

Inverting Unity Gain for LF157



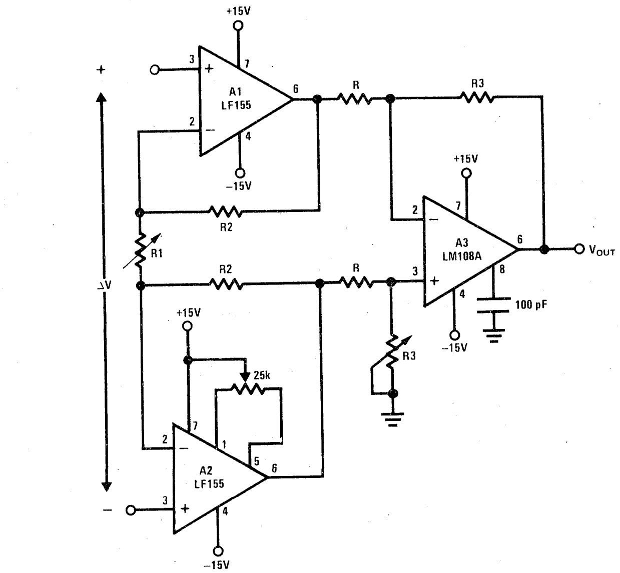
$$R1C1 \geq \frac{1}{(2\pi)(5\ \text{MHz})}$$

$$R1 = \frac{R2}{4}$$

$A_{V(DC)} = -1$
$f_{-3dB} \approx 5$ MHz

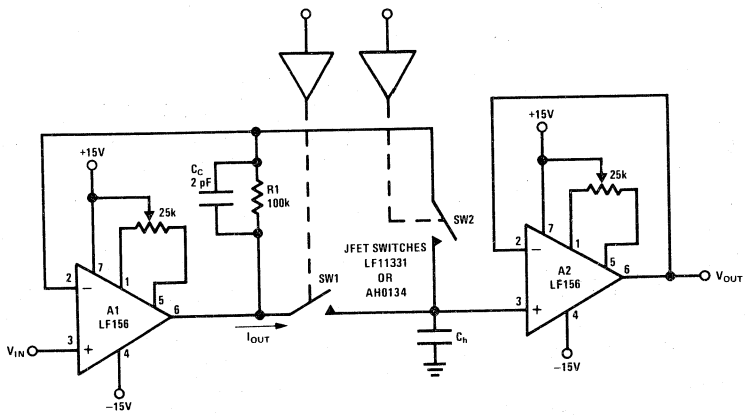
typical applications (con't)

High Impedance, Low Drift Instrumentation Amplifier



- $V_{OUT} = \frac{R3}{R}\left[\frac{2R2}{R1} + 1\right]\Delta V$, $V^- + 2V \leq V_{IN}$ Common-Mode $\leq V^+$
- System V_{OS} adjusted via A2 V_{OS} adjust
- Trim R3 to boost up CMRR to 120 dB. Instrumentation amplifier Resistor array RA201 (National Semiconductor) recommended

Fast Sample and Hold



- Both amplifiers (A1, A2) have feedback loops individually closed with stable responses (overshoot negligible)
- Acquisition time, T_A, estimated by:

$$T_A \cong \left[\frac{2R_{ON}, V_{IN}, C_h}{S_r}\right]^{1/2} \text{ provided that:}$$

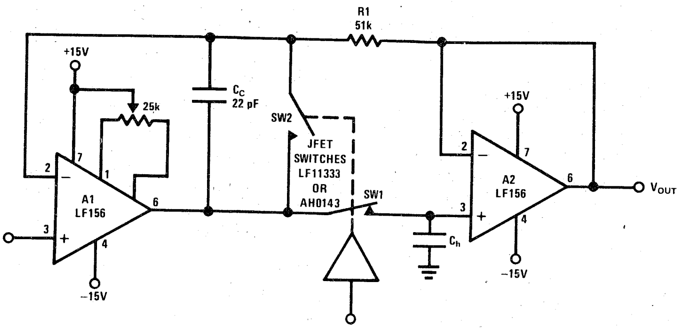
$$V_{IN} < 2\pi S_r R_{ON} C_h \text{ and } T_A > \frac{V_{IN} C_h}{I_{OUT\ MAX}}, \ R_{ON} \text{ is of SW1}$$

$$\text{If inequality not satisfied: } T_A \cong \frac{V_{IN} C_h}{20\text{ mA}}$$

- LF156 develops full S_r output capability for $V_{IN} \geq 1V$
- Addition of SW2 improves accuracy by putting the voltage drop across SW1 inside the feedback loop
- Overall accuracy of system determined by the accuracy of both amplifiers, A1 and A2

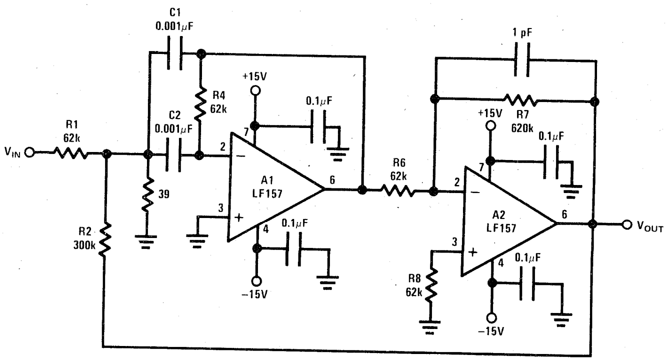
typical applications (con't)

High Accuracy Sample and Hold



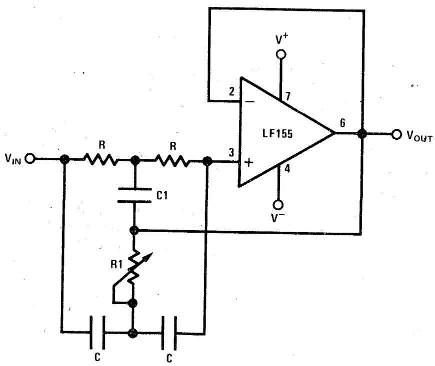
- By closing the loop through A2 the V_{OUT} accuracy will be determined uniquely by A1. No V_{OS} adjust required for A2.
- T_A can be estimated by same considerations as previously but, because of the added propagation delay in the feedback loop (A2) the overshoot is not negligible.
- Overall system slower than fast sample and hold
- R1, C_C: additional compensation
- Use LF156 for
  - ▲ Fast settling time
  - ▲ Low V_{OS}

High Q Band Pass Filter



- By adding positive feedback (R2) Q increases to 40
- f_{BP} = 100 kHz
- $\frac{V_{OUT}}{V_{IN}} = 10\sqrt{Q}$
- Clean layout recommended
- Response to a 1 Vp-p tone burst: 300µs

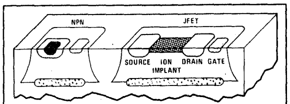
High Q Notch Filter



- 2R1 = R = 10 MΩ
  2C = C1 = 300 pF
- Capacitors should be matched to obtain high Q
- f_{NOTCH} = 120 Hz, notch = −55 dB, Q > 100
- Use LF155 for
  - ▲ Low I_B
  - ▲ Low supply current

3

Operational Amplifiers/Buffers



BI-FET Technology

LF13741 monolithic JFET input operational amplifier

general description

The LF13741 is a 741 with BI-FET input followers on the same die. Familiar operating characteristics – THOSE OF A 741 – with the added advantage of low input bias current make the LF13741 easy to use. Monolithic fabrication makes this "drop-in-replacement" operational amplifier economical as well as easy to use.

Applications in which the rugged LF13741 excels require a low input current, moderate speed amplifier or comparator – high impedance transducer amplifiers and slow comparators (reducing the problem of input/output coupling) for example. Photocell applications, buffers for high impedance, moderate speed sources (or where output speed is not needed) and buffers in Sample-and-Hold type systems where leakage from the hold capacitor node must be kept to a minimum, are some of the many applications in which the LF13741 provides the needed performance at low cost.

Systems designers can take full advantage of their knowledge of the 741 when designing with the LF13741 to achieve extremely rapid "design times." The LF13741 can also be used in existing sockets to make the "error budget" for input bias and/or offset currents negligible and in many cases eliminate trimming. For higher speed and lower noise use the LF155, LF156, LF157 series of BI-FET operational amplifiers.

features

- Low input bias current 50 pA
- Low input noise current 0.01 pA/$\sqrt{Hz}$
- High input impedance $5 \times 10^{11}\Omega$
- Familiar operating characteristics

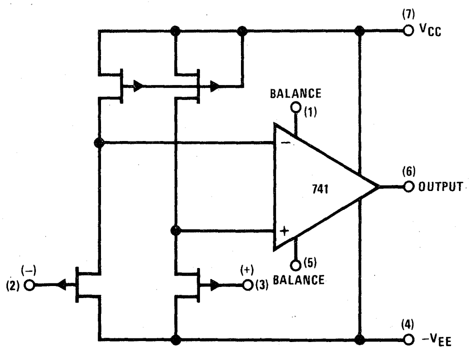
advantages

- FET inputs – 741 operating characteristics
- Low cost
- Ease of use
- Standard supplies
- Standard pin outs
- Tried and true design
- Rapid "design time"

applications

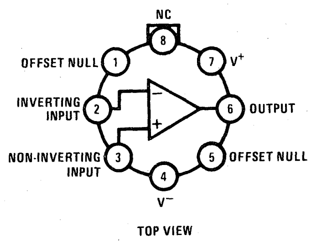
- Smoke detectors
- Optocoupler amplifiers
- High impedance buffers
- Low drift sample and hold circuits
- High input impedance, slow comparators
- Long time timers
- Low drift peak detectors
- Supply current monitors
- Low error budget systems

simplified schematic



All on one die.

connection diagram



TOP VIEW

Note: Pin 4 connected to case.

TO-99 Metal Can Package
Order Number LF13741H
See Package 11

absolute maximum ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	500 mW
TO-99 (H Package)	
Operating Temperature Range	0°C to +70°C
T_j(MAX)	100°C
Differential Input Voltage	±30V
Input Voltage Range (Note 2)	±16V
Output Short Circuit Duration	Continuous
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

dc electrical characteristics (Note 3)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{OS}	Input Offset Voltage	R_S = 10 kΩ, T_A = 25°C		5	15	mV
		Over Temperature			20	mV
$\Delta V_{OS}/\Delta T$	Average TC of Input Offset Voltage	R_S = 10 kΩ		10		μV/°C
I_{OS}	Input Offset Current	T_j = 25°C, (Notes 3, 4)		10	50	pA
		$T_j \leq$ 70°C			2	nA
I_B	Input Bias Current	T_j = 25°C, (Notes 3, 4)		50	200	pA
		$T_j \leq$ 70°C		11	8	nA
R_{IN}	Input Resistance	T_j = 25°C		5 x 10		Ω
A_{VOL}	Large Signal Voltage Gain	V_S = ±15V, T_A = 25°C	25	100		V/mV
		V_O = ±10V, R_L = 2 kΩ				
		Over Temperature	15			V/mV
V_O	Output Voltage Swing	V_S = ±15V, R_L = 10 kΩ	±12	±13		V
V_{CM}	Input Common-Mode Voltage Range	V_S = ±15V	±11	15.1		V
				−12		V
CMRR	Common-Mode Rejection Ratio	$R_S \leq$ 10 kΩ	70	90		dB
PSRR	Supply Voltage Rejection Ratio	(Note 5)	77	96		dB
I_S	Supply Current			2	4	mA

ac electrical characteristics (Note 3)

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
SR	Slew Rate	V_S = ±15V, T_A = 25°C		0.5		V/μs
GBW	Gain-Bandwidth Product	V_S = ±15V, T_A = 25°C		1.0		MHz
e_n	Equivalent Input Noise Voltage	T_A = 25°C, R_S = 100Ω				
		f = 100 Hz		50		$nV/\sqrt{Hz}$
		f = 1000 Hz		37		$nV/\sqrt{Hz}$
i_n	Equivalent Input Noise Current	T_j = 25°C				
		f = 100 Hz		0.01		$pA/\sqrt{Hz}$
		f = 1000 Hz		0.01		$pA/\sqrt{Hz}$

Note 1: The TO-99 package must be derated based on a thermal resistance of 150°C/W junction to ambient or 45°C/W junction to case.

Note 2: Unless otherwise specified the absolute maximum negative input voltage is equal to the negative power supply voltage.

Note 3: These specifications apply for V_S = ±15V and 0°C ≤ T_A ≤ +70°C. V_{OS}, I_B, and I_{OS} are measured at V_{CM} = 0.

Note 4: The input bias currents are junction leakage currents which approximately double for every 10°C increase in the junction temperature, T_j. Due to limited production test time, the input bias currents measured are correlated to junction temperature. In normal operation the junction temperature rises above the ambient temperature as a result of internal power dissipation, P_D. $T_j = T_A + \Theta_{jA} P_D$ where Θ_{jA} is the thermal resistance from junction to ambient. Use of a heat sink is recommended if input bias current is to be kept to a minimum.

Note 5: Supply Voltage Rejection Ratio is measured for both supply magnitudes increasing or decreasing simultaneously in accordance with common practice.

3

Operational Amplifiers/Buffers

LH0001*/LH0001C low power operational amplifier

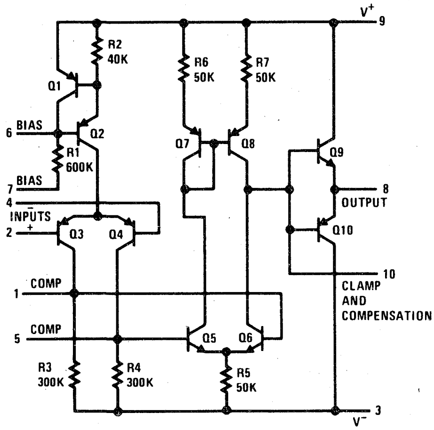
general description

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:

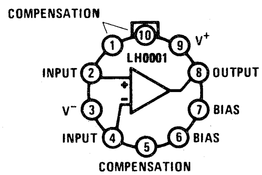
- Operation from ±5V to ±20V
- Very low offset voltage: typically 200 μV at 25°C, 600 μV at –55°C to 125°C
- Very low input offset current: typically 3 nA at 25°C, 6 nA at –55°C
- Low noise: typically 3 μV rms
- Frequency compensation with 2 small capacitors
- Output may be clamped at any desired level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



Metal Can Package



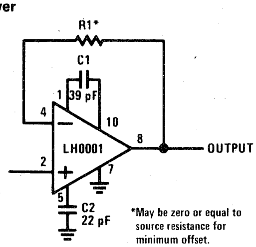
TOP VIEW

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.

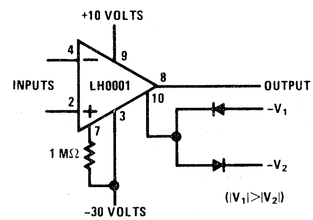
Order Number LH0001H
See Package 14B

typical applications

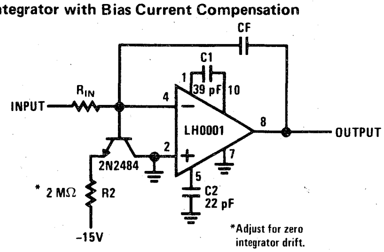
Voltage Follower



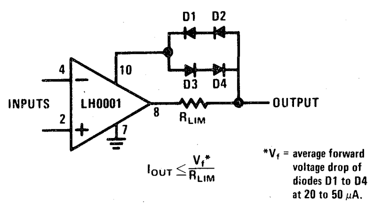
Voltage Comparator for Driving MOS Circuits



Integrator with Bias Current Compensation



External Current Limiting Method



*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)

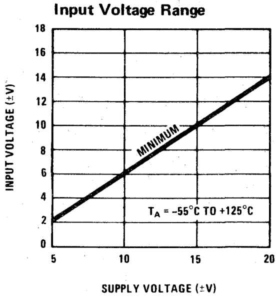
PARAMETER	TEMP (°C)	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	25 −55 to 125	$R_S \leq 5K$ $R_S \leq 5K$		0.2 0.6	1.0 2.0	mV mV
Input Offset Current	25 to 125 −55				20 100	nA nA
Input Bias Current	25 to 125 −55				100 300	nA nA
Supply Current (+)	25 125 −55	$V_S = \pm 20V$ $V_S = \pm 20V$ $V_S = \pm 20V$		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).

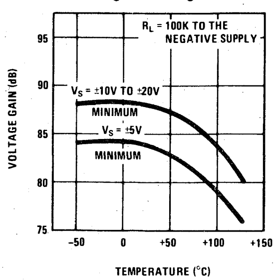
Note 2: These specifications apply for Pin 7 grounded, for $\pm 5V \leq V_S \leq \pm 20V$, with Capacitor C1 = 39 pF from Pin 1 to Pin 10, and C2 = 22 pF from Pin 5 to ground, unless otherwise specified.

guaranteed performance

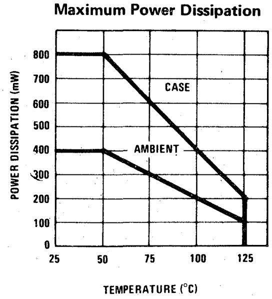
Input Voltage Range



Small Signal Voltage Gain

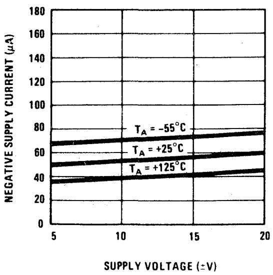


Maximum Power Dissipation

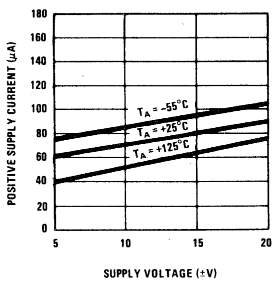


typical performance characteristics

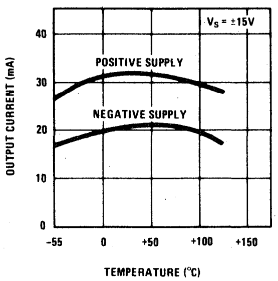
Negative Supply Current



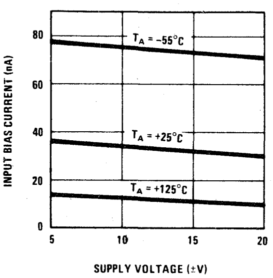
Positive Supply Currents



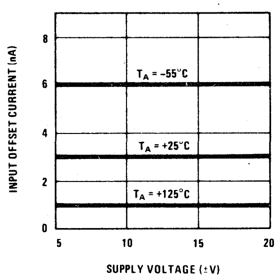
Short Circuit Output Current



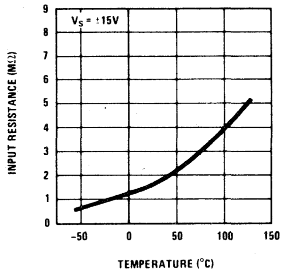
Input Bias Current



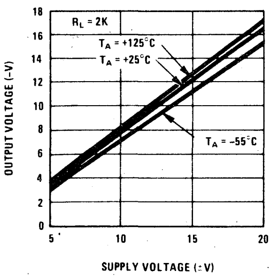
Input Offset Current



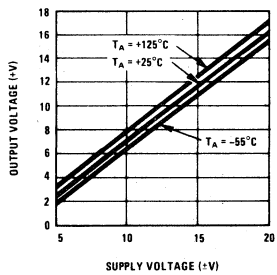
Input Resistance



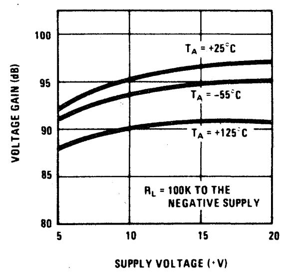
Negative Output Voltage Swing



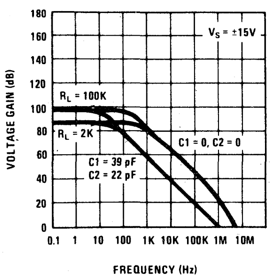
Positive Output Voltage Swing



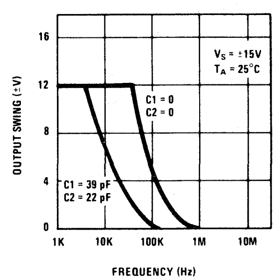
Voltage Gain



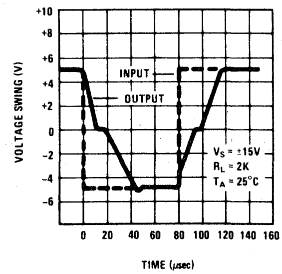
Open Loop Frequency Response



Large Signal Frequency Response



Voltage Follower Pulse Response



Operational Amplifiers/Buffers

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 $V_S = \pm 5V$ and less than 2 mW at $V_S = \pm 20V$. Open loop gain is greater than 50k and input bias current is typically 20 nA.

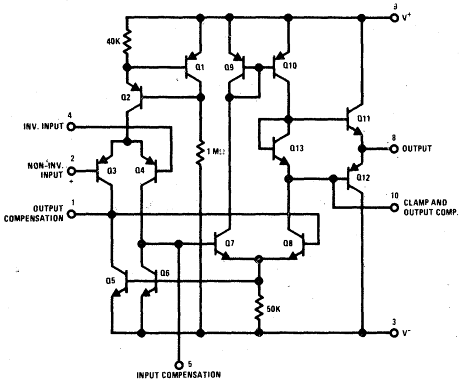
features

- 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.

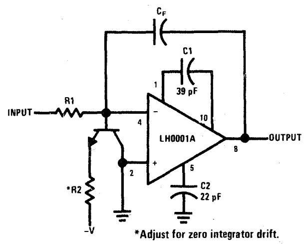
The LH0001A is specified for operation over the −55°C to +125°C military temperature range. The LH0001AC is specified for operation over the 0°C to +85°C temperature range.

schematic diagram*



*Pin shown for TO-5 package

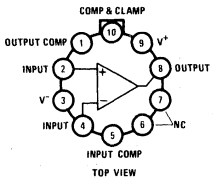
typical application*



Integrator with Bias Compensation

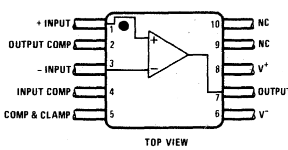
connection diagrams

Metal Can Package



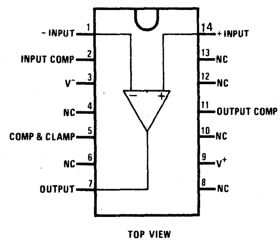
Order Number
LH0001AH or LH0001ACH
See Package 14B

Flat Package



Order Number
LH0001AF or LH0001ACF
See Package 3

Dual-In-Line Package



Order Number
LH0001AD or LH0001ACD
See Package 1

absolute maximum ratings

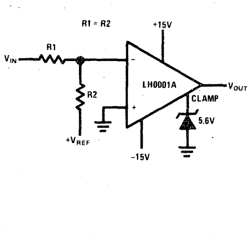
Supply Voltage		±20V
Power Dissipation (See curve)		400 mW
Differential Input Voltage		±7V
Input Voltage		$\pm V_S$
Short Circuit Duration		Continuous
Operating Temperature Range	LH0001A	−55°C to 125°C
	LH0001AC	−25°C to 85°C
Storage Temperature Range		−65°C to 150°C
Lead Temperature (Soldering, 10 sec)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

electrical characteristics (Note 1)

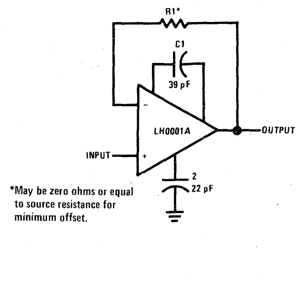
PARAMETERS	CONDITIONS	LH0001A			LH0001AC			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$R_S \leq 1k$, $T_A = 25°C$		1.0	2.5		2.0	5.0	mV
				4.0			7.0	mV
Input Bias Current	$T_A = 25°C$		20	100		20	200	nA
				300			300	nA
Input Offset Current	$T_A = 25°C$		5	20		20	60	nA
				100			100	nA
Supply 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 ±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.

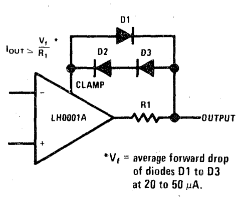
typical applications



TTL/DTL Compatible Comparator



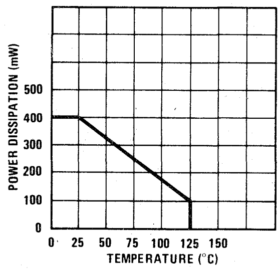
Voltage Follower



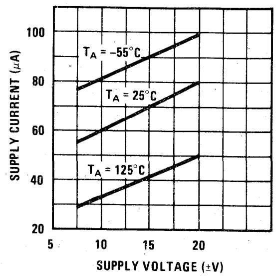
External Output Current Limiting

typical performance characteristics

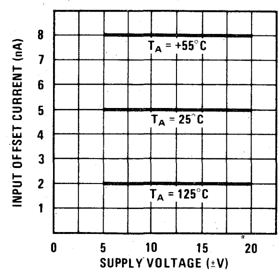
Maximum Power Dissipation



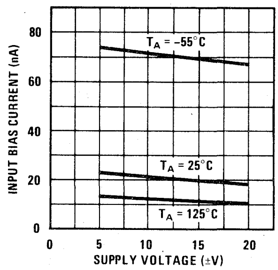
Supply Current



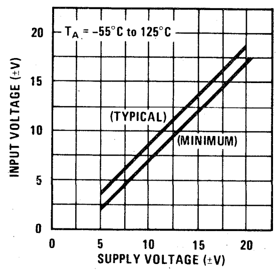
Input Offset Current



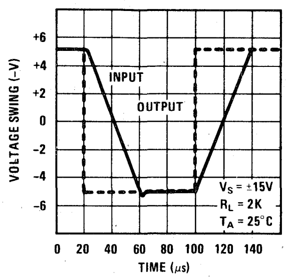
Input Bias Current



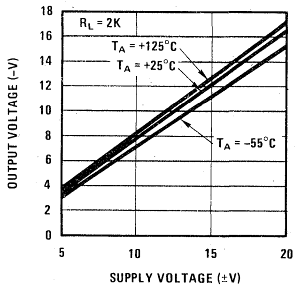
Input Voltage Range



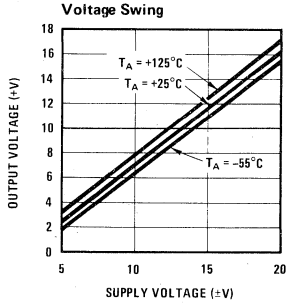
Voltage Follower Pulse Response



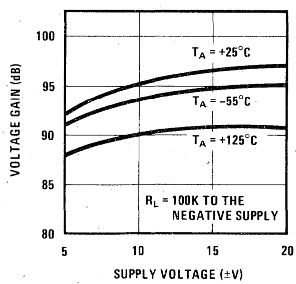
Negative Output Voltage Swing



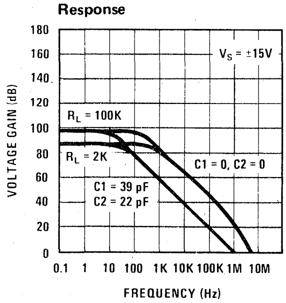
Positive Output Voltage Swing



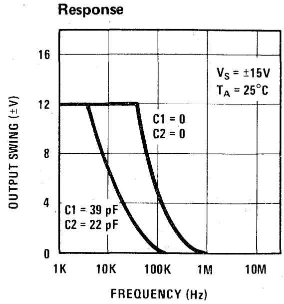
Voltage Gain



Open Loop Frequency Response



Large Signal Frequency Response



Operational Amplifiers/Buffers

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.

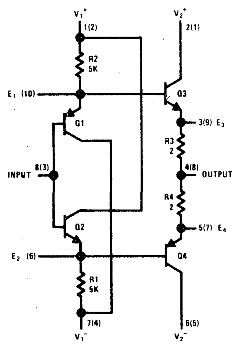
The LH0002 is available in an 8-lead low-profile TO-5 header; the LH0002C is also available in an 8-lead TO-5, and a 10-pin molded dual-in-line package.

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

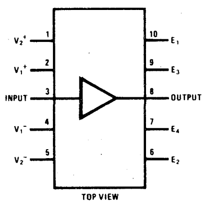
- Line driver
- 30 MHz buffer
- High speed D/A conversion
- Instrumentation buffer
- Precision current source

schematic and connection diagrams



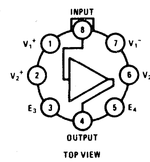
Pin numbers in parentheses denote pin connections for dual-in-line package.

Dual-In-Line Package



Order Number LH0002CN
See Package 21

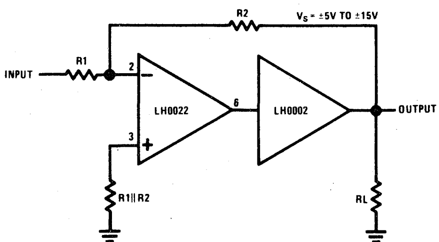
Metal Can Package



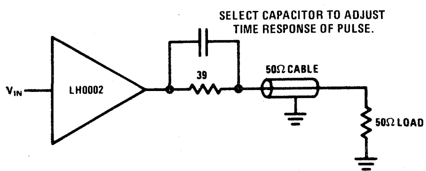
Order Number LH0002H or LH0002CH
See Package 11A

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)

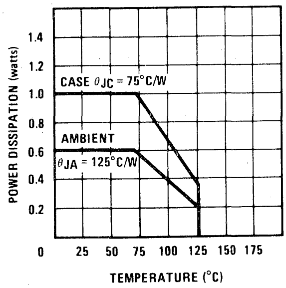
PARAMETERS	CONDITIONS	MIN	TYP	MAX	UNITS
Voltage Gain	R_S = 10 kΩ, R_L = 1.0 kΩ V_{IN} = 3.0 V_{PP}, f = 1.0 kHz T_A = −55°C to 125°C	.95	.97		
AC Current Gain	V_{IN} = 1.0 V_{rms} f = 1.0 kHz		40		A/mA
Input Impedance	R_S = 200 kΩ, V_{IN} = 1.0 V_{rms}, f = 1.0 kHz, R_L = 1.0 kΩ	180	400	–	kΩ
Output Impedance	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	–	%
Rise Time	R_L = 50Ω, ΔV_{IN} = 100mV		7	12	ns
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.

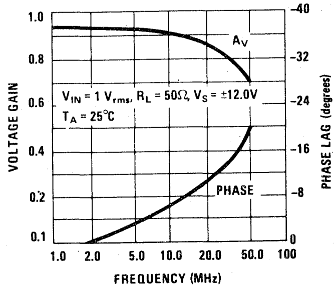
3

typical performance

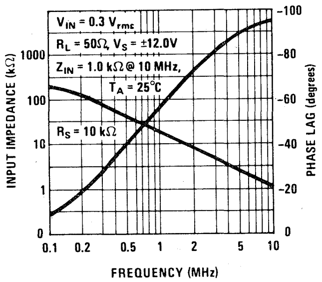
Maximum Power Dissipation



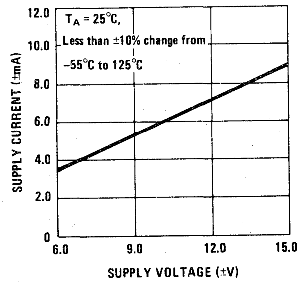
Frequency Response



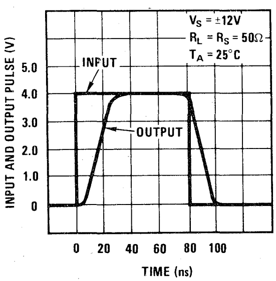
Input Impedance (Magnitude & Phase)



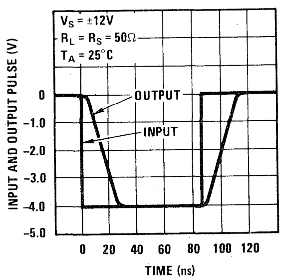
Supply Current



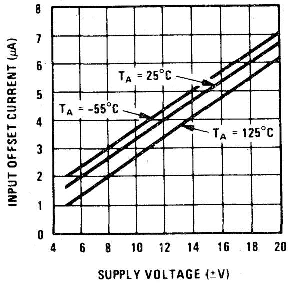
Positive Pulse



Negative Pulse



Input Offset Current



Operational Amplifiers/Buffers

LH0003/LH0003C* wide bandwidth operational amplifier

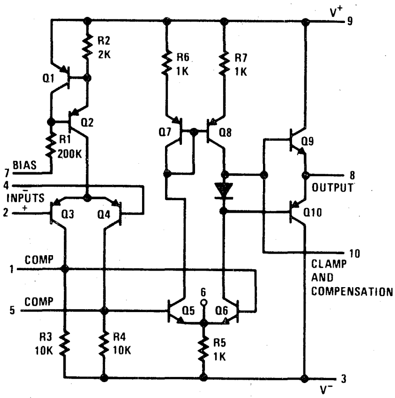
general description

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:

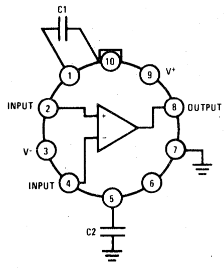
- Very low offset voltage — Typically 0.4 mV
- Large output swing — > ±10V into 100Ω load
- High CMRR — Typically > 90 dB
- Good large signal frequency response — 50 kHz to 400 kHz depending on compensation

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



Metal Can Package



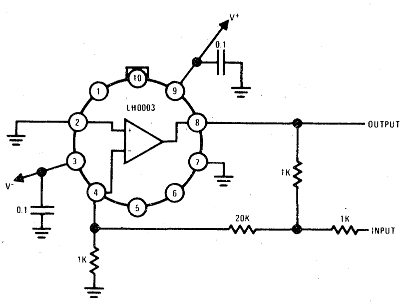
Order Number LH0003H or LH0003CH
See Package 14B

Circuit Gain	C_1 pF	C_2 pF	Slew Rate $R_L > 200\Omega$; 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

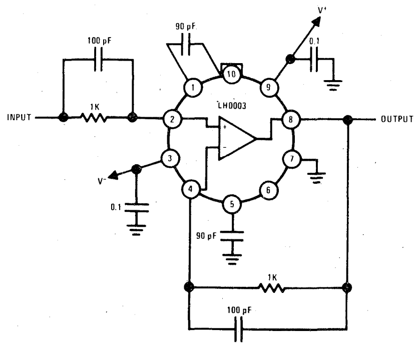
Typical Compensation

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)

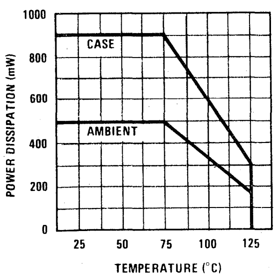
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$R_S < 1k$		0.4	3.0	mV
Input Offset Current			0.02	0.2	μA
Input Bias Current			0.4	2.0	μA
Supply Current	$V_S = \pm 20V$		1.2	3	mA
Voltage Gain	$R_L = 100k$, $V_S = \pm 15V$, $V_{OUT} = \pm 10V$	20	70		V/mV
Voltage Gain	$R_L = 2k$, $V_S = \pm 15V$, $V_{OUT} = \pm 10V$	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.

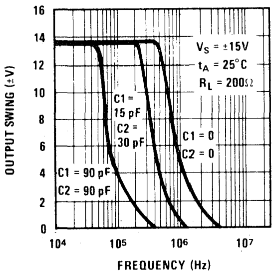
Note 2. Typical values are for $t_{AMBIENT} = 25°C$ unless otherwise specified.

typical performance

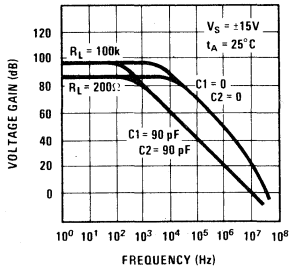
Maximum Power Dissipation



Large Signal Frequency Response



Open Loop Frequency Response



Operational Amplifiers/Buffers

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 5KΩ 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 two small capacitors.
- Low power consumption 8 mW at ±40V

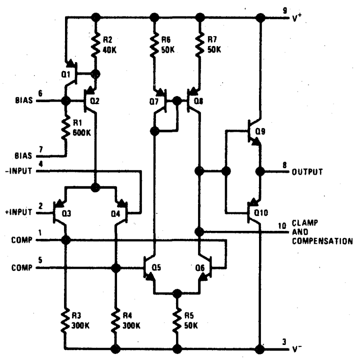
The LH0004's high gain and wide range of operating voltages make it ideal for applications requiring large output swing and low power dissipation.

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.

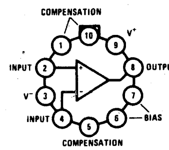
applications

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

schematic and connection diagrams



Metal Can Package



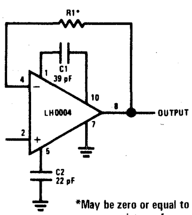
TOP VIEW

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 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 14B

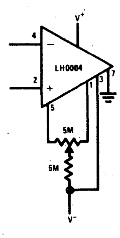
typical applications

Voltage Follower

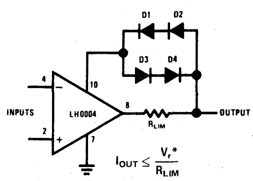


*May be zero or equal to source resistance for minimum offset.

Input Offset Voltage Adjust



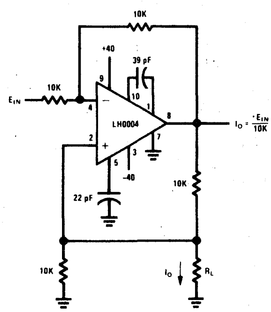
External Current Limiting Method



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

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

High Compliance Current Source



*Previously called NH0004/NH0004C

absolute maximum ratings

Supply Voltage, Continuous		±45V
Supply Voltage, Transient (≤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

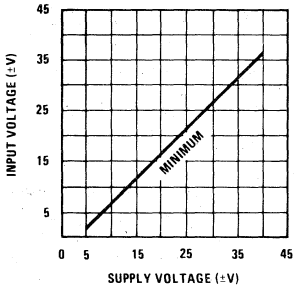
electrical characteristics (Note 1)

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

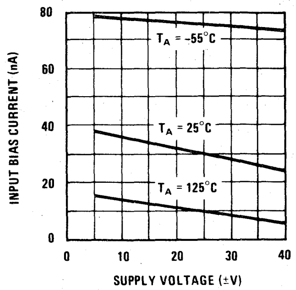
Note 1: These specifications apply for $\pm5V \leq V_S \leq \pm40V$, Pin 7 grounded, with capacitors C1 = 39 pF between Pin 1 and Pin 10, C2 = 22 pF between Pin 5 and ground, −55°C to 125°C for the LH0004, and 0°C to 85°C for the LH0004C unless otherwise specified.

typical performance

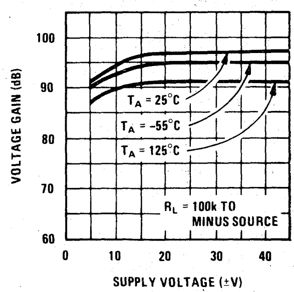
Input Voltage Range



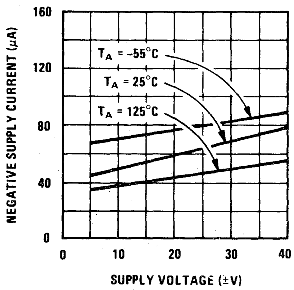
Input Bias Current



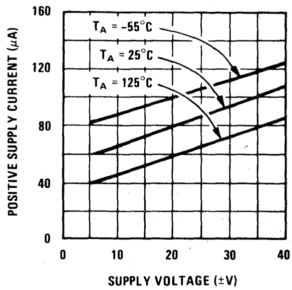
Voltage Gain



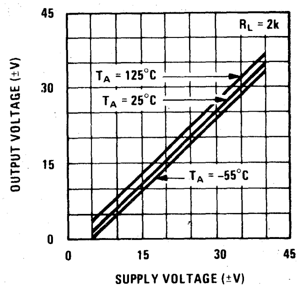
Negative Supply Current



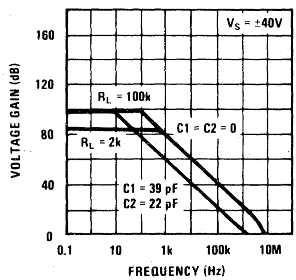
Positive Supply Current



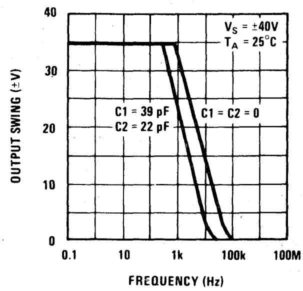
Output Voltage



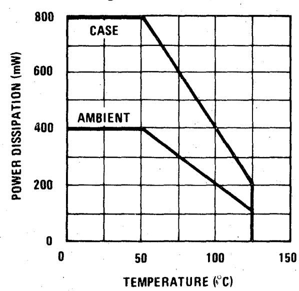
Open Loop Frequency Response



Large Signal Frequency Response



Package Power Dissipation



3

Operational Amplifiers/Buffers

LH0005/LH0005A* operational amplifier

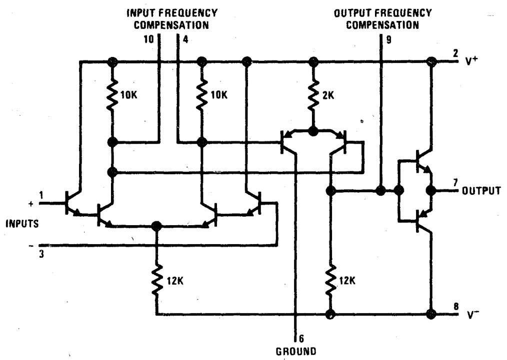
general description

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:

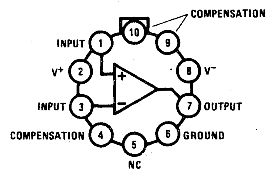
- Very high output current capability: ±50 mA into a 100 ohm load
- Low standby power dissipation: typically 60 mW at ±12V
- High input resistance: typically 2M at 25°C
- Full operating range: −55°C to +125°C
- Good high frequency response: unity gain at 30 MHz

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



Metal Can Package

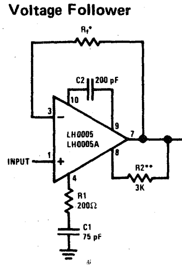


TOP VIEW

Order Number LH0005H or LH0005AH
See Package 14

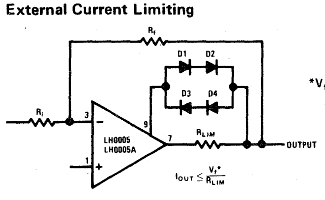
typical applications

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

External Current Limiting

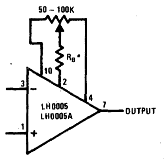


$I_{OUT} \leq \frac{V_f^*}{R_{LIM}}$

*V_f = Average forward voltage drop of diodes D_1 to D_4 at approx. 1 mA.

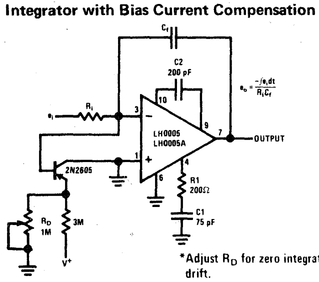
For continuous short circuit protection (V_S = ±12V, −55°C ≤ T_A ≤ +100°C) $R_{LIM} \geq 50\Omega$

Offset Balancing Circuit



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

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

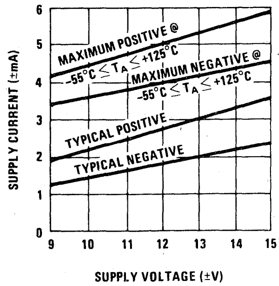
electrical characteristics (Note 1)

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 ≤ 20 kΩ	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

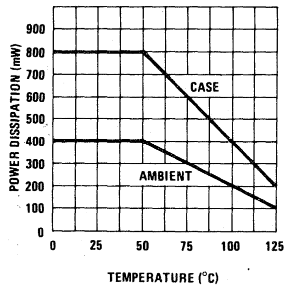
Note 1: These specifications apply for pin 6 grounded, V_S = ±12V, with Resistor R_1 = 200Ω in series with Capacitor C_1 = 75 pF from pin 4 to ground, and C_2 = 200 pF between pins 9 and 10 unless otherwise specified.

guaranteed performance characteristics

Supply Current

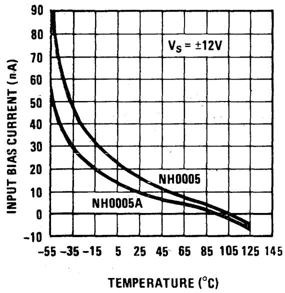


Maximum Power Dissipation

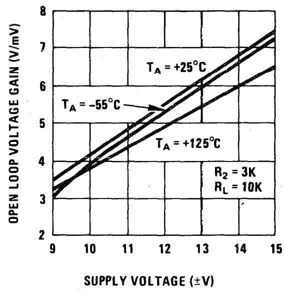


typical performance characteristics

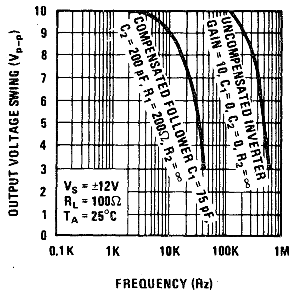
Input Bias Current



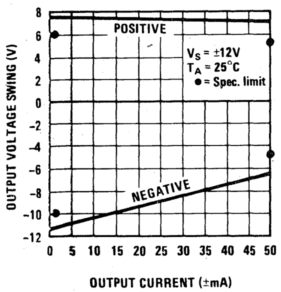
Voltage Gain



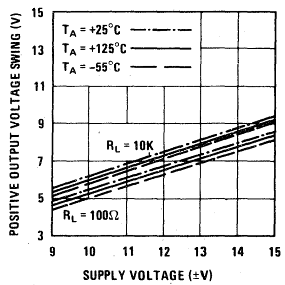
Loaded Output Voltage Swing



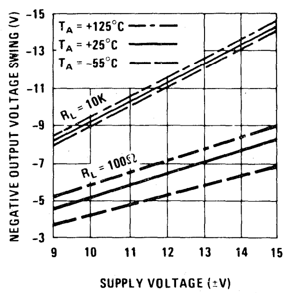
DC Output Voltage Swing



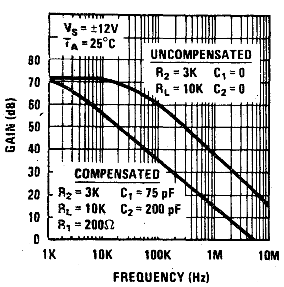
Positive Output Voltage Swing



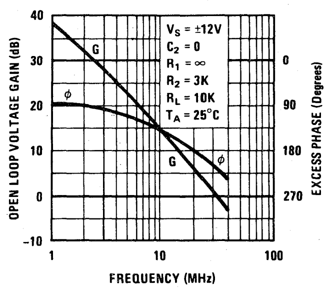
Negative Output Voltage Swing



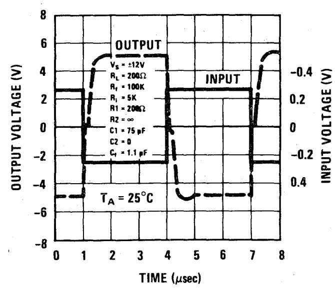
Frequency Response



Open Loop Gain vs Excess Phase



Inverting Pulse Response



Operational Amplifiers/Buffers

LH0005C* operational amplifier

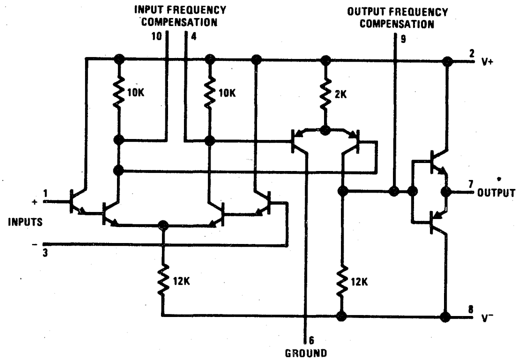
general description

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:

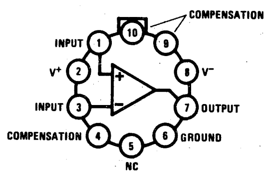
- Very high output current capability: ±40 mA into a 100 ohm load
- Low standby power dissipation: typically 60 mW at ±12V
- High input resistance: typically 2M at 25°C
- Operating range: 0° to 70°C
- Good high frequency response: unity gain at 30 MHz

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



Metal Can Package

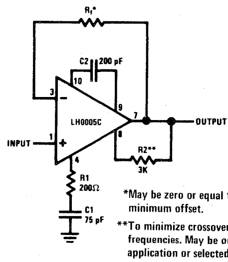


TOP VIEW

Order Number LH0005CH
See Package 14

typical applications

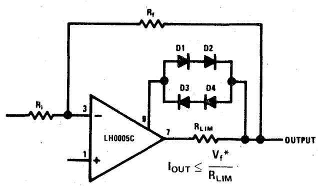
Voltage Follower



*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.

External Current Limiting

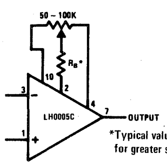


$I_{OUT} \le \frac{V_f^*}{R_{LIM}}$

For continuous short circuit protection ($V_S = \pm 12V$, $0°C \le T_A \le 70°C$, $R_{LIM} \ge 50\Omega$)

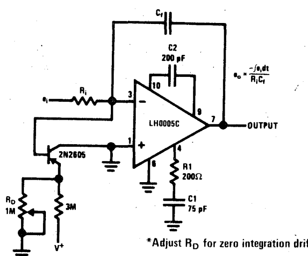
*V_f = average forward voltage drop of diodes D1 to D4 at approximately 1 mA.

Offset Balancing Circuit



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

Integrator With Bias Current Compensation



*Adjust R_D for zero integration drift.

*Previously called NH0005C

absolute maximum ratings

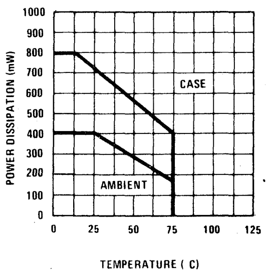
Supply Voltage	±20V
Power Dissipation (see Curve)	400 mW
Differential Input Voltage	±15V
Input Voltage	Equal to supply voltages
Peak Load Current	±100 mA
Storage Temperature Range	−55°C to +125°C
Operating Temperature Range	0°C to 85°C
Lead Temperature (soldering, 10 sec)	300°C

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} = ±5V	2	5		V/mV
Output Voltage Swing	$R_L = 10\ k\Omega$	−10		+6	V
	$R_L = 100\Omega$	−4	±6	+4	V
Input Resistance	T_A = 25°C	0.5	2		MΩ
Common Mode Rejection Ratio	V_{IN} = ±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 = ±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

Operational Amplifiers/Buffers

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

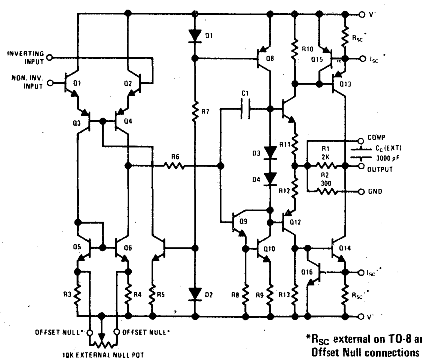
- Output current 1.0 Amp (LH0021) 0.2 Amp (LH0041)
- Output voltage swing ±12V into 10Ω (LH0021) ±14V into 100Ω (LH0041)
- Wide full power bandwidth 15 kHz
- Low standby power 100 mW at ±15V
- Low input offset voltage and current 1 mV and 20 nA
- High slew rate 3.0V/μs
- High open loop gain 100 dB

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.

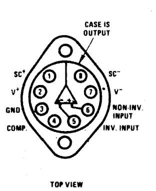
The LH0021 is supplied in a 8 pin TO-3 package rated at 20 watts with suitable heatsink. The LH0041 is supplied in both 12 pin TO-8 (2.5 watts with clip on heatsink) and a power 8 pin ceramic DIP (2 watts with suitable heatsink). The LH0021 and LH0041 are guaranteed over the temperature range of −55°C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

schematic and connection diagrams



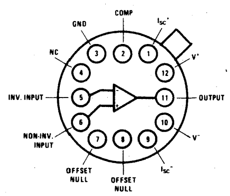
*R_{SC} external on TO-8 and TO-3 packages. R_{SC} internal on "J" package. Offset Null connections available only on TO-8 "G" package.

TO-3 Package



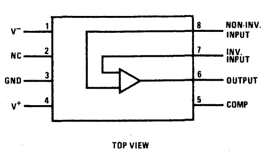
Order Number LH0021K or LH0021CK
See Package 19

TO-8 Package



Order Number LH0041G or LH0041CG
See Package 6

Ceramic DIP



Order Number LH0041CJ
See Package 40

3

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
	$V_S = \pm 15V$, $R_L = 10\Omega$, $T_C = 25°C$	±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	$R_S \leq 10\ k\Omega$, $T_A = 25°C$		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			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		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	$T_A = 25°C$		100	300		200	500	nA
				1.0			1.0	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	$R_S \leq 10\ k\Omega$, $\Delta V_{CM} = \pm 10V$	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	$V_S = \pm 15V$, $V_O = \pm 10V$, $R_L = 1\ k\Omega$, $T_A = 25°C$	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	$V_S = \pm 15V$, $R_L = 100\Omega$	±13.0	14.0		±13.0	±14.0		V
Output Short Circuit Current	$V_S = \pm 15V$, $T_A \cdot 25°C$ (Note 6)		200	300		200	300	mA
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

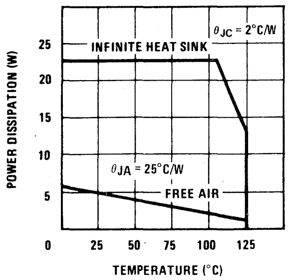
ac electrical characteristics for LH0041/LH0041C ($T_A = 25°C$, $V_S = \pm 15V$, $C_C = 3000\ pF$)

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

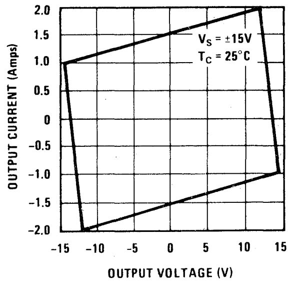
Note 1: Rating applies for supply voltages above ±15V. For supplies less than ±15V, rating is equal to supply voltage.
Note 2: Rating applies for LH0041G and LH0021K with $R_{SC} = 0\Omega$.
Note 3: Rating applies as long as package power rating is not exceeded.
Note 4: Specifications apply for $\pm 5V \leq V_S \pm 18V$, 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

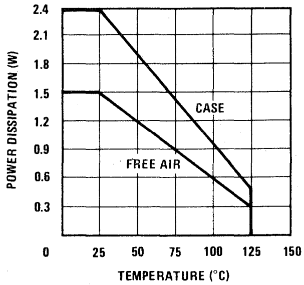
Power Derating-LH0021



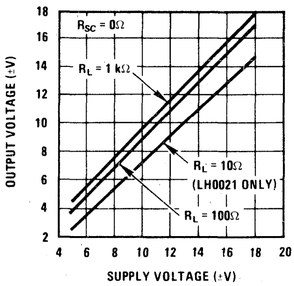
Safe Operating Area – LH0021



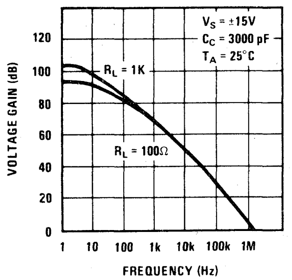
Package Power Dissipation LH0041/LH0041C



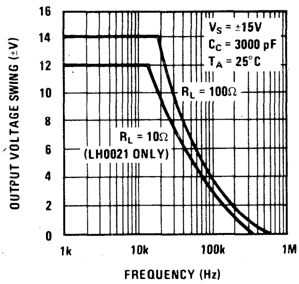
Output Voltage Swing



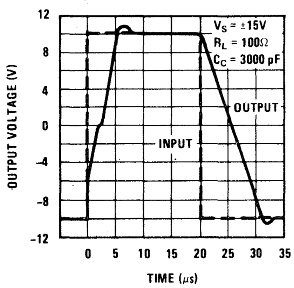
Open Loop Frequency Response



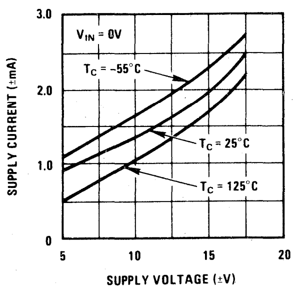
Large Signal Frequency Response



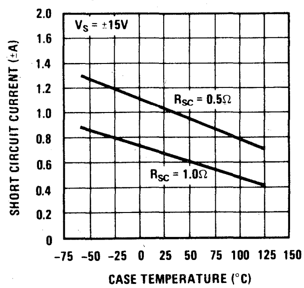
Voltage Follower Pulse Response



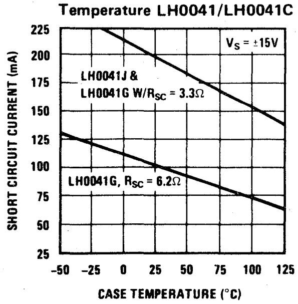
No Load Supply Current



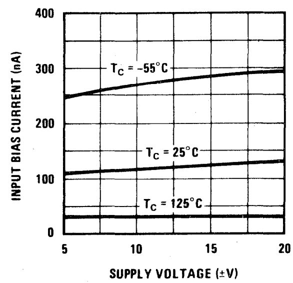
Short Circuit Current vs Temperature LH0021/LH0021C



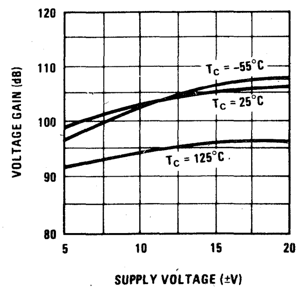
Short Circuit Current vs Temperature LH0041/LH0041C



Input Bias Current

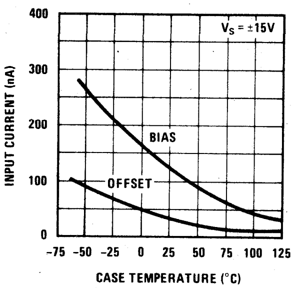


Voltage Gain

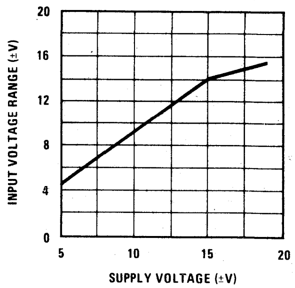


typical performance characteristics (con't)

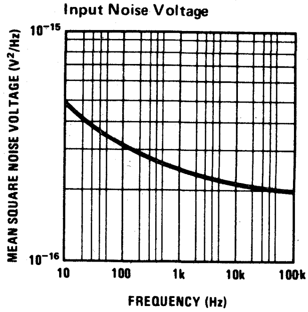
Input Current



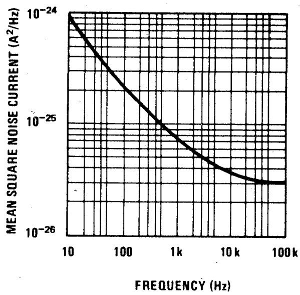
Input Voltage Range



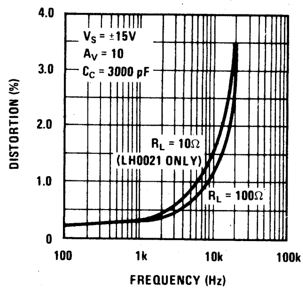
Input Noise Voltage



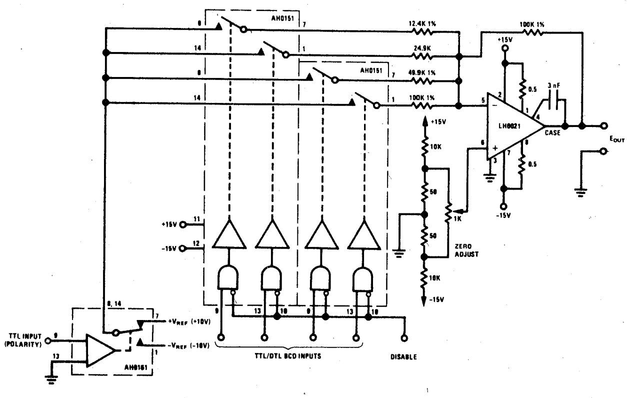
Input Noise Current



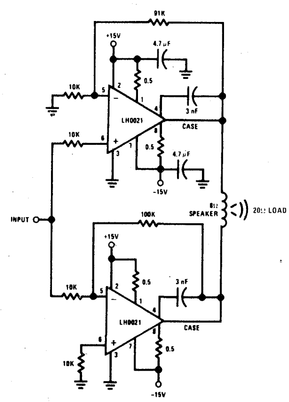
Distortion vs Frequency



typical applications

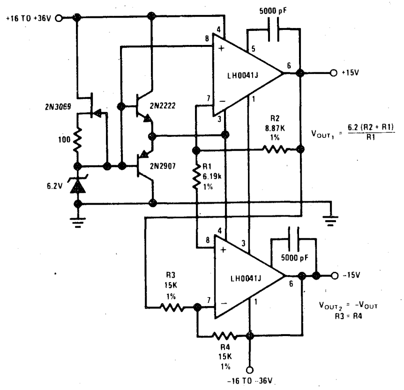


Programmable One Amp Power Supply

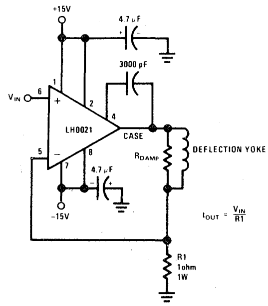


10 WATT (rms) Audio Amplifier

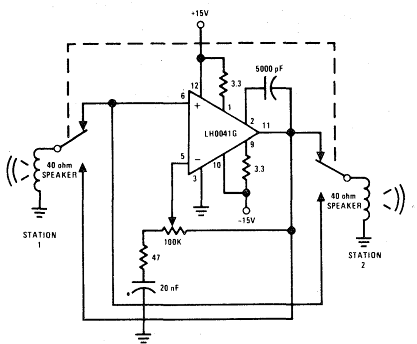
typical applications (con't)



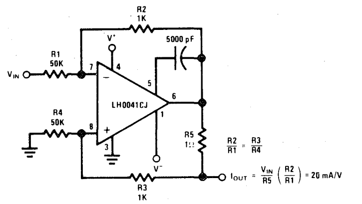
Dual Tracking One Amp Power Supply



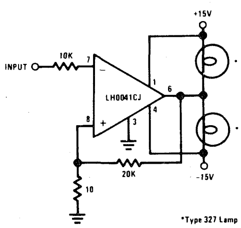
CRT Deflection Yoke Driver



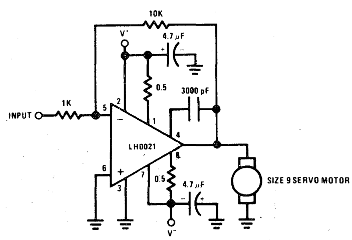
Two Way Intercom



Programmable High Current Source/Sink

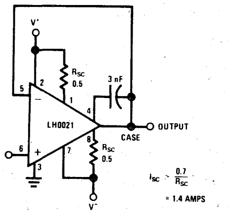


Power Comparator

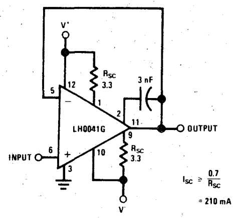


DC Servo Amplifier

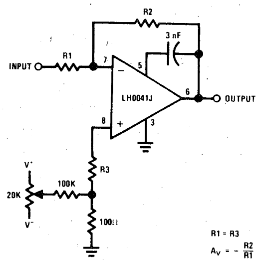
auxiliary circuits



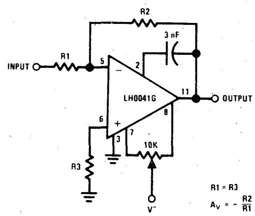
LH0021 Unity Gain Circuit with Short Circuit Limiting



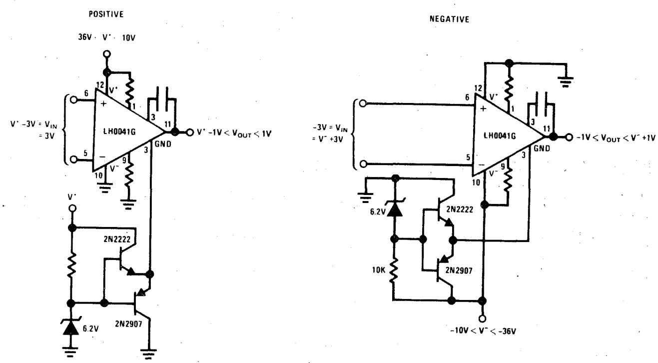
LH0041G Unity Gain with Short Circuit Limiting



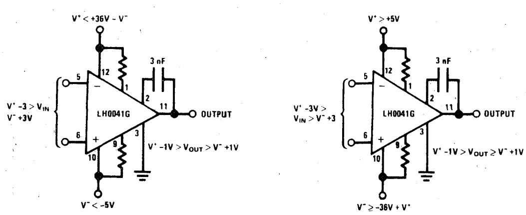
LH0041/LH0021 Offset Voltage Null Circuit (LH0041CJ Pin Connections Shown)*



LH0041G Offset Voltage Null Circuit*



Operation from Single Supplies



Operation from Non-Symmetrical Supplies

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

Operational Amplifiers/Buffers

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 500 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 – 500 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)

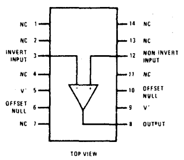
The LH0022/LH0042/LH0052 family of IC op amps are intended to fulfill a wide variety of applications for process control, medical instrumentation, and other systems requiring very low input currents and tightly matched input offsets. The LH0052 is particularly suited for long term high accuracy integrators 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.

For additional application information and information on other National operational amplifiers, see *Available Linear Applications Literature.*

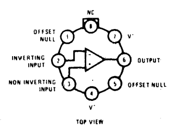
schematic and connection diagrams

Dual-In-Line Package

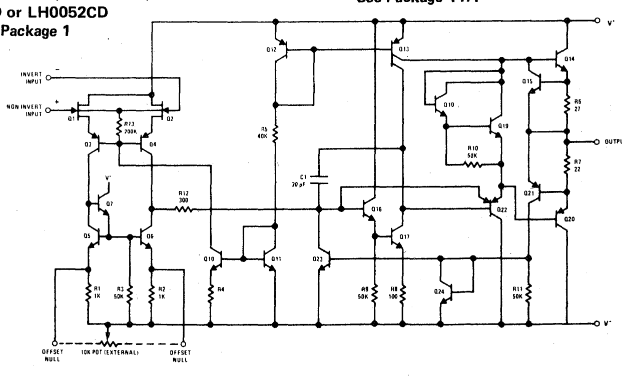


Order Number LH0022D, LH0022CD, LH0042D, LH0042CD, LH0052D or LH0052CD
See Package 1

Metal Can Package



Order Number LH0022H, LH0022CH, LH0042H, LH0042CH, LH0052H or LH0052CH
See Package 11A



*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 LH0022			LIMITS LH0022C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$R_S \le 100$ kΩ; T_A = 25°C, V_S = ±15V		2.0	4.0		3.5	6.0	mV
	$R_S \le 100$ kΩ, V_S = ±15V			5.0			7.0	mV
Temperature Coefficient of Input Offset Voltage	$R_S \le 100$ kΩ		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
				2.0			0.5	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	25	pA
				10			2.5	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 = ±15V	±12	±13.5		±12	±13.5		V
Common Mode Rejection Ratio	$R_S \le 10$ kΩ, V_{IN} = ±10V	80	90		70	90		dB
Supply Voltage Rejection Ratio	$R_S \le 10$ kΩ, ±5V $\le V_S \le$ ±15V	80	90		70	90		dB
Large Signal Voltage Gain	R_L = 2 kΩ, V_{OUT} = ±10V, T_A = 25°C, V_S = ±15V	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		2.0	2.5		2.4	2.8	mA
Power Consumption	V_S = ±15V			75			85	mW

3

dc electrical characteristics for LH0042/LH0042C

($T_A = 25°C$, $V_S = \pm15V$; unless otherwise specified)

PARAMETER	CONDITIONS	LIMITS LH0042 MIN	LIMITS LH0042 TYP	LIMITS LH0042 MAX	LIMITS LH0042C MIN	LIMITS LH0042C TYP	LIMITS LH0042C MAX	UNITS
Input Offset Voltage	$R_S \le 100\ k\Omega$		5.0	20		6.0	20	mV
Temperature Coefficient of Input Offset Voltage	$R_S \le 100\ k\Omega$		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	$R_S \le 10\ k\Omega$, $V_{IN} = \pm10V$	70	86		70	80		dB
Supply Voltage Rejection Ratio	$R_S \le 10\ k\Omega$, $\pm5V \le V_S \le \pm15V$	70	86		70	80		dB
Large Signal Voltage Gain	$R_L = 1\ k\Omega$, $V_{OUT} = \pm10V$	50	150		25	100		V/mV
Output Voltage Swing	$R_L = 1\ k\Omega$	±10	±12.5		±10	±12		V
Output Current Swing	$V_{OUT} = \pm10V$	±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 LH0052 MIN	LIMITS LH0052 TYP	LIMITS LH0052 MAX	LIMITS LH0052C MIN	LIMITS LH0052C TYP	LIMITS LH0052C MAX	UNITS
Input Offset Voltage	$R_S \le 100\ k\Omega$; $V_S = \pm15V$, $T_A = 25°C$		0.1	0.5		0.2	1.0	mV
	$R_S \le 100\ k\Omega$, $V_S = \pm15V$			1.0			1.5	mV
Temperature Coefficient of Input Offset Voltage	$R_S \le 100\ k\Omega$, $V_S = \pm15V$		2	5		5	10	μV/°C
Offset Voltage Drift with Time			2			4		μV/week
Input Offset Current	$T_A = 25°C$		0.01	0.5		0.02	1.0	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	2.5		1.0	5.0	pA
				2.5			0.5	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	$V_S = \pm15V$	±12	±13.5		±12	±13.5		V
Common Mode Rejection Ratio	$R_S \le 10\ k\Omega$, $V_{IN} = \pm10V$	80	90		76	90		dB
Supply Voltage Rejection Ratio	$R_S \le 10\ k\Omega$, $\pm5V \le V_S \le \pm15V$	80	90		76	90		dB
Large Signal Voltage Gain	$R_L = 2\ k\Omega$, $V_{OUT} = \pm10V$, $V_S = \pm15V$, $T_A = 25°C$	100	200		75	160		V/mV
	$R_L = 2\ k\Omega$, $V_{OUT} = \pm10V$, $V_S = \pm15V$	50			50			V/mV
Output Voltage Swing	$R_L = 1\ k\Omega$, $T_A = 25°C$ $V_S = \pm15V$	±10	±12.5		±10	±12		V
	$R_L = 2\ k\Omega$, $V_S = \pm15V$	±10			±10			V
Output Current Swing	$V_{OUT} = \pm10V$, $T_A = 25°C$	±10	±15		±10	±15		mA
Output Resistance			75			75		Ω
Output Short Circuit Current			25			25		mA
Supply Current	$V_S = \pm15V$		3.0	3.5		3.0	3.8	mA
Power Consumption	$V_S = \pm15V$			105			114	mW

ac electrical characteristics For all amplifiers (T_A = 25°C, V_S = ±15V)

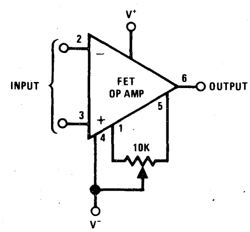
PARAMETER	CONDITIONS	LIMITS						UNITS
		LH0022/42/52			LH0022C/42C/52C			
		MIN	TYP	MAX	MIN	TYP	MAX	
Slew Rate	Voltage Follower	1.5	3.0		1.0	3.0		V/µs
Large Signal Bandwidth	Voltage Follower		40			40		kHz
Small Signal Bandwidth			1.0			1.0		MHz
Rise Time			0.3	1.5		0.3	1.5	µs
Overshoot			10	30		15	40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

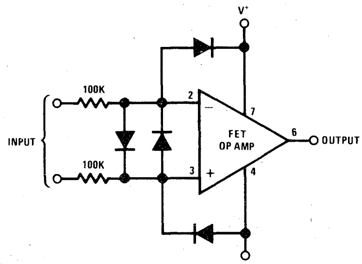
Note 2: Rating applies for minimum source resistance of 10 kΩ, for source resistances less than 10 kΩ, maximum differential input voltage is ±5V.

Note 3: Unless otherwise specified, these specifications apply for ±5V ≤ V_S ≤ ±20V and −55°C ≤ T_A ≤ ±125°C for the LH0022, LH0042 and LH0052 and −25°C ≤ T_A +85°C for the LH0022C, LH0042C and LH0052C. Typical values are given for T_A = 25°C.

auxiliary circuits (shown for TO-5 pin out)

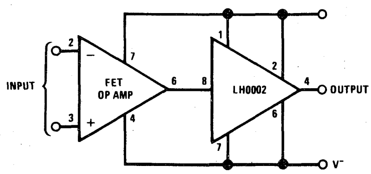


Offset Null



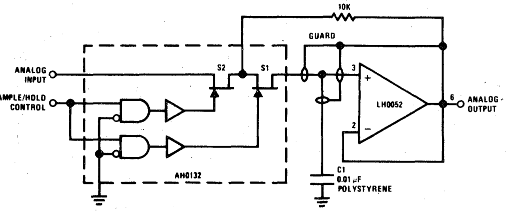
Note: All diodes are ultra low leakage

Protecting Inputs From ± 150V Transients

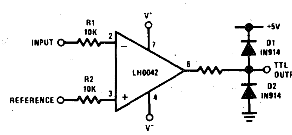


Boosting Output Drive to ±100 mA

typical applications

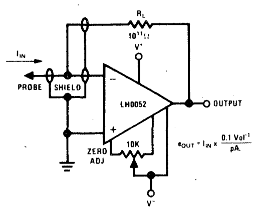


Alternate Low Drift Sample

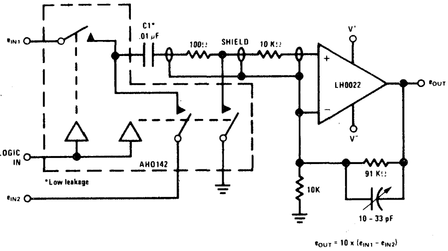


Precision Voltage Comparator

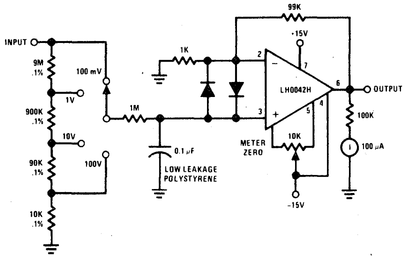
typical applications (con't)



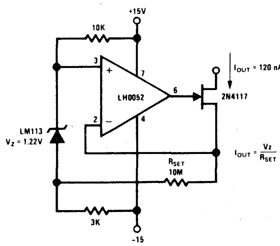
Picoamp Amplifier for pH Meters and Radiation Detectors



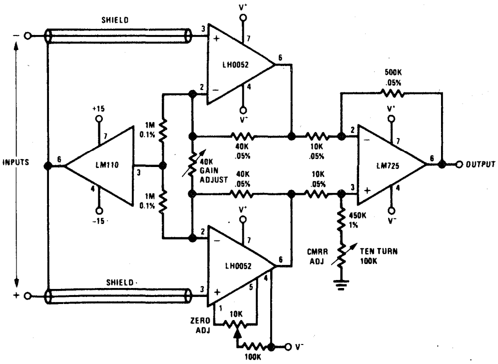
Precision Subtractor for Automatic Test Gear



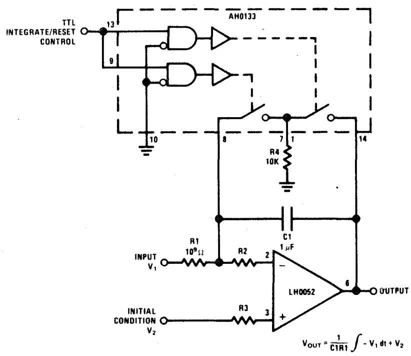
Sensitive Low Cost "VTVM"



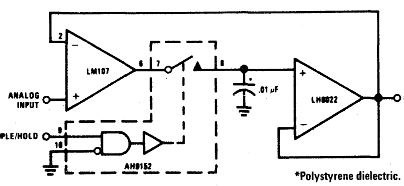
Ultra Low Level Current Source



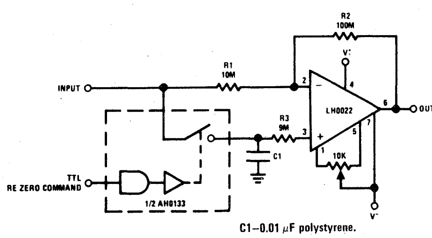
True Instrumentation Amplifier



Precision Integrator



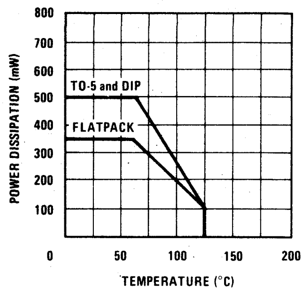
Precision Sample and Hold



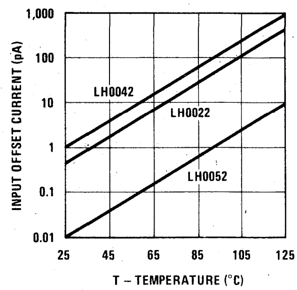
Re-Zeroing Amplifier

typical performance characteristics

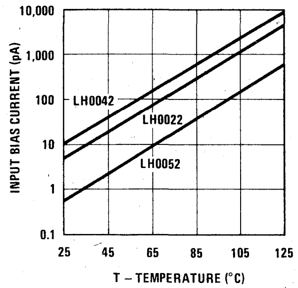
Maximum Power Dissipation



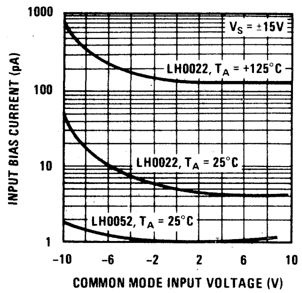
Input Offset Current vs Temperature



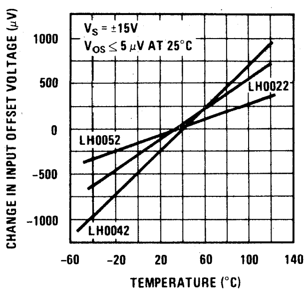
Input Bias Current vs Temperature



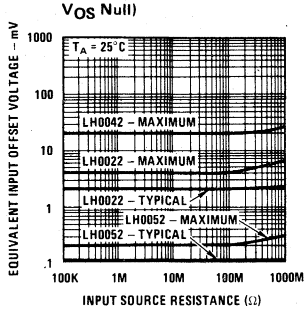
Input Bias Current vs Input Voltage



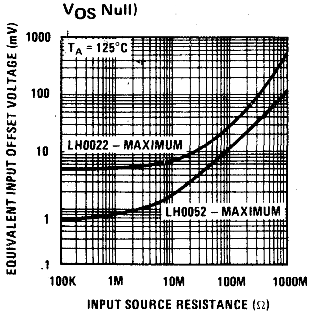
Input Offset Voltage vs Temperature



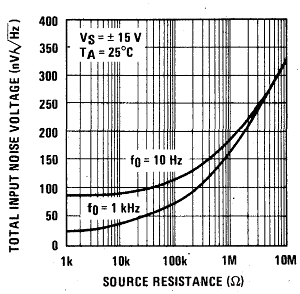
Offset Error (Without V_{OS} Null)



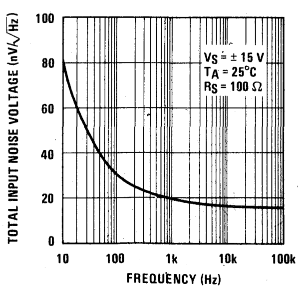
Offset Error (Without V_{OS} Null)



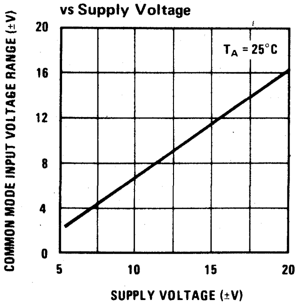
Total Input Noise Voltage* vs Source Resistance



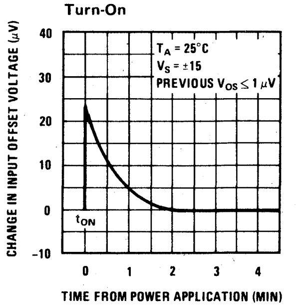
Total Input Noise Voltage* vs Frequency



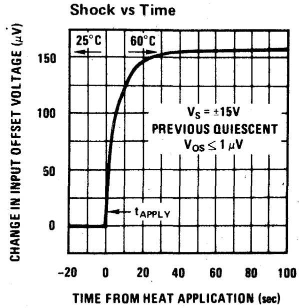
Common Mode Input Voltage vs Supply Voltage



Stabilization Time of Input Offset Voltage from Power Turn-On



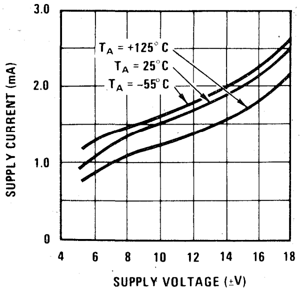
Change in Input Offset Voltage Due to Thermal Shock vs Time



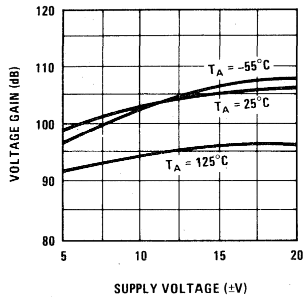
*Noise Voltage Includes Contribution from Source Resistance

typical performance characteristics (con't)

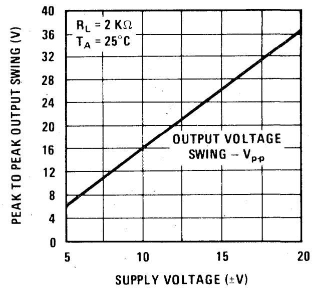
Supply Voltage vs Supply Current



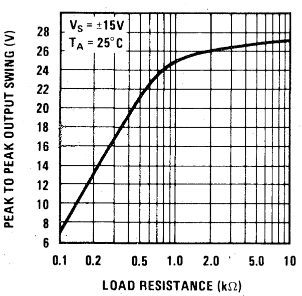
Voltage Gain



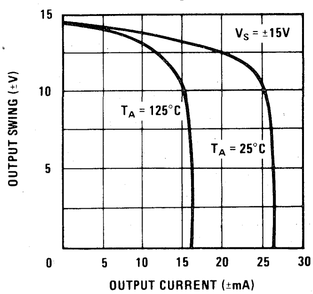
Output Swing vs Supply Voltage



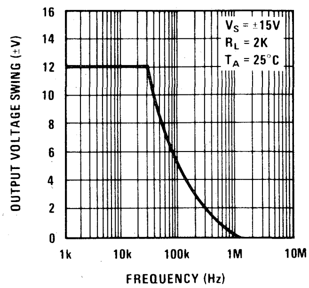
Output Voltage Swing vs Load Resistance



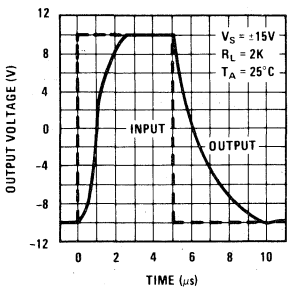
Current Limiting



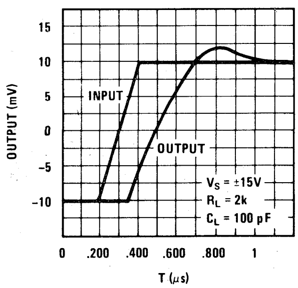
Output Voltage Swing vs Frequency



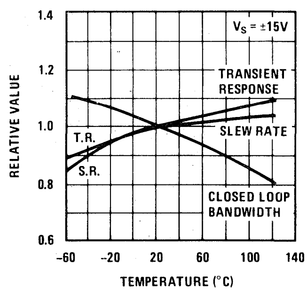
Voltage Follower Large Signal Response



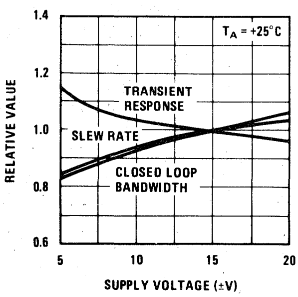
Transient Response



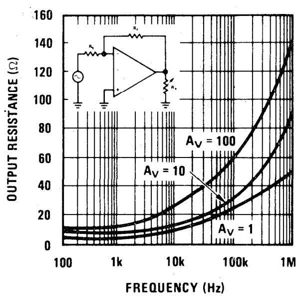
Frequency Characteristics vs Ambient Temperature



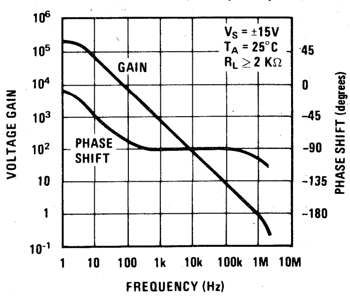
Frequency Characteristics vs Supply Voltage



Output Resistance vs Frequency



Open Loop Transfer Characteristics vs Frequency



Operational Amplifiers/Buffers

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.

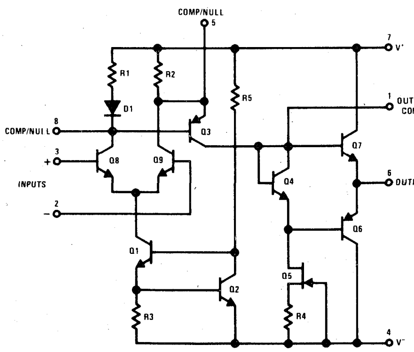
features

- 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

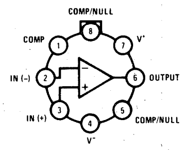
The LH0024/LH0024C's combination of wide bandwidth and high slew rate make it an ideal choice for a variety of high speed applications including active filters, oscillators, and comparators as well as many high speed general purpose applications.

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



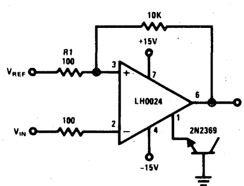
TOP VIEW

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

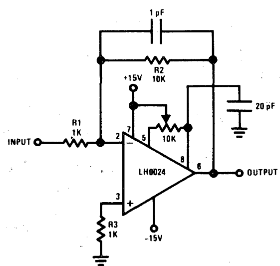
Order Number LH0024H or LH0024CH
See Package 11B

typical applications

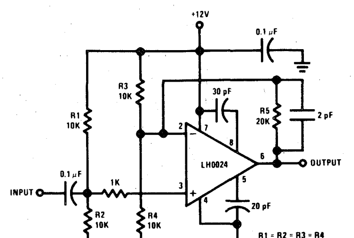
TTL Compatible Comparator



Offset Null



Video Amplifier



$A_V = \frac{R5 + (R3 \parallel R4)}{(R3) \parallel (R4)} = 5$

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	$V_S = \pm 15V$, $R_S = 50\Omega$ -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	$V_S = \pm 15V$, $R_L = 1k$, $T_A = 25°C$	4	5		3	4		V/mV
	$V_S = \pm 15V$, $R_L = 1k$	3			2.5			V/mV
Input Voltage Range	$V_S = \pm 15V$	±12	±13		±12	±13		V
Output Voltage Swing	$V_S = \pm 15V$, $R_L = 1k$, $T_A = 25°C$	±12	±13		±10	±13		V
	$V_S = \pm 15V$, $R_L = 1k$	±10			±10			V
Slew Rate	$V_S = \pm 15V$, $R_L = 1k$, $C_1 = C_2 = 30$ pF, $A_V = +1$, $T_A = 25°C$	400	500		250	400		V/μs
Common Mode Rejection Ratio	$V_S = \pm 15V$, $\Delta V_{IN} = \pm 10V$, $R_S = 50\Omega$		60			60		dB
Power Supply Rejection Ratio	$\pm 5V \leq V_S \leq \pm 18V$, $R_S = 50\Omega$		60			60		dB

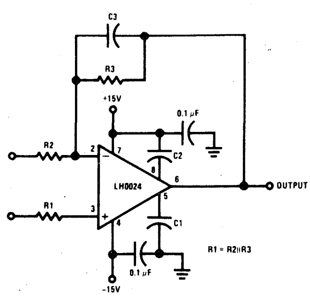
Note 1: These specifications apply for $V_S = \pm 15V$ and −55°C to +125°C for the LH0024 and −25°C to +85°C for the LH0024C.

frequency compensation

TABLE I

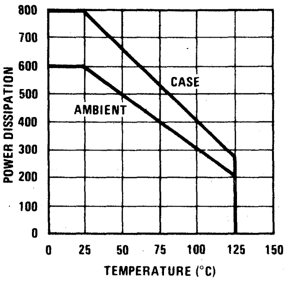
CLOSED LOOP GAIN	C_1	C_2	C_3
100	0	0	0
20	0	0	0
10	0	20 pF	1 pF
1	30 pF	30 pF	3 pF

Frequency Compensation Circuit

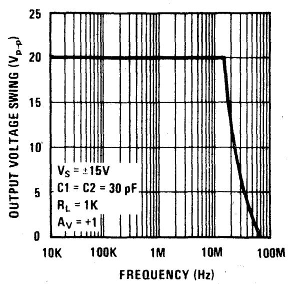


typical performance characteristics

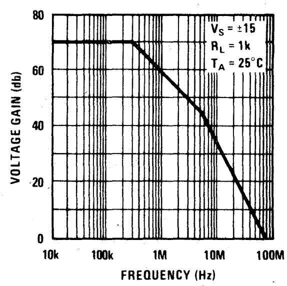
Maximum Power Dissipation



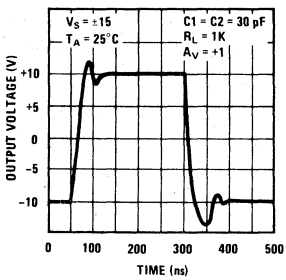
Large Signal Frequency Response



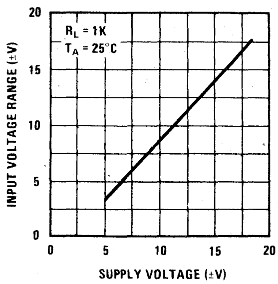
Open Loop Frequency Response



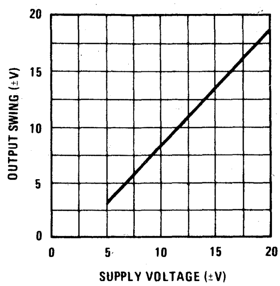
Voltage Follower Pulse Response



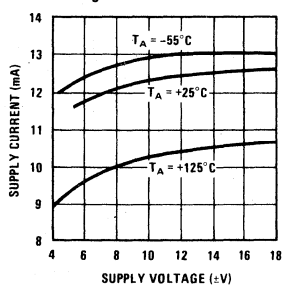
Input Voltage vs Supply Voltage



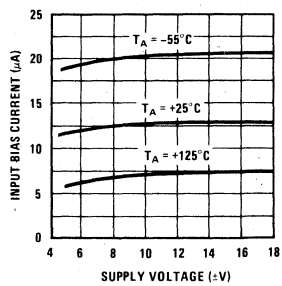
Output Voltage Swing



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/Buffers

LH0032/LH0032C ultra fast FET operational amplifier

general description

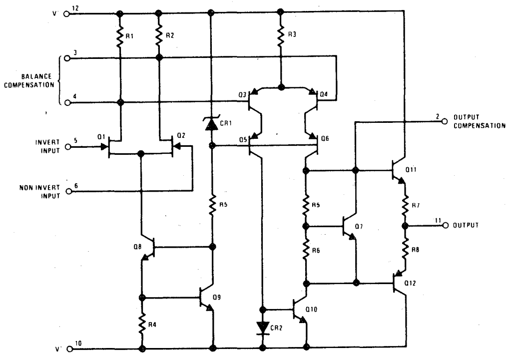
The LH0032/LH0032C is a high slew rate, high input impedance differential operational amplifier suitable for diverse application in fast signal handling. The high allowable differential input voltage, ease of output clamping, and high output drive capability particularly suit it for comparator applications. 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

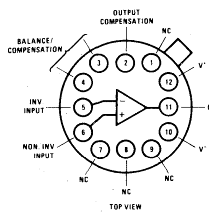
- High slew rate 500 V/μs
- High bandwidth 70 MHz
- High input impedance $10^{12}\Omega$
- Low input bias current 20 pA max
- Offset null with single pot
- Low input offset voltage 2 mV max
- No compensation for gains above 50

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

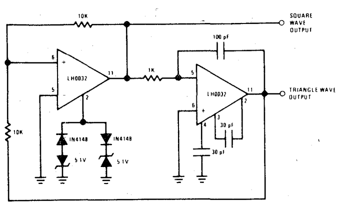


Note: For heat sink use thermalloy 2240 series or Wakefield 215-XX series.

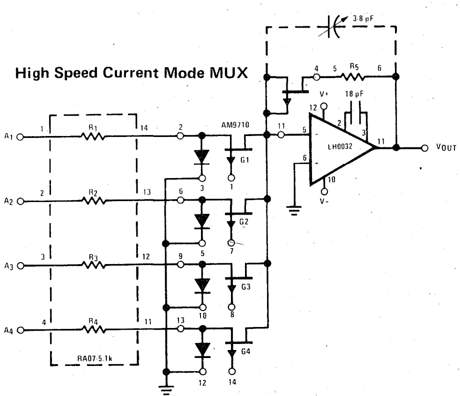
Order Number LH0032G or LH0032CG
See Package 6

typical applications

1 MHz Function Generator



High Speed Current Mode MUX



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

ac electrical characteristics (Note 2)

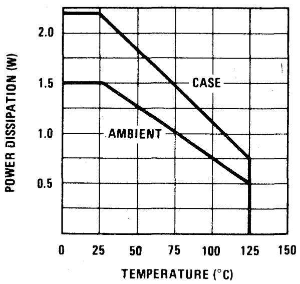
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Slew Rate	$A_V = +1$, $\Delta V_{IN} = 20V$	350	500		V/μs
Settling Time to 1% of Final Value	$A_V = -1$, $\Delta V_{IN} = 20V$		100		ns
Settling Time to 0.1% of Final Value	$A_V = -1$, $\Delta V_{IN} = 20V$		300		ns
Small Signal Rise Time	$A_V = +1$, $\Delta V_{IN}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

Note 1: These specifications apply at $V_S = \pm 15V$ and over −55°C to +125°C for the LH0032 and −25°C to +85°C for the LH0032C, unless otherwise specified.

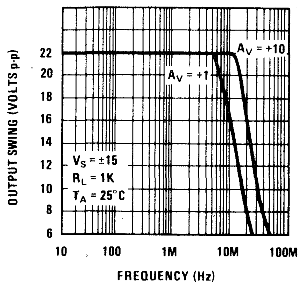
Note 2: These specifications apply for $V_S = \pm 15V$, $R_L = 1\ k\Omega$ and $T_A = 25°C$.

typical performance characteristics

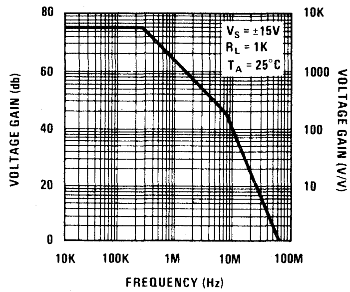
Maximum Power Dissipation



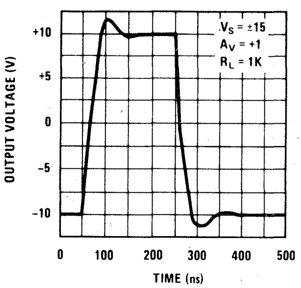
Large Signal Frequency Response



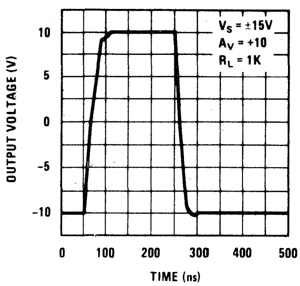
Open Loop Frequency Response



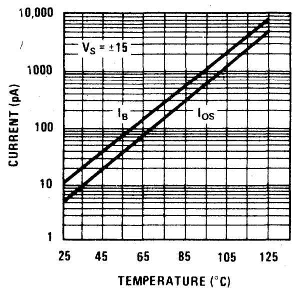
Large Signal Pulse Response



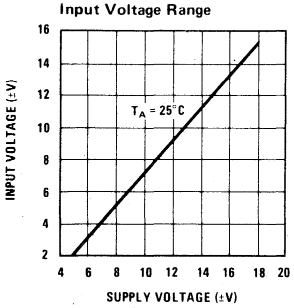
Large Signal Pulse Response



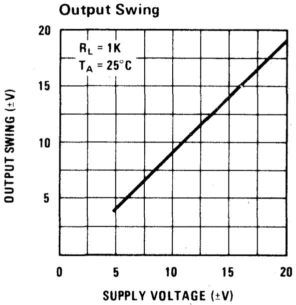
Input Bias and Offset Current vs Temperature



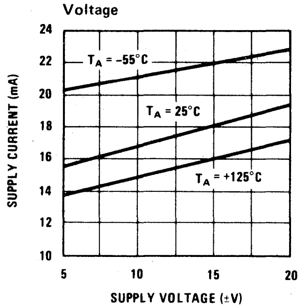
Input Voltage Range



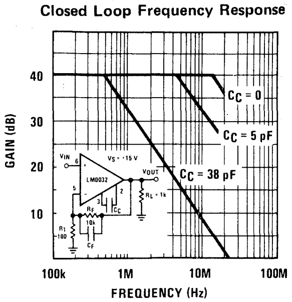
Output Swing



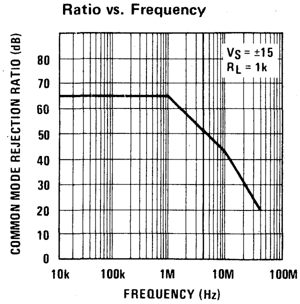
Supply Current vs Supply Voltage



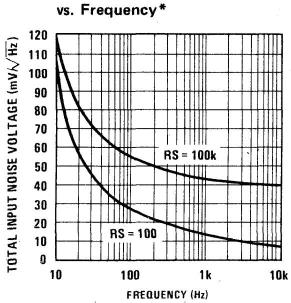
Closed Loop Frequency Response



Common Mode Rejection Ratio vs. Frequency



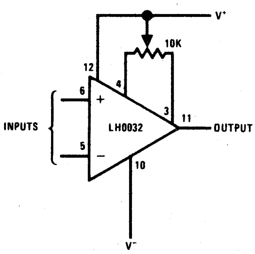
Total Input Noise Voltage vs. Frequency*



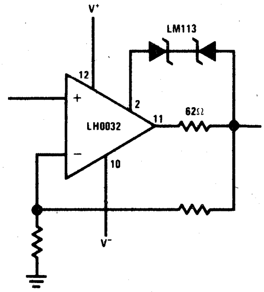
* Noise voltage includes contribution from source resistance.

auxiliary circuits

Offset Null

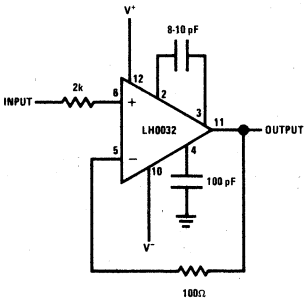


Output Short Circuit Protection

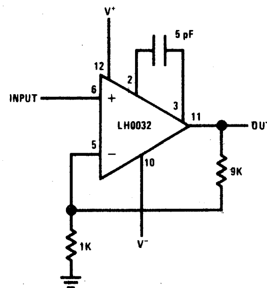


typical applications (con't)

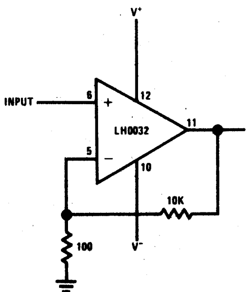
Unity Gain Amplifier



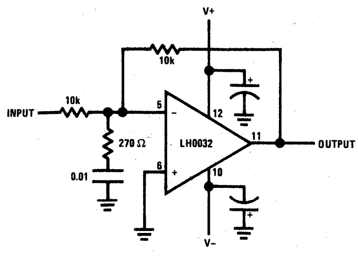
10X Buffer Amplifier



100X Buffer Amplifier



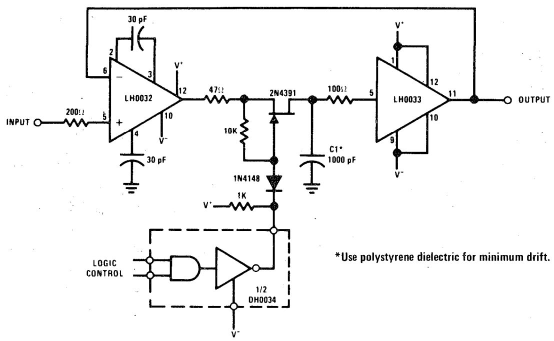
Non-Compensated Unity Gain Inverter



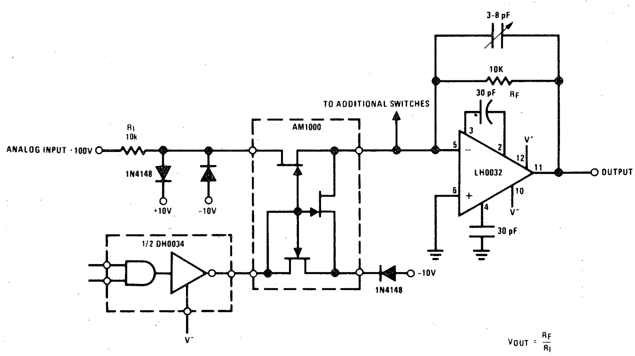
3

typical applications (con't)

High Speed Sample and Hold



Current Mode Multiplexer



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/Buffers

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

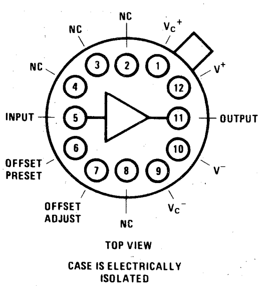
■ Damn fast (LH0063)	6000V/μs
■ Wide range single or dual supply operation	
■ Wide power bandwidth	DC to 100 MHz
■ High output drive	±10V with 50Ω load
■ Low phase non-linearity	2 degrees
■ Fast rise times	2 ns
■ High current gain	120 dB
■ High input resistance	10^{10} Ω

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.

3

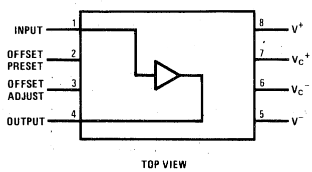
connection diagrams

Metal Can Package



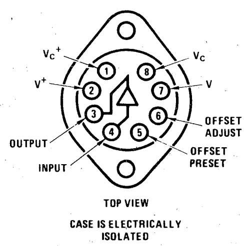
Order Number LH0033G or LH0033CG
See Package 6

Dual-In-Line Package



Order Number LH0033J or LH0033CJ
See Package 40

Metal Can Package



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, $-55°C \leq T_C \leq 125°C$		50			50		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	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 9 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 $-55°C \leq T_C \leq +125°C$ for the LH0033 and LH0063; and $-25°C \leq T_C \leq +85°C$ 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	$R_S \leq 100\,k\Omega$, $T_C = 25°C$		10	25		10	50	mV
	$R_S \leq 100\,k\Omega$			100			100	mV
Average Temperature Coefficient of Output Offset Voltage	$R_S \leq 100\,k\Omega$		300			300		μV/°C
Input Bias Current	$T_C = 25°C$		.1	.2		.1	.2	nA
				10			5	nA
Voltage Gain	$V_{IN} = \pm10V$, $R_S \leq 100\,k\Omega$, $R_L = 1\,k\Omega$	.96	.98	1	.96	.98	1	V/V
Voltage Gain	$V_{IN} = \pm10V$, $R_S \leq 100\,k\Omega$, $R_L = 50\Omega$, $T_C = 25°C$	.94	.96	.98	.92	.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	$V_{IN} = \pm10V$, $R_S \leq 100\,k\Omega$	.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

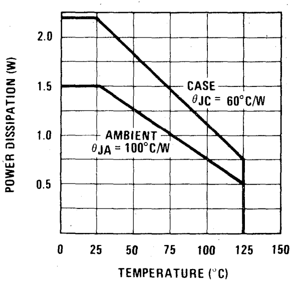
LH0063/LH0063C: ($T_C = 25°C$, $V_S = \pm15V$, $R_S = 50\Omega$, $R_L = 50\Omega$)

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		%

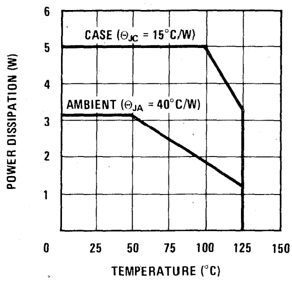
Note 1: Unless otherwise specified, these specifications apply for +15V applied to pins 1 and 12, −15V applied to pins 9 and 10, and pin 6 shorted to pin 7 for the LH0033/LH0033C. For the LH0063/LH0063C, specifications apply for +15V applied to pins 1 and 2, −15V applied to pins 7 and 8, and pin 5 shorted to pin 6. Unless otherwise noted, specifications apply over a temperature range of $-55°C \leq T_C \leq +125°C$ for the LH0033 and LH0063; and $-25°C \leq T_C \leq +85°C$ for the LH0033C and LH0063C. Typical values shown are for $T_C = 25°C$.

typical performance characteristics

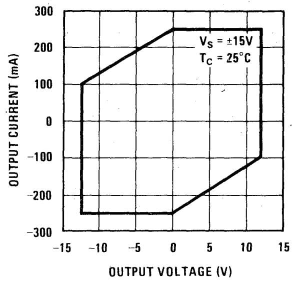
LH0033 Power Dissipation



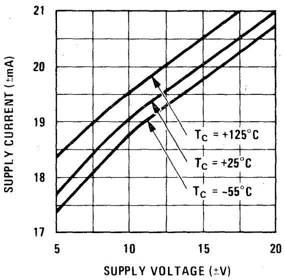
LH0063 Power Dissipation



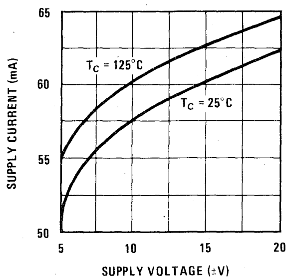
LH0063 DC Safe Operating Area



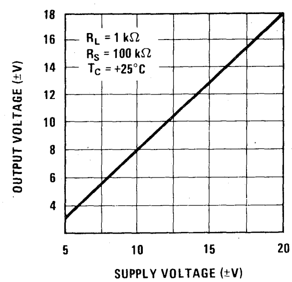
LH0033 Supply Current vs Supply Voltage



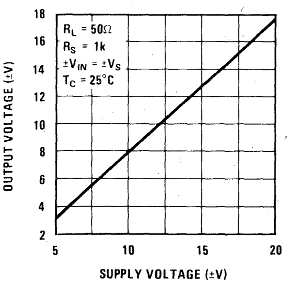
LH0063 Supply Current vs Supply Voltage



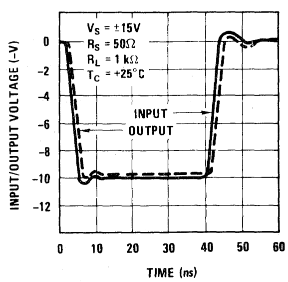
LH0033 Output Voltage vs Supply Voltage



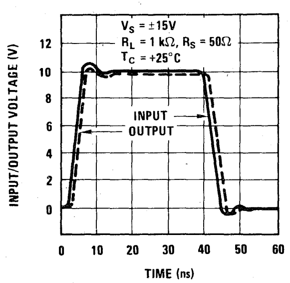
LH0063 Output Voltage vs Supply Voltage



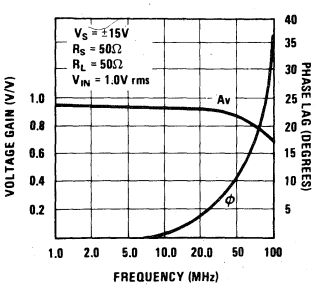
LH0033 Negative Pulse Response



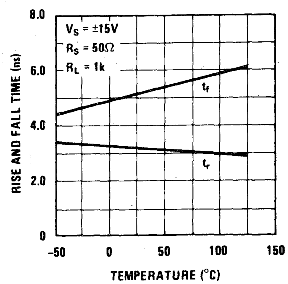
LH0033 Positive Pulse Response



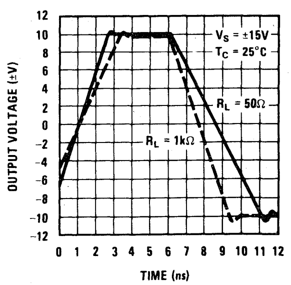
LH0033 Frequency Response



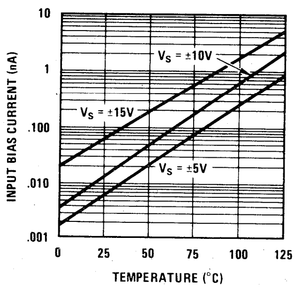
LH0033 Rise and Fall Time vs Temperature

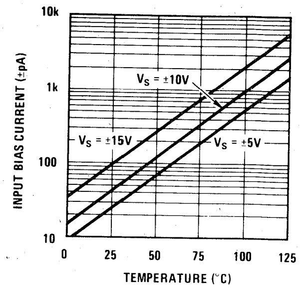


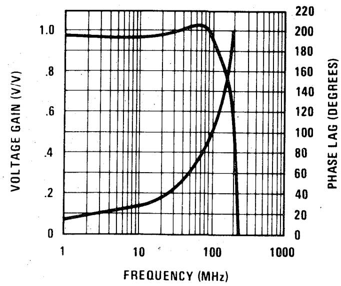
LH0063 Large Signal Pulse Response

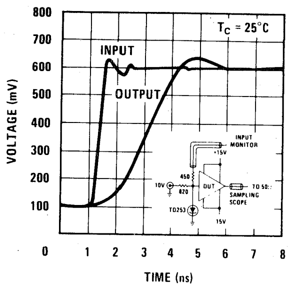


typical performance characteristics (con't)









3

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 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.

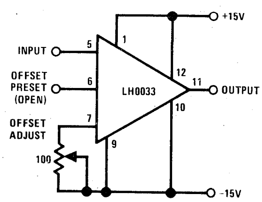


FIGURE 1. Offset Zero Adjust for LH0033 (Pin nos. shown for TO-8)

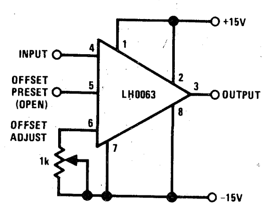


FIGURE 2. Offset Zero Adjust for LH0063

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:

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

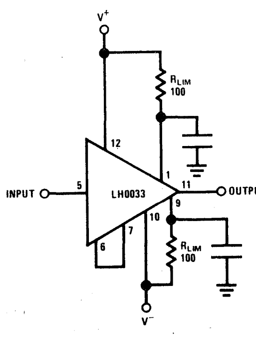


FIGURE 3. LH0033 Using Resistor Current Limiting

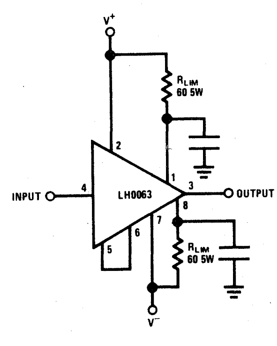


FIGURE 4. LH0063 Using Resistor Current Limiting

application hints (con't)

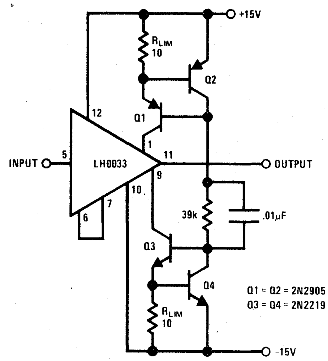


FIGURE 5. LH0033 Current Limiting Using Current Sources

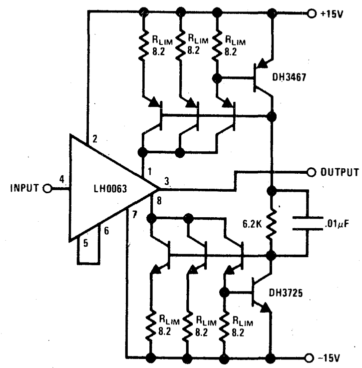


FIGURE 6. LH0063 Current Limiting Using Current Sources

Capacitive Loading: Both the LH0033 and LH0063 are designed to drive capacitive loads such as co-axial 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:

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

application hints (con't)

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

$$P_{diss_{pkg}} \geq P_{DC} + P_{AC}$$

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

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

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.

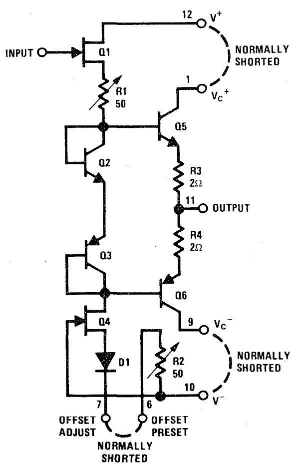
Hardware: In order to utilize the full drive capabilities of both devices, each should be mounted with a heat sink particularly for extended temperature operation. The cases of both are isolated from the circuit and may be connected to system chassis.

ACHTUNG!

Power supply bypassing is necessary to prevent oscillation with both the LH0033 and LH0063 in all circuits. Low inductance ceramic disc capacitors with the shortest practical lead lengths must be connected from each supply lead (within < ¼ to ½" of the device package) to a ground plane. Capacitors should be one or two 0.1μF in parallel for the LH0033; adding a 4.7μF solid tantalum capacitor will help in troublesome instances. For the LH0063, two 0.1μF ceramic and one 4.7μF solid tantalum capacitors in parallel will be necessary on each supply lead.

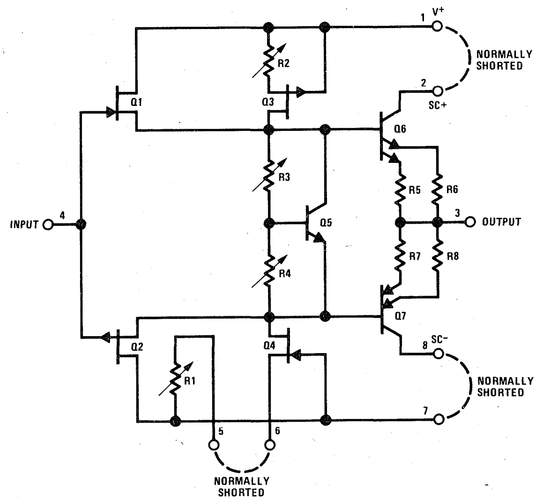
schematic diagrams

LH0033/LH0033C



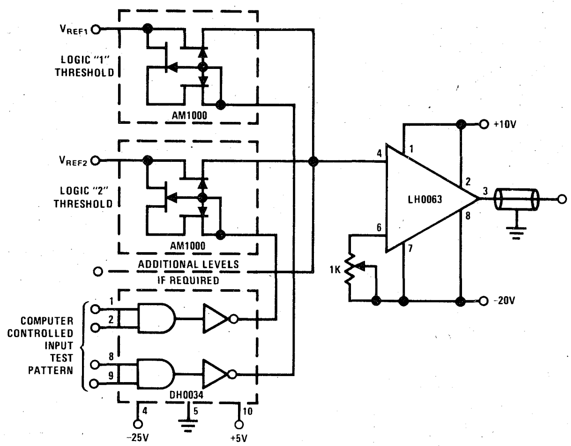
PIN NUMBERS SHOWN FOR TO-8 ("G") PACKAGE.

LH0063/LH0063C

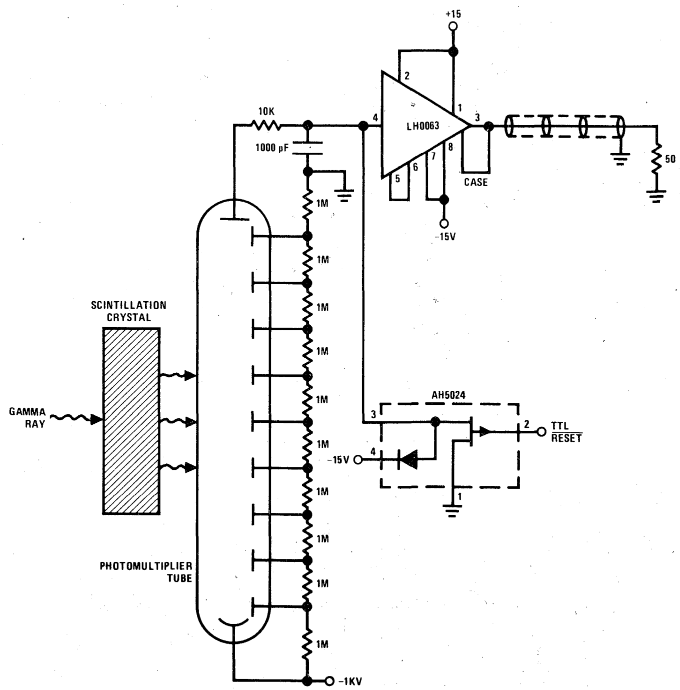


typical applications

High Speed Automatic Test Equipment Forcing Function Generator

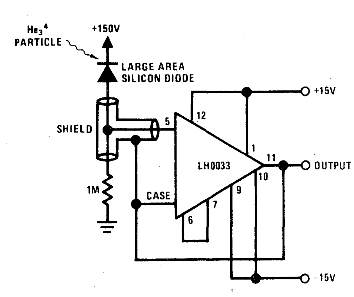


Gamma Ray Pulse Integrator

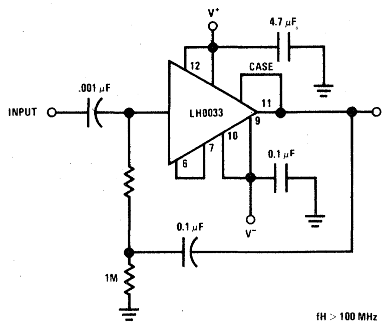


typical applications (con't)

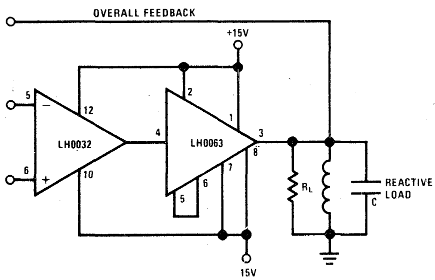
Nuclear Particle Detector



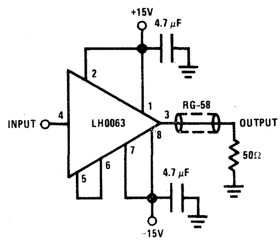
High Input Impedance AC Coupled Amplifier



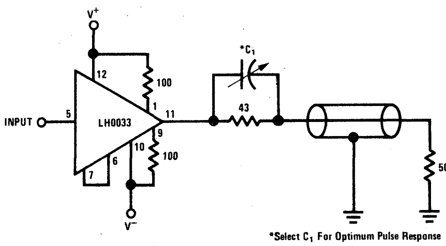
Isolation Buffer



Coaxial Cable Driver

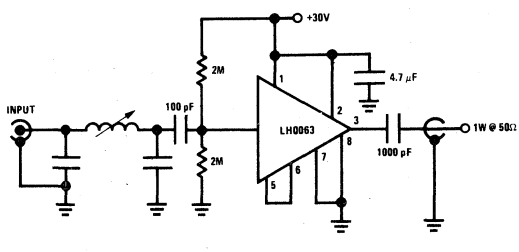


Coaxial Cable Driver



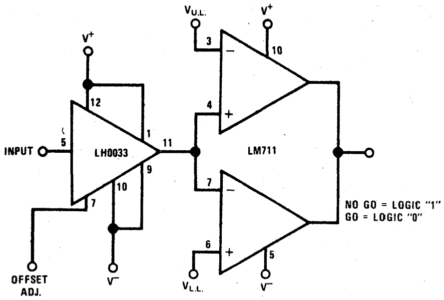
*Select C_1 For Optimum Pulse Response

1W CW Final Amplifier

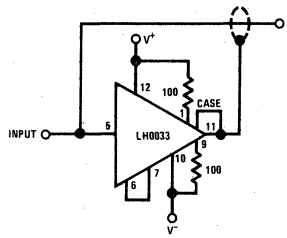


typical applications (con't)

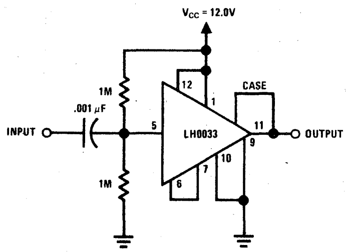
High Input Impedance Comparator With Offset Adjust



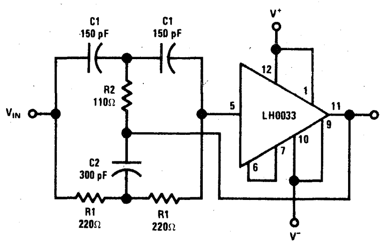
Instrumentation Shield/Line Driver



Single Supply AC Amplifier



4.5 MHz Notch Filter

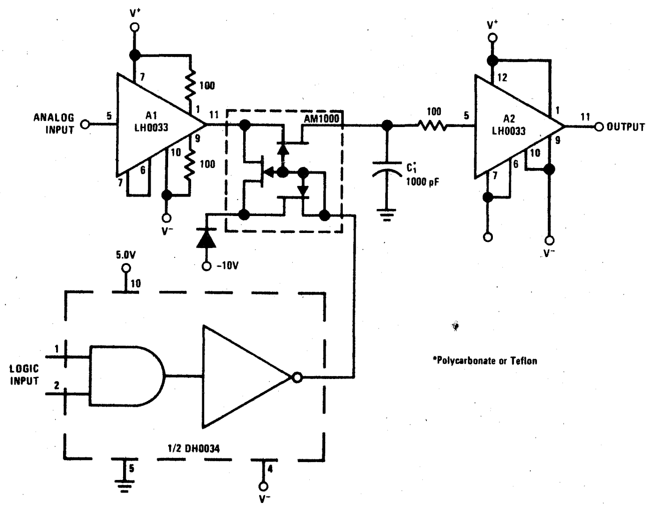


$f_O = \frac{1}{2\pi R1C1}$

$R1 = 2\,R2$

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

High Speed Sample & Hold



*Polycarbonate or Teflon

3

Operational Amplifiers/Buffers

LH0044 series precision low noise operational amplifiers

general description

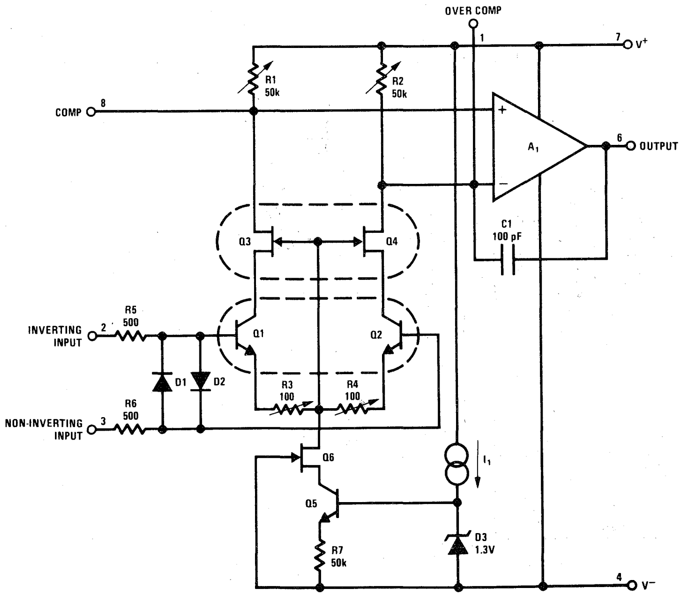
The LH0044 Series is a low noise, ultra-stable, high gain, precision operational amplifier family intended to replace either chopper-stabilized monolithic or modular amplifiers. The devices are particularly suited for differential mode, inverting, and non-inverting mode applications requiring very low initial offset, low offset drift, very high gain, high CMRR, and high PSRR. In addition, the LH0044 Series' low initial offset and offset drift eliminate costly and time consuming null adjustments at the systems level. The superior performance afforded by the LH0044 Series is made possible by advanced processing and testing techniques, as well as active laser trim of critical metal film resistors to minimize offset voltage and drift. Unique construction eliminates thermal feedback effects.

The LH0044 Series is an excellent choice for a wide range of precision applications including strain gauge bridges, thermocouple amplifiers, and ultrastable reference amplifiers. The LH0044 and LH0044A are guaranteed over the temperature range of −55°C to +125°C, and the LH0044AC, LH0044B, and LH0044C are guaranteed from −25°C to +85°C. The device is available in standard TO-5 op amp pin out and is compatible with LM108A, LM725, and LM741 type amplifiers.

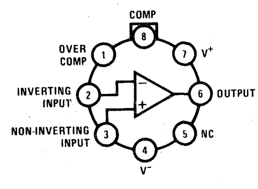
features

- Low input offset voltage — 25μV max
- Excellent long-term stability — ±1μV/month max
- Low offset drift — 0.5μV/°C max
- Very low noise — 0.7μVp-p max 0.1 Hz to 10 Hz
- High CMRR and PSRR — 120 dB min
- High open loop gain — 120 dB min
- Wide common-mode range — ±13V min
- Wide supply voltage range — ±2V to ±20V

equivalent circuit and connection diagram



Metal Can Package



TOP VIEW

Case is electrically isolated

Note: Compensation is not normally required. However, for maximum stability, a 0.01μF capacitor should be placed between pins 7 and 8 when device is used below closed loop gains of 10.

TO-5 Metal Can Package (H)
Order Number LH0044AH or LH0044H (-55°C to +125°C)
Order Number LH0044ACH, LH0044BH or LH0044CH (-25°C to +85°C)
See Package 11A

absolute maximum ratings

Supply Voltage	±20V
Power Dissipation	600 mW
Differential Input Voltage (Note 4)	±15V
Input Voltage (Note 5)	±15V
Output Short-Circuit Duration	Continuous
Operating Temperature Range	
LH0044, LH0044A	−55°C to +125°C
LH0044AC, LH0044B, LH0044C	−25°C to +85°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

dc electrical characteristics (Note 1)

PARAMETER	CONDITIONS	LIMITS LH0044A/LH0044AC MIN	TYP	MAX	LH0044/LH0044B/LH0044C MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = 25°C$, $R_S = 50\Omega$, $V_{CM} = 0V$		8	25		12	50	μV
	LH0044C Only						100	μV
Input Offset Voltage	$R_S = 50\Omega$, $V_{CM} = 0V$			50			150	μV
	LH0044A and LH0044B Only			75			75	μV
Average Input Offset Voltage Drift	$T_{MIN} \le T_A \le T_{MAX}$		0.1	0.5		0.2	1.0	μV/°C
	LH0044B Only						0.5	μV/°C
Long-Term Stability	(Note 2)		0.2	1		0.3	2	μV/month
Input Noise Voltage (Note 3)	BW = 0.1 Hz to 10 Hz, $R_S = 50\Omega$		0.35	0.7		0.35	0.8	μVp-p
	$R_S = 10\ k\Omega$ Imbalance		0.50	0.9		0.50	1.0	μVp-p
Thermal Feedback Coefficient			0.005			0.005		μV/mW
Open Loop Voltage Gain	$R_L = 10\ k\Omega$	120	145		114	140		dB
Common-Mode Rejection Ratio	$-10V \le V_{CM} \le +10V$	120	145		114	140		dB
Power Supply Rejection Ratio	$\pm 3V \le V_S \le \pm 18V$	120	145		114	140		dB
Input Voltage Range		±13	±13.8		±12	±13.5		V
Output Voltage Swing	$R_L = 10\ k\Omega$	±13	±13.7		±12	±13.5		V
Input Offset Current	$25°C \le T_A \le T_{MAX}$		1.0	2.5		1.5	5.0	nA
	$T_{MIN} \le T_A < 25°C$			5.0			10.0	nA
Average Input Offset Current Drift			5	40		15	80	pA/°C
Input Bias Current	$25°C \le T_A \le T_{MAX}$		8.5	15		10	30	nA
	$T_{MIN} \le T_A < 25°C$			50			100	nA
Average Input Bias Current Drift			50	300		100	600	pA/°C
Differential Input Impedance		5	10		2.5	8		MΩ
Common-Mode Input Impedance			2×10^{11}			2×10^{11}		Ω
Supply Current	$I_L = 0$		0.9	3.0		1.0	4.0	mA
Power Dissipation			27	90		30	120	mW

ac electrical characteristics $T_A = 25°C$, $V_S = \pm 15V$

PARAMETER	CONDITIONS	TYP	UNITS
Input Noise Voltage	$R_S = 1\ k\Omega$, $f_O = 10$ Hz	11	$nV/\sqrt{Hz}$
	$R_S = 1\ k\Omega$, $f_O = 1$ kHz	9	$nV/\sqrt{Hz}$
Slew Rate	$A_V = +1$, $R_L = 10\ k\Omega$, $V_{IN} = \pm 10V$	0.06	V/μs
Large Signal Bandwidth	$A_V = +1$, $R_L = 10\ k\Omega$, $V_{IN} = \pm 10V$	1	kHz
Overload Recovery Time	$A_V = +100$, $V_{IN} = -100$ mV, $\Delta V_{IN} = 200$ mV	5	μs
Small Signal Bandwidth	$A_V = +1$, $R_L = 10\ k\Omega$	400	kHz
Small Signal Rise Time	$A_V = +1$, $R_L = 10\ k\Omega$, $V_{IN} = 10$ mV	2.5	μs
Overshoot	$A_V = +1$, $R_L = 10\ k\Omega$, $V_{IN} = 10$ mV, $C_L = 100$ pF	10	%

Note 1: All specifications apply for all device grades, at $V_S = \pm 15V$, and from T_{MIN} to T_{MAX} unless otherwise specified. T_{MIN} is −55°C and T_{MAX} is +125°C for the LH0044A and LH0044. T_{MIN} is −25°C and T_{MAX} is +85°C for the LH0044AC, LH0044B and LH0044C. Typicals are given for $T_A = 25°C$.

Note 2: This parameter is not 100% tested; however, 90% of the devices are guaranteed to meet this specification after one month of operation and after initial turn-on stabilization.

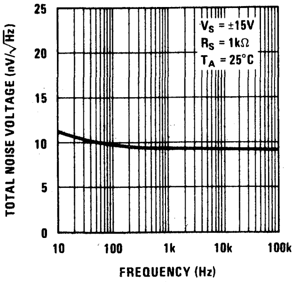
Note 3: Noise is 100% tested on the LH0044A, LH0044AC and LH0044B only. 90% of the LH0044 and LH0044C devices are guaranteed to meet this specification.

Note 4: The inputs are shunted by back-to-back diodes for over-voltage protection. Excessive current will flow for differential input voltages in excess of 1V. Input current should be limited to less than 1 mA.

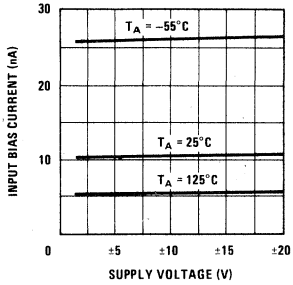
Note 5: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

typical performance characteristics

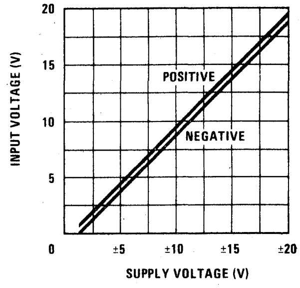
Total Input Noise Voltage vs Frequency



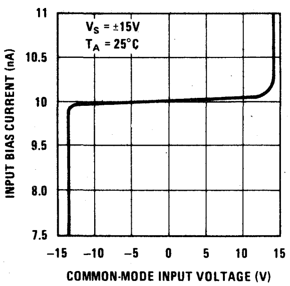
Input Bias Current



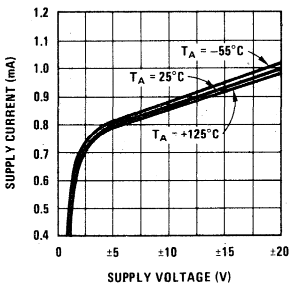
Input Voltage Range



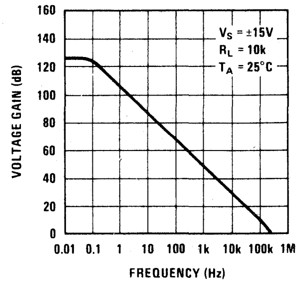
Input Bias Current vs Common-Mode Input Voltage



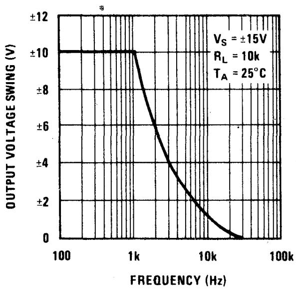
Supply Current vs Supply Voltage



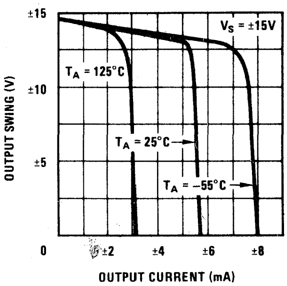
Open Loop Frequency Response



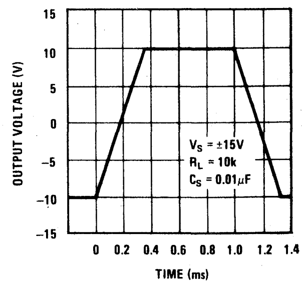
Large Signal Voltage Response



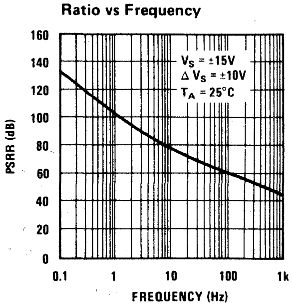
Output Swing



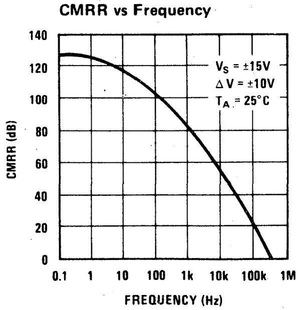
Large Signal Pulse Response



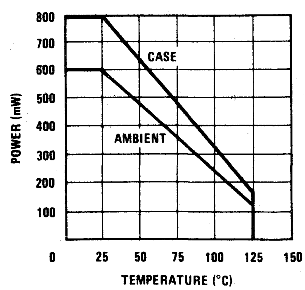
Power Supply Rejection Ratio vs Frequency



CMRR vs Frequency



Maximum Power Dissipation



applications information

LOW DRIFT CONSIDERATIONS

Achieving ultra-low drift in practical applications requires strict attention to board layout, thermocouple effects, and input guarding. For specific recommendations refer to AN-63 and AN-79.

A point worth stressing with regard to low drift specifications is testing of the LH0044. Simply stated—it is virtually impossible to test the device using a thermoprobe or other form of local heating. A one degree centigrade temperature gradient can account for tens of microvolts of virtual offset (or drift). The test circuit of *Figure 1* is recommended for use in a stabilized oven or continuously stirred oil bath with the entire circuit inside the oven or bath. Isothermal layout of the resistors is advised in order to minimize thermocouple induced EMF's.

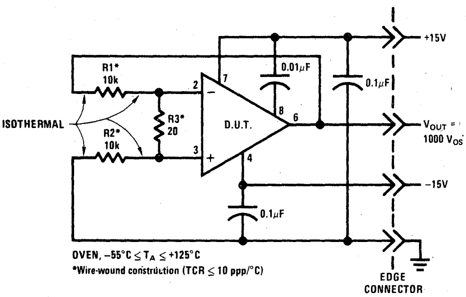


FIGURE 1. LH0044 Temperature Test Circuit

OVER COMPENSATION

The LH0044 may be overcompensated in order to minimize noise bandwidth by paralleling the internal 100 pF capacitor with an external capacitor connected between pins 1 and 6. Unity gain frequency may be predicted by:

$$f = \frac{4 \times 10^{-5}}{100\text{ pF} + C_{ext}\text{ pF}} \text{ (Hz)}$$

COMPENSATION

For closed loop gains in excess of 10, no external components are required for frequency stability. However, for gains of 10 or less, a 0.01μF disc capacitor is recommended between pin 7 (V^+) and pin 8 (Comp). An improvement in ac PSRR will also be realized by use of the 0.01μF capacitor.

OFFSET NULL

In general, further nulling of LH0044 is neither necessary nor recommended. For most applications the specified initial offset is sufficient.

However, for those applications requiring additional null, an obvious temptation might be to place a pot between pins 1 and 8 with the wiper returned to V^+. This technique will usually result in reduced gain and increased offset drift due to mismatch in the TCR of the pot and R1 and R2. The technique is, therefore, not generally recommended.

The recommended technique for offset nulling the LH0044 is shown in *Figure 2.* Null is accomplished in A_2 and all errors are divided by the closed loop gain of the LH0044. Additional offset and drift incurred due to use of A_2 is less than 1μV/V for V^+ and V^- changes and 0.01μV/°C drift for the values shown in *Figure 2.*

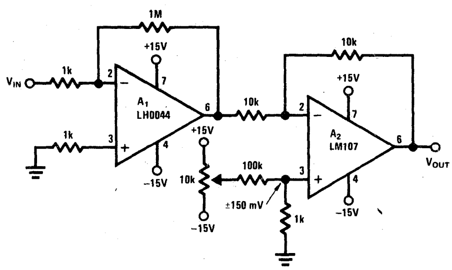
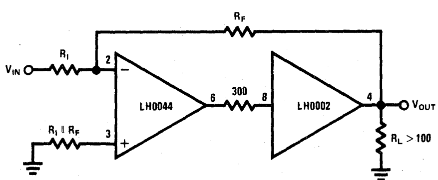
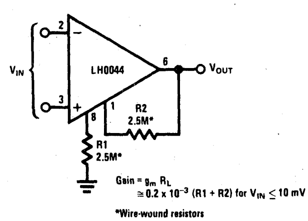


FIGURE 2. LH0044 Null Technique

typical applications

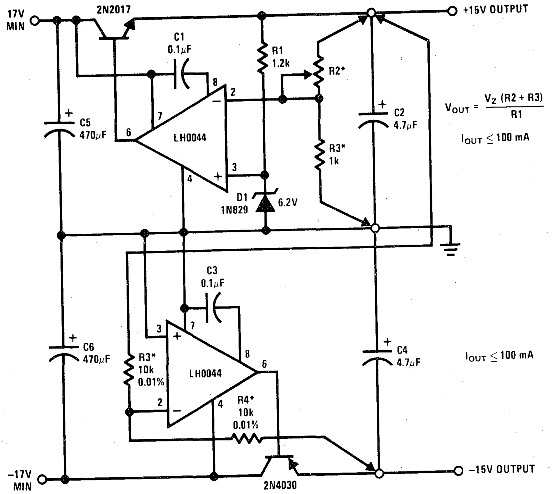


Buffered Output for Heavy Loads



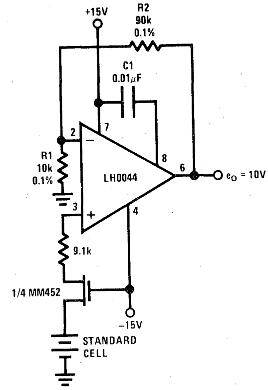
X1000 Instrumentation Amp

typical applications (con't)

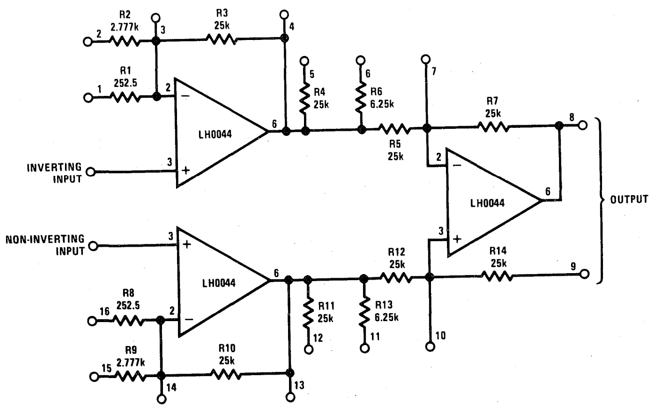


*Wire-wound for minimum drift.
Line and load regulation ≤ 0.005%

Precision Dual Tracking Regulator



10V Reference Supply

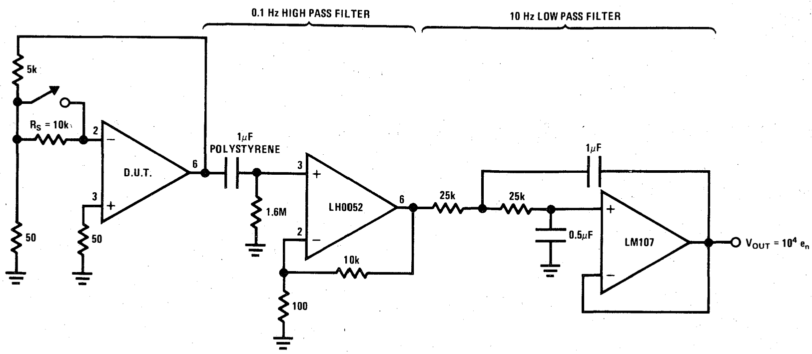


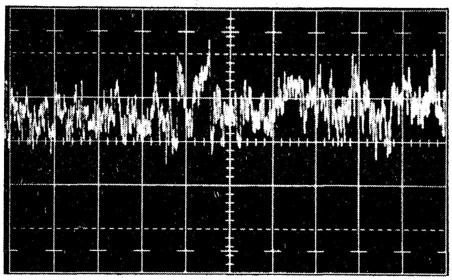
All resistors are part of National's RA201 resistor array.

OVERALL GAIN	INPUT STAGE GAIN	OUTPUT STAGE GAIN	JUMPER PINS ON RA201
X1	X1	X1	–
X2	X1	X2	5 to 7, 12 to 10
X5	X1	X5	6 to 7, 11 to 10
X10	X10	X1	2 to 15
X20	X10	X2	2 to 15, 5 to 7, 12 to 10
X50	X10	X5	2 to 15, 6 to 7, 11 to 10
X100	X100	X1	1 to 16
X200	X100	X2	1 to 16, 5 to 7, 12 to 10
X500	X100	X5	1 to 16, 6 to 7, 11 to 10
X995	X199	X5	1 to 14, 6 to 7, 11 to 10

Precision Instrumentation Amplifier

noise test circuit





VERT: 200 nV/DIV
HORIZ: 5 SEC/DIV

Operational Amplifiers/Buffers

LH0061/LH0061C 0.5 amp wide band operational amplifier

general description

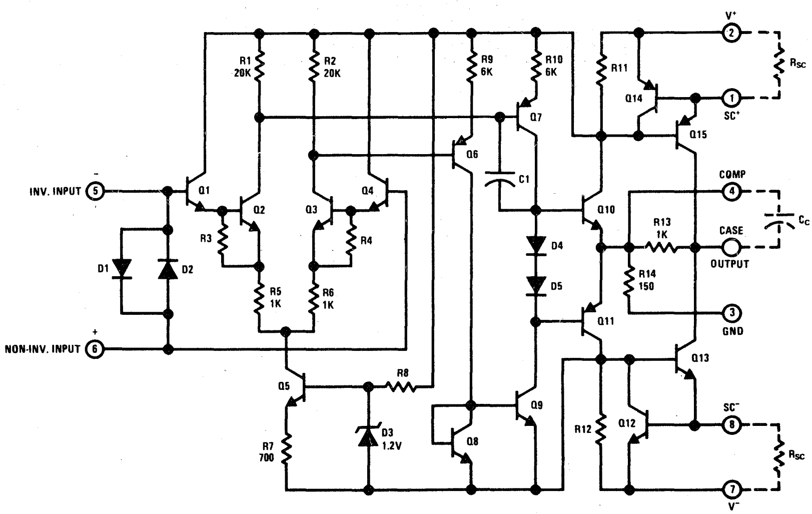
The LH0061/LH0061C is a wide band, high speed, operational amplifier capable of supplying currents in excess of 0.5 ampere at voltage levels of ±12V. Output short circuit protection is set by external resistors, and compensation is accomplished with a single external capacitor. With a suitable heat sink 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.

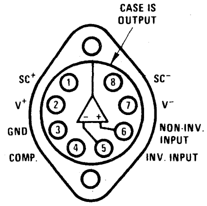
features

■ Output current	0.5 Amp
■ Wide large signal bandwidth	1 MHz
■ High slew rate	70V/μs
■ Low standby power	240 mW
■ Low input current	300 nA Max

schematic and connection diagrams



TO-3 Package



TOP VIEW

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 LH0061 MIN	LH0061 TYP	LH0061 MAX	LH0061C MIN	LH0061C TYP	LH0061C MAX	UNITS
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	$A_V = +1$, $R_L = 100\Omega$	25	70		25	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		%

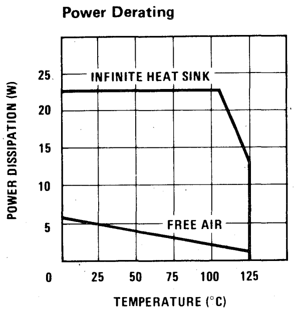
Note 1: Specifications apply for $\pm 5V \leq V_S \leq \pm 18V$, $C_C = 3000$ pF, and $-55°C \leq T_C \leq +125°C$ for the LH0061K and $-25°C \leq T_C \leq +85°C$ for the LH0061CK. Typical values are for $T_C = 25°C$.

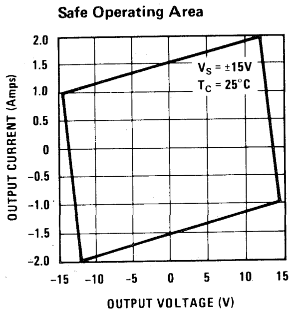
Note 2: The inputs are shunted with back-to-back diodes for overvoltage protection. Excessive current will flow if a differential voltage in excess of 1V is applied between the inputs without limiting resistors.

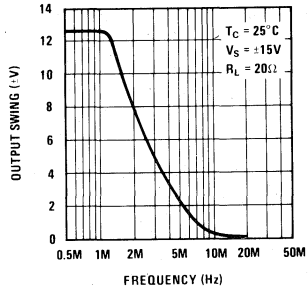
Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 4: Rating applies as long as package power rating is not exceeded.

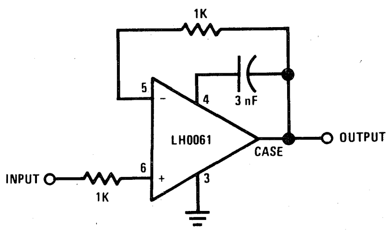
typical performance characteristics



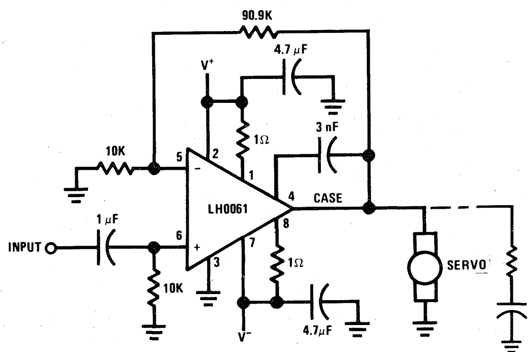




typical applications



Unity Gain Driver



AC Servo Amplifier

Operational Amplifiers/Buffers

LH0062/LH0062C high speed FET op amp

general description

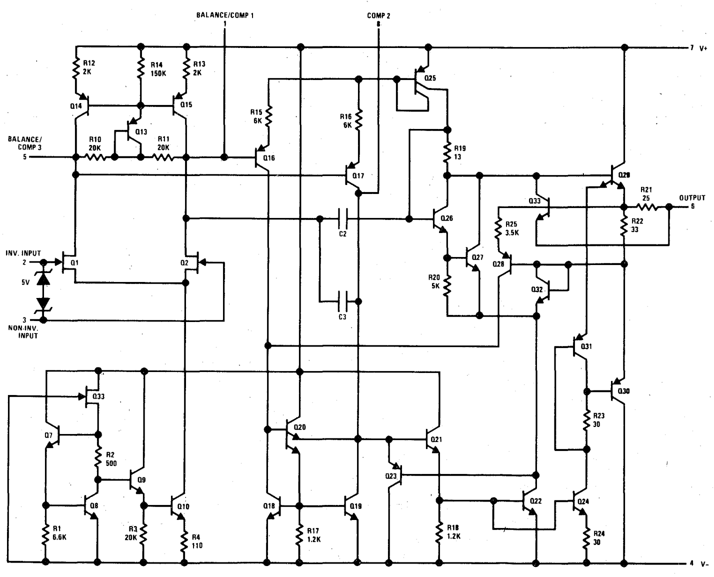
The LH0062/LH0062C is a precision, high speed FET input operational amplifier with more than an order of magnitude improvement in slew rate and bandwidth over conventional FET IC op amps. In addition it features very closely matched input characteristics, very high input impedance, and ultra low input 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 $+125^\circ$C while the LH0062C is specified to operate over a -25°C to $+85^\circ$C temperature range.

features

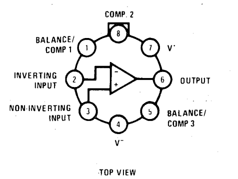
- High slew rate — 70 V/μs
- Wide bandwidth — 15 MHz
- Settling time (0.1%) — 1μs
- Low input offset voltage — 2 mV
- Low input offset current — 1 pA
- Wide supply range — ±5V to ±20V
- Internal 6 dB/octave frequency compensation
- Pin compatible with std IC op amps (TO-5 pkg)

schematic and connection diagrams*



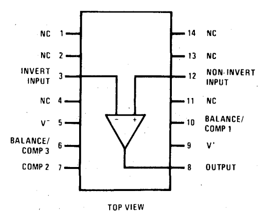
*Pin Numbers Shown for TO-5 Package

Metal Can Package



Order Number LH0062H or LH0062CH See Package 11A

Dual-In-Line Package



Order Number LH0062D or LH0062CD See Package 1

absolute maximum ratings

Supply Voltage	±20V
Power Dissipation (see graph)	500 mW
Input Voltage (Note 1)	±15V
Differential Input Voltage (Note 2)	±30V
Short Circuit Duration	Continuous
Operating Temperature	
LH0062,	−55°C to +125°C
LH0062C,	−25°C to +85°C
Storage Temperature Range	−65°C to +150°C
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	$R_S \le 100\ k\Omega$; $T_A = 25°C$		2	5		10	15	mV
	$R_S \le 100\ k\Omega$			7			20	mV
Temperature Coefficient of Input Offset Voltage	$R_S \le 100\ k\Omega$		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	$R_S \le 10\ k\Omega$, $V_{IN} = \pm 10V$	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	$R_L = 2\ k\Omega$, $V_{OUT} = \pm 10V$, $T_A = 25°C$, $V_S = \pm 15V$	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

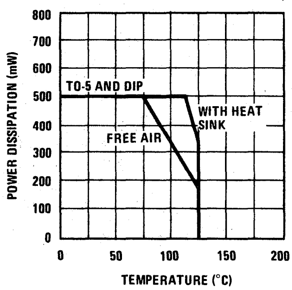
Note 1: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

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

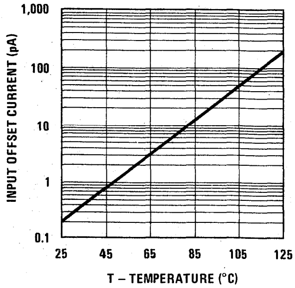
Note 3: Unless otherwise specified, these specifications apply for $\pm 5V \le V_S \le \pm 20V$ and $-55°C \le T_A \le +125°C$ for the LH0062 and $-25°C \le T_A \le +85°C$ for LH0062C. Typical values are given for $T_A = 25°C$. Power supplies should be bypassed with 0.1 µF ceramic capacitors.

typical performance characteristics

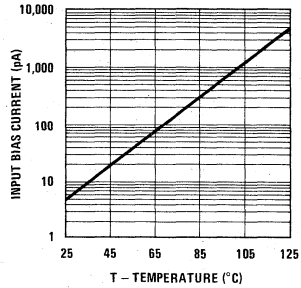
Maximum Power Dissipation



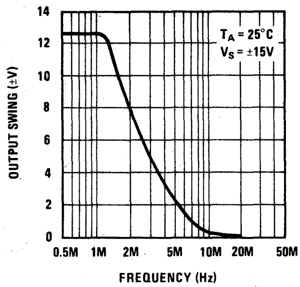
Input Offset Current vs Temperature



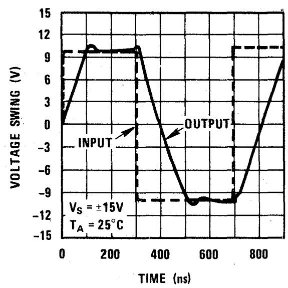
Input Bias Current vs Temperature



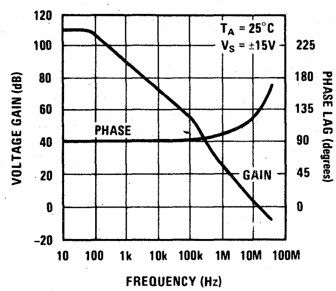
Large Signal Frequency Response



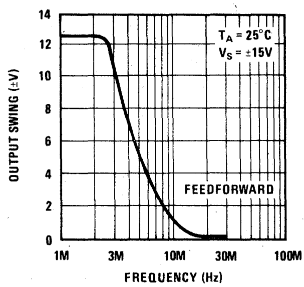
Voltage Follower Pulse Response



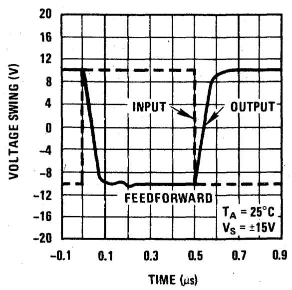
Open Loop Frequency Response



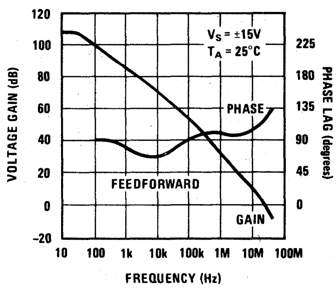
Large Signal Frequency Response



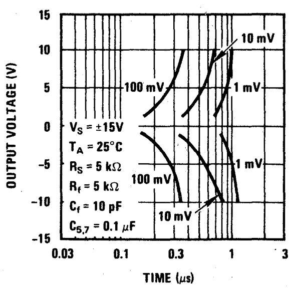
Inverter Pulse Response



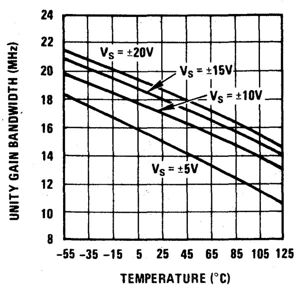
Open Loop Frequency Response



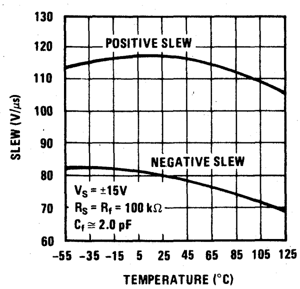
Inverter Settling Time



Unity Gain Bandwidth

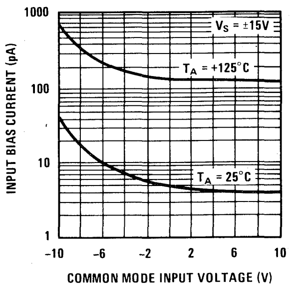


Voltage Follower Slew Rate

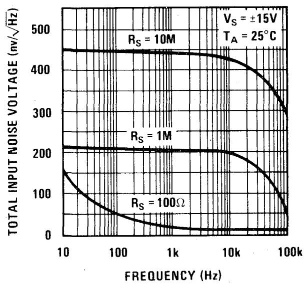


typical performance characteristics (con't)

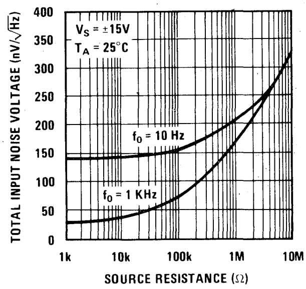
Input Bias Current vs Input Voltage



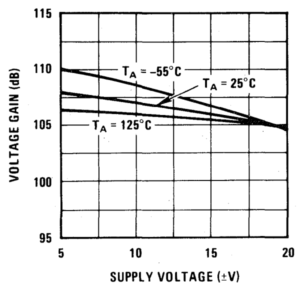
Total Input Noise Voltage* vs Frequency



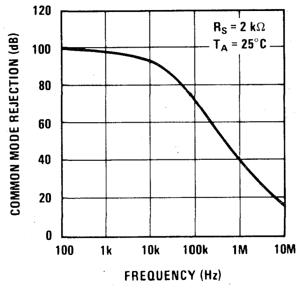
Total Input Noise Voltage* vs Source Resistance



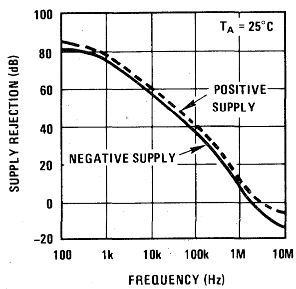
Voltage Gain



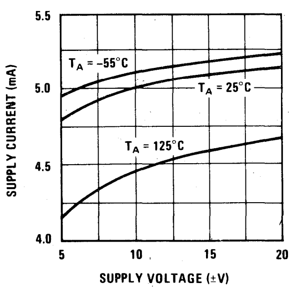
Common Mode Rejection



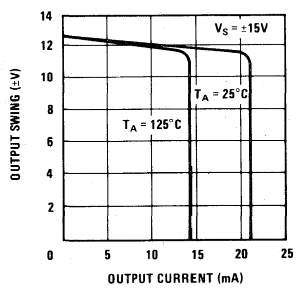
Power Supply Rejection



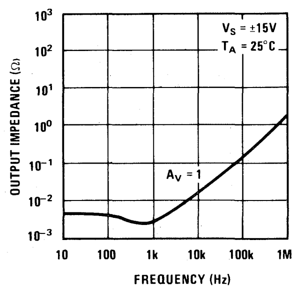
Supply Current



Current Limiting



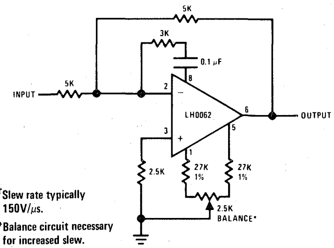
Closed Loop Output Impedance



*Noise Voltage Includes Contribution from Source Resistance

auxiliary circuits

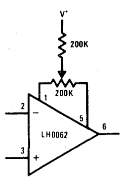
Feedforward Compensation for Greater Inverting Slew Rate†



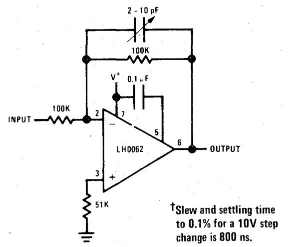
†Slew rate typically 150V/μs.

*Balance circuit necessary for increased slew.

Offset Balancing



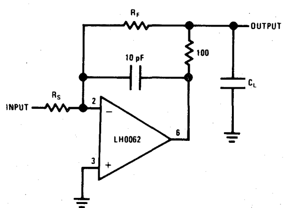
Compensation for Minimum Settling† Time



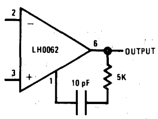
†Slew and settling time to 0.1% for a 10V step change is 800 ns.

auxiliary circuits (con't)

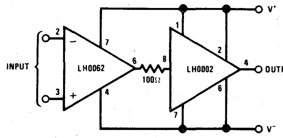
Isolating Large Capacitive Loads



Overcompensation

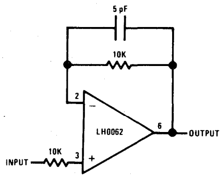


Boosting Output Drive to ±100 mA

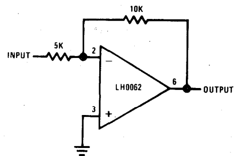


typical applications*

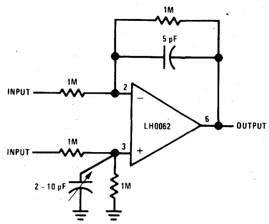
Fast Voltage Follower



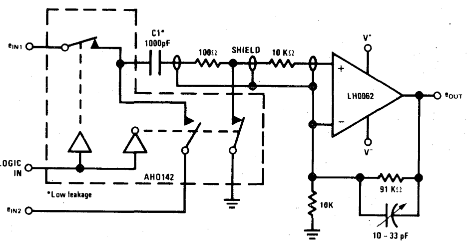
Fast Summing Amplifier



Differential Amplifier

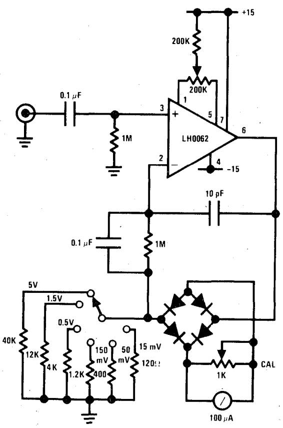


High Speed Subtractor

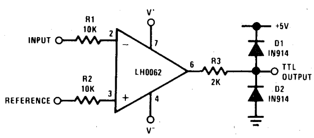


$e_{OUT} = 10 \times (e_{IN1} - e_{IN2})$

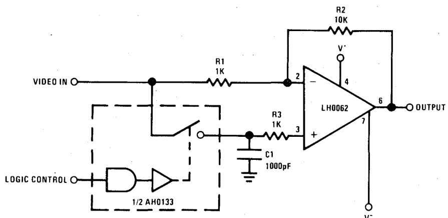
Wide Range AC Voltmeter



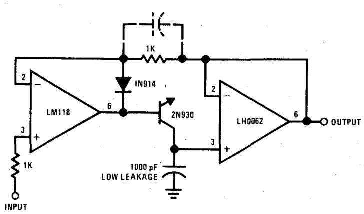
Fast Precision Voltage Comparator



Video DC Restoring Amplifier



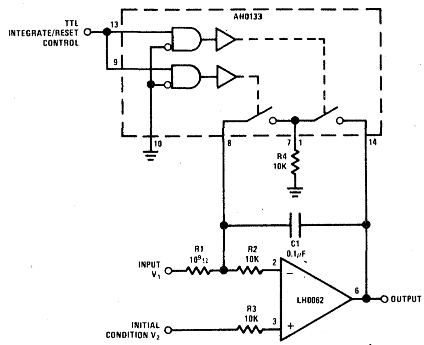
High Speed Positive Peak Detector



*Pin numbers shown for TO-5 package

typical applications* (con't)

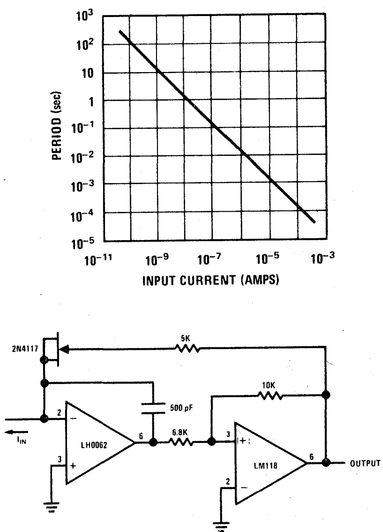
Precision Integrator



$$V_{OUT} = \frac{1}{C1\,R1} \int -V_1\,dt + V_2$$

*Pin numbers shown for TO-5 package

Precision Wide Range Current to Period Converter



Operational Amplifiers/Buffers

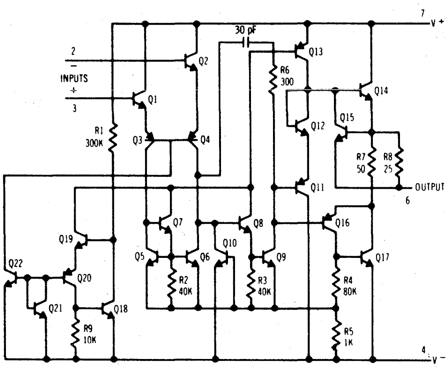
LH101 operational amplifier general description

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:

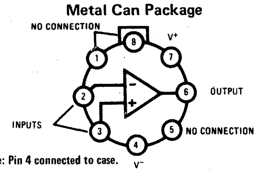
- Operation guaranteed for supply voltages from ±5V to ±20V
- Low current drain – even with the output saturated
- No latch-up when common-mode range is exceeded
- Continuous short-circuit protection
- Input transistors protected from excessive input voltage.

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



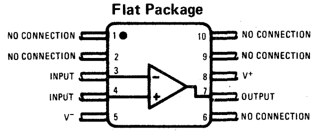
Metal Can Package



Note: Pin 4 connected to case.

Order Number LH101H
See Package 11A

Flat Package

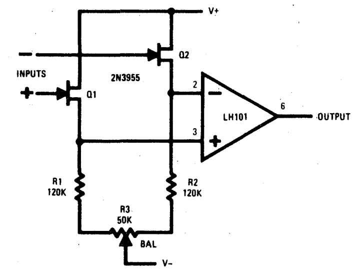


Note: Pin 5 connected to bottom of package.

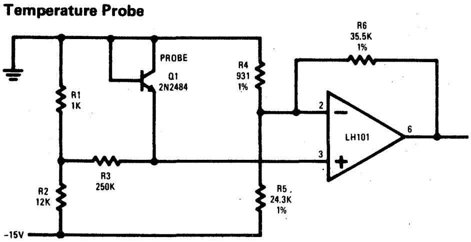
Order Number LH101F
See Package 3

typical applications **

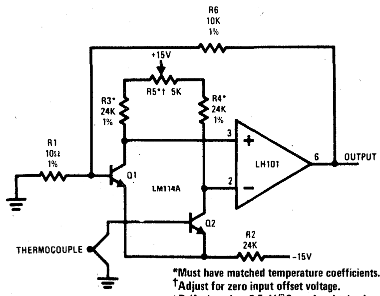
FET Operational Amplifier



Temperature Probe

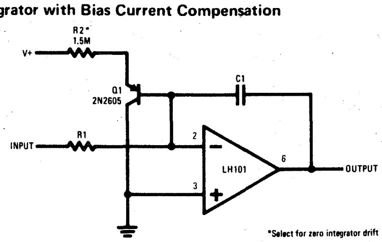


Low Drift Thermocouple Amplifier‡



*Must have matched temperature coefficients.
†Adjust for zero input offset voltage.
‡Drifts less than 0.5μV/°C can be obtained consistently.

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

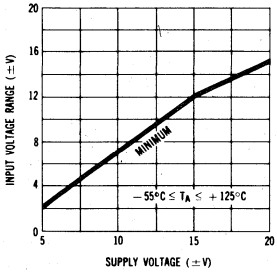
electrical characteristics (note 4)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage	$T_A = 25°C$, $R_S \leq 10k\Omega$		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	$T_A = 25°C$, $V_S = \pm 20V$		1.8	3.0	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm 15V$ $V_{OUT} = \pm 10V$, $R_L \geq 2k\Omega$	50	160		V/mV
Input Offset Voltage	$R_S \leq 10k\Omega$			6.0	mV
Average Temperature Coefficient of Input Offset Voltage	$R_S \leq 50\Omega$		3.0		μV/°C
	$R_S \leq 10k\Omega$		6.0		μV/°C
Input Offset Current	$T_A = +125°C$		10	200	nA
	$T_A = -55°C$		100	500	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	$V_S = \pm 15V$, $V_{OUT} = \pm 10V$ $R_L \geq 2k\Omega$	25			V/mV
Output Voltage Swing	$V_S = \pm 15V$, $R_L = 10k\Omega$	±12	±14		V
	$R_L = 2k\Omega$	±10	±13		V
Input Voltage Range	$V_S = \pm 15V$	±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

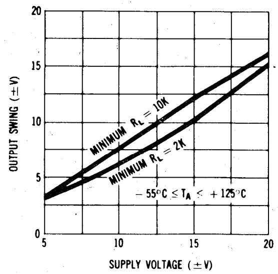
Note 1: For operating at elevated temperatures, the device must be derated based on a 150°C maximum junction temperature and a thermal resistance of 150°C/W junction to ambient or 45°C/W junction to case for the metal-can package. For the flat package, the derating is based on a thermal resistance of 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 $-55°C \leq T_A \leq 125°C$, $\pm 5V \leq V_S \leq \pm 20V$ and C1 = 30 pF unless otherwise specified.

guaranteed performance characteristics

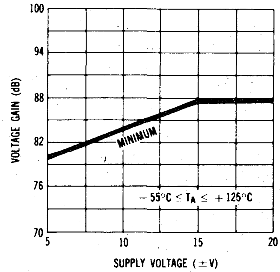
Input Voltage Range



Output Swing

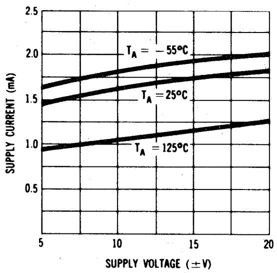


Voltage Gain

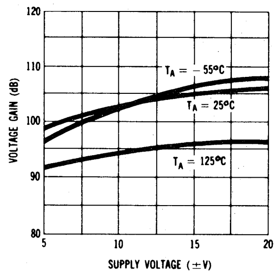


typical performance characteristics

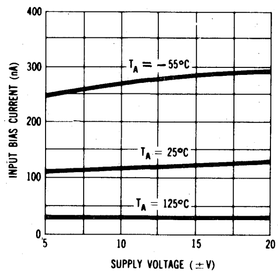
Supply Current



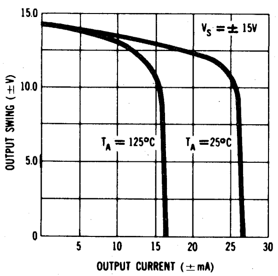
Voltage Gain



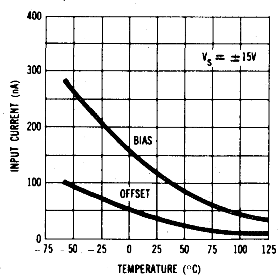
Input Bias Current



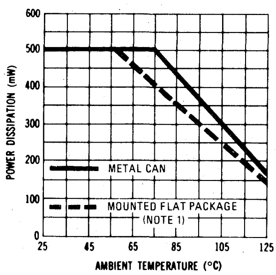
Current Limiting



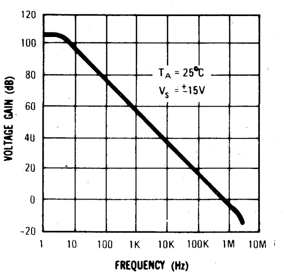
Input Current



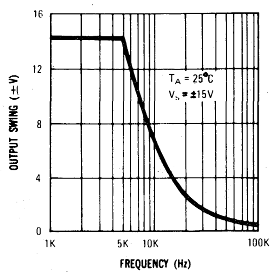
Maximum Power Dissipation



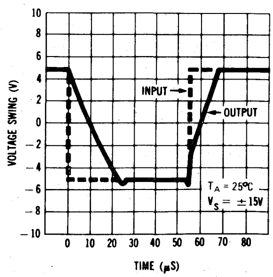
Open Loop Frequency Response



Large Signal Frequency Response



Voltage Follower Pulse Response



3

Operational Amplifiers/Buffers

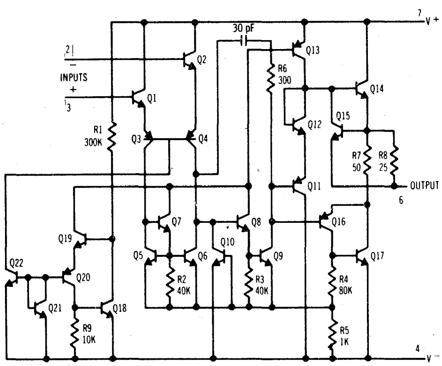
LH201 operational amplifier general description

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:

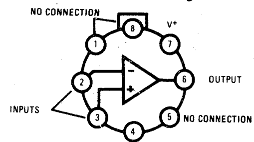
- Operation guaranteed for supply voltages from ±5V to ±20V
- Low current drain – even with the output saturated
- No latch-up when common-mode range is exceeded
- Continuous short-circuit protection
- Input transistors protected from excessive input voltage.

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



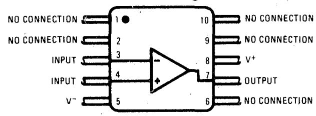
Metal Can Package



Note: Pin 4 connected to case.

Order Number LH201H
See Package 11A

Flat Package

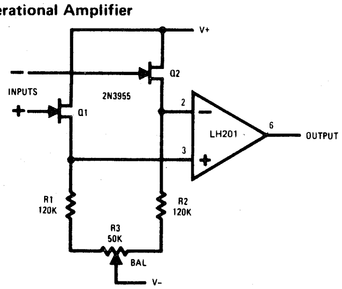


Note: Pin 5 connected to bottom of package.

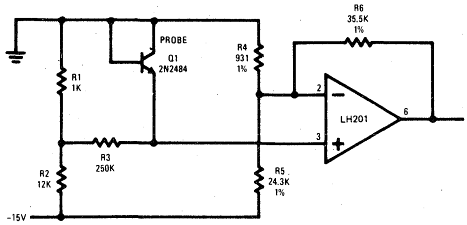
Order Number LH201F
See Package 3

typical applications**

FET Operational Amplifier

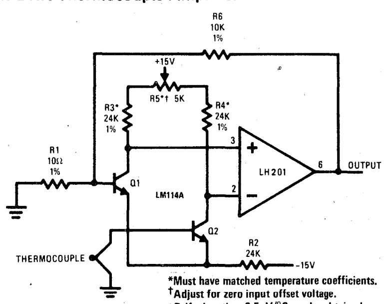


Temperature Probe



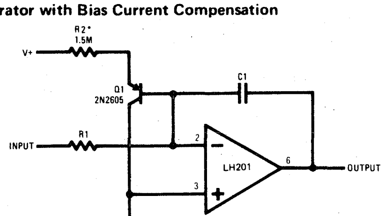
**Pin connections shown are for metal can.

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.

Integrator with Bias Current Compensation



*Select for zero integrator drift.

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

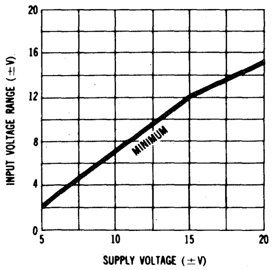
electrical characteristics (note 4)

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

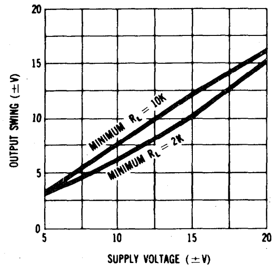
Note 1: For operating at elevated temperatures, the device must be derated based on a 150°C maximum junction temperature and a thermal resistance of 150°C/W junction to ambient or 45°C/W junction to case for the metal-can package. For the flat package, the derating is based on a thermal resistance of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

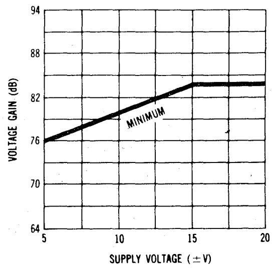
Input Voltage Range



Output Swing

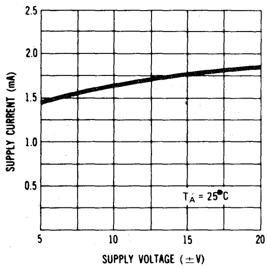


Voltage Gain

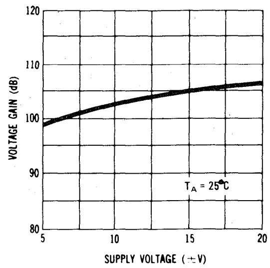


typical performance characteristics

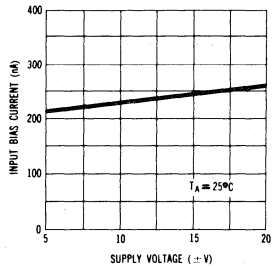
Supply Current



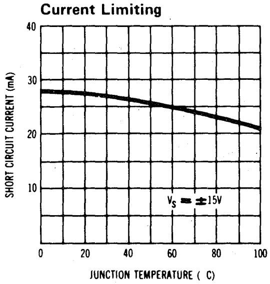
Voltage Gain



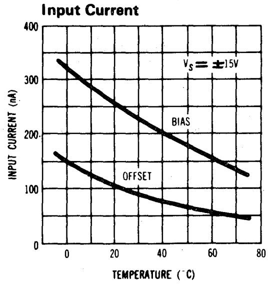
Input Bias Current



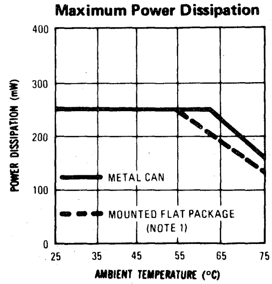
Current Limiting



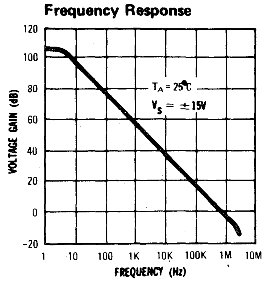
Input Current



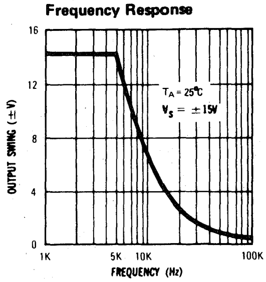
Maximum Power Dissipation



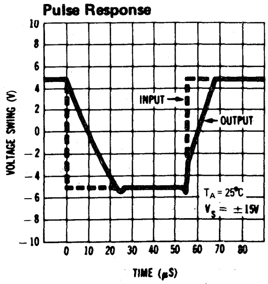
Open Loop Frequency Response



Large Signal Frequency Response



Voltage Follower Pulse Response



Operational Amplifiers/Buffers

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:

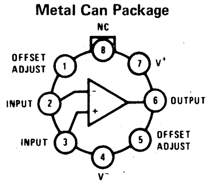
- Internal 6 dB/octave frequency compensation
- Unity gain slew rate in excess of 6 V/μs
- Unity gain bandwidth of 1 MHz
- Input offset is adjustable with a single 10k pot
- Pin compatible with LM741, LM709, LM101A, and μA740
- Excellent offset current match over temperature, typically 100 pA
- Output 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

Metal Can Package

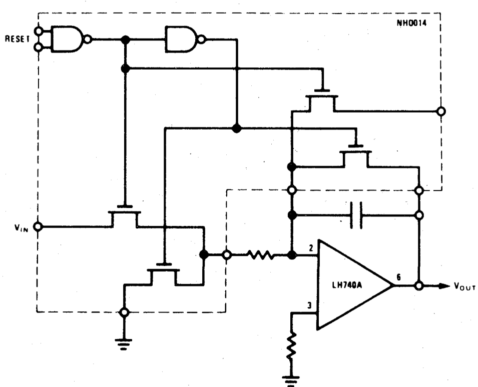


TOP VIEW

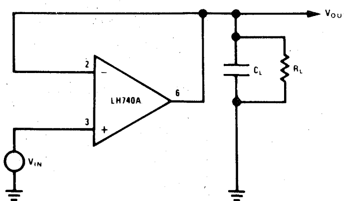
Order Number LH740AH or LH740ACH
See Package 11A

typical applications

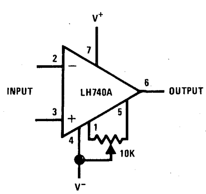
Integrator



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

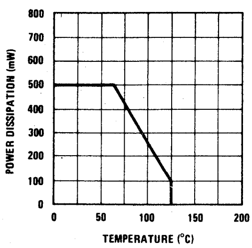
electrical characteristics (Note 1 (V_S = ±15V, T_A = 25°C unless otherwise noted)

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 kΩ, 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

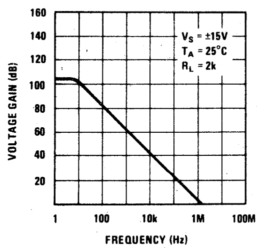
Note 1: For supply voltages less than ±10V, the absolute maximum input voltage is equal to the supply voltage.

typical performance characteristics

Maximum Power Dissipation



Open Loop Frequency Response



Operational Amplifiers/Buffers

LH2101A/LH2201A/LH2301A dual high performance op amp

general description

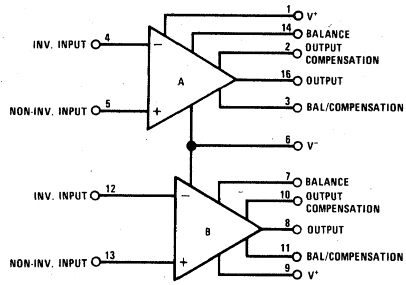
The LH2101A series of dual operational amplifiers are two LM101A type op amps in a single hermetic package. Featuring all the same performance characteristics of the single, these duals offer in addition closer thermal tracking, lower weight, reduced insertion cost, and smaller size than two singles. 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

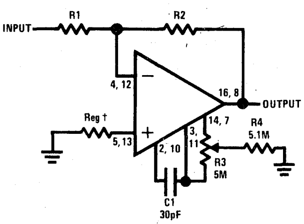


Order Number LH2101AD, LH2201AD or LH2301AD
See Package 2

Order Number LH2101AF, LH2201AF or LH2301AF
See Package 5

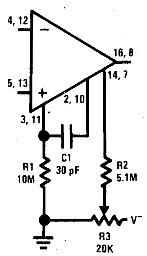
auxiliary circuits

Inverting Amplifier with Balancing Circuit

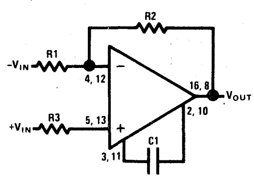


†May be zero or equal to parallel combination of R1 and R2 for minimum offset.

Alternate Balancing Circuit



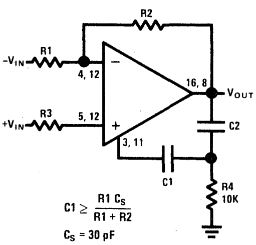
Single Pole Compensation



$C1 \geq \frac{R1\ C_S}{R1 + R2}$

$C_S = 30\ pF$

Two Pole Compensation

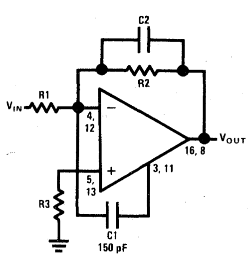


$C1 \geq \frac{R1\ C_S}{R1 + R2}$

$C_S = 30\ pF$

$C2 = 10\ C1$

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	$-55^\circ C$ to $125^\circ C$
LH2201A	$-25^\circ C$ to $85^\circ C$
LH2301A	$0^\circ C$ to $70^\circ C$
Storage Temperature Range	$-65^\circ C$ to $150^\circ C$
Lead Temperature (Soldering, 10 sec)	$300^\circ C$

electrical characteristics each side (Note 3)

PARAMETER	CONDITIONS	LIMITS LH2101A	LIMITS LH2201A	LIMITS LH2301A	UNITS
Input Offset Voltage	$T_A = 25^\circ C$, $R_S \leq 50\ k\Omega$	2.0	2.0	7.5	mV Max
Input Offset Current	$T_A = 25^\circ C$	10	10	50	nA Max
Input Bias Current	$T_A = 25^\circ C$	75	75	250	nA Max
Input Resistance	$T_A = 25^\circ C$	1.5	1.5	0.5	MΩ Min
Supply Current	$T_A = 25^\circ C$, $V_S = \pm 20V$	3.0	3.3	3.0	mA Max
Large Signal Voltage Gain	$T_A = 25^\circ C$, $V_S = \pm 15V$ $V_{OUT} = \pm 10V$, $R_L \geq 2\ k\Omega$	50	50	25	V/mV Min
Input Offset Voltage	$R_S \leq 50\ k\Omega$	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	$25^\circ C \leq T_A \leq 125^\circ C$ $-55^\circ C \leq T_A \leq 25^\circ C$	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	$T_A = +125^\circ C$, $V_S = \pm 20V$	2.5	2.5		mA Max
Large Signal Voltage Gain	$V_S = \pm 15V$, $V_{OUT} = \pm 10V$ $R_L \geq 2\ k\Omega$	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	$R_S \leq 50\ k\Omega$	80	80	70	dB Min
Supply Voltage Rejection Ratio	$R_S \leq 50\ k\Omega$	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 $\pm 5V \leq V_S \leq \pm 20V$ and $-55^\circ C \leq T_A \leq 125^\circ C$, unless otherwise specified. With the LH2201A, however, all temperature specifications are limited to $-25^\circ C \leq T_A \leq 85^\circ C$. For the LH2301A these specifications apply for $0^\circ C \leq T_A \leq 70^\circ C$, $\pm 5V$ and $\leq V_S \leq \pm 15V$. Supply current and input voltage range are specified as $V_S = \pm 15V$ for the LH2301A. $C_1 = 30\ pF$ unless otherwise specified.

Operational Amplifiers/Buffers

LH2108/LH2208/LH2308, LH2108A/LH2208A/LH2308A dual super beta op amp

general description

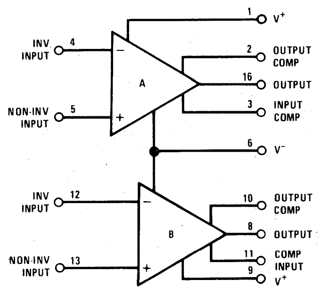
The LH2108A/LH2208A/LH2308A and LH2108/LH2208/LH2308 series of dual operational amplifiers are two LM108A or LM108 type op amps in a single hermetic package. Featuring all the same performance characteristics of the single device, these duals also offer closer thermal tracking, lower weight, reduced 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

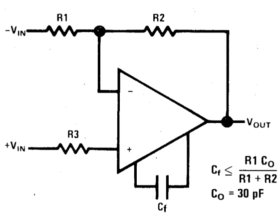
connection diagram



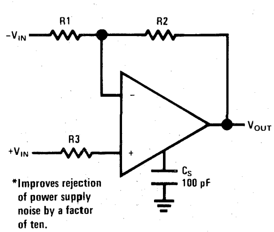
Order Number LH2108AD, LH2208AD, LH2308AD, LH2108D, LH2208D, or LH2308D
See Package 2

auxiliary circuits

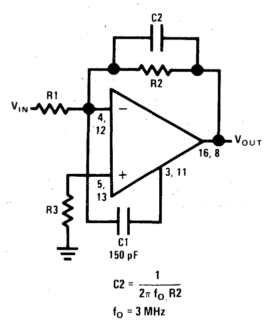
Standard Compensation Circuit



Alternate * Frequency Compensation



Feedforward Compensation



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	Continuous
Operating Temperature Range	
LH2108A/LH2108	−55°C to +125°C
LH2208A/LH2208	−25°C to +85°C
LH2308A/LH2308	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
		LH2108	LH2206	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	$T_A = 25°C$ $V_S = \pm 15V$ $V_{OUT} = \pm 10V$, $R_L \geq 10\ k\Omega$	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	$V_S = \pm 15V$, $V_{OUT} = \pm 10V$ $R_L \geq 10\ k\Omega$	25	25	15	V/mV Min
Output Voltage Swing	$V_S = \pm 15V$, $R_L = 10\ k\Omega$	±13	±13	±13	V Min
Input Voltage Range	$V_S = \pm 15V$	±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	$T_A = 25°C$ $V_S = \pm 15V$ $V_{OUT} = \pm 10V$, $R_L > 10\ k\Omega$	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	$V_S = \pm 15V$, $V_{OUT} = \pm 10V$ $R_L \geq 10\ k\Omega$	40	40	60	V/mV Min
Output Voltage Swing	$V_S = \pm 15V$, $R_L = 10\ k\Omega$	±13	±13	±13	V Min
Input Voltage Range	$V_S = \pm 15V$	±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 $\pm 5V \leq V_S \leq \pm 20V$ 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 $\pm 5V \leq V_S \leq 15V$ and $0°C \leq T_A \leq 70°C$.

Operational Amplifiers/Buffers

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.

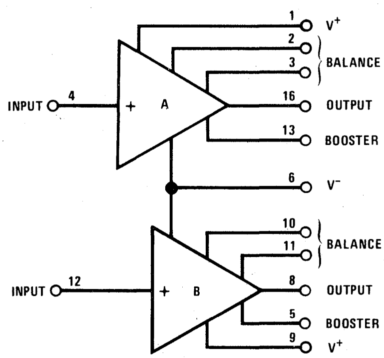
The LH2110 is specified for operation over the −55°C to +125°C military temperature range. The LH2210 is specified for operation over the −25°C to +85°C temperature range. The LH2310 is specified for operation over the 0°C to +70°C temperature range.

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

3

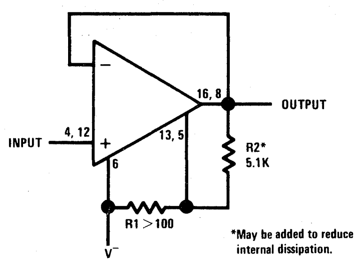
connection diagram



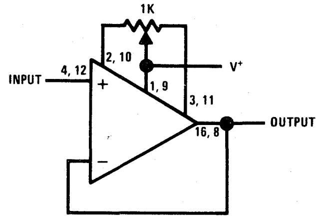
Order Number LH2110D, LH2210D or LH2310D
See Package 2

Order Number LH2110F, 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	$T_A = 25°C$, $V_S = ±15V$, $V_{OUT} = ±10V$, $R_L = 8\ k\Omega$	.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	$-55°C \leq T_A \leq 85°C$	6	6	10	μV/°C Typ
	$T_A = 125°C$	12	12	–	μV/°C Typ
Input Bias Current		10	10	10	nA Max
Large Signal Voltage Gain	$V_S = ±15V$, $V_{OUT} = ±10V$, $R_L = 10\ k\Omega$	.999	.999	.999	V/V Min
Output Voltage Swing (Note 5)	$V_S = ±15V$, $R_L = 10\ k\Omega$	±10	±10	±10	V Min
Supply Current (Each Amplifier)	$T_A = 125°C$	4.0	4.0	–	mA Max
Supply Voltage Rejection Ratio	$±5V \leq V_S \leq ±18V$	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 $±5V \leq V_S \leq ±18V$ 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/Buffers

LH24250/LH24250C dual programmable micropower op amp

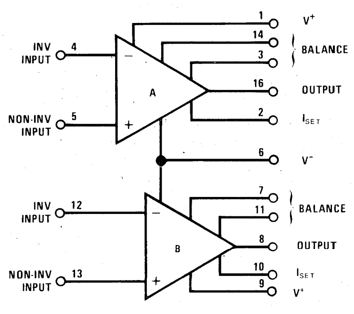
general description

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

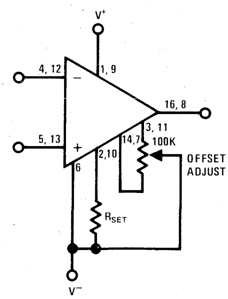
connection diagram and auxiliary circuit



Order Number LH24250F or LH24250CF
See Package 5

Order Number LH24250D or LH24250CD
See Package 2

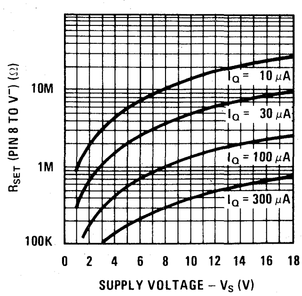
Offset Null Circuit



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



Operational Amplifiers/Buffers

LM101/LM201, LM101A/LM201A/LM301A operational amplifiers

general description

The LM101 series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. 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:

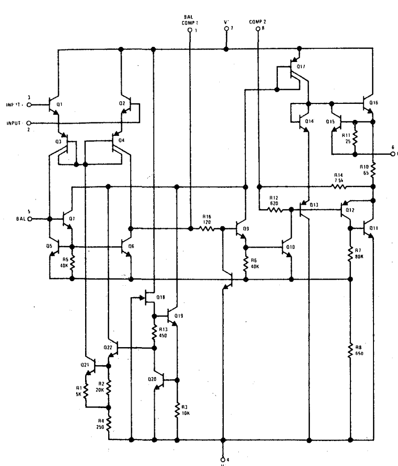
- Offset voltage 3 mV maximum over temperature (LM101A/LM201A)
- Input current 100 nA maximum over temperature (LM101A/LM201A)
- Offset current 20 nA maximum over temperature (LM101A/LM201A)
- Guaranteed drift characteristics
- Offsets guaranteed over entire common mode and supply voltage ranges
- Slew 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.

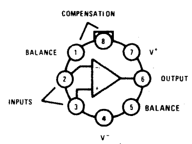
The LM101A series offers the features of the LM101, which makes its application nearly foolproof. In addition, the device provides better accuracy and lower noise in high impedance circuitry. The low input currents also make it particularly well suited for long interval integrators or timers, sample 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 LM101/LM101A is guaranteed over a temperature range of −55°C to +125°C, the LM201A from −25°C to +85°C, and the LM201/LM301A from 0°C to +70°C.

schematic** and connection diagrams Top Views



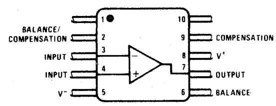
Metal Can Package



Note: Pin 4 connected to case.

Order Number LM101H, LM201H, LM101AH, LM201AH or LM301AH
See Package 11

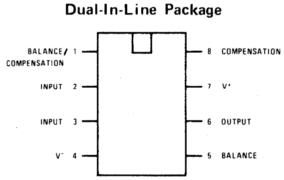
Flat Package



Note: Pin 5 connected to bottom of package.

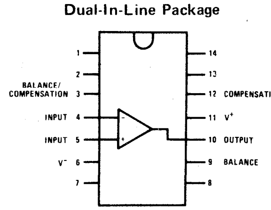
Order Number LM101F, LM201F, LM101AF or LM201AF
See Package 3

Dual-In-Line Package



Order Number LM201J or LM301AJ
See Package 15
Order Number LM301AN
See Package 20

Dual-In-Line Package



Note: Pin 6 connected to bottom of package.

Order Number LM101AD or LM201AD
See Package 2B
Order Number LM101AJ-14, LM201AJ-14, LM301AJ, LM101J-14 or LM201J-14
See Package 16

**Pin connections shown are for metal can.

absolute maximum ratings

	LM101/LM101A/LM201A	LM201	LM301A
Supply Voltage	±22V	±22V	±18V
Power Dissipation (Note 1)	500 mW	500 mW	500 mW
Differential Input Voltage	±30V	±30V	±30V
Input Voltage (Note 2)	±15V	±15V	±15V
Output Short Circuit Duration (Note 3)	Indefinite	Indefinite	Indefinite
Operating Temperature Range	−55°C to +125°C (LM101, LM101A) −25°C to +85°C (LM201A)	0°C to +70°C	0°C to +70°C
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C	300°C	300°C

electrical characteristics (Note 4)

PARAMETER	CONDITIONS	LM101A/LM201A			LM301A			LM101			LM201			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$T_A = 25°C$													
LM101A, LM201A, LM301A	$R_S \leq 50\ k\Omega$		0.7	2.0		2.0	7.5							mV
LM101, LM201	$R_S \leq 10\ k\Omega$								1.0	5.0		2.0	7.5	mV
Input Offset Current	$T_A = 25°C$		1.5	10		3.0	50		40	200		100	500	nA
Input Bias Current	$T_A = 25°C$		30	75		70	250		120	500		250	1500	nA
Input Resistance	$T_A = 25°C$	1.5	4.0		0.5	2.0		0.3	0.8		0.1	0.4		MΩ
Supply Current	$T_A = 25°C$													
	$V_S = \pm 20V$		1.8	3.0					1.8	3.0		1.8	3.0	mA
	$V_S = \pm 15V$					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		25	160		50	160		20	150		V/mV
Input Offset Voltage	$R_S \leq 50\ k\Omega$			3.0			10							mV
	$R_S \leq 10\ k\Omega$									6.0			10	mV
Average Temperature Coefficient of Input Offset Voltage	$R_S \leq 50\ k\Omega$		3.0	15		6.0	30		3.0			6.0		μV/°C
	$R_S \leq 10\ k\Omega$								6.0			10		μV/°C
Input Offset Current				20			70							nA
	$T_A = T_{MAX}$								10	200		50	400	nA
	$T_A = T_{MIN}$								100	500		150	750	nA
Average Temperature Coefficient of Input Offset Current	$25°C \leq T_A \leq T_{MAX}$		0.01	0.1		0.01	0.3							nA/°C
	$T_{MIN} \leq T_A \leq 25°C$		0.02	0.2		0.02	0.6							nA/°C
Input Bias Current				0.1			0.3			1.5			2.0	μA
Supply Current	$T_A = T_{MAX}$, $V_S = \pm 20V$		1.2	2.5										μA
Large Signal Voltage Gain	$V_S = \pm 15V$, $V_{OUT} = \pm 10V$, $R_L \geq 2k$	25			15			25			15			V/mV
Output Voltage Swing	$V_S = \pm 15V$													
	$R_L = 10\ k\Omega$	±12	±14		±12	±14		±12	±14		±12	±14		V
	$R_L = 2\ k\Omega$	±10	±13		±10	±13		±10	±13		±10	±13		V
Input Voltage Range	$V_S = \pm 20V$	±15												V
	$V_S = \pm 15V$				±12			±12			±12			V
Common-Mode Rejection Ratio	$R_S \leq 50\ k\Omega$	80	96		70	90								dB
	$R_S \leq 10\ k\Omega$							70	90		65	90		dB
Supply Voltage Rejection Ratio	$R_S \leq 50\ k\Omega$	80	96		70	96								dB
	$R_S \leq 10\ k\Omega$							70	90		70	90		dB

Note 1: The maximum junction temperature of the LM101/LM101A is 150°C, and that of the LM201/LM201A/LM301A 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 187°C/W, junction to ambient.

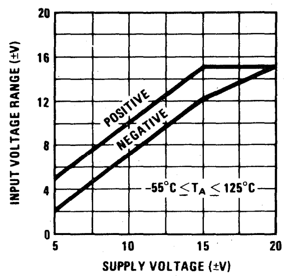
Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: Continuous short circuit is allowed for case temperatures to 125°C and ambient temperatures to 75°C for LM101/LM101A/LM201A, and 70°C and 55°C respectively for LM201/LM301A.

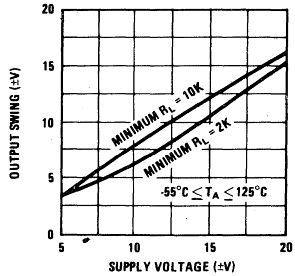
Note 4: Unless otherwise specified, these specifications apply for C1 = 30 pF, $\pm 5V \leq V_S \leq \pm 20V$ and $-55°C \leq T_A \leq +125°C$ (LM101/LM101A), $\pm 5V \leq V_S \leq \pm 20V$ and $-25°C \leq T_A \leq +85°C$ (LM201A), $\pm 5V \leq V_S \leq \pm 20V$ and $0°C \leq T_A \leq +70°C$ (LM201) and $\pm 5V \leq V_S \leq \pm 15V$ and $0°C \leq T_A \leq +70°C$ (LM301A).

guaranteed performance characteristics LM101A/LM201A

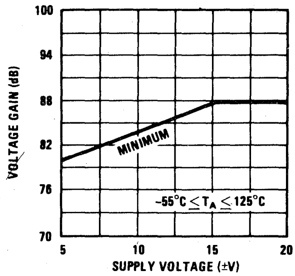
Input Voltage Range



Output Swing

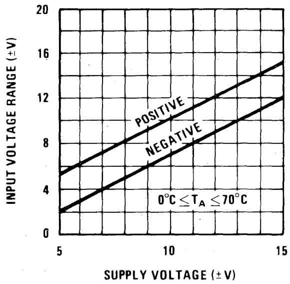


Voltage Gain

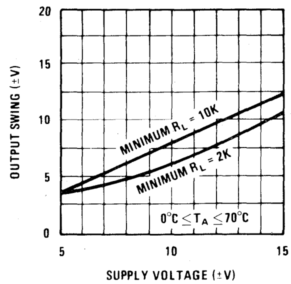


guaranteed performance characteristics LM301A

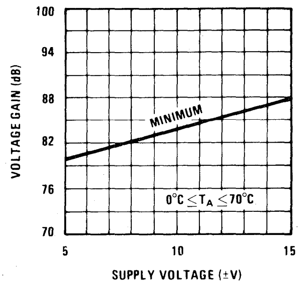
Input Voltage Range



Output Swing

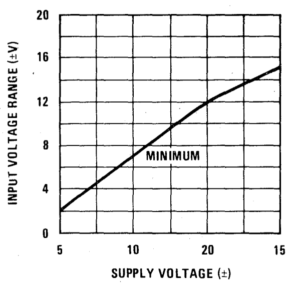


Voltage Gain

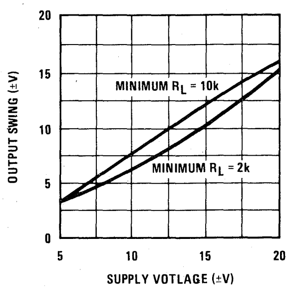


guaranteed performance characteristics LM101/LM201

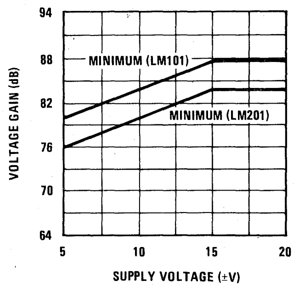
Input Voltage Range



Output Swing

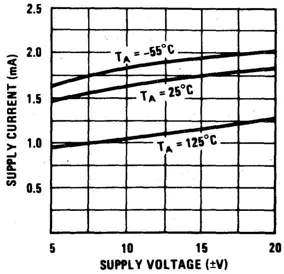


Voltage Gain

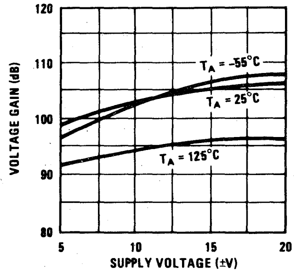


typical performance characteristics

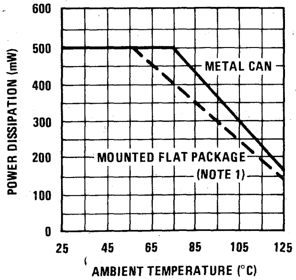
Supply Current



Voltage Gain

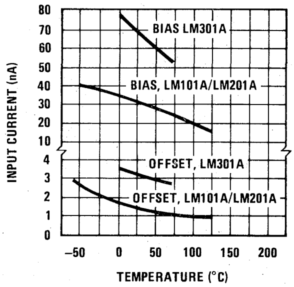


Maximum Power Dissipation

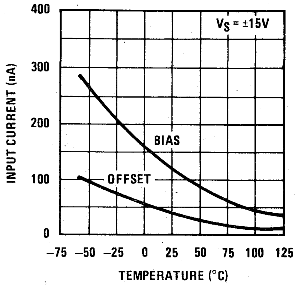


typical performance characteristics

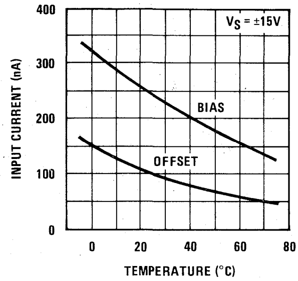
Input Current, LM101A/LM201A/LM301A



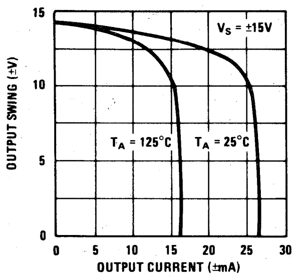
Input Current, LM101



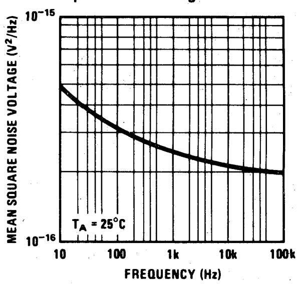
Input Current, LM201



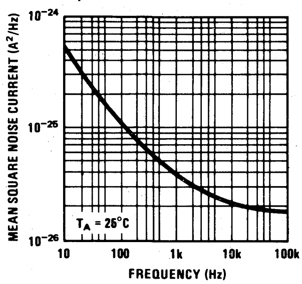
Current Limiting



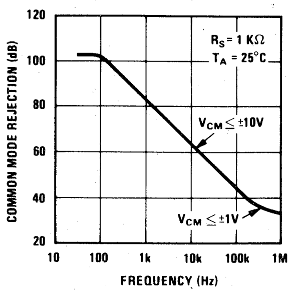
Input Noise Voltage



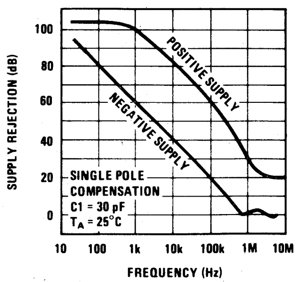
Input Noise Current



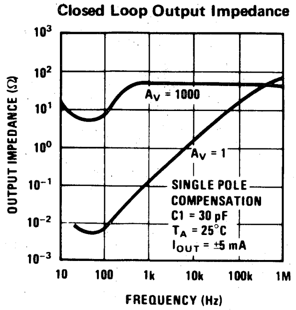
Common Mode Rejection



Power Supply Rejection

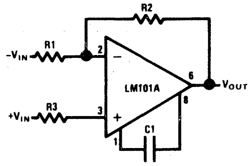


Closed Loop Output Impedance



typical performance characteristics for various compensation circuits**

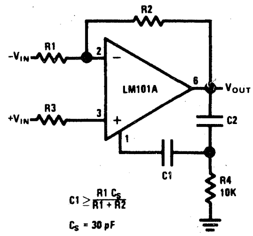
Single Pole Compensation



$C1 \geq \frac{R1\ C_S}{R1 + R2}$

C_S = 30 pF

Two Pole Compensation

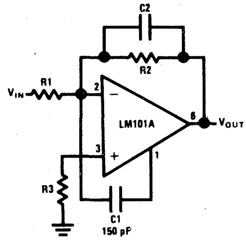


$C1 \geq \frac{R1\ C_S}{R1 + R2}$

C_S = 30 pF

C2 = 10 C1

Feedforward Compensation

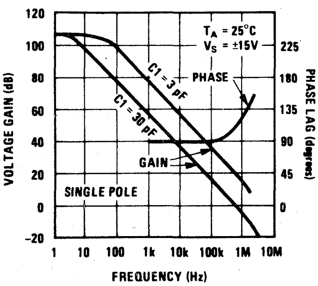


$C2 = \frac{1}{2\pi f_o R2}$

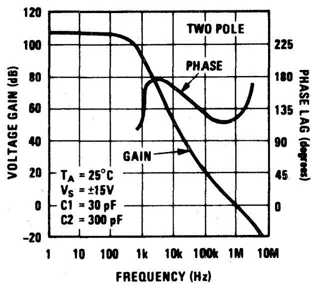
f_o = 3 MHz

**Pin connections shown are for metal can.

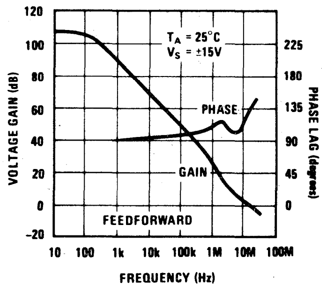
Open Loop Frequency Response



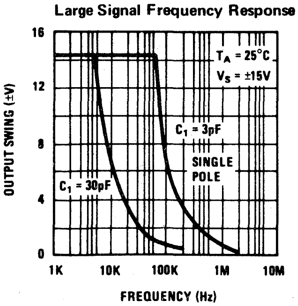
Open Loop Frequency Response



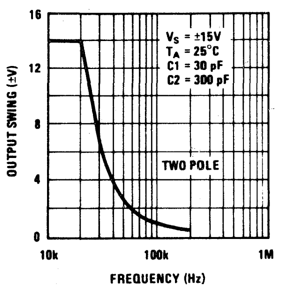
Open Loop Frequency Response



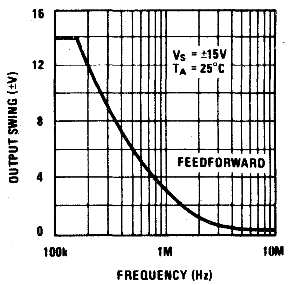
Large Signal Frequency Response



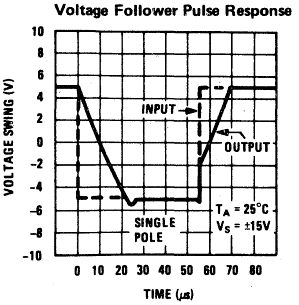
Large Signal Frequency Response



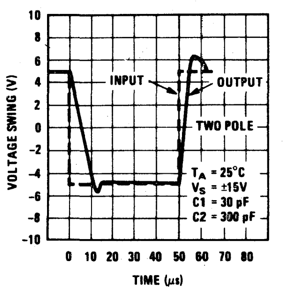
Large Signal Frequency Response



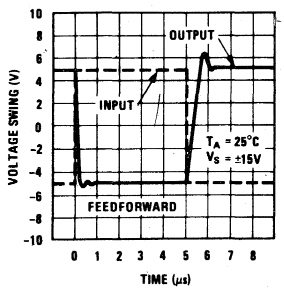
Voltage Follower Pulse Response



Voltage Follower Pulse Response

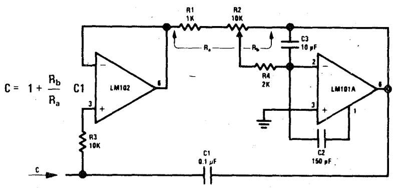


Inverter Pulse Response



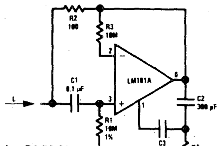
typical applications **

Variable Capacitance Multiplier



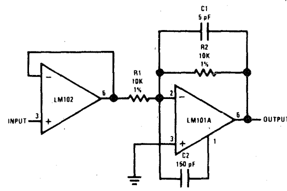
$C = 1 + \frac{R_b}{R_a} C1$

Simulated Inductor

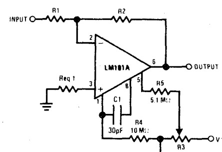


$L \cong R1\ R2\ C1$
$R_S = R2$
$R_P = R1$

Fast Inverting Amplifier With High Input Impedance

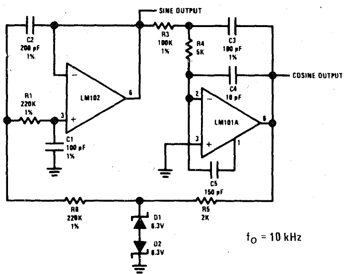


Inverting Amplifier with Balancing Circuit



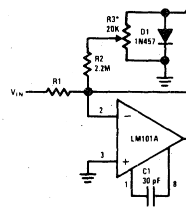
†May be zero or equal to parallel combination of R1 and R2 for minimum offset.

Sine Wave Oscillator



$f_O = 10$ kHz

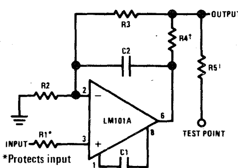
Integrator with Bias Current Compensation



*Adjust for zero integrator drift. Current drift typically 0.1 nA/°C over −55°C to +125°C temperature range.

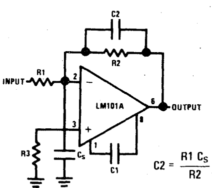
application hints**

Protecting Against Gross Fault Conditions



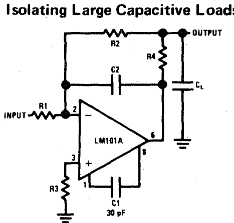
*Protects input
†Protects output
‡Protects output—not needed when R4 is used.

Compensating For Stray Input Capacitances Or Large Feedback Resistor



$C2 = \frac{R1\ C_S}{R2}$

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.

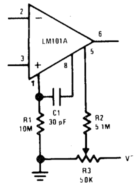
Although the LM101A is relatively unaffected by supply bypassing, this cannot be ignored altogether. Generally it is necessary to bypass the supplies to ground at least once on every circuit card, and more bypass points may be required if more than five amplifiers are used. When feed-forward compensation 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.

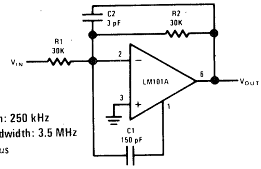
3

typical applications** (con't)

Standard Compensation and Offset Balancing Circuit

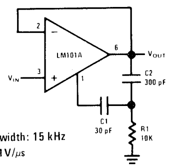


Fast Summing Amplifier



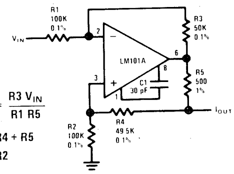
Power Bandwidth: 250 kHz
Small Signal Bandwidth: 3.5 MHz
Slew Rate: 10V/μs

Fast Voltage Follower



Power Bandwidth: 15 kHz
Slew Rate: 1V/μs

Bilateral Current Source

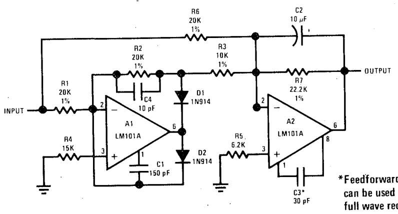


$$I_{OUT} = \frac{R3\ V_{IN}}{R1\ R5}$$

R3 = R4 + R5

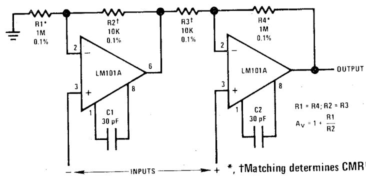
R1 = R2

Fast AC/DC Converter*



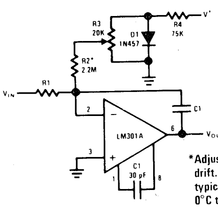
*Feedforward compensation can be used to make a fast full wave rectifier without a filter.

Instrumentation Amplifier



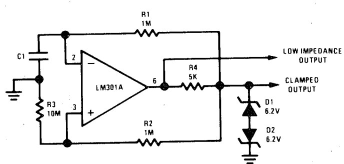
*, †Matching determines CMRR.

Integrator with Bias Current Compensation

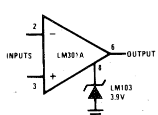


*Adjust for zero integrator drift. Current drift typically 0.1 nA/°C over 0°C to 70°C temperature range.

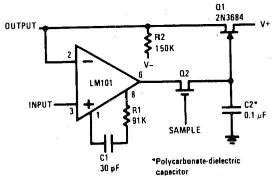
Low Frequency Square Wave Generator



Voltage Comparator for Driving RTL Logic or High Current Driver

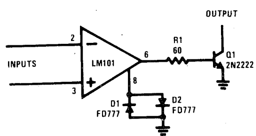


Low Drift Sample and Hold



*Polycarbonate-dielectric capacitor

Voltage Comparator for Driving DTL or TTL Integrated Circuits



**Pin connections shown are for metal can.

Operational Amplifiers/Buffers

LM102/LM202/LM302 voltage followers

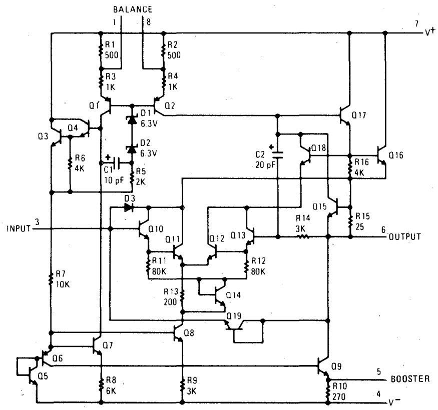
general description

The LM102 series are high-gain operational amplifiers designed specifically for unity-gain voltage follower applications. Built on a single silicon chip, the devices incorporate 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:

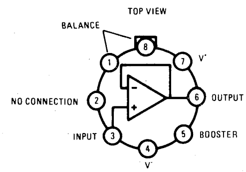
- Fast slewing — 10V/μs
- Low input current — 10 nA (max)
- High input resistance — 10,000 MΩ
- No external frequency compensation required
- Simple offset balancing with optional 1K potentiometer
- Plug-in replacement for both the LM101 and LM709 in voltage follower applications.

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



Metal Can Package

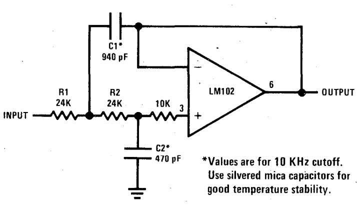


Note: Pin 4 connected to case.

Order Number LM102H, LM202H or LM302H
See Package 11

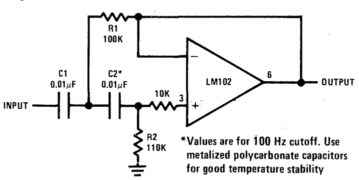
typical applications **

Low Pass Active Filter



*Values are for 10 KHz cutoff. Use silvered mica capacitors for good temperature stability.

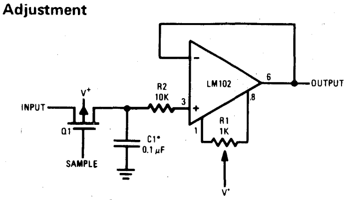
High Pass Active Filter



*Values are for 100 Hz cutoff. Use metalized polycarbonate capacitors for good temperature stability

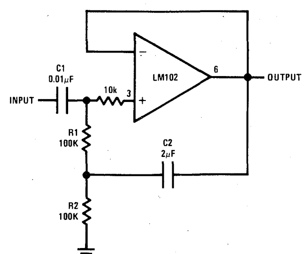
**Pin connections shown are for metal can.

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	LM102	−55°C to 125°C
	LM202	−25°C to 85°C
	LM302	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	LM102			LM202			LM302			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$T_A = 25°C$		2	5		3	10		5	15	mV
Input Bias Current	$T_A = 25°C$		3	10		7	15		10	30	nA
Input Resistance	$T_A = 25°C$	10^{10}	10^{12}		10^{10}	10^{12}		10^{9}	10^{12}		Ω
Input Capacitance				3.0		3.0			3.0		pF
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm15V$, $V_{OUT} = \pm10V$, $R_L = 8\ k\Omega$	0.999	0.9996		0.999	0.9995	1.0	0.9985	0.9995	1.0	V/V
Output Resistance	$T_A = 25°C$		0.8	2.5		0.8	2.5		0.8	2.5	Ω
Supply Current	$T_A = 25°C$		3.5	5.5		3.5	5.5		3.5	5.5	mA
Input Offset Voltage				7.5			15			20	mV
Offset Voltage Temperature Drift			6			15			20		μV/°C
Input Bias Current	$T_A = T_{AMAX}$		3	10		1.5	5.0		3.0	15	nA
	$T_A = T_{AMIN}$		30	100		30	50		20	50	nA
Large Signal Voltage Gain	$V_S = \pm15V$, $V_{OUT} = \pm10V$ $R_L = 10\ k\Omega$	0.999									
Output Voltage Swing	$V_S = \pm15V$, $R_L = 10\ k\Omega$, (Note 5)	±10			±10			±10			V
Supply Current	$T_A = 125°C$		2.6	4.0							mA
Supply Voltage Rejection Ratio	$\pm12V \le V_S \le \pm18V$	60			60			60			dB

Note 1: The maximum junction temperature of the LM102 is 150°C, while that of the LM202 is 100°C and that of the LM302 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.

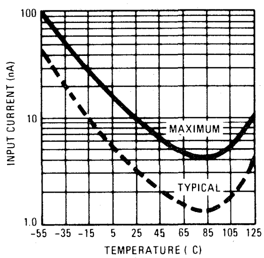
Note 3: Continuous short circuit for the LM102 and LM202 is allowed for case temperatures to 125°C and ambient temperatures to 70°C. For the LM302, continuous short circuit is allowed for 70°C case or 55°C ambient temperature. It is necessary to insert a resistor greater than 2 kΩ in series with the input when the amplifier is driven from low impedance sources to prevent damage when the output is shorted.

Note 4: These specifications apply for $\pm5V \le V_S \le \pm18V$ and $-55°C \le T_A \le 125°C$ for the LM102, $-25°C \le T_A \le 85°C$ for the LM202, and $0°C \le T_A \le 70°C$ for the LM302 unless otherwise specified.

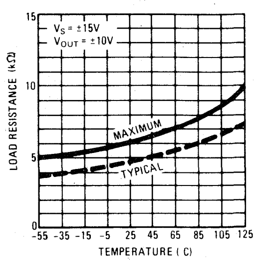
Note 5: Increased output swing under load can be obtained by connecting an external resistor between the booster and V^- terminals. See curve.

guaranteed performance characteristics LM102

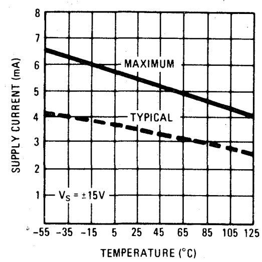
Input Current



Output Swing

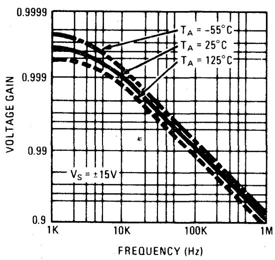


Supply Current

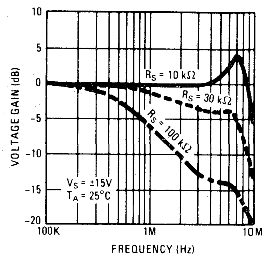


typical performance characteristics LM102

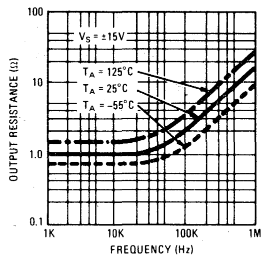
Voltage Gain



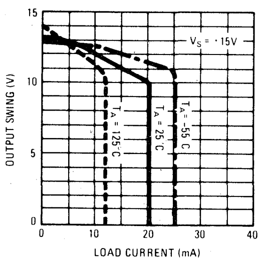
Voltage Gain



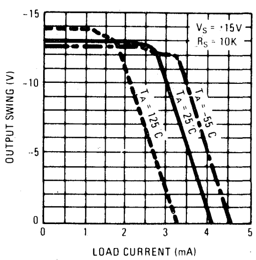
Output Resistance



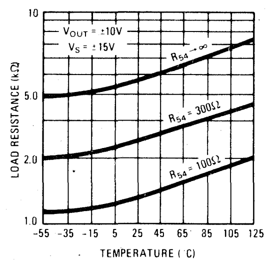
Positive Output Swing



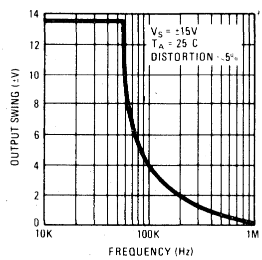
Negative Output Swing



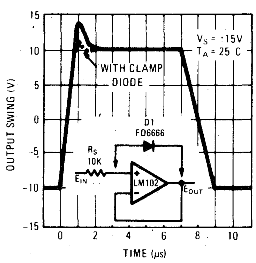
Output Swing



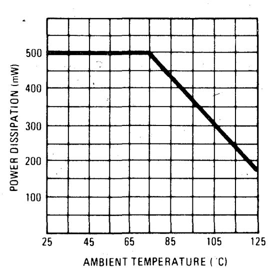
Large Signal Frequency Response



Large Signal Pulse Response



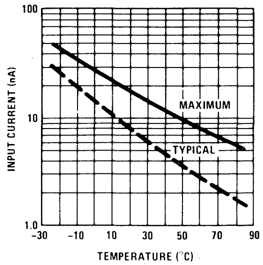
Maximum Power Dissipation



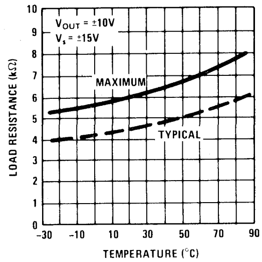
3

guaranteed performance characteristics LM202

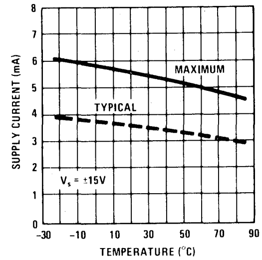
Input Current



Output Swing

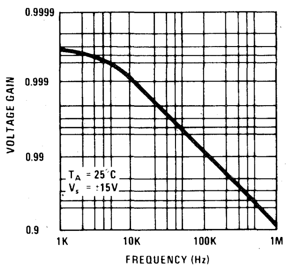


Supply Current

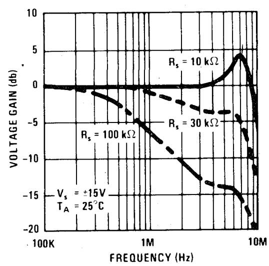


typical performance characteristics LM202

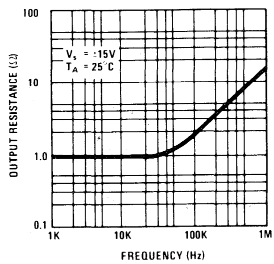
Voltage Gain



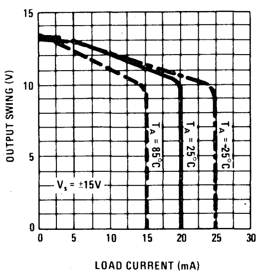
Voltage Gain



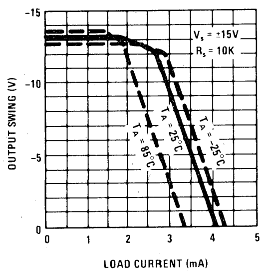
Output Resistance



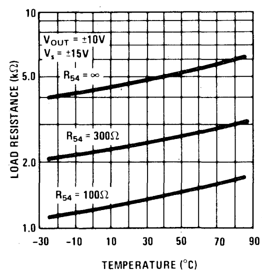
Positive Output Swing



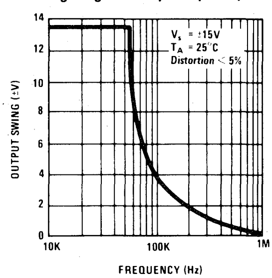
Negative Output Swing



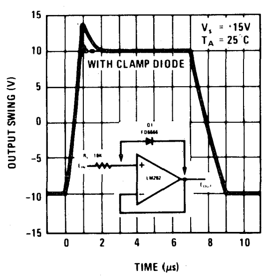
Output Swing



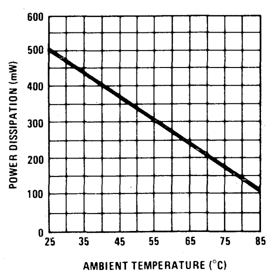
Large Signal Frequency Response



Large Signal Pulse Response

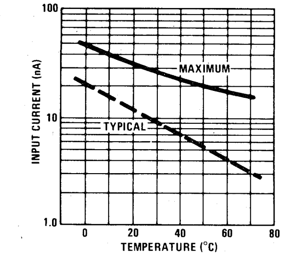


Maximum Power Dissipation

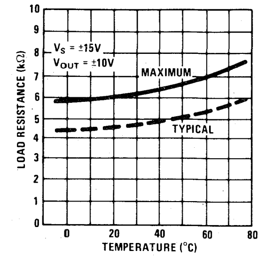


guaranteed performance characteristics LM302

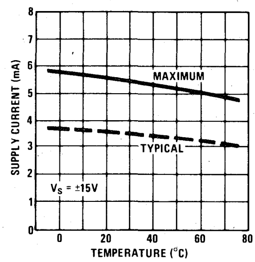
Input Current



Output Swing

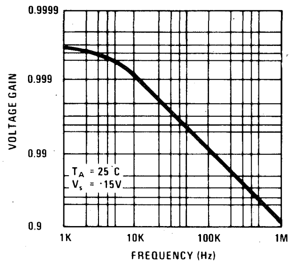


Supply Current

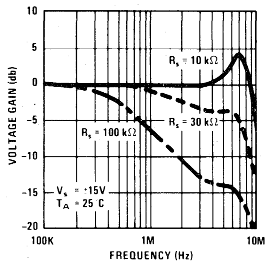


typical performance characteristics LM302

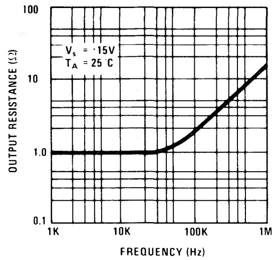
Voltage Gain



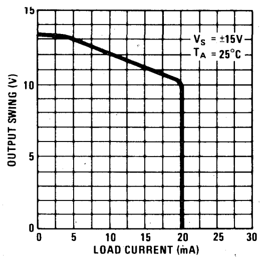
Voltage Gain



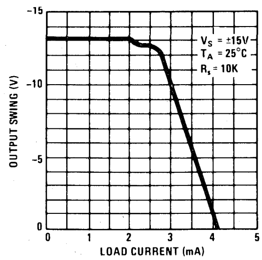
Output Resistance



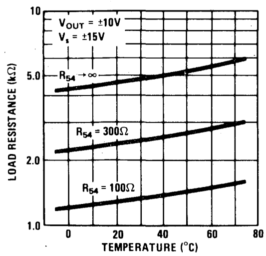
Positive Output Swing



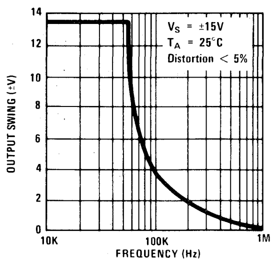
Negative Output Swing



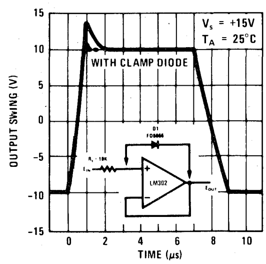
Output Swing



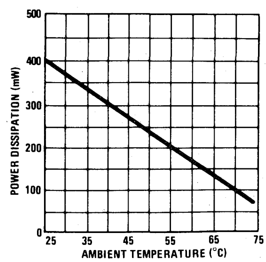
Large Signal Frequency Response



Large Signal Pulse Response



Maximum Power Dissipation



3

Operational Amplifiers/Buffers

LM107/LM207/LM307 operational amplifier

general description

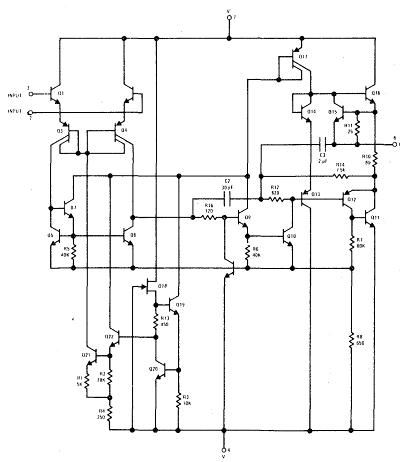
The LM107 series are complete, general purpose operational amplifiers, with the necessary frequency compensation built into the chip. Advanced processing techniques make the input currents a factor of ten lower than industry standards like the 709. Yet, they are a direct, plug-in replacement for the 709, LM101, LM101A and 741.

- Offset voltage 3 mV maximum over temperature
- Input current 100 nA maximum over temperature
- Offset current 20 nA maximum over temperature
- Guaranteed drift characteristics

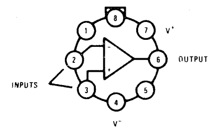
The LM107 series offers the features of the LM101, which makes its application nearly foolproof. In addition, the device provides better accuracy and lower noise in high impedance circuitry. The low input currents also make it particularly well suited for long interval integrators or timers, sample and 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 LM107 is guaranteed over a −55°C to +125°C temperature range, the LM207 from −25°C to +85°C and the LM307 from 0°C to +70°C.

schematic** and connection diagrams



Metal Can Package

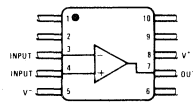


Note: Pin 4 connected to case.

TOP VIEW

Order Number LM107H, LM207H or LM307H
See Package 11

Flat Package

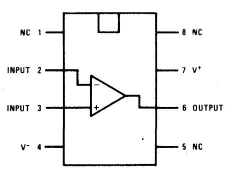


Note: Pin 5 connected to bottom of package.

TOP VIEW

Order Number LM107F or LM207F
See Package 3

Dual-In-Line Package

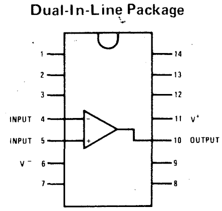


Note: Pin 4 connected to bottom of package.

TOP VIEW

Order Number LM107J, LM207J or LM307J
See Package 15
Order Number LM307N
See Package 20

Dual-In-Line Package



Note: Pin 6 connected to bottom of package.

TOP VIEW

Order Number LM107D, LM207D or LM307D
See Package 2B
Order Number LM107J-14, LM207J-14 or LM307J-14
See Package 16

absolute maximum ratings

	LM107/LM207	LM307
Supply Voltage	±22V	±18V
Power Dissipation (Note 1)	500 mW	500 mW
Differential Input Voltage	±30V	±30V
Input Voltage (Note 2)	±15V	±15V
Output Short-Circuit Duration	Indefinite	Indefinite
Operating Temperature Range		
(LM107)	−55°C to +125°C	0°C to +70°C
(LM207)	−25°C to +85°C	
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C	300°C

	T_{MIN}	T_{MAX}
LM107	−55°C	+125°C
LM207	−25°C	+85°C
LM307	0°C	+70°C

electrical characteristics (Note 3)

PARAMETER	CONDITIONS	LM107/LM207 MIN	LM107/LM207 TYP	LM107/LM207 MAX	LM307 MIN	LM307 TYP	LM307 MAX	UNITS
Input Offset Voltage	$T_A = 25°C$, $R_S \leq 50\ k\Omega$		0.7	2.0		2.0	7.5	mV
Input Offset Current	$T_A = 25°C$		1.5	10		3.0	50	nA
Input Bias Current	$T_A = 25°C$		30	75		70	250	nA
Input Resistance	$T_A = 25°C$	1.5	4.0		0.5	2.0		MΩ
Supply Current	$T_A = 25°C$							
	$V_S = \pm 20V$		1.8	3.0				mA
	$V_S = \pm 15V$					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		25	160		V/mV
Input Offset Voltage	$R_S \leq 50\ k\Omega$			3.0			10	mV
Average Temperature Coefficient of Input Offset Voltage			3.0	15		6.0	30	μV/°C
Input Offset Current				20			70	nA
Average Temperature Coefficient of Input Offset Current	$25°C \leq T_A \leq T_{MAX}$		0.01	0.1		0.01	0.3	nA/°C
	$T_{MIN} \leq T_A \leq 25°C$		0.02	0.2		0.02	0.6	nA/°C
Input Bias Current				100			300	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			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	$V_S = \pm 20V$	±15						V
	$V_S = \pm 15V$				±12			V
Common Mode Rejection Ratio	$R_S \leq 50\ k\Omega$	80	96		70	90		dB
Supply Voltage Rejection Ratio	$R_S \leq 50\ k\Omega$	80	96		70	96		dB

Note 1: The maximum junction temperature of the LM107 is 150°C, and the LM207/LM307 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.

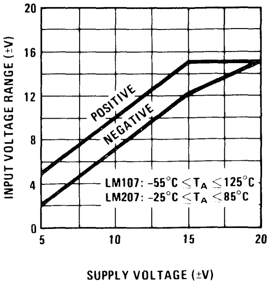
Note 2: For supply voltages less than −15V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: These specifications apply for $\pm 5V \leq V_S \leq +20V$ and $-55°C \leq T_A \leq +125°C$ for the LM107 or $-25°C \leq T_A \leq +85°C$ for the LM207, and $0°C \leq T_A \leq +70°C$ and $\pm 5V \leq V_S \leq \pm 15V$ for the LM307 unless otherwise specified.

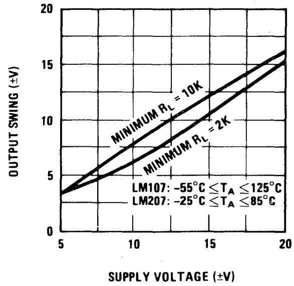
3

guaranteed performance characteristics LM107/LM207

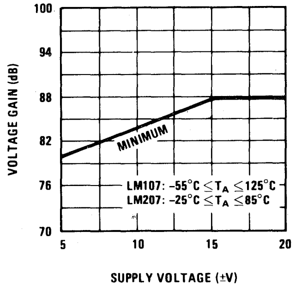
Input Voltage Range



Output Swing

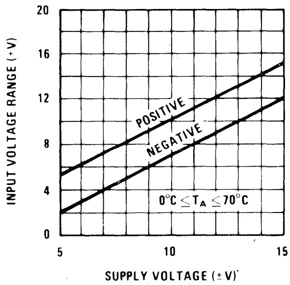


Voltage Gain

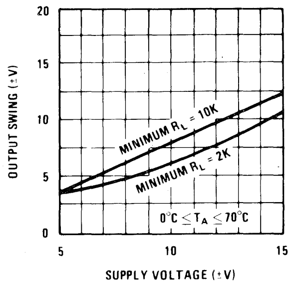


guaranteed performance characteristics LM307

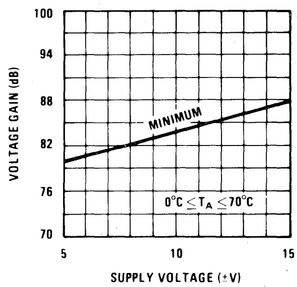
Input Voltage Range



Output Swing

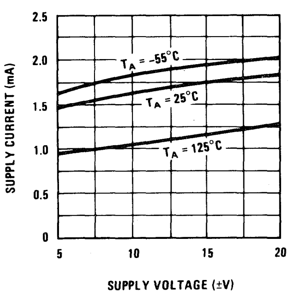


Voltage Gain

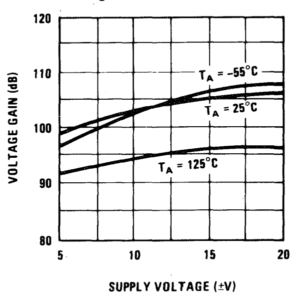


typical performance characteristics

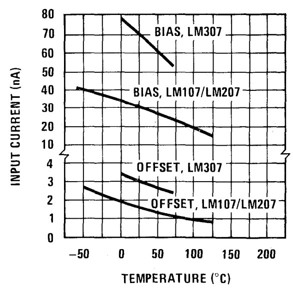
Supply Current



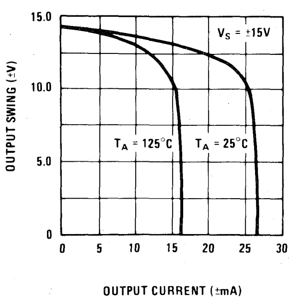
Voltage Gain



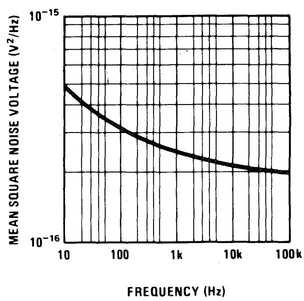
Input Current



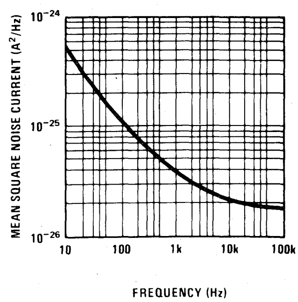
Current Limiting



Input Noise Voltage

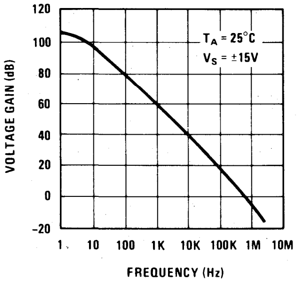


Input Noise Current

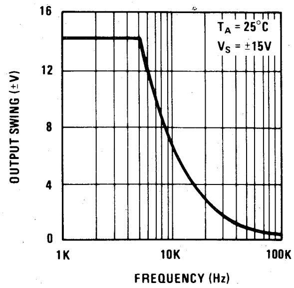


typical performance characteristics (con't)

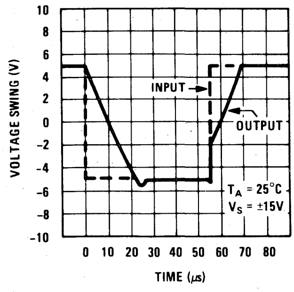
Open Loop Frequency Response



Large Signal Frequency Response

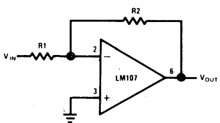


Voltage Follower Pulse Response



typical applications **

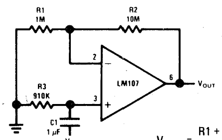
Inverting Amplifier



$V_{OUT} = -\frac{R2}{R1} V_{IN}$

$R_{IN} = R1$

Non-Inverting AC Amplifier

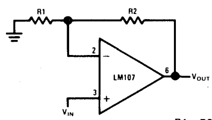


$V_{OUT} = \frac{R1 + R2}{R1} V_{IN}$

$R_{IN} = R3$

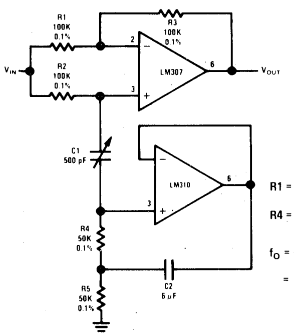
$R3 = R1/R2$

Non-Inverting Amplifier



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

Tunable Notch Filter



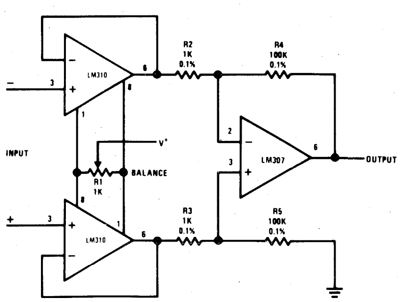
$R1 = R2 = R3$

$R4 = R5 = \frac{R1}{2}$

$f_O = \frac{1}{2\pi\sqrt{C1\ C2\ (R2)^2}}$

$= 60\ Hz$

Differential Input Instrumentation Amplifier



**Pin connections shown are for metal can.

Operational Amplifiers/Buffers

LM108/LM208/LM308 operational amplifier

general description

The LM108 series 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 5μV/°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.

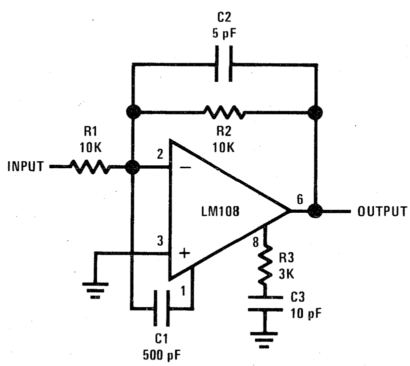
The devices operate with supply voltages from ±2V to ±20V and have sufficient supply rejection to use unregulated supplies. Although the circuit is interchangeable with and uses the same compensation as the LM101A, an alternate compensation scheme can be used to make it particularly insensitive to power 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 LM108 is guaranteed from −55°C to +125°C, the LM208 from −25°C to +85°C, and the LM308 from 0°C to +70°C.

typical applications



LM108 with Feedforward Compensation

absolute maximum ratings

	LM108/LM208	LM308
Supply Voltage	±20V	±18V
Power Dissipation (Note 1)	500 mW	500 mW
Differential Input Current (Note 2)	±10 mA	±10 mA
Input Voltage (Note 3)	±15V	±15V
Output Short-Circuit Duration	Indefinite	Indefinite
Operating Temperature Range (LM108)	−55°C to +125°C	0°C to +70°C
(LM208)	−25°C to +85°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 (Note 4)

PARAMETER	CONDITIONS	LM108/LM208			LM308			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$T_A = 25°C$		0.7	2.0		2.0	7.5	mV
Input Offset Current	$T_A = 25°C$		0.05	0.2		0.2	1	nA
Input Bias Current	$T_A = 25°C$		0.8	2.0		1.5	7	nA
Input Resistance	$T_A = 25°C$	30	70		10	40		MΩ
Supply Current	$T_A = 25°C$		0.3	0.6		0.3	0.8	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm 15V$, $V_{OUT} = \pm 10V$, $R_L \geq 10\ k\Omega$	50	300		25	300		V/mV
Input Offset Voltage				3.0			10	mV
Average Temperature Coefficient of Input Offset Voltage			3.0	15		6.0	30	μV/°C
Input Offset Current				0.4			1.5	nA
Average Temperature Coefficient of Input Offset Current			0.5	2.5		2.0	10	pA/°C
Input Bias Current				3.0			10	nA
Supply Current	$T_A = 125°C$		0.15	0.4				mA
Large Signal Voltage Gain	$V_S = \pm 15V$, $V_{OUT} = \pm 10V$ $R_L \geq 10\ k\Omega$	25			15			V/mV
Output Voltage Swing	$V_S = \pm 15V$, $R_L = 10\ k\Omega$	±13	±14		±13	±14		V
Input Voltage Range	$V_S = \pm 15V$	±13.5			±14			V
Common-Mode Rejection Ratio		85	100		80	100		dB
Supply Voltage Rejection Ratio		80	96		80	96		dB

Note 1: The maximum junction temperature of the LM108 is 150°C, for the LM208, 100°C and for the LM308, 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.

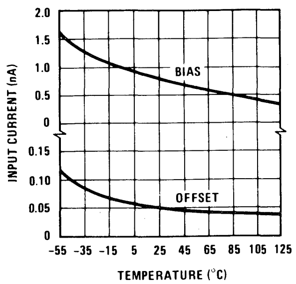
Note 2: The inputs are shunted with back-to-back diodes for overvoltage protection. Therefore, excessive current will flow if a differential input voltage in excess of 1V is applied between the inputs unless some limiting resistance is used.

Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

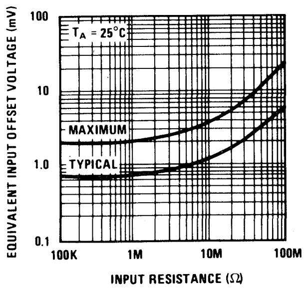
Note 4: These specifications apply for $\pm 5V \leq V_S \leq \pm 20V$ and $-55°C \leq T_A \leq 125°C$, unless otherwise specified. With the LM208, however, all temperature specifications are limited to $-25°C \leq T_A \leq 85°C$, and for the LM308 they are limited to $0°C \leq T_A \leq 70°C$.

typical performance characteristics LM108/LM208

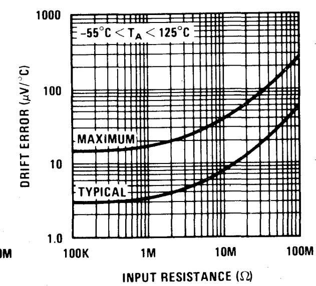
Input Currents



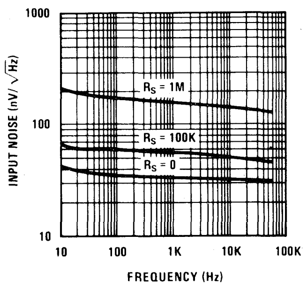
Offset Error



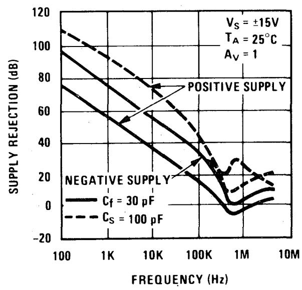
Drift Error



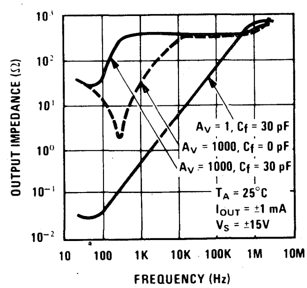
Input Noise Voltage



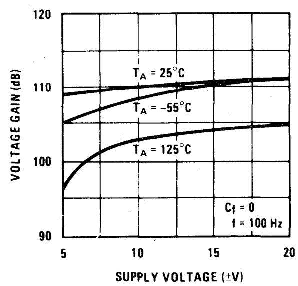
Power Supply Rejection



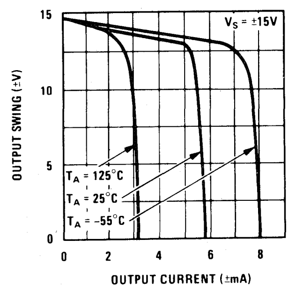
Closed Loop Output Impedance



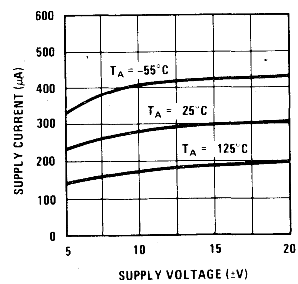
Voltage Gain



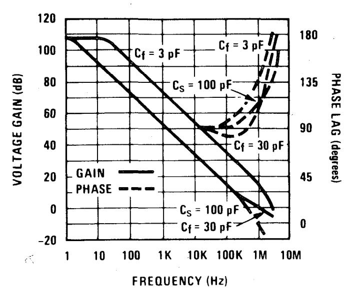
Output Swing



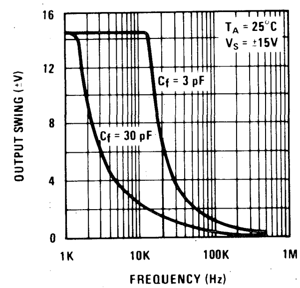
Supply Current



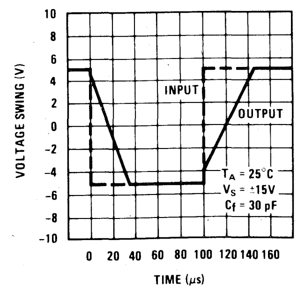
Open Loop Frequency Response



Large Signal Frequency Response

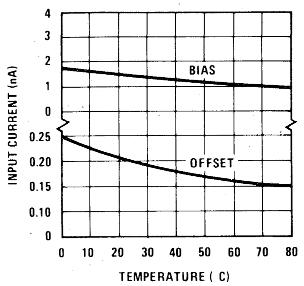


Voltage Follower Pulse Response

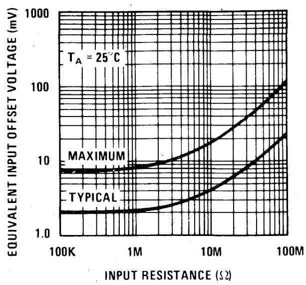


typical performance characteristics LM308

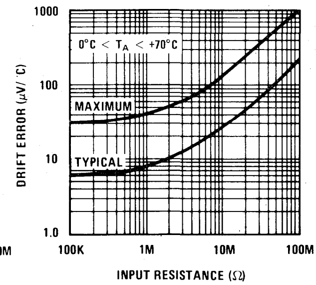
Input Currents



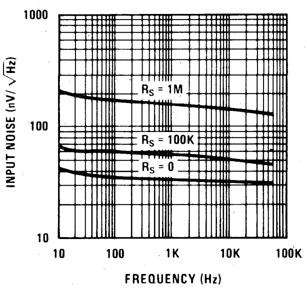
Offset Error



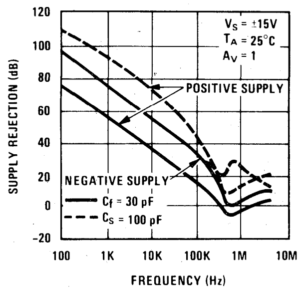
Drift Error



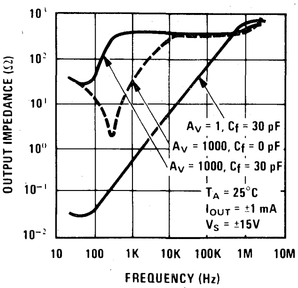
Input Noise Voltage



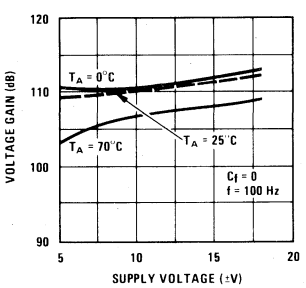
Power Supply Rejection



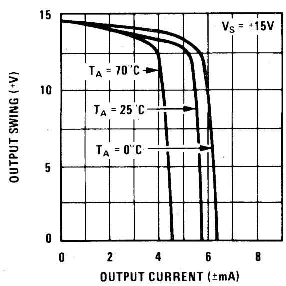
Closed Loop Output Impedance



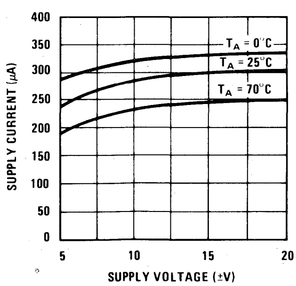
Voltage Gain



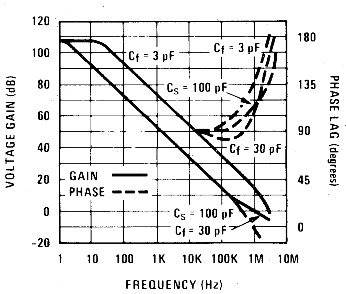
Output Swing



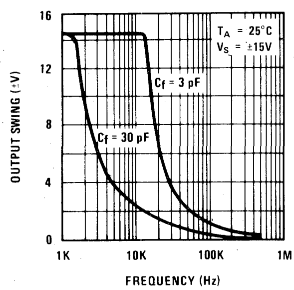
Supply Current



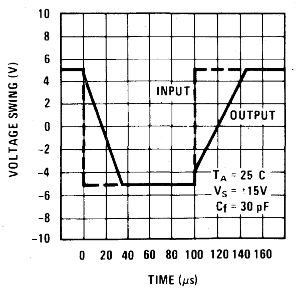
Open Loop Frequency Response



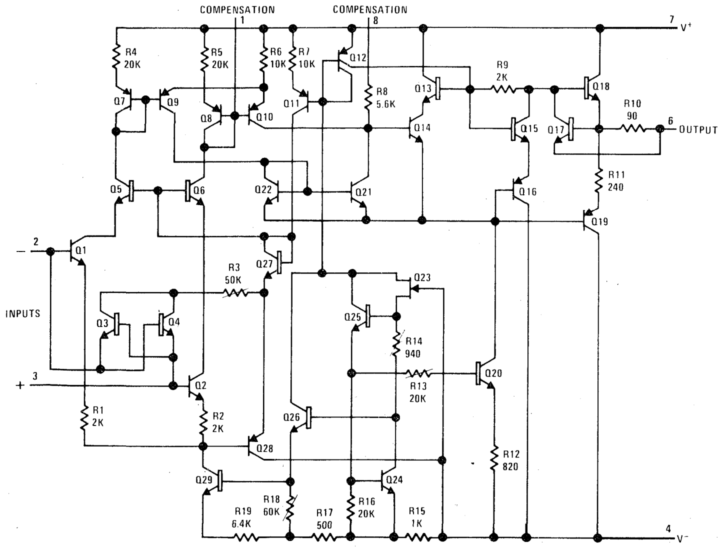
Large Signal Frequency Response



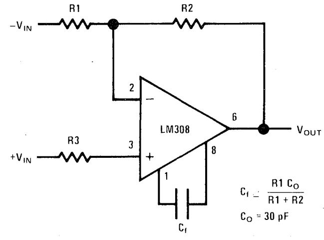
Voltage Follower Pulse Response



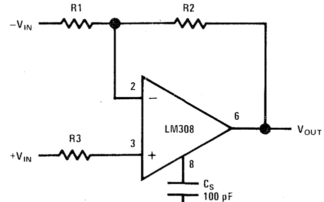
schematic diagram and compensation circuits



Standard Compensation Circuit



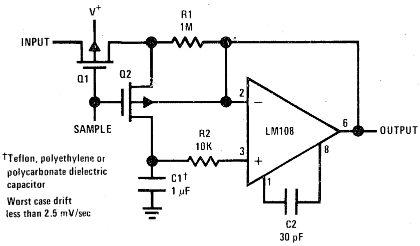
Alternate* Frequency Compensation



*Improves rejection of power supply noise by a factor of ten.

typical applications (con't)

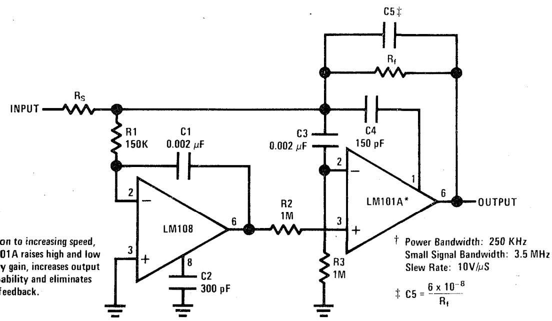
Sample and Hold*



†Teflon, polyethylene or polycarbonate dielectric capacitor

Worst case drift less than 2.5 mV/sec

Fast† Summing Amplifier



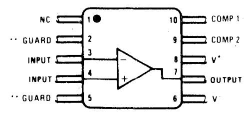
* In addition to increasing speed, the LM101A raises high and low frequency gain, increases output drive capability and eliminates thermal feedback.

† Power Bandwidth: 250 KHz
Small Signal Bandwidth: 3.5 MHz
Slew Rate: 10V/µS

‡ $C5 = \frac{6 \times 10^{-8}}{R_f}$

connection diagrams

Flat Package

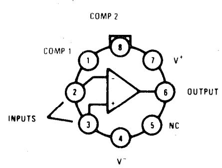


Note: Pin 6 connected to bottom of package.

TOP VIEW

Order Number LM108F or LM208F
See Package 3

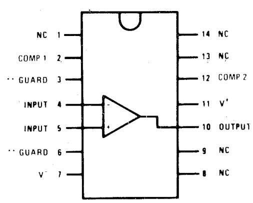
Metal Can Package



Note: Pin 4 connected to case.

Order Number LM108H LM208H or LM308H
See Package 11

Dual-In-Line Package



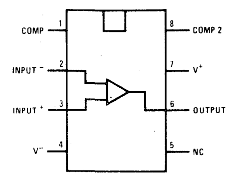
Note: Pin 7 connected to bottom of package.

TOP VIEW

Order Number LM108D, LM208D or LM308D
See Package 1

Order Number LM108J, LM208J or LM308J
See Package 16

Dual-In-Line Package



TOP VIEW

Order Number LM308N
See Package 20

*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.

Operational Amplifiers/Buffers

LM108A/LM208A/LM308A, LM308A-1, LM308A-2 operational amplifiers

general description

The LM108/LM108A series 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 ±18V 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:

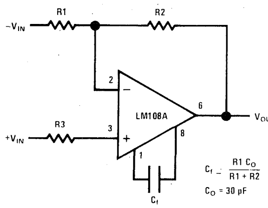
- Offset voltage guaranteed less than 0.5 mV
- Maximum input bias current of 3.0 nA over temperature
- Offset current less than 400 pA over temperature
- Supply current of only 300 μA, even in saturation
- Guaranteed 5 μV/°C drift.
- Guaranteed 1 μV/°C for LM308A-1

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.

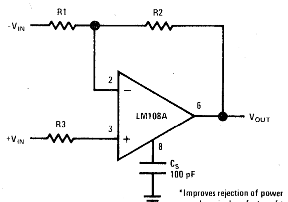
The LM208A is identical to the LM108A, except that the LM208A has its performance guaranteed over a −25°C to 85°C temperature range, instead of −55°C to 125°C. The LM308A devices have slightly-relaxed specifications and performance guaranteed over a 0°C to 70°C temperature range.

compensation circuits

Standard Compensation Circuit

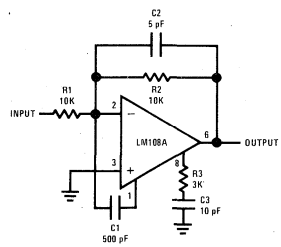


Alternate* Frequency Compensation



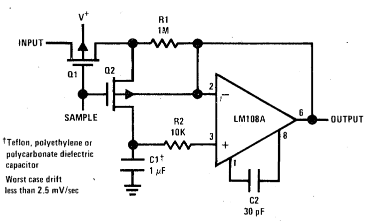
*Improves rejection of power supply noise by a factor of ten.

Feedforward Compensation



typical applications

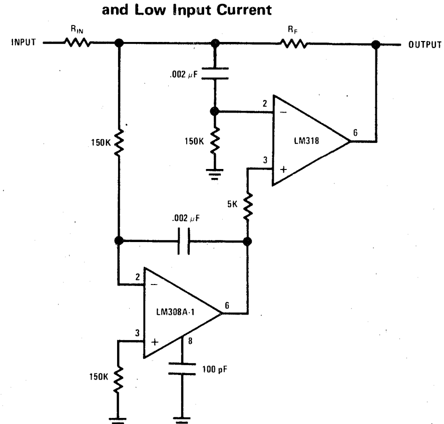
Sample and Hold*



†Teflon, polyethylene or polycarbonate dielectric capacitor

Worst case drift less than 2.5 mV/sec

High Speed Amplifier with Low Drift and Low Input Current



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

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	$T_A = 25°C$, $V_S = ±15V$ $V_{OUT} = ±10V$, $R_L \geq 10\ k\Omega$	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	$V_S = ±15V$, $V_{OUT} = ±10V$ $R_L \geq 10\ k\Omega$	40			V/mV
Output Voltage Swing	$V_S = ±15V$, $R_L = 10\ k\Omega$	±13	±14		V
Input Voltage Range	$V_S = ±15V$	±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 $±5V \leq V_S \leq ±20V$ 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, LM308A-1, LM308A-2

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	$T_A = 25°C$, $V_S = ±15V$		0.3	0.8	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = ±15V$, $V_{OUT} = ±10V$, $R_L \geq 10\ k\Omega$	80	300		V/mV
Input Offset Voltage	$V_S = ±15V$, $R_S = 100\Omega$				
LM308A				0.73	mV
LM308A-1				0.54	mV
LM308A-2				0.59	mV
Average Temperature Coefficient of Input Offset Voltage	$V_S = ±15V$, $R_S = 100\Omega$				
LM308A			2.0	5.0	μV/°C
LM308A-1			0.6	1.0	μV/°C
LM308A-2			1.3	2.0	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	$V_S = ±15V$, $V_{OUT} = ±10V$ $R_L \geq 10\ k\Omega$	60			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		96	110		dB
Supply Voltage Rejection Ratio		96	110		dB

Note 1: The maximum junction temperature of the LM308A, LM308-1 and LM308-2 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.

application hints

A very low drift amplifier poses some uncommon application and testing problems. Many sources of error can cause the apparent circuit drift to be much higher than would be predicted.

Thermocouple effects caused by temperature gradient across dissimilar metals are perhaps the worst offenders. Only a few degrees gradient can cause hundreds of microvolts of error. The two places this shows up, generally, are the package-to printed circuit board interface and temperature gradients across resistors. Keeping package leads short and the two input leads close together help greatly.

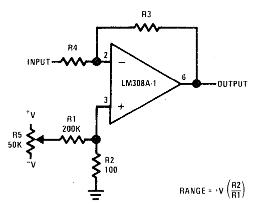
Resistor choice as well as physical placement is important for minimizing thermocouple effects. Carbon, oxide film and some metal film resistors can cause large thermocouple errors. Wirewound resistors of evenohm or manganin are best since they only generate about 2 $\mu V/^{\circ}C$ referenced to copper. Of course, keeping the resistor ends at the same temperature is important. Generally, shielding a low drift stage electrically and thermally will yield good results.

Resistors can cause other errors besides gradient generated voltages. If the gain setting resistors do not track with temperature a gain error will result. For example a gain of 1000 amplifier with a constant 10 mV input will have a 10V output. If the resistors mistrack by 0.5% over the operating temperature range, the error at the output is 50 mV. Referred to input, this is a 50 μV error. All of the gain fixing resistor should be the same material.

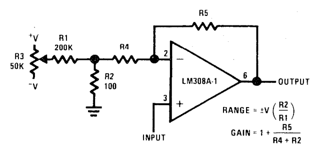
Offset balancing the LM308A-1 can be a problem since there is no easy offset adjustment incorporated into the circuit. These devices are selected for low drift with no offset adjustment to the internal circuitry, so any change of the internal currents will change the drift – probably for the worse. Offset adjustment must be done at the input. The three most commonly needed circuits are shown here.

Testing low drift amplifiers is also difficult. Standard drift testing technique such as heating the device in an oven and having the leads available through a connector, thermoprobe, or the soldering iron method – do not work. Thermal gradients cause much greater errors than the amplifier drift. Coupling microvolt signal through connectors is especially bad since the temperature difference across the connector can be 50°C or more. The device under test along with the gain setting resistor should be isothermal. The following circuit will yield good results if well constructed.

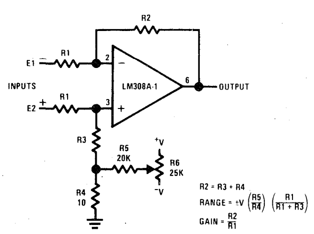
Offset Adjustment for Inverting Amplifiers



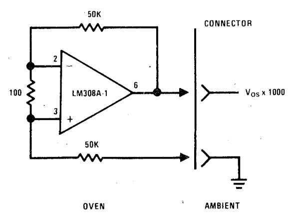
Offset Adjustment for Non-Inverting Amplifiers



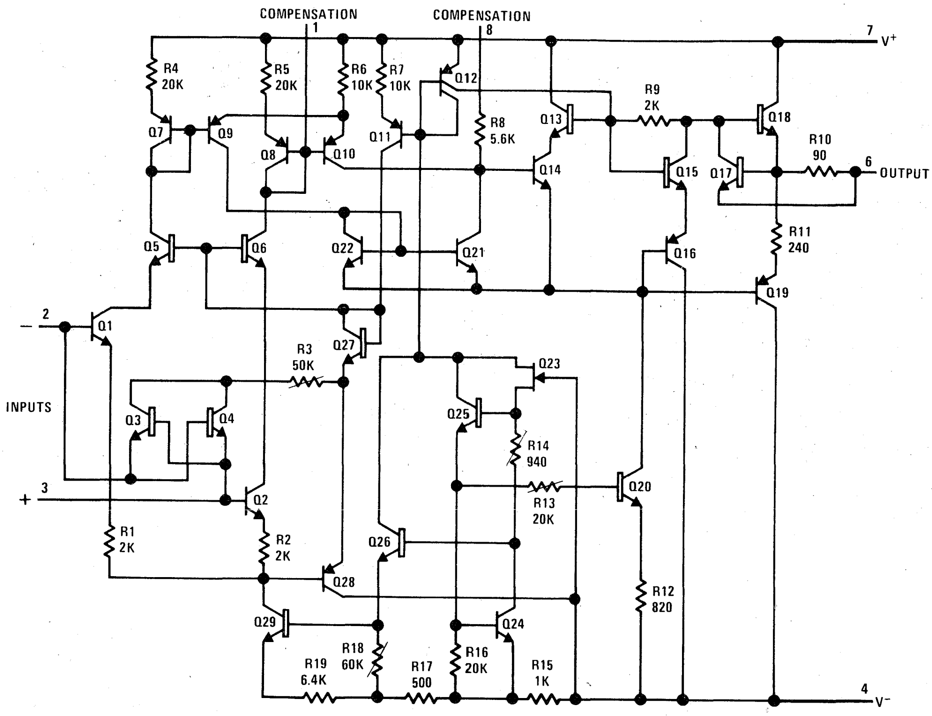
Offset Adjustment for Differential Amplifiers



Drift Measurement Circuit



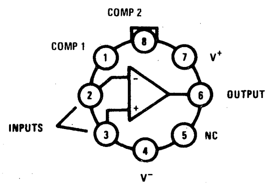
schematic diagram*



*Pin connections shown on schematic diagram refer to TO-5 package.

connection diagrams

Metal Can Package

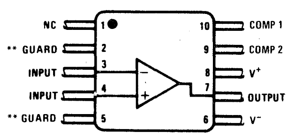


Note: Pin 4 connected to case.

**Unused pin (no internal connection) to allow for input anti-leakage guard ring on printed circuit board layout.

Order Number LM108AH, LM208AH, LM308AH, LM308AH-1 or LM308AH-2
See Package 11

Flat Package

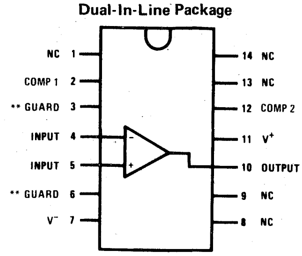


Note: Pin 6 connected to bottom of package.

TOP VIEW

Order Number LM108AF or LM208AF
See Package 3

Dual-In-Line Package



Note: Pin 7 connected to bottom of package.

TOP VIEW

Order Number LM108AD, LM208AD or LM308AD
See Package 1
Order Number LM108AJ, LM208AJ, or LM308AJ
See Package 16

3

Operational Amplifiers/Buffers

LM110/LM210/LM310 voltage follower

general description

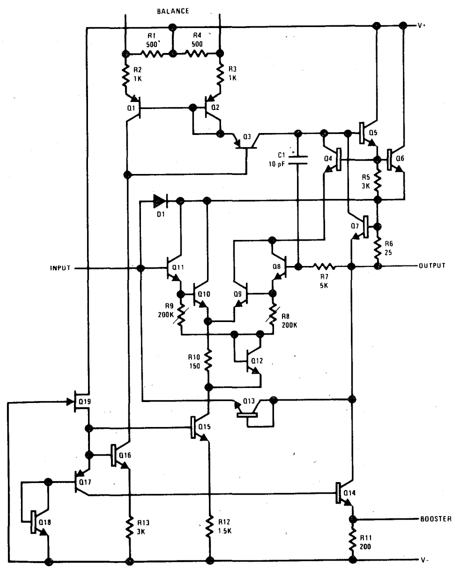
The LM110 series are monolithic operational amplifiers internally connected as unity-gain non-inverting amplifiers. They use super-gain transistors in the input stage to get low bias current without sacrificing speed. Directly interchangeable with 101, 741 and 709 in voltage follower applications, these 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

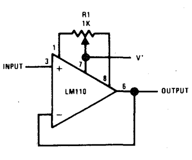
The LM110 series are useful in fast sample and hold circuits, active filters, or as general-purpose buffers. Further, the frequency response is enough better than standard IC amplifiers that the followers can be included in the feedback loop without introducing instability. They are plug-in replacements for the LM102 series voltage followers, offering lower offset voltage, drift, bias current and noise in addition to higher speed and wider operating voltage range.

The LM110 is specified over a temperature range $-55^\circ C \leq T_A \leq +125^\circ C$, the LM210 from $-25^\circ C \leq T_A \leq +85^\circ C$ and the LM310 from $0^\circ C \leq T_A \leq +70^\circ C$.

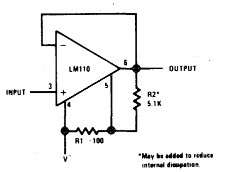
schematic diagram



auxiliary circuits

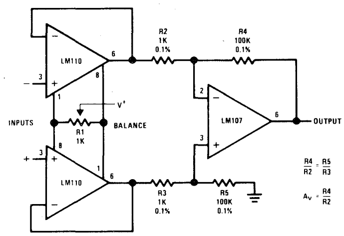


Offset Balancing Circuit

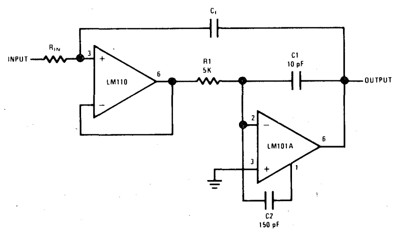


Increasing Negative Swing Under Load

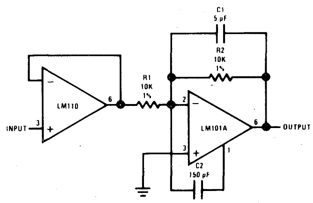
typical applications



Differential Input Instrumentation Amplifier



Fast Integrator with Low Input Current



Fast Inverting Amplifier with High Input Impedance

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
	LM310	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	LM110			LM210			LM310			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$T_A = 25°C$		1.5	4.0		1.5	4.0		2.5	7.5	mV
Input Bias Current	$T_A = 25°C$		1.0	3.0		1.0	3.0		2.0	7.0	μV nA
Input Resistance	$T_A = 25°C$	10^{10}	10^{12}		10^{10}	10^{12}		10^{10}	10^{12}		Ω
Input Capacitance			1.5			1.5			1.5		pF
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = ±15V$ $V_{OUT} = ±10V$, $R_L = 8\ k\Omega$	0.999	0.9999		0.999	0.9999		0.999	0.9999		V/V
Output Resistance	$T_A = 25°C$		0.75	2.5		0.75	2.5		0.75	2.5	Ω
Supply Current	$T_A = 25°C$		3.9	5.5		3.9	5.5		3.9	5.5	mA
Input Offset Voltage				6.0			6.0			10	mV
Offset Voltage Temperature Drift	$-55°C \leq T_A \leq +85°C$		6			6					μV/°C
	$T_A = 125°C$		12			12					μV/°C
	$0°C \leq T_A \leq +70°C$								10		μV/°C
Input Bias Current				10			10			10	nA
Large Signal Voltage Gain	$V_S = ±15V$, $V_{OUT} = ±10V$ $R_L = 10\ k\Omega$	0.999			0.999			0.999			V/V
Output Voltage Swing (Note 5)	$V_S = ±15V$, $R_L = 10\ k\Omega$	±10			±10			±10			V
Supply Current	$T_A = 125°C$		2.0	4.0		2.0	4.0				mA
Supply Voltage Rejection Ratio	$±5V \leq V_S \leq ±18V$	70	80		70	80		70	80		dB

Note 1: The maximum junction temperature of the LM110 is 150°C, of the LM210 is 100°C, and 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.

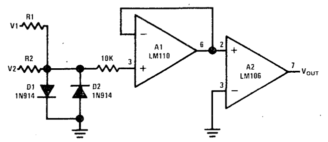
Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: Continuous short circuit for the LM110 and LM210 is allowed for case temperatures to 125°C and ambient temperatures to 70°C, and for the LM310, 70°C case temperature or 55°C ambient temperature. 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.

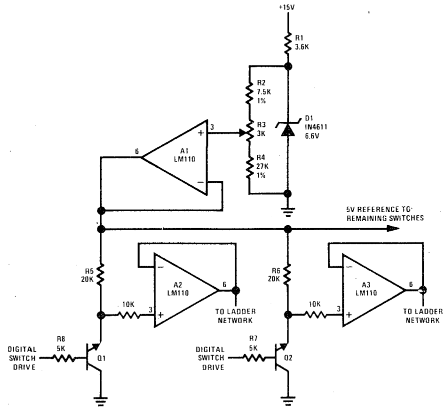
Note 4: These specifications apply for $±5V \leq V_S \leq ±18V$ and $-55°C \leq T_A \leq 125°C$ for the LM110, $-25°C \leq T_A \leq 85°C$ for the LM210, and $0°C \leq T_A \leq 70°C$ for the LM310 unless otherwise specified.

Note 5: Increased output swing under load can be obtained by connecting an external resistor between the booster and V⁻ terminals. See curve.

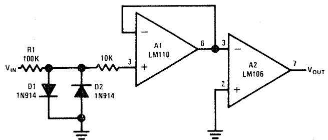
typical applications



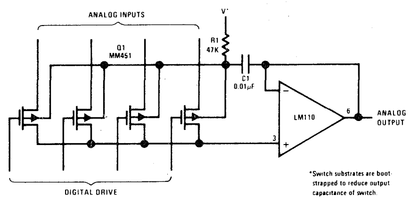
Comparator for Signals of Opposite Polarity



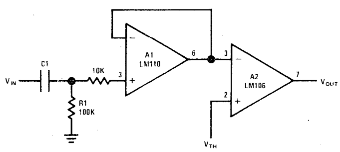
Driver for A/D Ladder Network



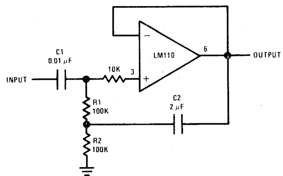
Zero Crossing Detector



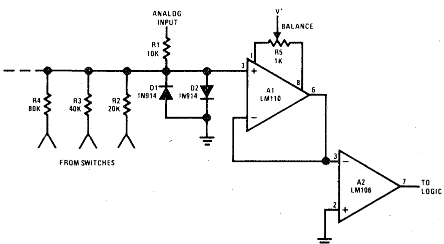
Buffer for Analog Switch*



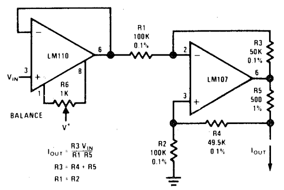
Comparator for AC Coupled Signals



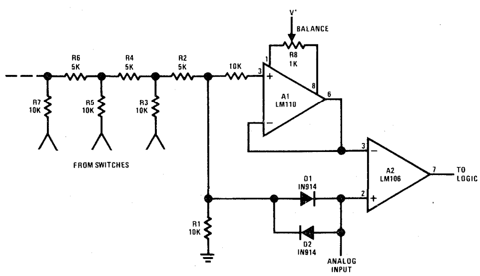
High Input Impedance AC Amplifier



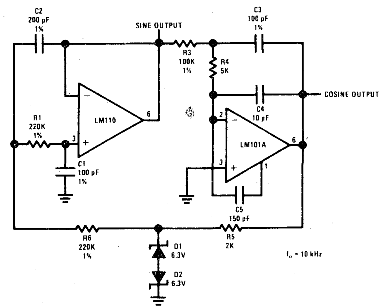
Comparator for A/D Converter
Using a Binary-Weighted Network



Bilateral Current Source

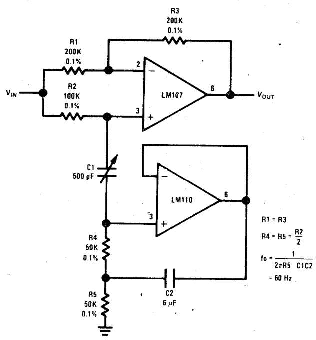


Comparator for A/D Converter
Using a Ladder Network

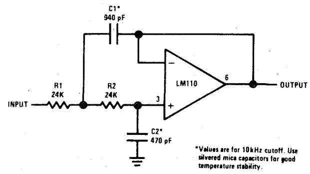


Sine Wave Oscillator

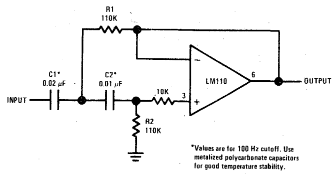
typical applications



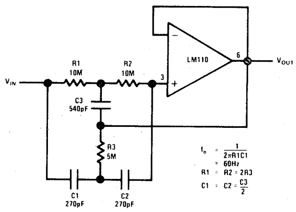
Tunable Notch Filter



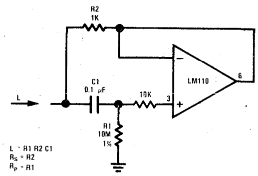
Low Pass Active Filter



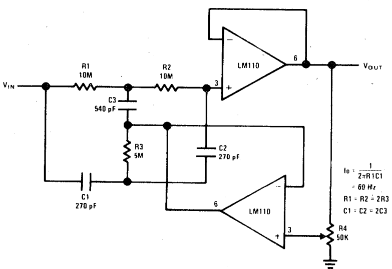
High Pass Active Filter



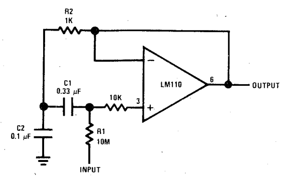
High Q Notch Filter



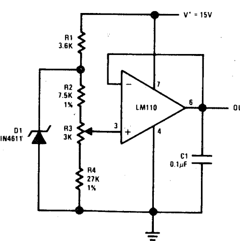
Simulated Inductor



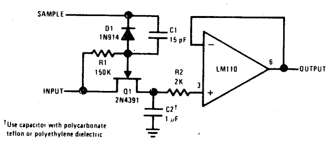
Adjustable Q Notch Filter



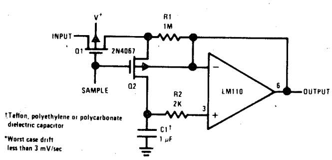
Bandpass Filter



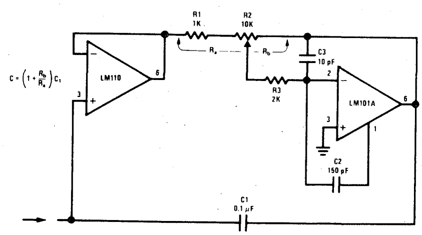
Buffered Reference Source



Sample and Hold



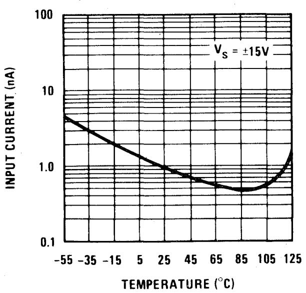
Low Drift Sample and Hold*



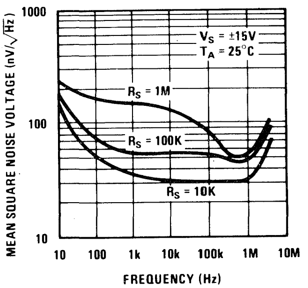
Variable Capacitance Multiplier

typical performance characteristics (LM110/LM210)

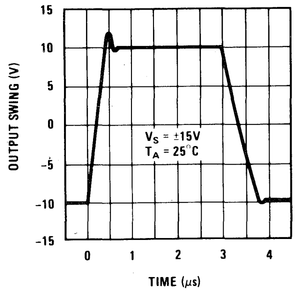
Input Current



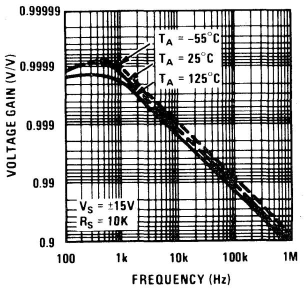
Output Noise Voltage



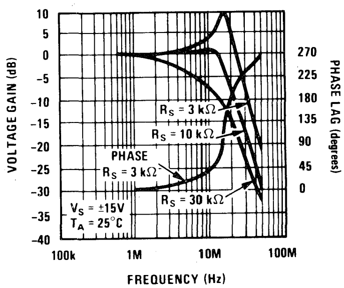
Large Signal Pulse Response



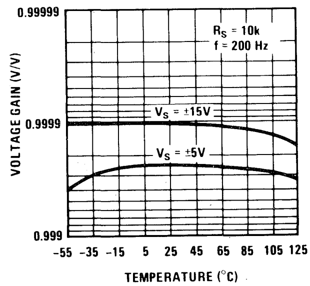
Voltage Gain



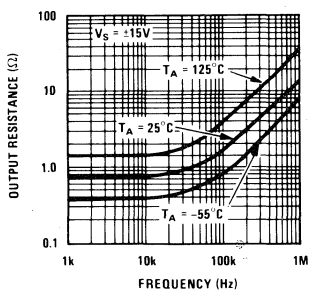
Voltage Gain



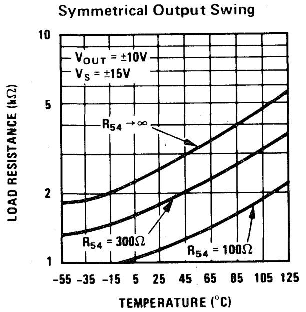
Voltage Gain



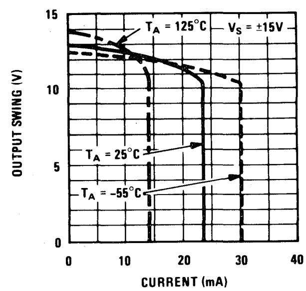
Output Resistance



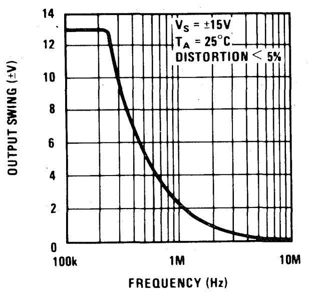
Symmetrical Output Swing



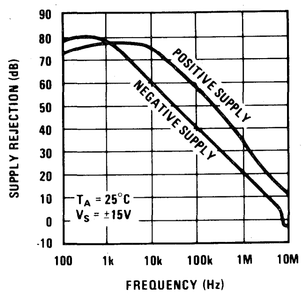
Positive Output Swing



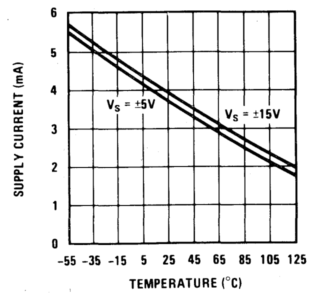
Large Signal Frequency Response



Power Supply Rejection

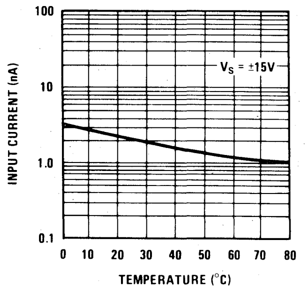


Supply Current

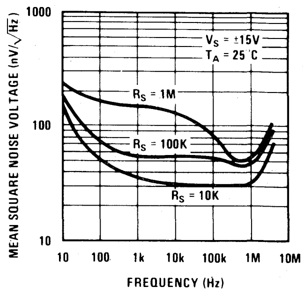


typical performance characteristics (LM310)

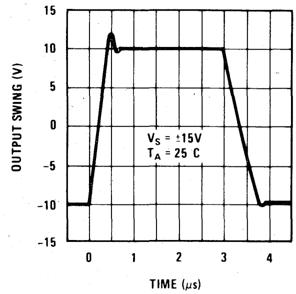
Input Current



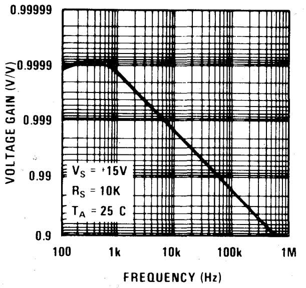
Output Noise Voltage



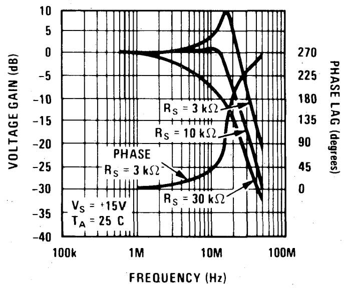
Large Signal Pulse Response



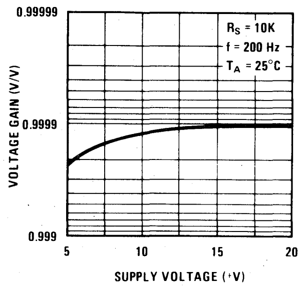
Voltage Gain



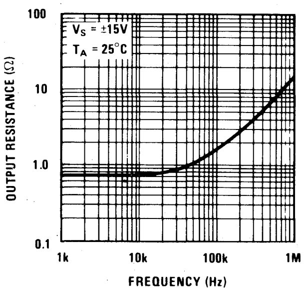
Voltage Gain



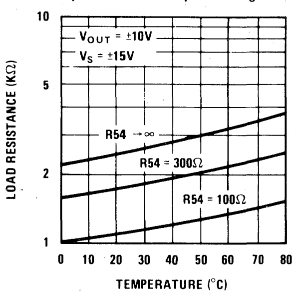
Voltage Gain



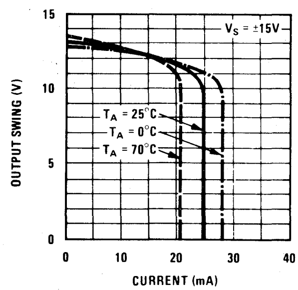
Output Resistance



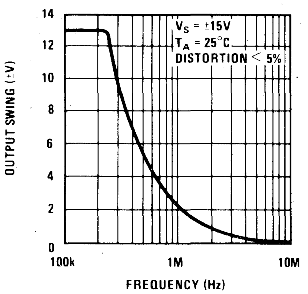
Symmetrical Output Swing



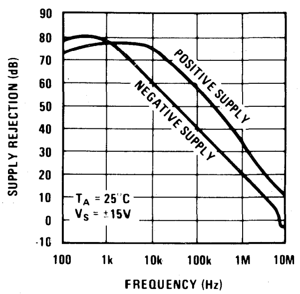
Positive Output Swing



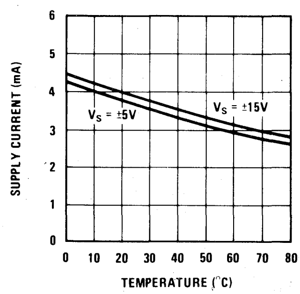
Large Signal Frequency Response



Power Supply Rejection

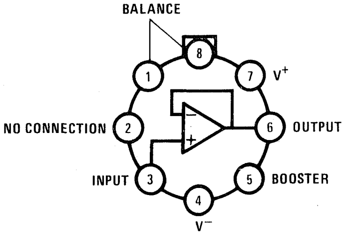


Supply Current



connection diagrams

Flat Package

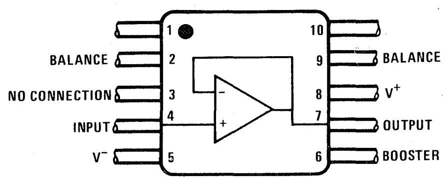


NOTE: Pin 4 connected to case.

TOP VIEW

Order Number LM110H, LM210H or LM310H
See Package 11

Metal Can Package

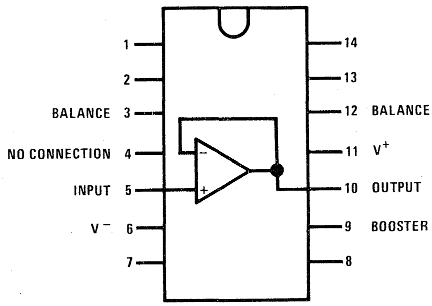


NOTE: Pin 5 connected to bottom of package.

TOP VIEW

Order Number LM110F, LM210F or LM310F
See Package 3

Dual-In-Line Package



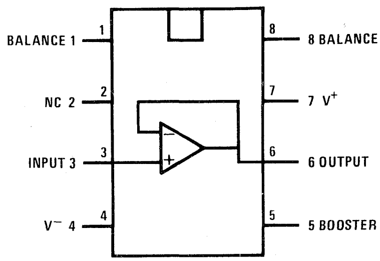
NOTE: Pin 6 connected to bottom of package.

TOP VIEW

Order Number LM110D, LM210D or LM310D
See Package 1

Order Number LM110J, LM210J or LM310J
See Package 16

Dual-In-Line Package



TOP VIEW

Order Number LM310N
See Package 20

Order Number LM310J-8
See Package 15

Operational Amplifiers/Buffers

LM112/LM212/LM312 operational amplifier

general description

The LM112 series 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:

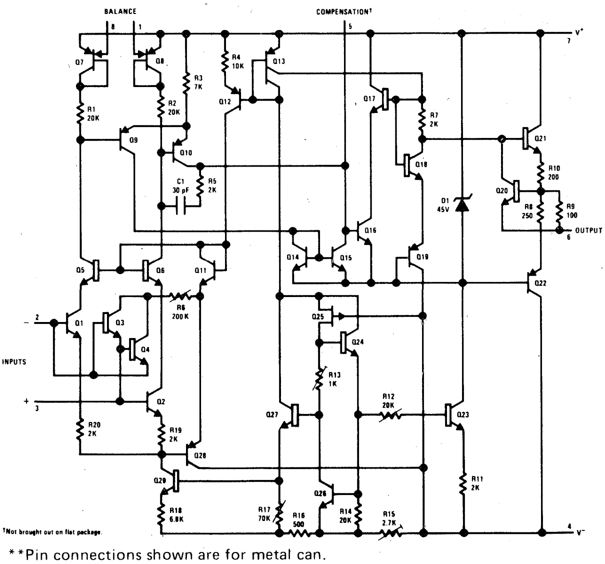
- Maximum input bias current of 3 nA over temperature
- Offset current less than 400 pA over temperature
- Low noise
- Guaranteed drift specifications

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. The LM312 is guaranteed over a 0°C to 70°C temperature range.

3

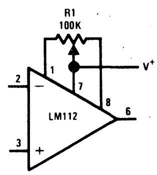
schematic diagram**



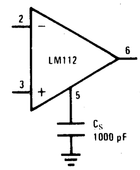
**Pin connections shown are for metal can.

auxiliary circuits**

Offset Balancing

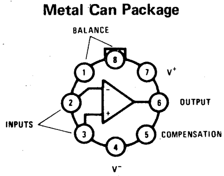


Overcompensation for Greater Stability Margin



connection diagrams

Metal Can Package

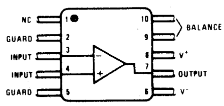


Note: Pin 4 connected to case.

TOP VIEW

Order Number LM112H, LM212H, or LM312H
See Package 11

Flat Package

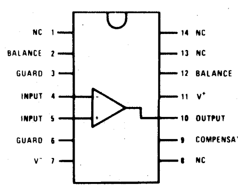


Note: Pin 6 connected to bottom of package.
Compensation terminal not brought out on flat package.

TOP VIEW

Order Number LM112F, LM212F or LM312F
See Package 3

Dual-In-Line Package



Note: Pin 7 connected to bottom of package.

TOP VIEW

Order Number LM112D, LM212D or LM312D
See Package 1

absolute maximum ratings

	LM112/LM212	LM312
Supply Voltage	±20V	±18V
Power Dissipation (Note 1)	500 mW	500 mW
Differential Input Current (Note 2)	±10 mA	±10 mA
Input Voltage (Note 3)	±15V	±15V
Output Short-Circuit Duration	Indefinite	Indefinite
Operating Temperature Range		0°C to +70°C
LM112	−55°C to +125°C	
LM212	−25°C to +85°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 (Note 4)

PARAMETER	CONDITIONS	LM112/LM212			LM312			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$T_A = 25°C$		0.7	2.0		2.0	7.5	mV
Input Offset Current	$T_A = 25°C$		0.05	0.2		0.2	1	nA
Input Bias Current	$T_A = 25°C$		0.8	2.0		1.5	7	nA
Input Resistance	$T_A = 25°C$	30	70		10	40		MΩ
Supply Current	$T_A = 25°C$		0.3	0.6		0.3	0.8	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm15V$ $V_{OUT} = \pm10V$, $R_L \geq 10\ k\Omega$	50	300		25	300		V/mV
Input Offset Voltage				3.0			10	mV
Average Temperature Coefficient of Input Offset Voltage			3.0	15		6.0	30	μV/°C
Input Offset Current				0.4			1.5	nA
Average Temperature Coefficient of Input Offset Current			0.5	2.5		2.0	10	pA/°C
Input Bias Current				3.0			10	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			15			V/mV
Output Voltage Swing	$V_S = \pm15V$, $R_L = 10\ k\Omega$	±13	±14		±13	±14		V
Input Voltage Range	$V_S = \pm15V$	±13.5			±14			V
Common-Mode Rejection Ratio		85	100		80	100		dB
Supply Voltage Rejection Ratio		80	96		80	96		dB

Note 1: The maximum junction temperature of the LM112 is 150°C, LM212 is 100°C and 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.

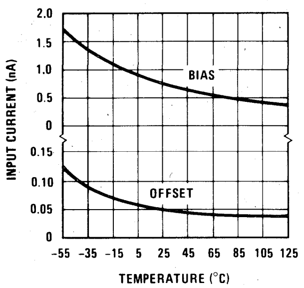
Note 2: The inputs are shunted with shunt diodes for overvoltage protection. Therefore, excessive current will flow if a differential input voltage in excess of 1V is applied between the inputs unless some limiting resistance is used.

Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

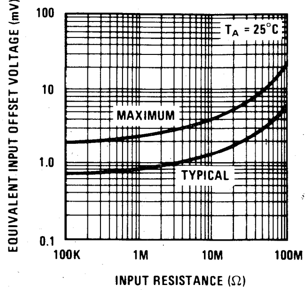
Note 4: These specifications apply for $\pm5V \leq V_S \leq \pm20V$ and $-55°C \leq T_A \leq +125°C$ (LM112), $-25°C \leq T_A \leq +85°C$ (LM212), $\pm5V \leq V_S \leq \pm15V$ and $0°C \leq T_A \leq +70°C$ (LM312) unless otherwise noted.

typical performance characteristics LM112/LM212

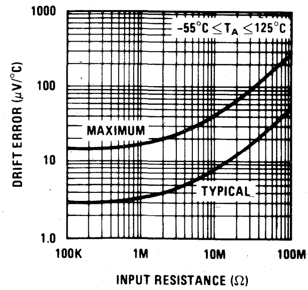
Input Currents



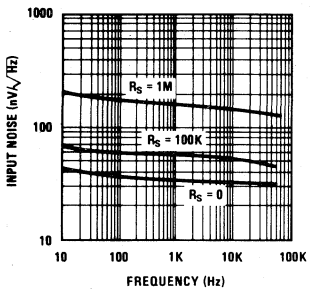
Offset Error



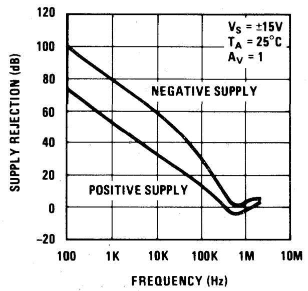
Drift Error



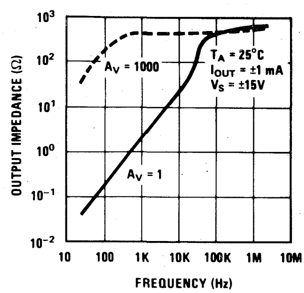
Input Noise Voltage



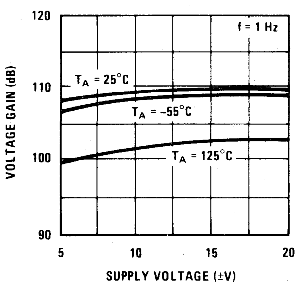
Power Supply Rejection



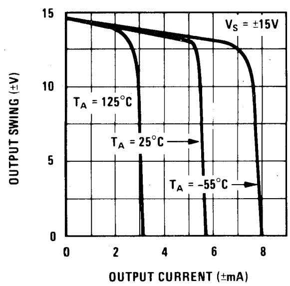
Closed Loop Output Impedance



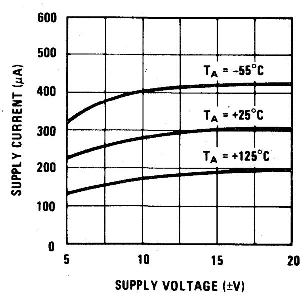
Voltage Gain



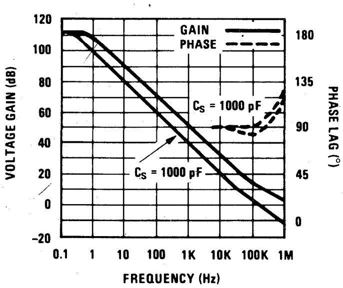
Output Swing



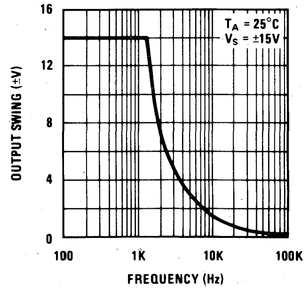
Supply Current



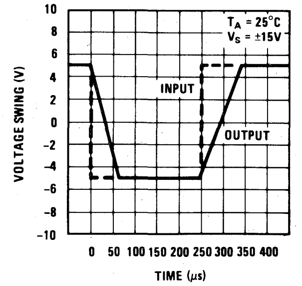
Open Loop Frequency Response



Large Signal Frequency Response



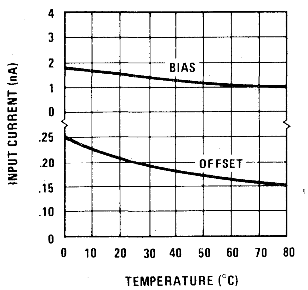
Voltage Follower Pulse Response



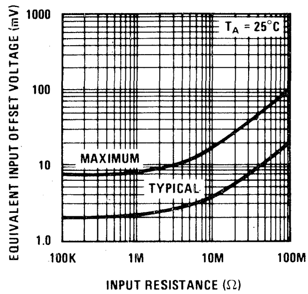
3

typical performance characteristics LM312

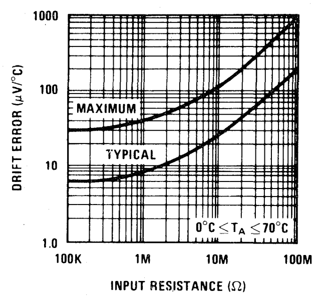
Input Currents



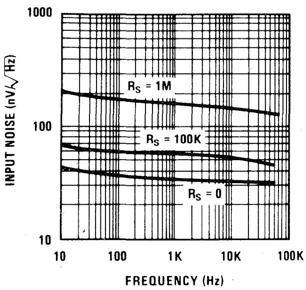
Offset Error



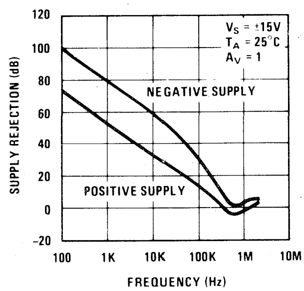
Drift Error



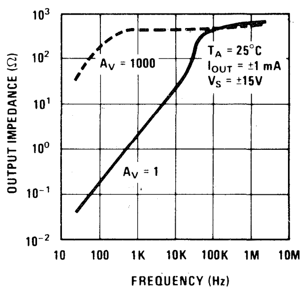
Input Noise Voltage



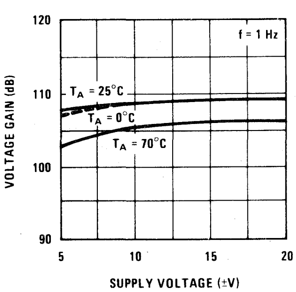
Power Supply Rejection



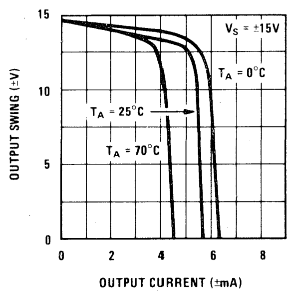
Closed Loop Output Impedance



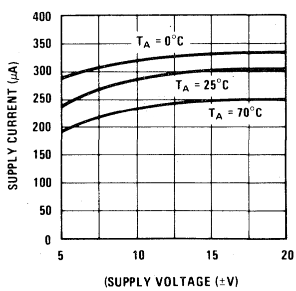
Voltage Gain



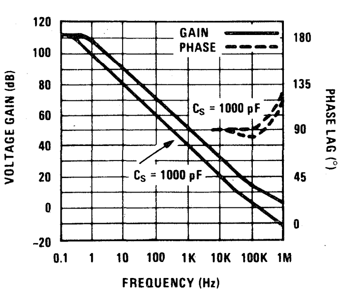
Output Swing



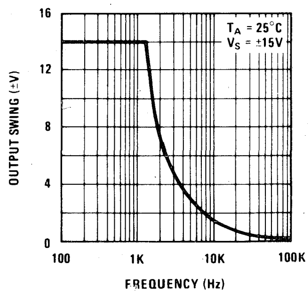
Supply Current



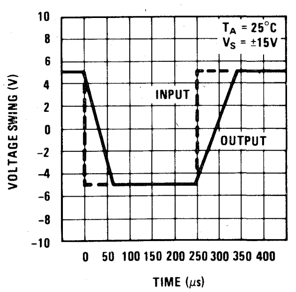
Open Loop Frequency Response



Large Signal Frequency Response



Voltage Follower Pulse Response



Operational Amplifiers/Buffers

LM118/LM218/LM318 operational amplifier

general description

The LM118 series 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

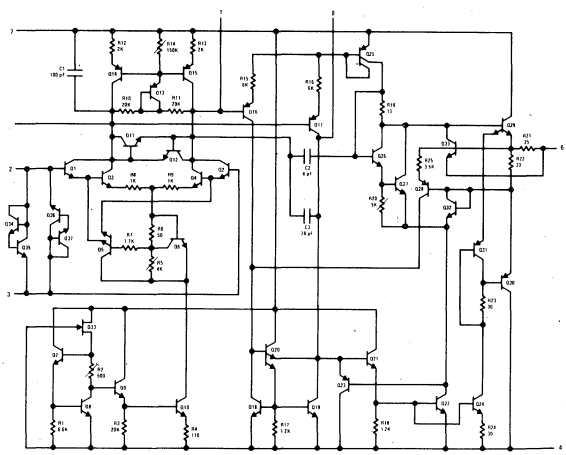
- 15 MHz small signal bandwidth
- Guaranteed 50V/μs slew rate
- Maximum bias current of 250 nA
- Operates from supplies of ±5V to ±20V
- Internal frequency compensation
- Input and output overload protected
- Pin compatible with general purpose op amps

The LM118 series 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.

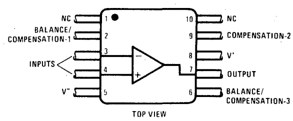
The high speed and fast settling time of these op amps make them useful in A/D converters, oscillators, active filters, sample and hold circuits, or general purpose amplifiers. These devices are easy to apply and offer an order of magnitude better AC performance than industry standards such as the LM709.

The LM218 is identical to the LM118 except that the LM218 has its performance specified over a −25°C to +85°C temperature range. The LM318 is specified from 0°C to +70°C.

schematic and connection diagrams

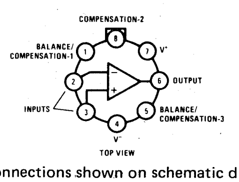


Flat Package



Order Number LM118F or LM218F
See Package 3

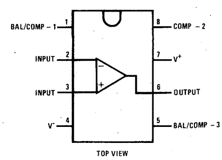
Metal Can Package*



*Pin connections shown on schematic diagram and typical applications are for TO-5 package.

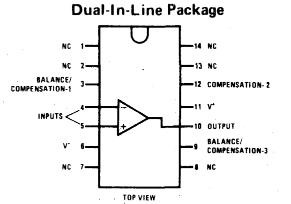
Order Number LM118H, LM218H or LM318H
See Package 11

Dual-In-Line Package



Order Number LM318N
See Package 20

Dual-In-Line Package



Order Number LM118D, LM218D or 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	
LM118	−55°C to +125°C
LM218	−25°C to +85°C
LM318	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	LM118/LM218			LM318			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$T_A = 25°C$		2	4		4	10	mV
Input Offset Current	$T_A = 25°C$		6	50		30	200	nA
Input Bias Current	$T_A = 25°C$		120	250		150	500	nA
Input Resistance	$T_A = 25°C$	1	3		0.5	3		MΩ
Supply Current	$T_A = 25°C$		5	8		5	10	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = ±15V$ $V_{OUT} = ±10V$, $R_L \geq 2\ k\Omega$	50	200		25	200		V/mV
Slew Rate	$T_A = 25°C$, $V_S = ±15V$, $A_V = 1$	50	70		50	70		V/μs
Small Signal Bandwidth	$T_A = 25°C$, $V_S = ±15V$		15			15		MHz
Input Offset Voltage				6			15	mV
Input Offset Current				100			300	nA
Input Bias Current				500			750	nA
Supply Current	$T_A = 125°C$		4.5	7				
Large Signal Voltage Gain	$V_S = ±15V$, $V_{OUT} = ±10V$ $R_L \geq 2\ k\Omega$	25			20			V/mV
Output Voltage Swing	$V_S = ±15V$, $R_L = 2\ k\Omega$	±12	±13		±12	±13		V
Input Voltage Range	$V_S = ±15V$	±11.5			±11.5			V
Common-Mode Rejection Ratio		80	100		70	100		dB
Supply Voltage Rejection Ratio		70	80		65	80		dB

Note 1: The maximum junction temperature of the LM118 is 150°C, the LM218 is 100°C, and 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. 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.

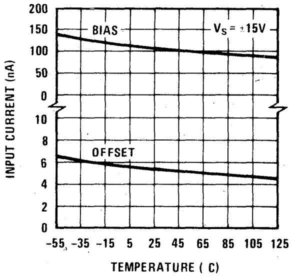
Note 2: The inputs are shunted with back-to-back diodes for overvoltage protection. Therefore, excessive current will flow if a differential input voltage in excess of 1V is applied between the inputs unless some limiting resistance is used.

Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

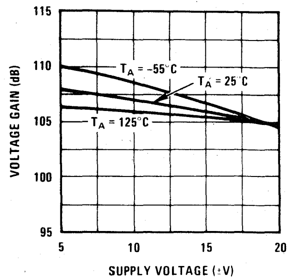
Note 4: These specifications apply for $±5V \leq V_S \leq ±20V$ and $-55°C \leq T_A \leq +125°C$, (LM118), $-25°C \leq T_A \leq +85°C$ (LM218), and $0°C \leq T_A \leq +70°C$ (LM318). Also, power supplies must be bypassed with 0.1μF disc capacitors.

typical performance characteristics LM118, LM218

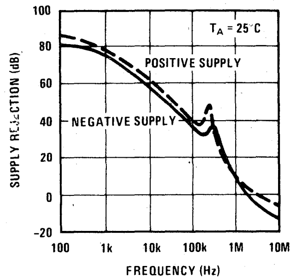
Input Current



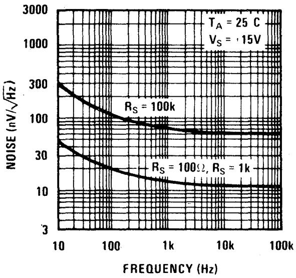
Voltage Gain



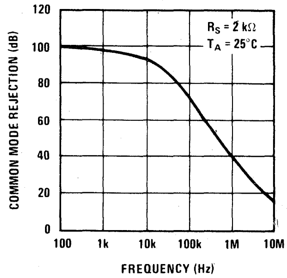
Power Supply Rejection



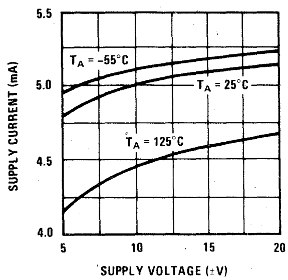
Input Noise Voltage



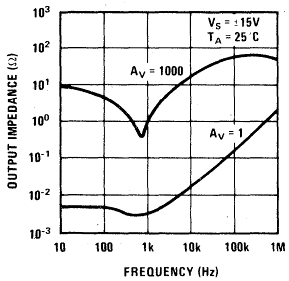
Common Mode Rejection



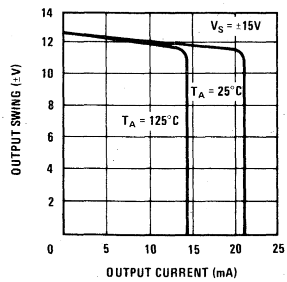
Supply Current



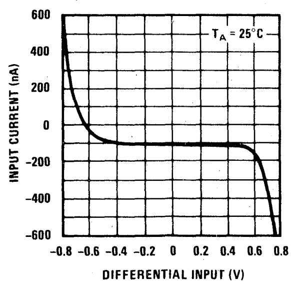
Closed Loop Output Impedance



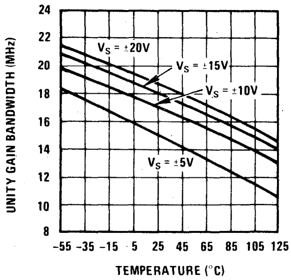
Current Limiting



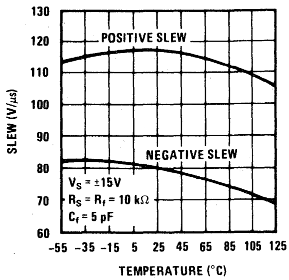
Input Current



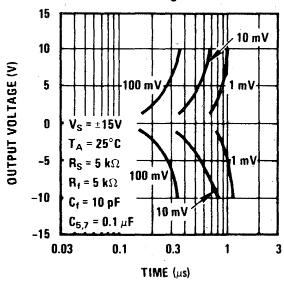
Unity Gain Bandwidth



Voltage Follower Slew Rate

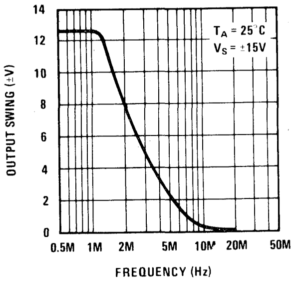


Inverter Settling Time

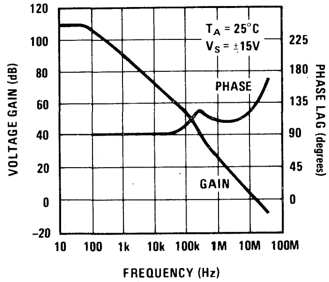


typical performance characteristics LM118, LM218

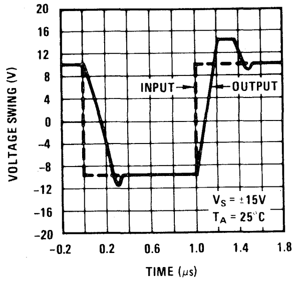
Large Signal Frequency Response



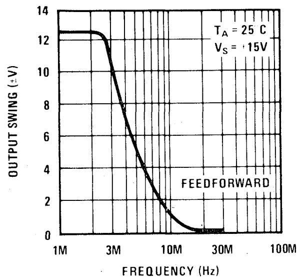
Open Loop Frequency Response



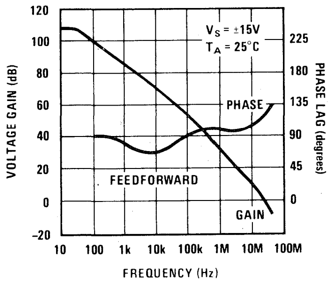
Voltage Follower Pulse Response



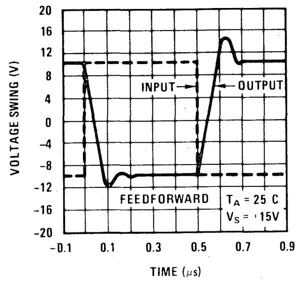
Large Signal Frequency Response



Open Loop Frequency Response

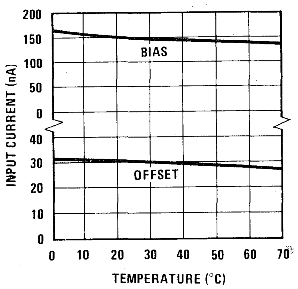


Inverter Pulse Response

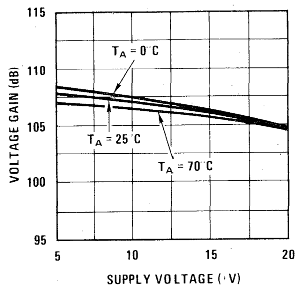


typical performance characteristics LM318

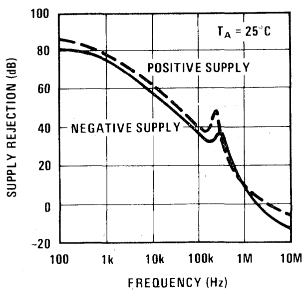
Input Current



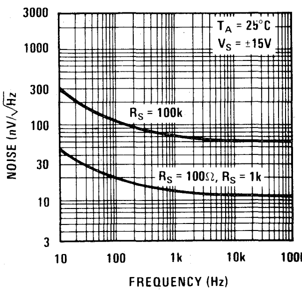
Voltage Gain



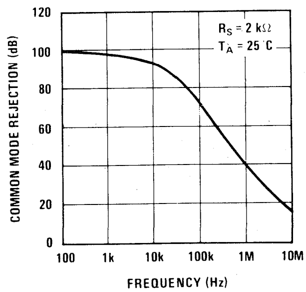
Power Supply Rejection



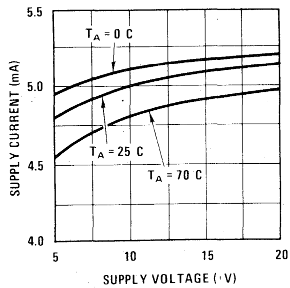
Input Noise Voltage



Common Mode Rejection

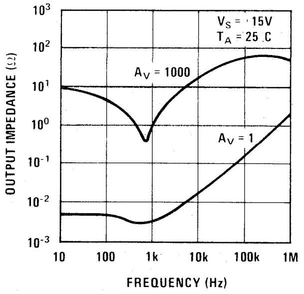


Supply Current

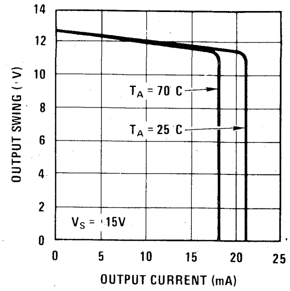


typical performance characteristics LM318 (Cont'd)

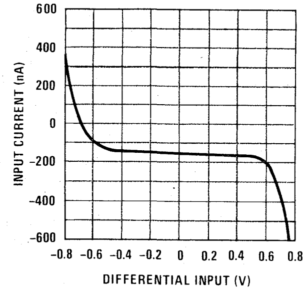
Closed Loop Output Impedance



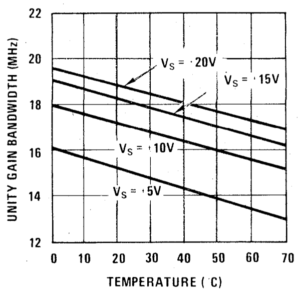
Current Limiting



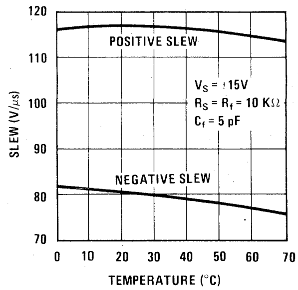
Input Current



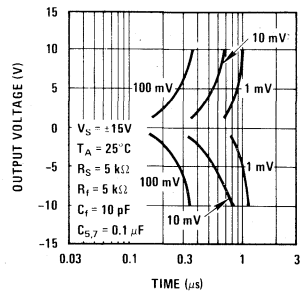
Unit Gain Bandwidth



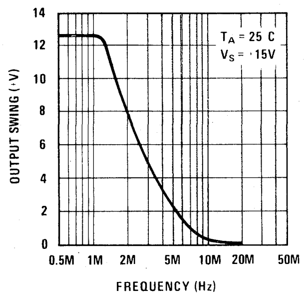
Voltage Follower Slew Rate



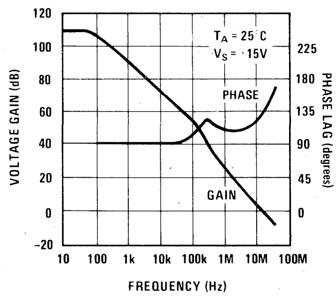
Inverter Settling Time



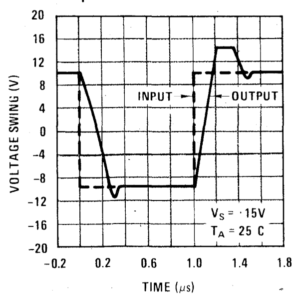
Large Signal Frequency Response



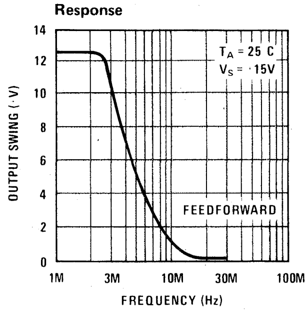
Open Loop Frequency Response



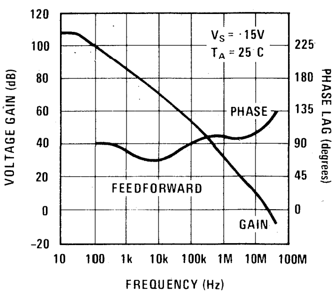
Voltage Follower Pulse Response



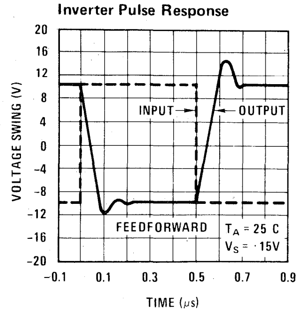
Large Signal Frequency Response



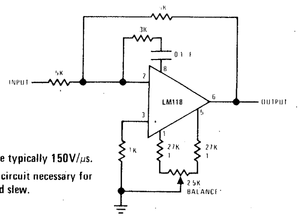
Open Loop Frequency Response



Inverter Pulse Response

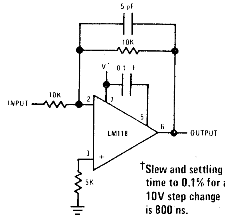


auxiliary circuits



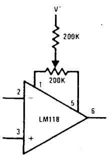
†Slew rate typically 150V/μs.
*Balance circuit necessary for increased slew.

Feedforward Compensation for Greater Inverting Slew Rate†

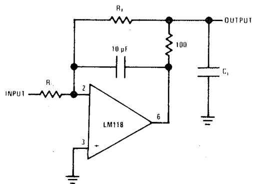


†Slew and settling time to 0.1% for a 10V step change is 800 ns.

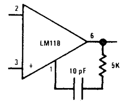
Compensation for Minimum Settling† Time



Offset Balancing

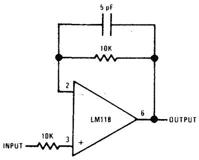


Isolating Large Capacitive Loads

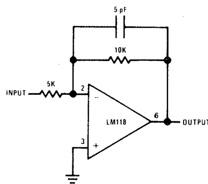


Overcompensation

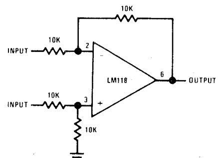
typical applications



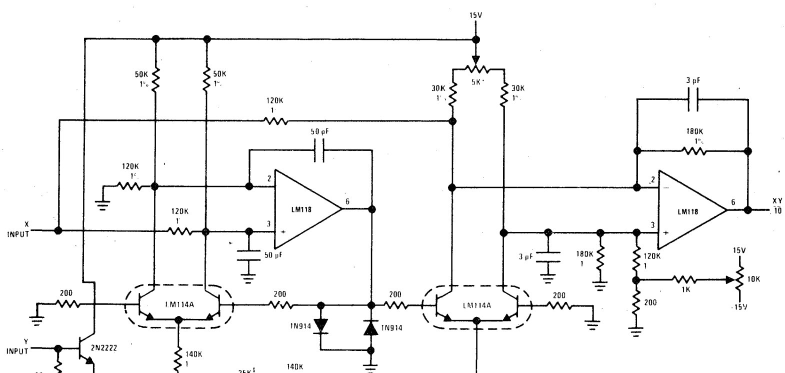
Fast Voltage Follower



Fast Summing Amplifier



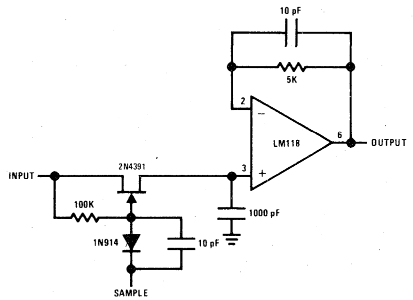
Differential Amplifier



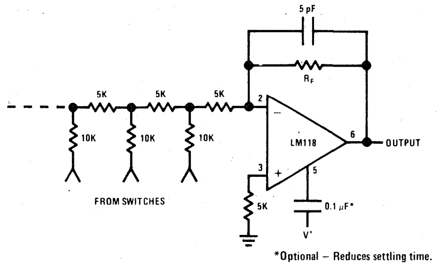
Output zero.
* "Y" zero
+ "X" zero
‡ Full scale adjust.

Four Quadrant Multiplier

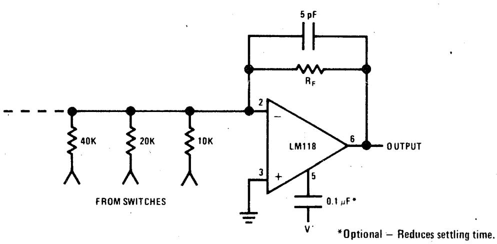
typical applications (con't)



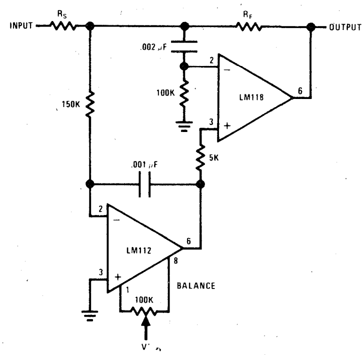
Fast Sample and Hold



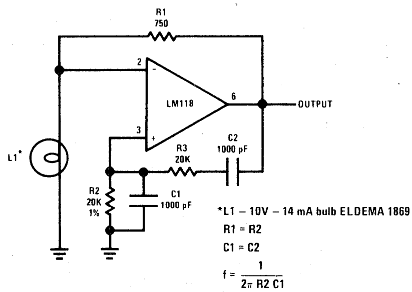
D/A Converter Using Ladder Network



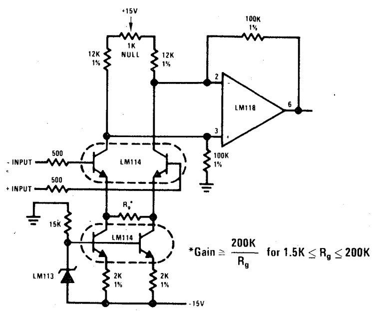
D/A Converter Using Binary Weighted Network



Fast Summing Amplifier with Low Input Current



Wein Bridge Sine Wave Oscillator



Instrumentation Amplifier

3

Operational Amplifiers/Buffers

LM124/LM224/LM324, LM124A/LM224A/LM324A, LM2902 low power quad operational amplifiers

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

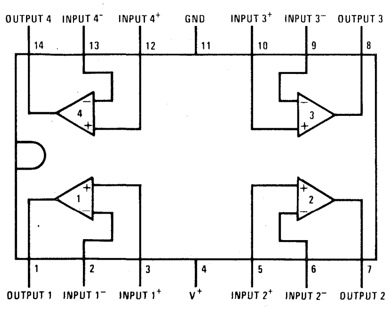
- Eliminates need for dual supplies
- Four internally compensated op amps in a single package
- Allows directly sensing near GND and V_{OUT} also goes to GND
- Compatible with all forms of logic
- Power drain suitable for battery operation

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



TOP VIEW

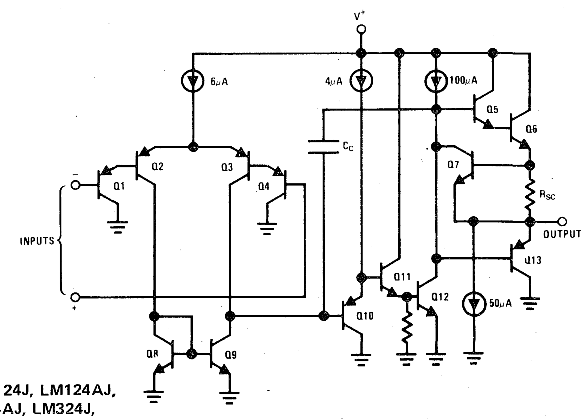
Order Number LM124D, LM124AD, LM224D or LM224AD
See Package 1

Order Number LM124F, LM124AF, LM224F or LM224AF
See Package 4

Order Number LM124J, LM124AJ, LM224J, LM224AJ, LM324J, LM324AJ or LM2902J
See Package 16

Order Number LM324N, LM324AN or LM2902N
See Package 22

schematic diagram (Each Amplifier)



absolute maximum ratings

	LM124/LM224/LM324 LM124A/LM224A/LM324A	LM2902
Supply Voltage, V^+	32 V_{DC} or ±16 V_{DC}	26 V_{DC} or ±13 V_{DC}
Differential Input Voltage	32 V_{DC}	26 V_{DC}
Input Voltage	−0.3 V_{DC} to +32 V_{DC}	−0.3 V_{DC} to +32 V_{DC}
Power Dissipation (Note 1)		
Molded DIP	570 mW	570 mW
Cavity DIP	900 mW	
Flat Pack	800 mW	
Output Short-Circuit to GND (One Amplifier) (Note 2) $V^+ \leq 15\ V_{DC}$ and $T_A = 25°C$	Continuous	Continuous

	LM124/LM224/LM324 LM124A/LM224A/LM324A	LM2902
Input Current ($V_{IN} < -0.3\ V_{OL}$) (Note 3)	50 mA	
Operating Temperature Range		−40°C to +85°C
LM324/LM324A	0°C to +70°C	
LM224/LM224A	−25°C to +85°C	
LM124/LM124A	−55°C to +125°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 (V^+ = +5.0 V_{DC}, Note 4)

PARAMETER	CONDITIONS	LM124A			LM224A			LM324A			LM124/LM224			LM324			LM2902			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	T_A = 25°C, (Note 5)		1	2		1	3		2	3		±2	±5		±2	±7		±2	±7	mV_{DC}
Input Bias Current (Note 6)	$I_{IN(+)}$ or $I_{IN(-)}$, T_A = 25°C		20	50		40	80		45	100		45	150		45	250		45	250	nA_{DC}
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, T_A = 25°C		2	10		2	15		5	30		±3	±30		±5	±50		±5	±50	nA_{DC}
Input Common-Mode Voltage Range (Note 7)	V^+ = 30 V_{DC}, T_A = 25°C	0		V^+−1.5	0		V^+−1.5	0		V^+−1.5	0		V^+−1.5	0		V^+−1.5	0		V^+−1.5	V_{DC}
Supply Current	$R_L = \infty$, V_{CC} = 30V, (LM2902 V_{CC} = 26V)		1.5	3		1.5	3		1.5	3		1.5	3		1.5	3		1.5	3	mA_{DC}
	$R_L = \infty$ On All Op Amps Over Full Temperature Range		0.7	1.2		0.7	1.2		0.7	1.2		0.7	1.2		0.7	1.2		0.7	1.2	mA_{DC}
	T_A = 25°C																		3	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		50	100		25	100		50	100		25	100			100		V/mV
Output Voltage Swing	$R_L = 2\ k\Omega$, T_A = 25°C (LM2902 $R_L \geq 10\ k\Omega$)										0		V^+−1.5	0		V^+−1.5	0		V^+−1.5	V_{DC}
Common-Mode Rejection Ratio	DC, T_A = 25°C	70	85		70	85		65	85		70	85		65	70		50	70		dB
Power Supply Rejection Ratio	DC, T_A = 25°C	65	100		65	100		65	100		65	100		65	100		50	100		dB
Amplifier-to-Amplifier Coupling (Note 8)	f = 1 kHz to 20 kHz, T_A = 25°C (Input Referred)		−120			−120			−120			−120			−120			−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		20	40		20	40		20	40		20	40		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		10	20		10	20		10	20		10	20		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		12	50		12	50		12	50		12	50					μA_{DC}
Short Circuit to Ground	T_A = 25°C, (Note 2)		40	60		40	60		40	60		40	60		40	60		40	60	mA_{DC}

electrical characteristics (con't)

PARAMETER	CONDITIONS	LM124A			LM224A			LM324A			LM124/LM224			LM324			LM2902			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	(Note 5)			4			4			5			±7			±9			±10	mV_{DC}
Input Offset Voltage Drift	$R_S = 0\Omega$		7	20		7	20		7	30		7			7			7		$\mu V/^\circ C$
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$			30			30			75			±100			±150		45	±200	nA_{DC}
Input Offset Current Drift			10	200		10	200		10	300		10			10			10		$pA_{DC}/^\circ C$
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$		40	100		40	100		40	200		40	300		40	500		40	500	nA_{DC}
Input Common-Mode Voltage Range (Note 7)	$V^+ = 30\ V_{DC}$	0		V^+-2	0		V^+-2	0		V^+-2	0		V^+-2	0		V^+-2	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			25			15			25			15			15			V/mV
Output Voltage Swing																				
V_{OH}	$V^+ = +30\ V_{DC}$, $R_L = 2\ k\Omega$	26			26			26			26			26			22			V_{DC}
	$R_L \geq 10\ k\Omega$	27	28		27	28		27	28		27	28		27	28		23	24		V_{DC}
V_{OL}	$V^+ = 5\ V_{DC}$, $R_L \leq 10\ k\Omega$		5	20		5	20		5	20		5	20		5	20		5	100	mV_{DC}
Output Current																				
Source	$V_{IN}^+ = +1\ V_{DC}$, $V_{IN}^- = 0\ V_{DC}$, $V^+ = 15\ V_{DC}$	10	20		10	20		10	20		10	20		10	20		10	20		mA
Sink	$V_{IN}^- = +1\ V_{DC}$, $V_{IN}^+ = 0\ V_{DC}$, $V^+ = 15\ V_{DC}$	10	15		5	8		5	8		5	8		5	8		5	8		mA
Differential Input Voltage	(Note 7)			V^+			V^+			V^+			V^+			V^+			V^+	V_{DC}

Note 1: For operating at high temperatures, the LM324/LM324A, 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. The LM224/LM224A and LM124/LM124A 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. Destructive dissipation can result from simultaneous shorts on all amplifiers.

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 $-55^\circ C \leq T_A \leq +125^\circ C$, unless otherwise stated. With the LM224/LM224A, all temperature specifications are limited to $-25^\circ C \leq T_A \leq +85^\circ C$, the LM324/LM324A temperature specifications are limited to $0^\circ C \leq T_A \leq +70^\circ C$, and the LM2902 specifications are limited to $-40^\circ C \leq T_A \leq +85^\circ C$.

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 $V^+ - 1.5\ V_{DC}$).

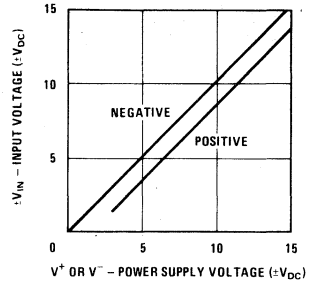
Note 6: The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.

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 ($+26\ V_{DC}$ for LM2902).

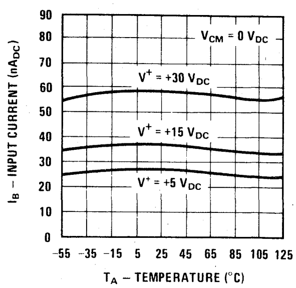
Note 8: Due to proximity of external components, insure that coupling is not originating via stray capacitance between these external parts. This typically can be detected as this type of capacitive increases at higher frequencies.

typical performance characteristics

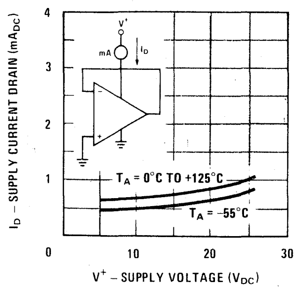
Input Voltage Range



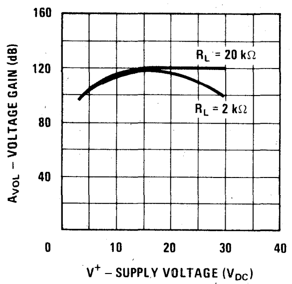
Input Current



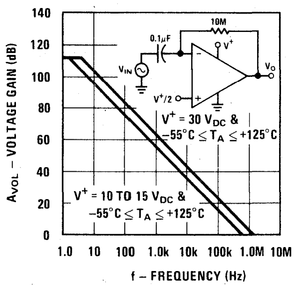
Supply Current



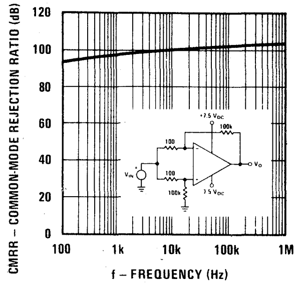
Voltage Gain



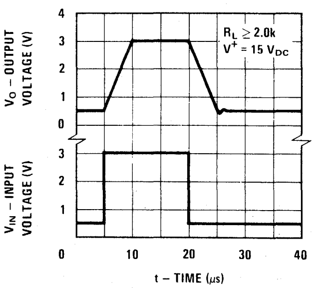
Open Loop Frequency Response



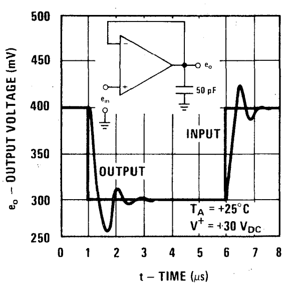
Common Mode Rejection Ratio



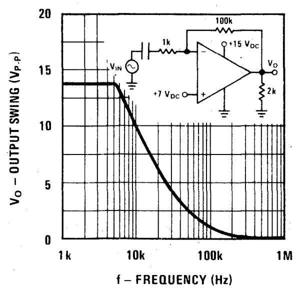
Voltage Follower Pulse Response



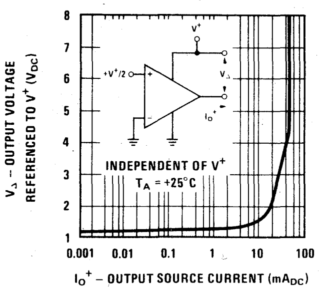
Voltage Follower Pulse Response (Small Signal)



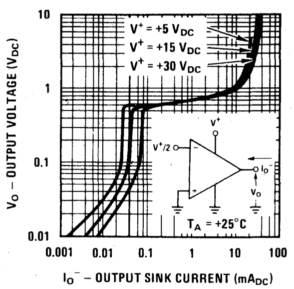
Large Signal Frequency Response



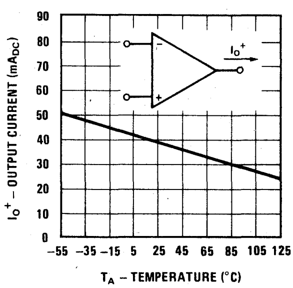
Output Characteristics Current Sourcing



Output Characteristics Current Sinking

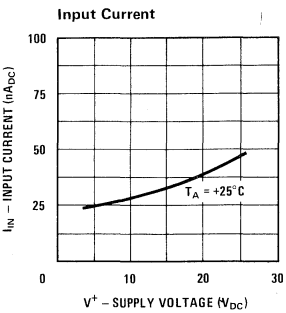


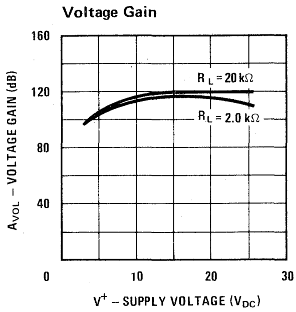
Current Limiting



3

typical performance characteristics (LM2902 only)





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.

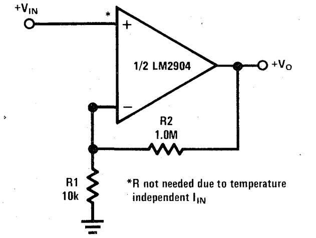
The bias network of the LM124 establishes a drain current which is independent of the magnitude of the power supply voltage over the range of from 3 V_{DC} to 30 V_{DC}.

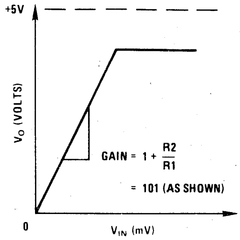
Output short circuits either to ground or to the positive power supply should be of short time duration. Units can be destroyed, not as a result of the short circuit current causing metal fusing, but rather due to the large increase in IC chip dissipation which will cause eventual failure due to excessive 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.

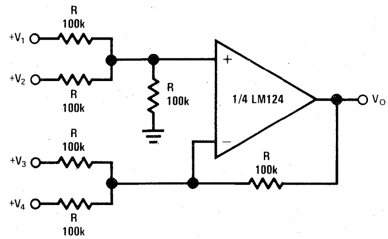
typical single-supply applications ($V^+ = 5.0\ V_{DC}$)

Non-Inverting DC Gain (0V Input = 0V Output)



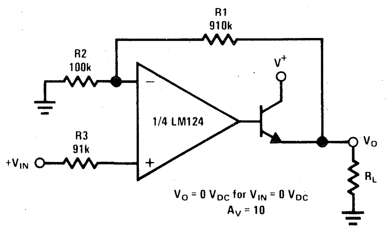


DC Summing Amplifier
($V_{IN'S} \geq 0\ V_{DC}$ AND $V_O \geq 0\ V_{DC}$)

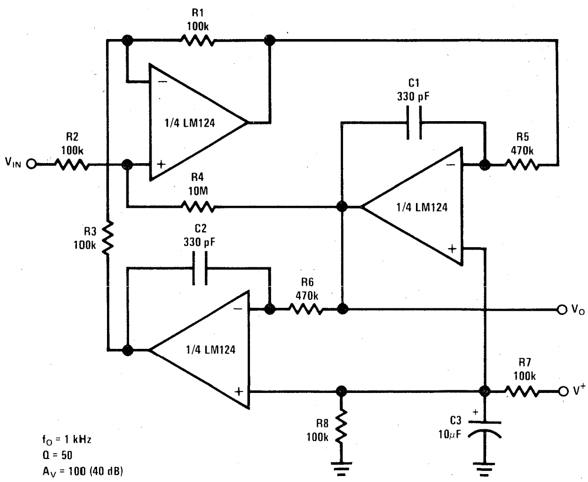


Where: $V_O = V_1 + V_2 \quad V_3 \quad V_4$
$(V_1 + V_2) \geq (V_3 + V_4)$ to keep $V_O > 0\ V_{DC}$

Power Amplifier

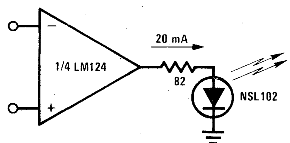


"BI-QUAD" RC Active Bandpass Filter

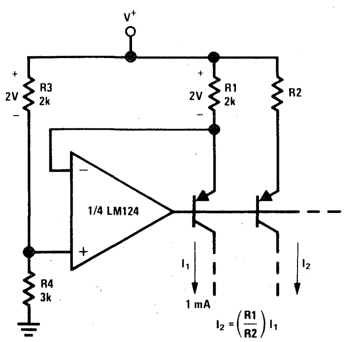


$f_O = 1$ kHz
$Q = 50$
$A_V = 100$ (40 dB)

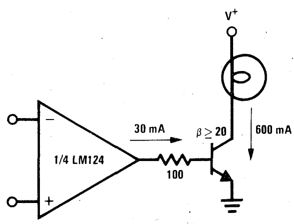
LED Driver



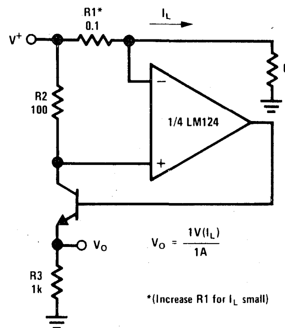
Fixed Current Sources



Lamp Driver

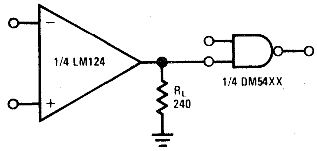


Current Monitor

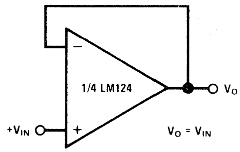


typical single-supply applications (con't) ($V^+ = 5.0\ V_{DC}$)

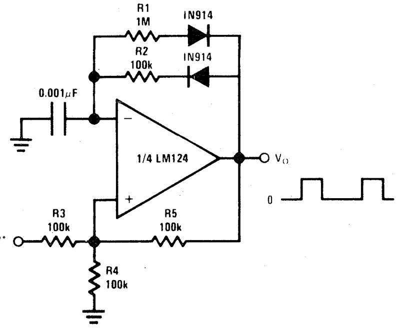
Driving TTL



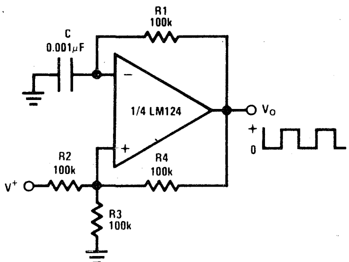
Voltage Follower



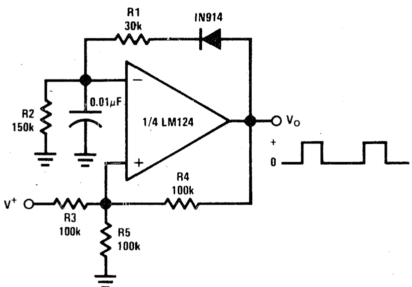
Pulse Generator



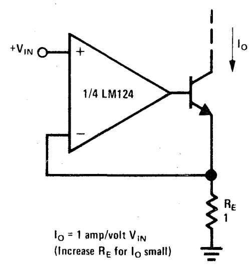
Squarewave Oscillator



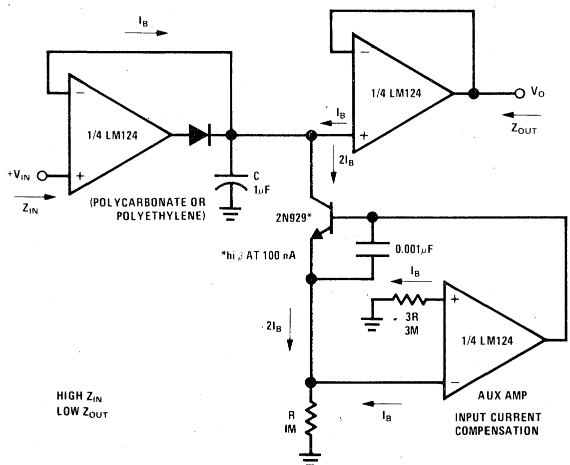
Pulse Generator



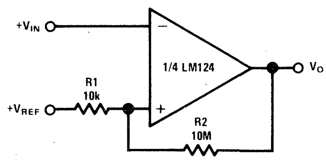
High Compliance Current Sink



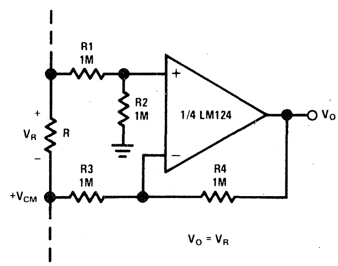
Low Drift Peak Detector



Comparator with Hysteresis



Ground Referencing A Differential Input Signal



typical single-supply applications (con't) ($V^+ = 5.0\ V_{DC}$)

Voltage Controlled Oscillator Circuit

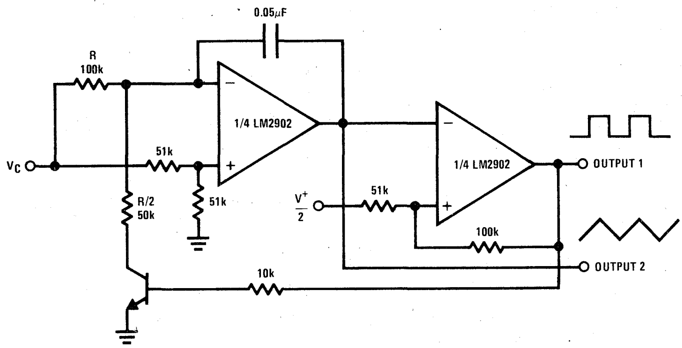
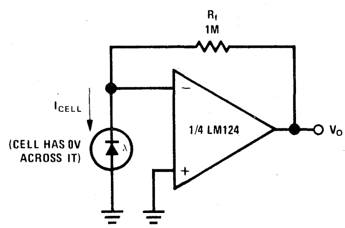
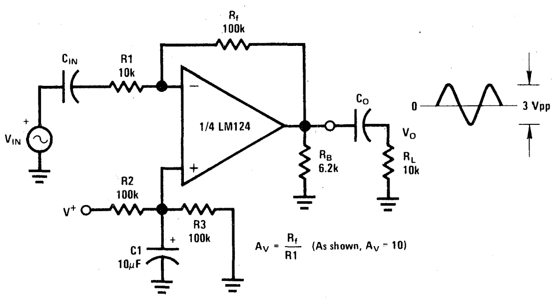


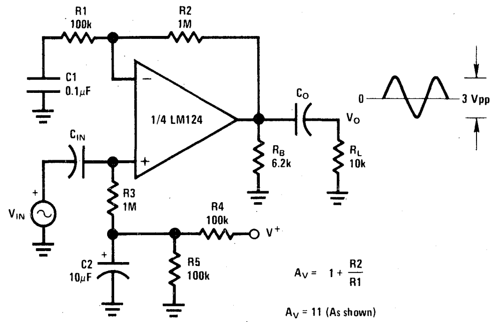
Photo Voltaic-Cell Amplifier



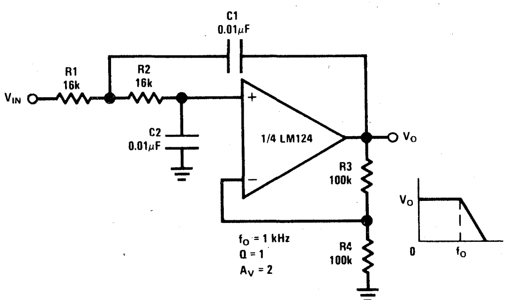
AC Coupled Inverting Amplifier



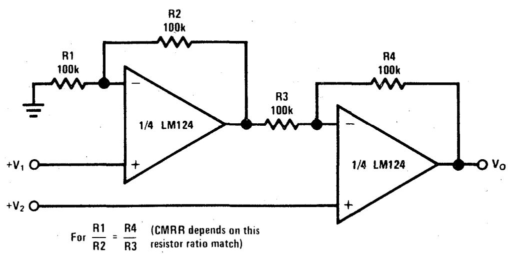
AC Coupled Non-Inverting Amplifier



DC Coupled Low-Pass RC Active Filter



High Input Z, DC Differential Amplifier



For $\frac{R1}{R2} = \frac{R4}{R3}$ (CMRR depends on this resistor ratio match)

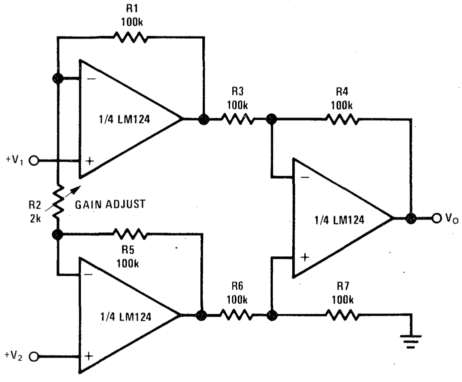
$V_O = 1 + \frac{R4}{R3}\ (V_2 - V_1)$

As shown: $V_O = 2(V_2 - V_1)$

3

typical single-supply applications (con't) ($V^+ = 5.0\ V_{DC}$)

High Input Z Adjustable-Gain DC Instrumentation Amplifier

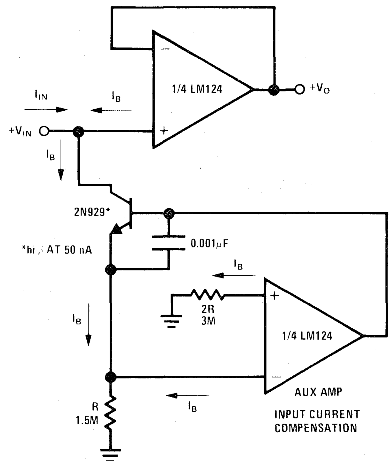


If R1 = R5 & R3 = R4 = R6 = R7 (CMRR depends on match)

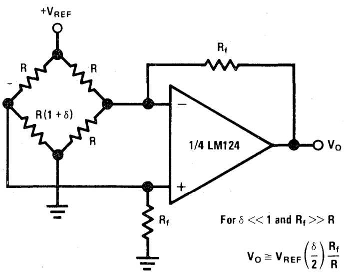
$$V_O = 1 + \frac{2R1}{R2}(V_2 - V_1)$$

As shown $V_O = 101\ (V_2 - V_1)$

Using Symmetrical Amplifiers to Reduce Input Current (General Concept)



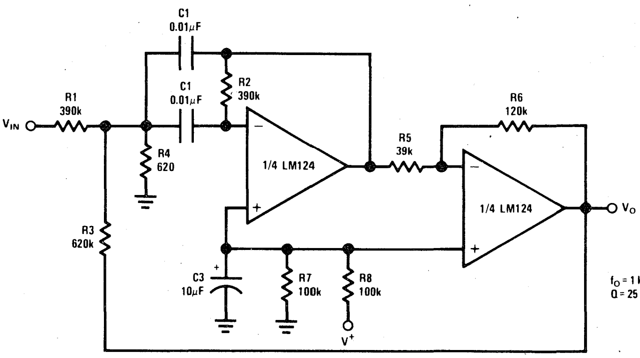
Bridge Current Amplifier



For $\delta << 1$ and $R_f >> R$

$$V_O \cong V_{REF}\left(\frac{\delta}{2}\right)\frac{R_f}{R}$$

Bandpass Active Filter



$f_O = 1$ kHz
$Q = 25$

Operational Amplifiers/Buffers

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

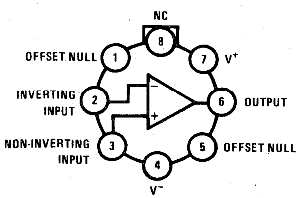
- Wide supply voltage range ±4.0V to ±40V
- Large output voltage swing ±37V
- Wide input common-mode range ±38V
- Input overvoltage protection Full ±40V
- Supply current is virtually independent of supply voltage and temperature

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

connection diagrams

Metal Can Package

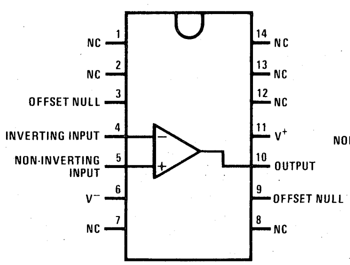


NOTE: Pin 4 connected to case.

TOP VIEW

Order Number LM143H or LM343H
See Package 11

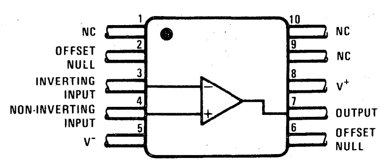
Dual-In-Line Package



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 (Note 1)

	LM143	LM343
Supply Voltage	±40V	±34V
Power Dissipation (Note 1)	680 mW	680 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)

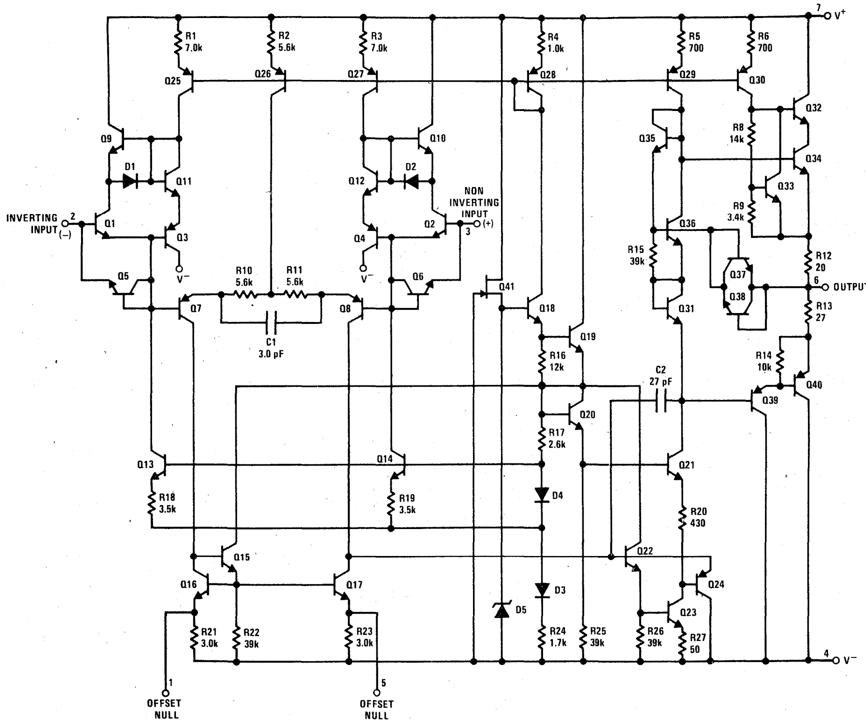
PARAMETER	CONDITIONS	LM143			LM343			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	T_A = 25°C		2.0	5.0		2.0	8.0	mV
Input Offset Current	T_A = 25°C		1.0	3.0		1.0	10	nA
Input Bias Current	T_A = 25°C		8.0	20		8.0	40	nA
Supply Voltage Rejection Ratio	T_A = 25°C		10	100		10	200	μV/V
Output Voltage Swing	T_A = 25°C, $R_L \geq 5$ kΩ	22	25		20	25		V
Large Signal Voltage Gain	T_A = 25°C, V_{OUT} = ±10V, $R_L \geq 100$ kΩ	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	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-P}, R_L = 5 kΩ, THD ≤ 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	$R_L \geq 100$ kΩ, T_A = Max $R_L \geq 100$ kΩ, T_A = Min	50k 50k	150k 220k		50k 50k	150k 220k		V/V V/V
Output Voltage Swing	$R_L \geq 5.0$ kΩ, T_A = Max $R_L \geq 5.0$ kΩ, T_A = Min	22 22	26 25		20 20	26 25		V V

Note 1: Absolute maximum ratings are not necessarily concurrent, and care must be taken not to exceed the maximum junction temperature of the LM143 (150°C) or the LM343 (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.

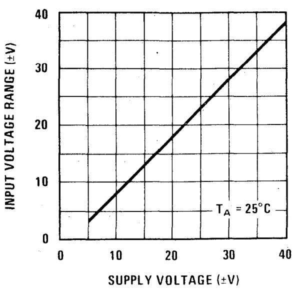
Note 3: These specifications apply for V_S = ±28V. For LM143, T_A = max = 125°C and T_A = min = −55°C. For LM343, T_A = max = 70°C and T_A = min = 0°C.

schematic diagram

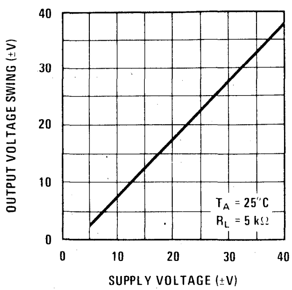


typical performance characteristics

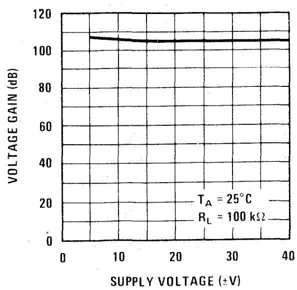
Input Voltage Range



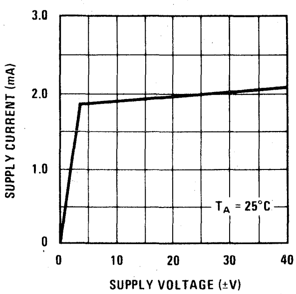
Output Voltage Swing



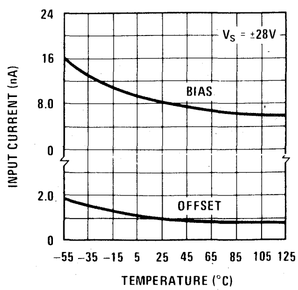
Voltage Gain



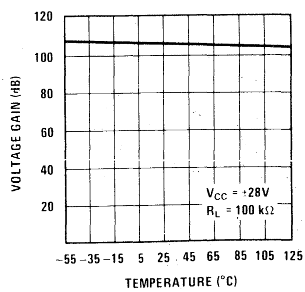
Supply Current



Input Current

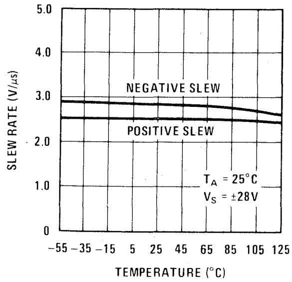


Voltage Gain

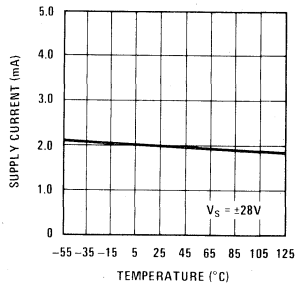


typical performance characteristics (con't)

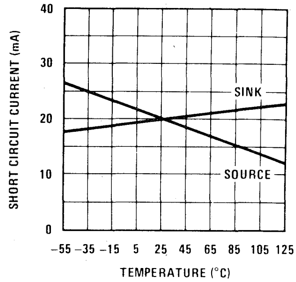
Voltage Follower Slew Rate



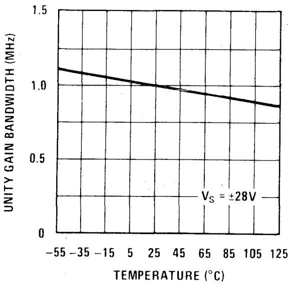
Supply Current



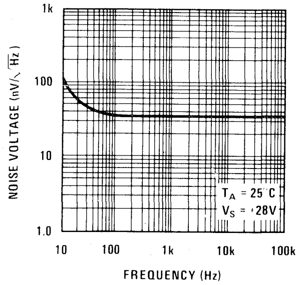
Short Circuit Current



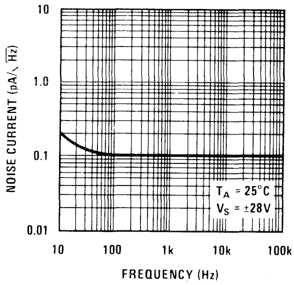
Unity Gain Bandwidth



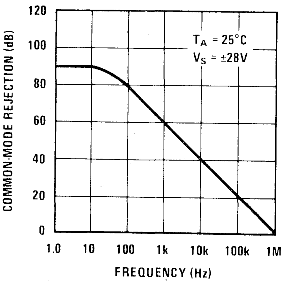
Input Noise Voltage



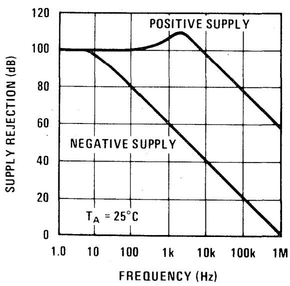
Input Noise Current



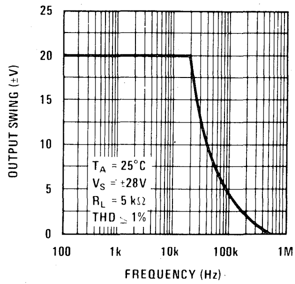
Common-Mode Rejection



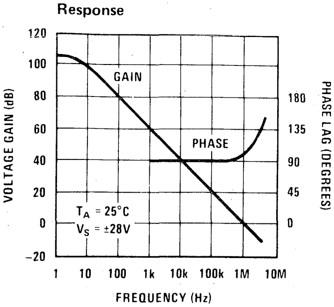
Power Supply Rejection



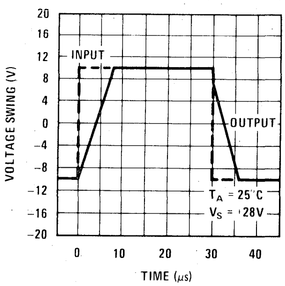
Large Signal Frequency Response



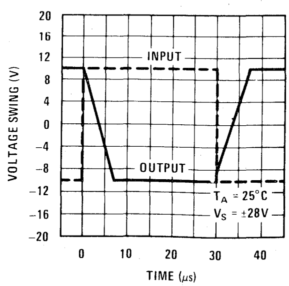
Open Loop Frequency Response



Voltage Follower Pulse Response



Inverter Pulse Response



application hints (See AN-127)

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 limited duration when operating at higher supply voltages. Units can be destroyed by any combination of high ambient temperature, high supply voltages, and high power dissipation which results in excessive die temperature. This is also true when driving low impedance or reactive loads or loads that can revert to low impedance; for example, the LM143 can drive most general purpose op amps outside of the 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.

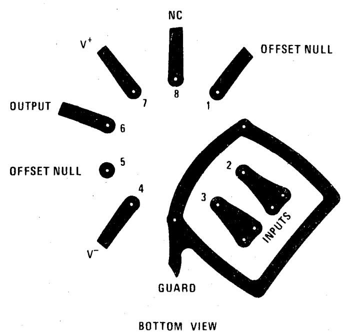


FIGURE 1. Printed Circuit Layout for Input Guarding with TO-5 Package

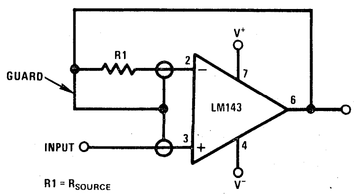


FIGURE 2. Guarded Voltage Follower

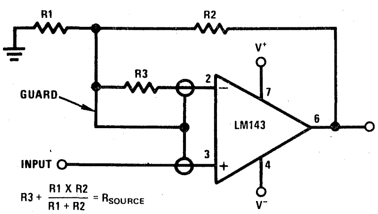


FIGURE 3. Guarded Non-Inverting Amplifier

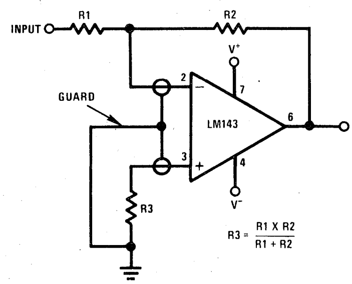
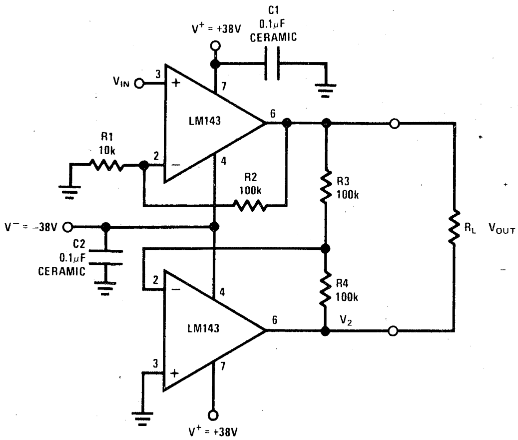
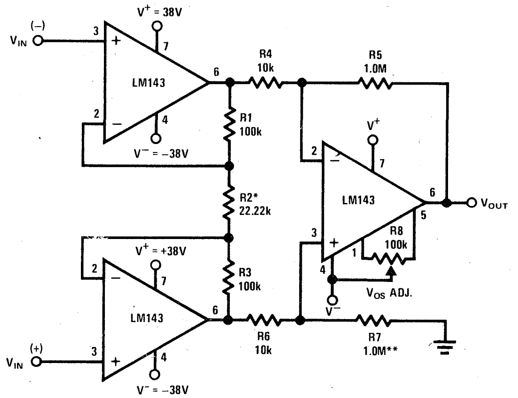


FIGURE 4. Guarded Inverting Amplifier

typical applications ‡ (For more detail see AN-127)



130 Vp-p Drive Across a Floating Load

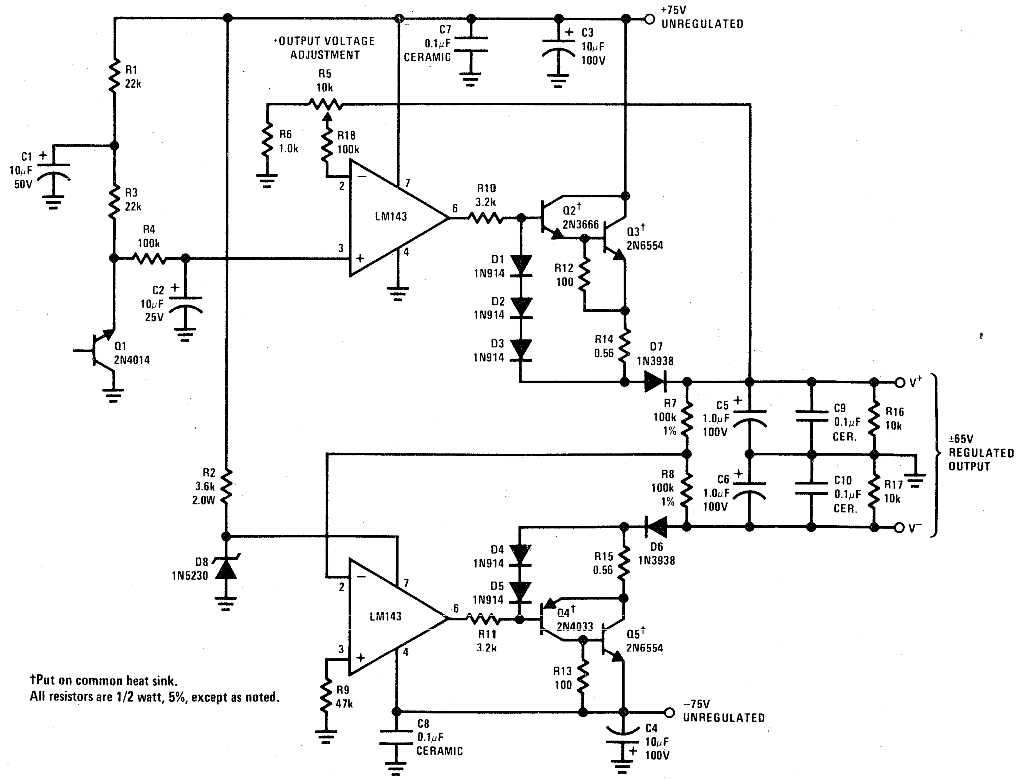


$A_V = \left(1 + \frac{2\,R1}{R2}\right)\frac{R5}{R4}$ WHERE: R4 = R6, R5 = R7

*R2 may be adjustable to trim the gain.

**R7 may be adjusted to compensate for the resistance tolerance of R4 – R7 for best CMR.

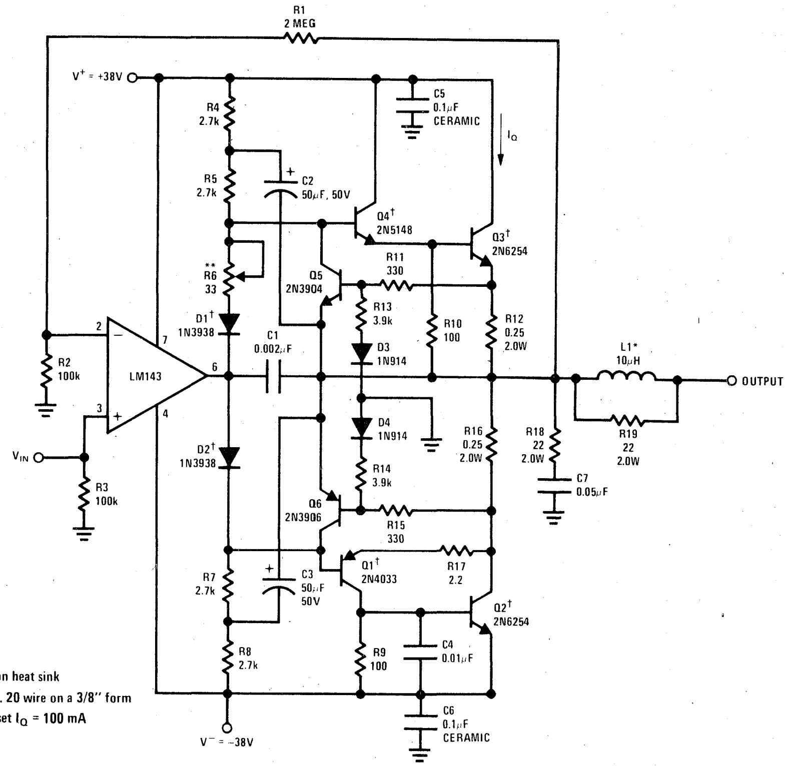
±34V Common-Mode Instrumentation Amplifier



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)

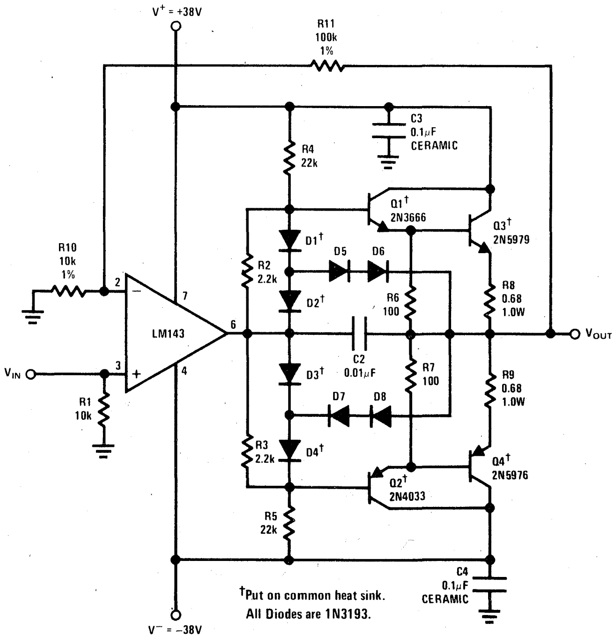


†Put on common heat sink

*34 turns of no. 20 wire on a 3/8" form

**Adjust R6 to set I_Q = 100 mA

90W Audio Power Amplifier with Safe Area Protection



†Put on common heat sink.
All Diodes are 1N3193.

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/Buffers

LM144/LM344 high voltage, high slew rate operational amplifier

general description

The LM144 is a general purpose high voltage, uncompensated operational amplifier featuring operation to ±36V, complete input overvoltage protection up to the supply voltages and input currents comparable to those of other super-β op amps. Increased slew rate, together with high common-mode and supply rejection, insure excellent performance at high supply voltages. Operating characteristics, in particular supply current, slew rate and gain, are virtually independent of supply voltage and temperature. Furthermore, due to thermal symmetry on the die, gain is unaffected by output loading at high supply voltages.

With the unique advantages of low input current, high gain, and high slew rate, the LM144 can increase accuracy and useful frequency range in many existing applications. For example, the LM144 is a plug-in replacement for the LM101A, as well as other general purpose op amps.

The LM144 can be compensated with a single capacitor, thus giving the user the ability to optimize ac parameters to suit the application. For example, in applications such as audio power amplifiers, the LM144 with a gain of 10 can provide a ±30V output swing, a slew rate of approximately 30V/μs, and a 120 kHz full power bandwidth. In applications where capacitive loads or cables must be driven, the LM144 can be overcompensated for increased stability.

The LM344 is similar to the LM144 for applications in less severe supply voltage and temperature environments.

features

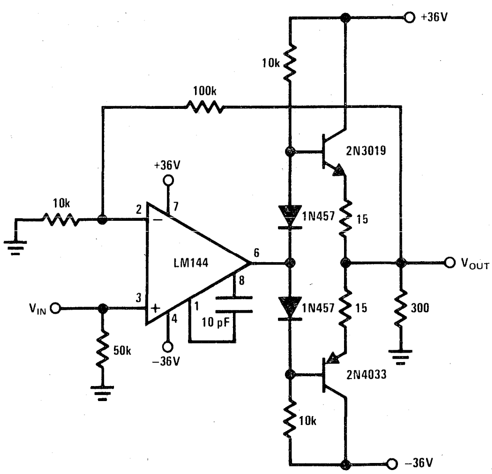
- External compensation provides large power bandwidth ($A_V \geq 10$) — 120 kHz
- Wide operating voltage range — ±4.0V to ±36V
- Large output voltage swing — ±30V
- Wide input common-mode range
- Input overvoltage protection
- Electrical characteristics independent of supply voltage and temperature

unique characteristics

- Low input bias current — 8.0 nA
- Low input offset current — 1.0 nA
- High slew rate ($A_V \geq 10$) — 30V/μs
- High voltage gain — 100k min
- Offset voltage null capability

typical application

Large Power Bandwidth, Current Boosted Audio Line Driver



absolute maximum ratings (These ratings are not concurrent)

	LM144	LM344
Supply Voltage	±40V	±34V
Power Dissipation (Note 1)	680 mW	680 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)

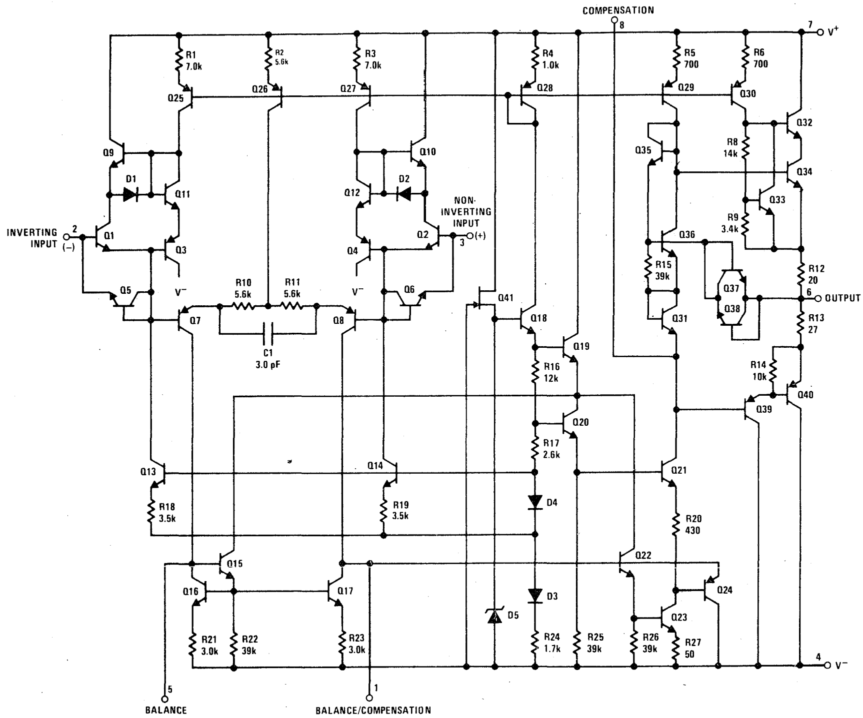
PARAMETER	CONDITIONS	LM144			LM344			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	T_A = 25°C		2.0	5.0		2.0	8.0	mV
Input Offset Current	T_A = 25°C		1.0	3.0		1.0	10	nA
Input Bias Current	T_A = 25°C		8.0	20		8.0	40	nA
Supply Voltage Rejection Ratio	T_A = 25°C		10	100		10	200	μV/V
Output Voltage Swing	T_A = 25°C, $R_L \geq 5\,k\Omega$	22	25		20	25		V
Large Signal Voltage Gain	T_A = 25°C, $V_{OUT} = \pm 10V$, $R_L \geq 100\,k\Omega$	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	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
	T_A = 25°C, A_V = 10, C1 = 3 pF		30			30		V/μs
Power Bandwidth	T_A = 25°C, V_{OUT} = 40 $V_{p\text{-}p}$, $R_L = 5\,k\Omega$, THD ≤ 1%, A_V = 1		20k			20k		Hz
Unity Gain Frequency	T_A = 25°C		1.0M			1.0M		Hz
Input Offset Voltage	T_A = Max			6.0			10	mV
	T_A = Min			6.0			10	mV
Input Offset Current	T_A = Max		0.8	4.5		0.8	14	nA
	T_A = Min		1.8	7.0		1.8	14	nA
Input Bias Current	T_A = Max		5.0	35		5.0	55	nA
	T_A = Min		16	35		16	55	nA
Large Signal Voltage Gain	$R_L \geq 100\,k\Omega$, T_A = Max	50k	150k		50k	150k		V/V
	$R_L \geq 100\,k\Omega$, T_A = Min	50k	220k		50k	220k		V/V
Output Voltage Swing	$R_L \geq 5.0\,k\Omega$, T_A = Max	22	26		20	26		V
	$R_L \geq 5.0\,k\Omega$, T_A = Min	22	25		20	25		V

Note 1: The maximum junction temperature of the LM144 is 150°C, while that of the LM344 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 LM144 and less than ±34V for the LM344, the absolute maximum input voltage is equal to the supply voltage.

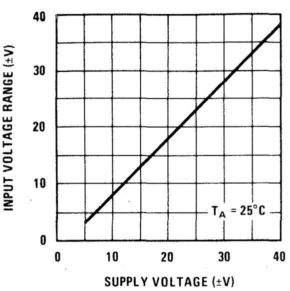
Note 3: These specifications apply for V_S = ±28V. For the LM144, T_A = max = 125°C and T_A = min = −55°C. For the LM344, T_A = max = 70°C and T_A = min = 0°C.

schematic diagram

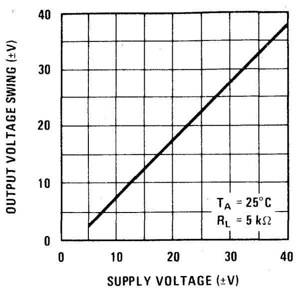


typical performance characteristics

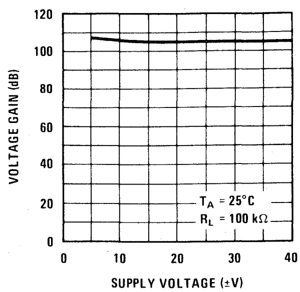
Input Voltage Range



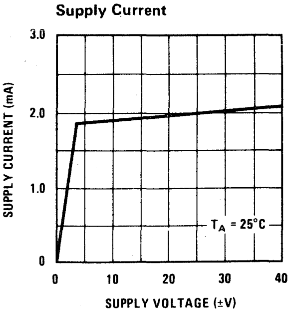
Output Voltage Swing



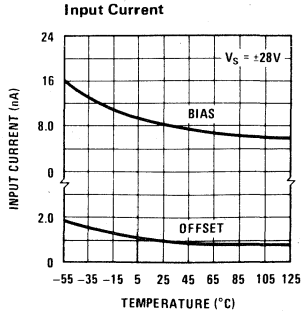
Voltage Gain



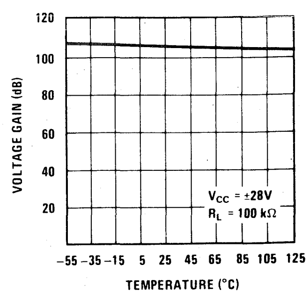
Supply Current



Input Current

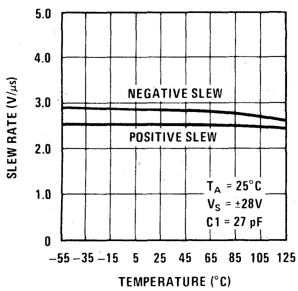


Voltage Gain

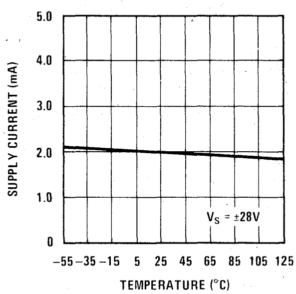


typical performance characteristics (con't)

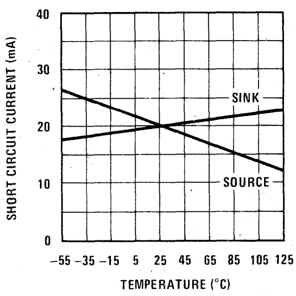
Voltage Follower Slew Rate



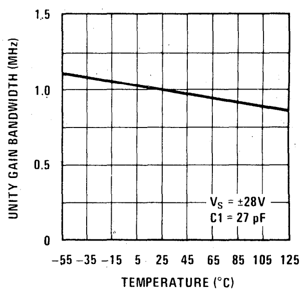
Supply Current



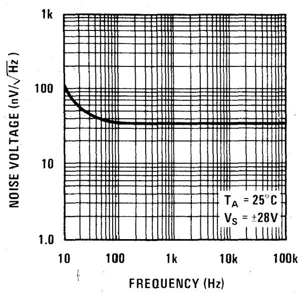
Short Circuit Current



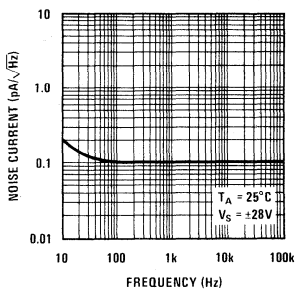
Unity Gain Bandwidth



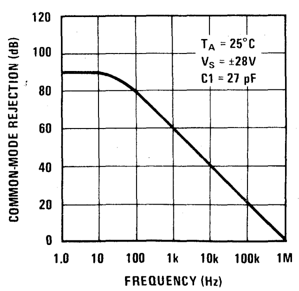
Input Noise Voltage



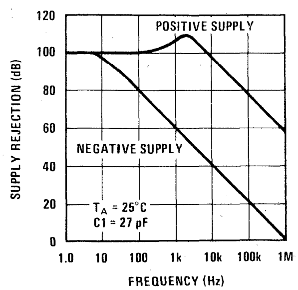
Input Noise Current



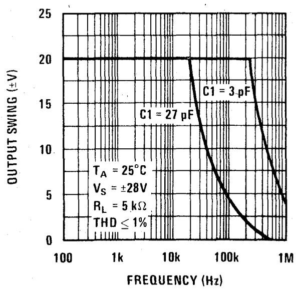
Common-Mode Rejection



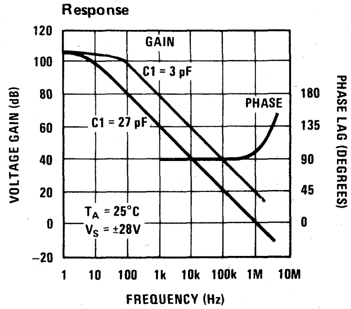
Power Supply Rejection



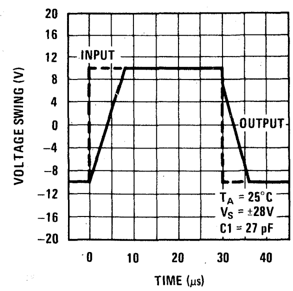
Large Signal Frequency Response



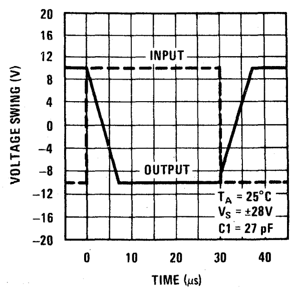
Open Loop Frequency Response



Voltage Follower Pulse Response



Inverter Pulse Response



application hints (See Also AN-127)

The LM144 is designed for trouble-free operation at any supply voltage up to a maximum of ±40V. Input over-voltage 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 LM144 remains virtually blow-out proof.

Although output short circuits to ground or either supply can be sustained indefinitely for supply voltages, below ±18V, these short circuits should be of limited duration when operating at higher supply voltages. Units can be destroyed by any combination of high ambient temperature, high supply voltages, and high power dissipation which results in excessive die temperature. This is also true when driving low impedance or reactive loads or loads that can revert to low impedance; for example, the LM144 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 operation 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.

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. See *Figures 5, 6 and 7.*

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.

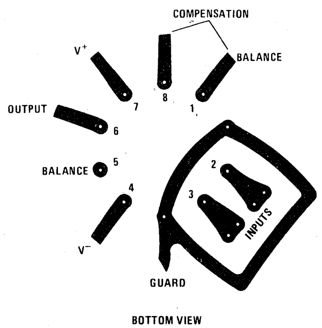


FIGURE 1. Printed Circuit Layout for Input Guarding with TO-5 Package

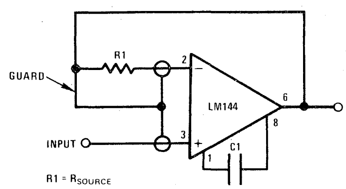


FIGURE 2. Guarded Voltage Follower

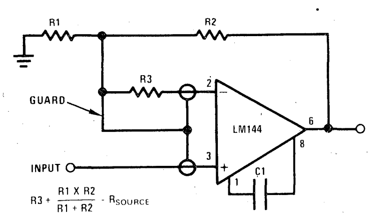


FIGURE 3. Guarded Non-Inverting Amplifier

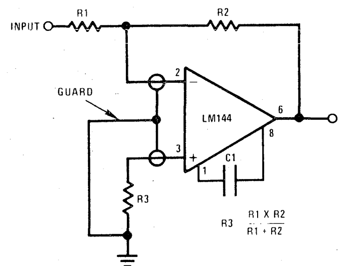


FIGURE 4. Guarded Inverting Amplifier

application hints (con't)

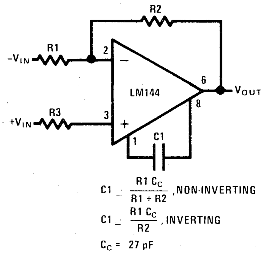


FIGURE 5. Single Pole Compensation

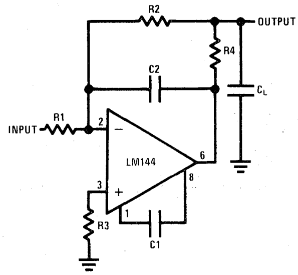


FIGURE 6. Isolating Large Capacitive Loads

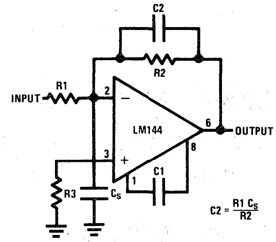


FIGURE 7. Compensating For Stray Input Capacitances or Large Feedback Resistor

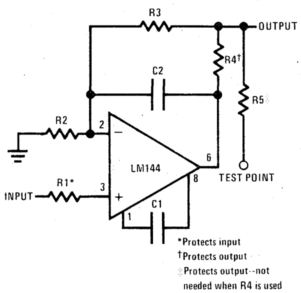


FIGURE 8. Protecting Against Gross Fault Conditions

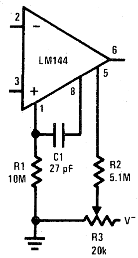
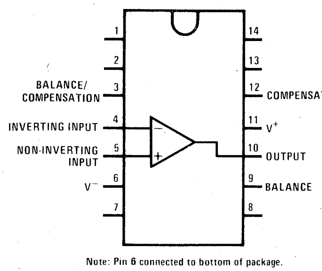


FIGURE 9. Balancing Circuit

connection diagrams

Dual-In-Line Package

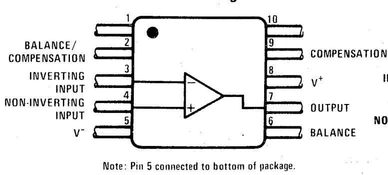


Note: Pin 6 connected to bottom of package.

TOP VIEW

Order Number LM144D or LM344D
See Package 1

Flat Package

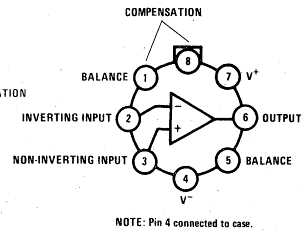


Note: Pin 5 connected to bottom of package.

TOP VIEW

Order Number LM144F
See Package 3

Metal Can Package



NOTE: Pin 4 connected to case.

TOP VIEW

Order Number LM144H or LM344H
See Package 11

3

Operational Amplifiers/Buffers

LM148, LM149 quad 741 op amps

LM148/LM248/LM348 quad 741 op amps
LM149/LM249/LM349 wide band decompensated ($A_{V(MIN)} = 5$)

general description

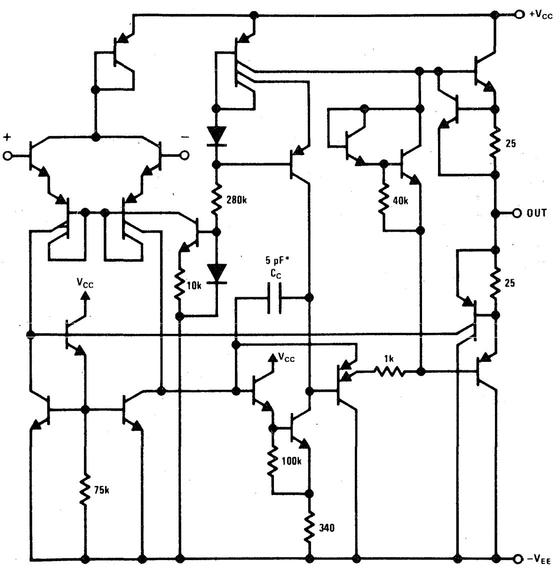
The LM148 series is a true quad 741. It consists of four independent, high gain, internally compensated, low power operational amplifiers which have been designed to provide functional characteristics identical to those of the familiar 741 operational amplifier. In addition the total supply current for all four amplifiers is comparable to the supply current of a single 741 type op amp. Other features include input offset currents and input bias current which are much less than those of a standard 741. Also, excellent isolation between amplifiers has been achieved by independently biasing each amplifier and using layout techniques which minimize thermal coupling. The LM149 series has the same features as the LM148 plus a gain bandwidth product of 4 MHz at a gain of 5 or greater.

The LM148 can be used anywhere multiple 741 or 1558 type amplifiers are being used and in applications where amplifier matching or high packing density is required.

features

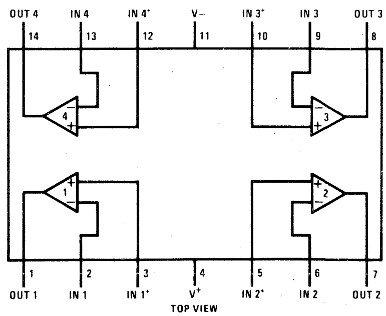
- 741 op amp operating characteristics
- Low supply current drain — 0.6 mA/Amplifier
- Class AB output stage—no crossover distortion
- Pin compatible with the LM124
- Low input offset voltage — 1 mV
- Low input offset current — 4 nA
- Low input bias current — 30 nA
- Gain bandwidth product
  - LM148 (unity gain) — 1.0 MHz
  - LM149 ($A_V \geq 5$) — 4 MHz
- High degree of isolation between amplifiers — 120 dB
- Overload protection for inputs and outputs

schematic and connection diagrams



*1 pF on the LM149

Dual-In-Line and Flat Package



Order Number LM148D, LM248D, LM348D, LM149D, LM249D or LM349D
See Package 1
Order Number LM248J, LM348J, LM249J or LM349J
See Package 16
Order Number LM148F or LM149F
See Package 4
Order Number LM348N or LM349N
See Package 22

absolute maximum ratings

		LM148/LM149	LM248/LM249	LM348/LM349
Supply Voltage		±22V	±18V	±18V
Differential Input Voltage		±44V	±36V	±36V
Input Voltage		±22V	±18V	±18V
Output Short Circuit Duration (Note 1)		Continuous	Continuous	Continuous
Power Dissipation (P_d at 25°C) and Thermal Resistance (θ_{jA}), (Note 2)				
Molded DIP (N)	P_d	–	–	500 mW
	θ_{jA}	–	–	150°C/W
Cavity DIP (D) (J)	P_d	900 mW	900 mW	900 mW
	θ_{jA}	100°C/W	100°C/W	100°C/W
Flat Pack (F)	P_d	675 mW	–	–
	θ_{jA}	185°C/W	–	–
Maximum Junction Temperature (T_{jMAX})		150°C	110°C	100°C
Operating Temperature Range		$-55°C \leq T_A \leq +125°C$	$-25°C \leq T_A \leq +85°C$	$0°C \leq T_A \leq +70°C$
Storage Temperature Range		−65°C to +150°C	−65°C to +150°C	−65°C to +150°C
Lead Temperature (Soldering, 60 seconds)		300°C	300°C	300°C

electrical characteristics (Note 3)

PARAMETER	CONDITIONS	LM148/LM149			LM248/LM249			LM348/LM349			UNITS
		MIN	TYP	MAX	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		1.0	6.0	mV
Input Offset Current	$T_A = 25°C$		4	25		4	50		4	50	nA
Input Bias Current	$T_A = 25°C$		30	100		30	200		30	200	nA
Input Resistance	$T_A = 25°C$	0.8	2.5		0.8	2.5		0.8	2.5		MΩ
Supply Current All Amplifiers	$T_A = 25°C$, $V_S = \pm 15V$		2.4	3.6		2.4	4.5		2.4	4.5	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		25	160		25	160		V/mV
Amplifier to Amplifier Coupling	$T_A = 25°C$, f = 1 Hz to 20 kHz (Input Referred) See Crosstalk Test Circuit		−120			−120			−120		dB
Small Signal Bandwidth	$T_A = 25°C$ LM148 series		1.0			1.0			1.0		MHz
	$T_A = 25°C$ LM149 series		4.0			4.0			4.0		MHz
Phase Margin	$T_A = 25°C$ LM148 series ($A_V = 1$)		60			60			60		degrees
	$T_A = 25°C$ LM149 series ($A_V = 5$)		60			60			60		degrees
Slew Rate	$T_A = 25°C$ LM148 series ($A_V = 1$)		0.5			0.5			0.5		V/μs
	$T_A = 25°C$ LM149 series ($A_V = 5$)		2.0			2.0			2.0		V/μs
Output Short Circuit Current	$T_A = 25°C$		25			25			25		mA
Input Offset Voltage	$R_S \leq 10\ k\Omega$			6.0			7.5			7.5	mV
Input Offset Current				75			125			100	nA
Input Bias Current				325			500			400	nA
Large Signal Voltage Gain	$V_S = \pm 15V$, $V_{OUT} = \pm 10V$, $R_L > 2\ k\Omega$	25			15			15			V/mV
Output Voltage Swing	$V_S = \pm 15V$, $R_L = 10\ k\Omega$,	±12	±13		±12	±13		±12	±13		V
	$R_L = 2\ k\Omega$	±10	±12		±10	±12		±10	±12		V
Input Voltage Range	$V_S = \pm 15V$	±12			±12			±12			V
Common-Mode Rejection Ratio	$R_S \leq 10\ k\Omega$	70	90		70	90		70	90		dB
Supply Voltage Rejection	$R_S \leq 10\ k\Omega$	77	96		77	96		77	96		dB

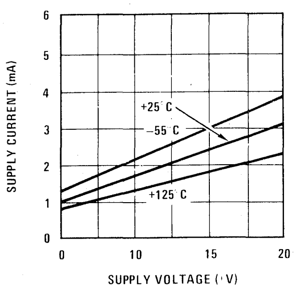
Note 1: Any of the amplifier outputs can be shorted to ground indefinitely; however, more than one should not be simultaneously shorted as the maximum junction temperature will be exceeded.

Note 2: The maximum power dissipation for these devices must be derated at elevated temperatures and is dictated by T_{jMAX}, θ_{jA}, and the ambient temperature, T_A. The maximum available power dissipation at any temperature is $P_d = (T_{jMAX} - T_A)/\theta_{jA}$ or the 25°C P_{dMAX}, whichever is less.

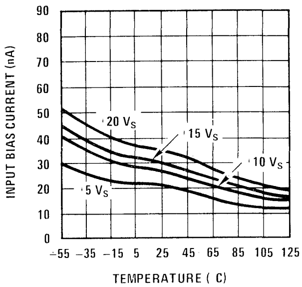
Note 3: These specifications apply for $V_S = \pm 15V$ and over the absolute maximum operating temperature range ($T_L \leq T_A \leq T_H$) unless otherwise noted.

typical performance characteristics

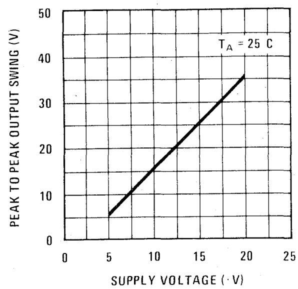
Supply Current



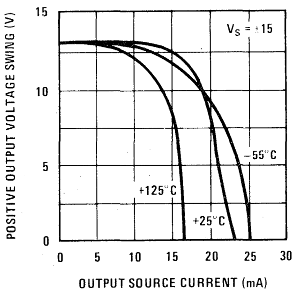
Input Bias Current



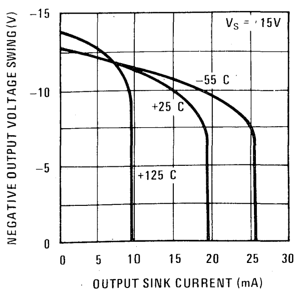
Voltage Swing



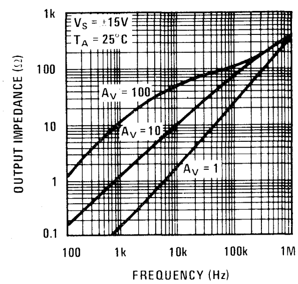
Positive Current Limit



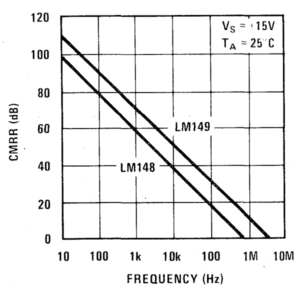
Negative Current Limit



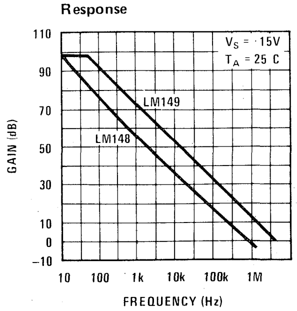
Output Impedance



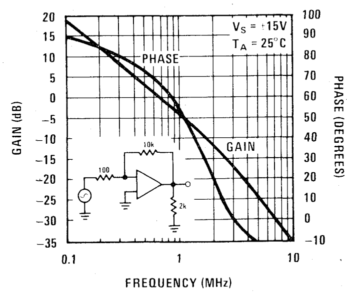
Common-Mode Rejection Ratio



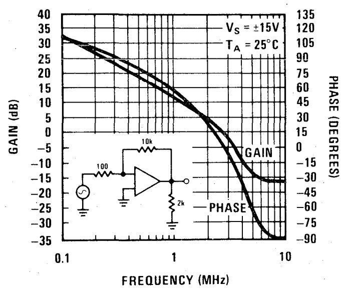
Open Loop Frequency Response



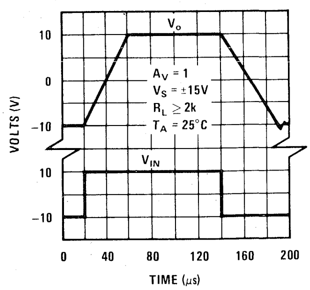
Bode Plot LM148



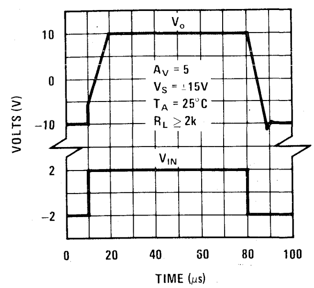
Bode Plot LM149



Large Signal Pulse Response (LM148)

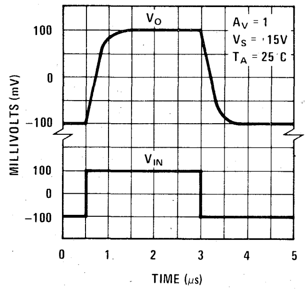


Large Signal Pulse Response (LM149)

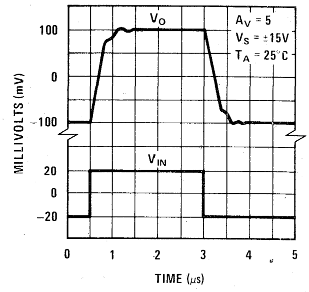


typical performance characteristics (con't)

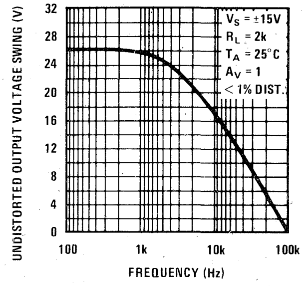
Small Signal Pulse Response (LM148)



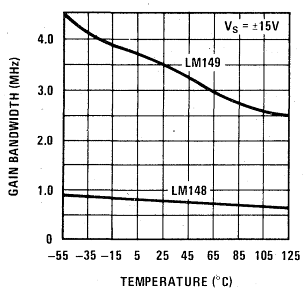
Small Signal Pulse Response (LM149)



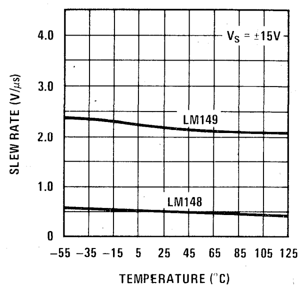
Undistorted Output Voltage Swing



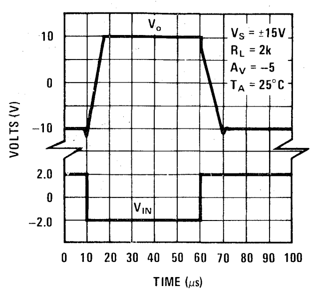
Gain Bandwidth



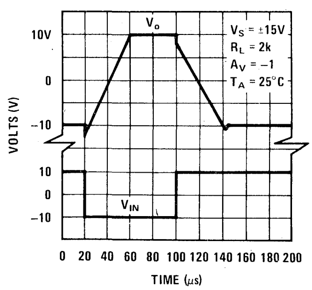
Slew Rate



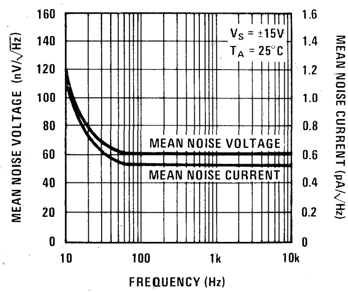
Inverting Large Signal Pulse Response (LM149)



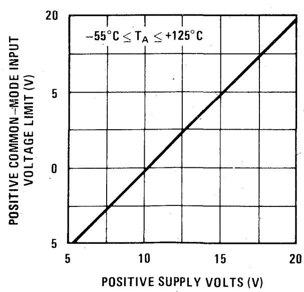
Inverting Large Signal Pulse Response (LM148)



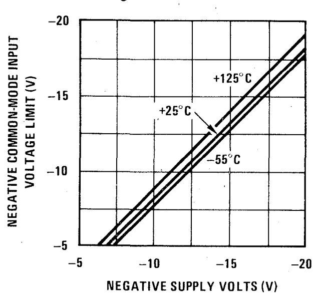
Input Noise Voltage and Noise Current



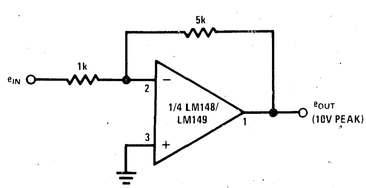
Positive Common-Mode Input Voltage Limit

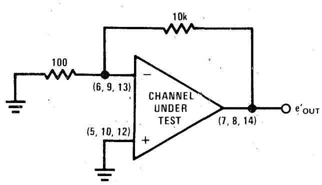


Negative Common-Mode Input Voltage Limit



cross talk test circuits





$$\text{Crosstalk} = -20 \log \frac{e'_{OUT}}{101 \times e_{OUT}} \text{ (dB)}$$

$V_S = \pm 15V$

application hints

The LM148 series are quad low power 741 op amps. In the proliferation of quad op amps, these are the first to offer the convenience of familiar, easy to use operating characteristics of the 741 op amp. In those applications where 741 op amps have been employed, the LM148 series op amps can be employed directly with no change in circuit performance.

The LM149 series has the same characteristics as the LM148 except it has been decompensated to provide a wider bandwidth. As a result the part requires a minimum gain of 5.

The package pin-outs are such that the inverting input of each amplifier is adjacent to its output. In addition, the amplifier outputs are located in the corners of the package which simplifies PC board layout and minimizes package related capacitive coupling between amplifiers.

The input characteristics of these amplifiers allow differential input voltages which can exceed the supply voltages. In addition, if either of the input voltages is within the operating common-mode range, the phase of the output remains correct. If the negative limit of the operating common-mode range is exceeded at both inputs, the output voltage will be positive. For input voltages which greatly exceed the maximum supply voltages, either differentially or common-mode, resistors should be placed in series with the inputs to limit the current.

Like the LM741, these amplifiers can easily drive a 100 pF capacitive load throughout the entire dynamic output voltage and current range. However, if very large capacitive loads must be driven by a non-inverting unity gain amplifier, a resistor should be placed between the output (and feedback connection) and the capacitance to reduce the phase shift resulting from the capacitive loading.

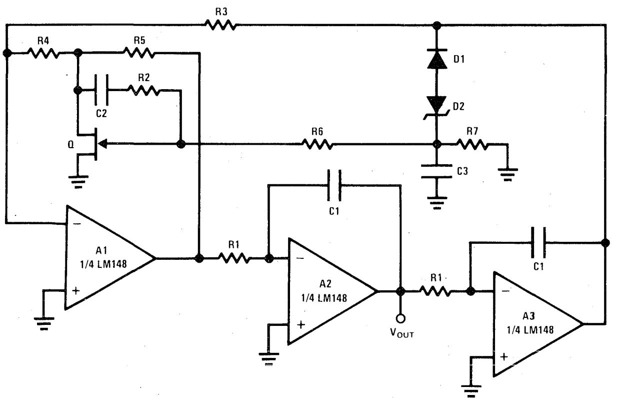
The output current of each amplifier in the package is limited. Short circuits from an output to either ground or the power supplies will not destroy the unit. However, if multiple output shorts occur simultaneously, the time duration should be short to prevent the unit from being destroyed as a result of excessive power dissipation in the IC chip.

As with most amplifiers, care should be taken with lead dress, component placement and supply decoupling in order to ensure stability. For example, resistors from the output to an input should be placed with the body close to the input to minimize "pickup" and maximize the frequency of the feedback pole which capacitance from the input to ground creates.

A feedback pole is created when the feedback around any amplifier is resistive. The parallel resistance and capacitance from the input of the device (usually the inverting input) to ac ground set the frequency of the pole. In many instances the frequency of this pole is much greater than the expected 3 dB frequency of the closed loop gain and consequently there is negligible effect on stability margin. However, if the feedback pole is less than approximately six times the expected 3 dB frequency a lead capacitor should be placed from the output to the input of the op amp. The value of the added capacitor should be such that the RC time constant of this capacitor and the resistance it parallels is greater than or equal to the original feedback pole time constant.

typical applications-LM148

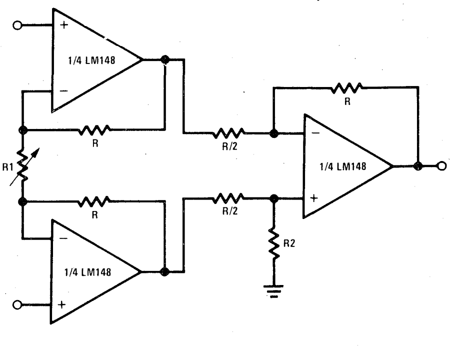
One Decade Low Distortion Sinewave Generator



$$f = \frac{1}{2\pi R1C1} \times \sqrt{K}, \quad K = \frac{R4R5}{R3}\left(\frac{1}{r_{DS}} + \frac{1}{R4} + \frac{1}{R5}\right), \quad r_{DS} \cong \frac{R_{ON}}{\left(1 - \frac{V_{GS}}{V_P}\right)^{1/2}}$$

f_{MAX} = 5 kHz, THD $\leq$ 0.03%
R1 = 100k pot., C1 = 0.0047μF, C2 = 0.01μF, C3 = 0.1μF, R2 = R6 = R7 = 1M, R3 = 5.1k, R4 = 12Ω, R5 = 240Ω, Q = NS5102, D1 = 1N914, D2 = 3.6V avalanche diode (ex. LM103), $V_S = \pm 15V$
A simpler version with some distortion degradation at high frequencies can be made by using A1 as a simple inverting amplifier, and by putting back to back zeners in the feedback loop of A3.

Low Cost Instrumentation Amplifier

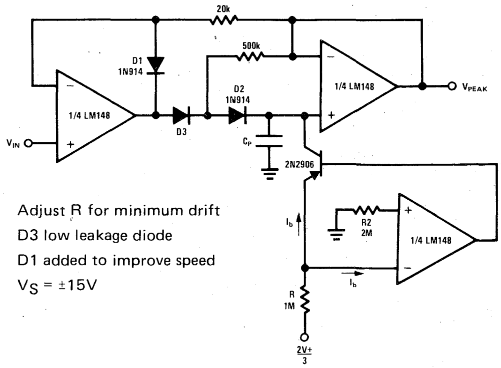


$$V_{OUT} = 2\left(\frac{2R}{R1} + 1\right), \quad V_S^- - 3V \leq V_{IN\ CM} \leq V_S^+ - 3V,$$

$V_S = \pm 15V$
R = R2, trim R2 to boost CMRR

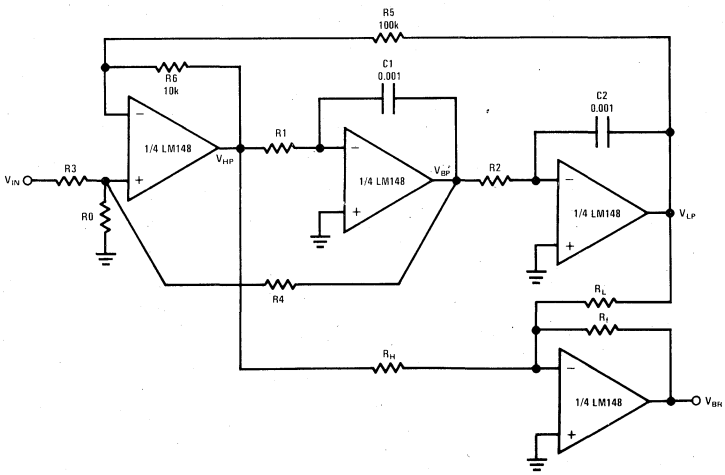
typical applications-LM148(con't)

Low Drift Peak Detector with Bias Current Compensation



Adjust R for minimum drift
D3 low leakage diode
D1 added to improve speed
$V_S = \pm 15V$

Universal State-Space Filter



Tune Q through R0,
For predictable results: $f_O\, Q \leq 4 \times 10^4$
Use Band Pass output to tune for Q

$$\frac{V(s)}{V_{IN}(s)} = \frac{N(s)}{D(s)}, \quad D(s) = S^2 + \frac{S\omega_o}{Q} + \omega_o^2$$

$$N_{HP}(s) = S^2 H_{OHP}, \quad N_{BP}(s) = \frac{-S\omega_O H_{OBP}}{Q} \qquad N_{LP} = \omega_o^2 H_{OLP}$$

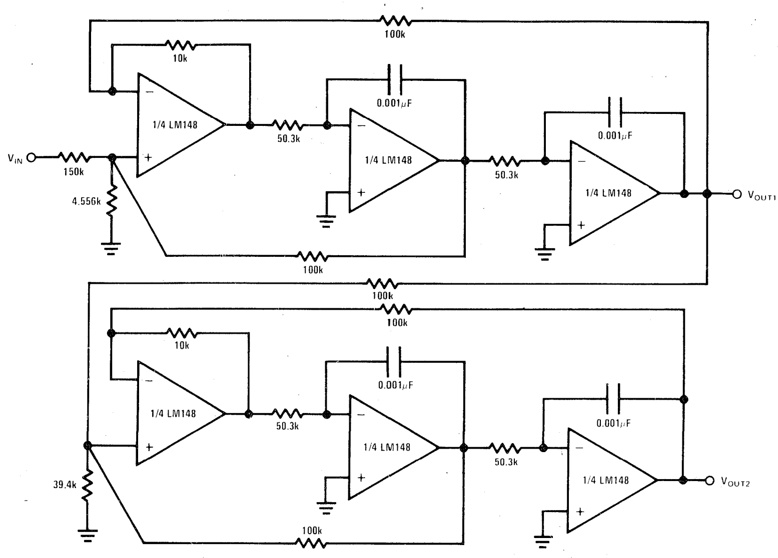
$$f_o = \frac{1}{2\pi}\sqrt{\frac{R6}{R5}}\sqrt{\frac{1}{t1\,t2}}, \quad t_i = R_i C_i, \quad Q = \left(\frac{1 + R4/R3 + R4/R0}{1 + R6/R5}\right)\left(\frac{R6}{R5}\,\frac{t_1}{t_2}\right)^{1/2}$$

$$f_{NOTCH} = \frac{1}{2\pi}\left(\frac{R_H}{R_L t_1 t_2}\right)^{1/2}, \quad H_{OHP} = \frac{1 + R6/R5}{1 + R3/R0 + R3/R4}, \quad H_{OBP} = \frac{1 + R4/R3 + R4/R0}{1 + R3/R0 + R3/R4}$$

$$H_{OLP} = \frac{1 + R5/R6}{1 + R3/R0 + R3/R4}$$

typical applications-LM148(con't)

A 1 kHz 4 Pole Butterworth

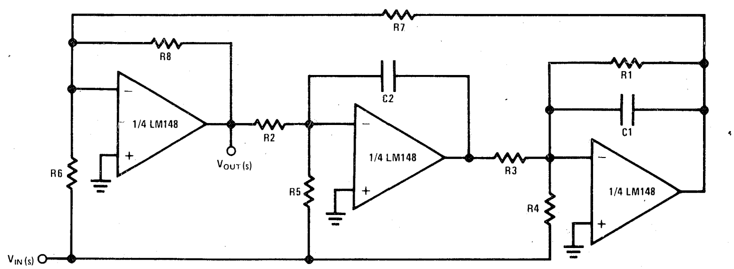


Use general equations, and tune each section separately

$Q_{1stSECTION} = 0.541$, $Q_{2ndSECTION} = 1.306$

The response should have 0 dB peaking

A 3 Amplifier Bi-Quad Notch Filter



$$Q = \sqrt{\frac{R8}{R7}} \times \frac{R1C1}{\sqrt{R3C2R2C1}}, \quad f_O = \frac{1}{2\pi}\sqrt{\frac{R8}{R7}} \times \frac{1}{\sqrt{R2R3C1C2}}, \quad f_{NOTCH} = \frac{1}{2\pi}\sqrt{\frac{R6}{R3R5R7C1C2}}$$

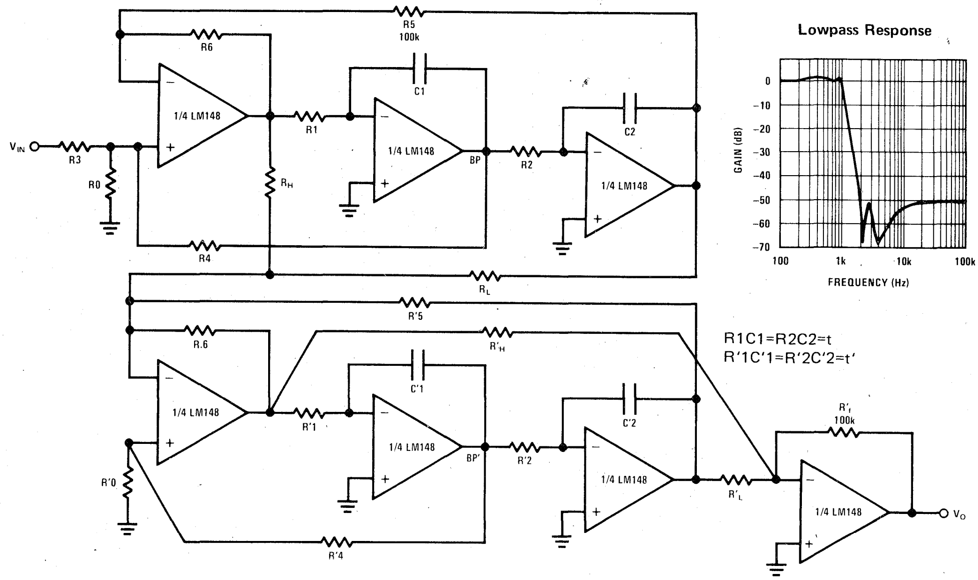
Necessary condition for notch: $\frac{1}{R6} = \frac{R1}{R4R7}$

Ex: f_{NOTCH} = 3 kHz, Q = 5, R1 = 270k, R2 = R3 = 20k, R4 = 27k, R5 = 20k, R6 = R8 = 10k, R7 = 100k, C1 = C2 = 0.001μF

Better noise performance than the state-space approach

typical applications-LM148(con't)

A 4th Order 1 kHz Elliptic Filter (4 Poles, 4 Zeros)



f_C = 1 kHz, f_S = 2 kHz, f_P = 0.543, f_Z = 2.14, Q = 0.841, f'_P = 0.987, f'_Z = 4.92, Q' = 4.403, normalized to ripple BW

$$f_P = \frac{1}{2\pi}\sqrt{\frac{R6}{R5}} \times \frac{1}{t},\quad f_Z = \frac{1}{2\pi}\sqrt{\frac{R_H}{R_L}} \times \frac{1}{t},\quad Q = \left(\frac{1 + R4\|R3 + R4\|R0}{1 + R6\|R5}\right) \times \sqrt{\frac{R6}{R5}},\quad Q' = \sqrt{\frac{R'6}{R'5}}\ \frac{1 + R'4\|R'0}{1 + R'6\|R'5 + R'6\|R_P}$$

$$R_P = \frac{R_H R_L}{R_H + R_L}$$

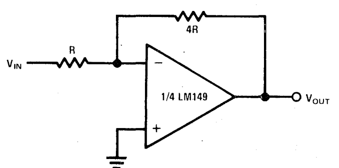
Use the BP outputs to tune Q, Q', tune the 2 sections separately

R1 = R2 = 92.6k, R3 = R4 = R5 = 100k, R6 = 10k, R0 = 107.8k, R_L = 100k, R_H = 155.1k,

R'1 = R'2 = 50.9k, R'4 = R'5 = 100k, R'6 = 10k, R'0 = 5.78k, R'_L = 100k, R'_H = 248.12k, R'f = 100k. All capacitors are 0.001μF.

typical applications-LM149

Minimum Gain to Insure LM149 Stability



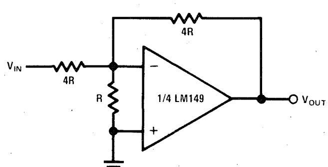
$$A_{CL(S)} = \frac{V_{OUT}}{V_{IN}} = \frac{-4}{\left(1 + \frac{5}{A_{OL(s)}}\right)} \cong -4$$

$$V_O \Big|_{V_{IN} = 0} \cong \pm 5\ V_{OS}$$

Power BW = 40 kHz

Small Signal BW = G BW/5

The LM149 as a Unity Gain Inverter



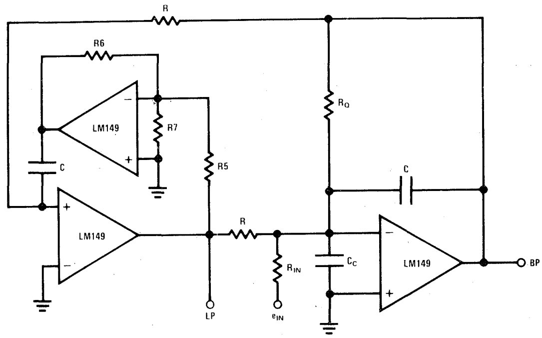
$$A_{CL(s)} = \frac{V_{OUT}}{V_{IN}} = \left(\frac{-1}{1 + \frac{6}{A_{OL(s)}}}\right) \cong -1$$

$$V_O \Big|_{V_{IN} = 0} \cong \pm 5\ V_{OS}$$

Small signal BW = G BW/5

typical applications-LM149(con't)

Non-inverting-Integrator Bandpass Filter



For stability purposes: $R7 = R6/4$, $10R6 = R5$, $C_C = 10C$

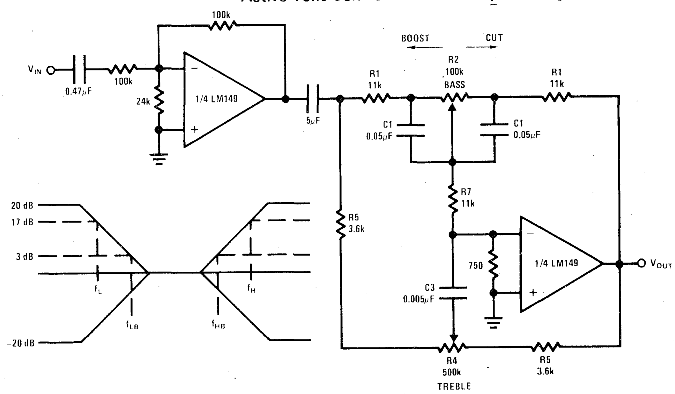
$$f_O = \frac{1}{2\pi}\sqrt{\frac{R5}{R6}} \times \frac{1}{RC}, \quad Q = \frac{R_Q}{R}\sqrt{\frac{R5}{R6}}, \quad Ho_{BP} = \frac{R_Q}{R_{IN}}$$

$(f_{O(MAX)}, Q_{MAX}) = 20$ kHz, 10

Better Q sensitivity with respect to open loop gain variations than the state variable filter.

R7, C_C added for compensation

Active Tone Control with Full Output Swing (No Slew Limiting at 20 kHz)



$V_S = \pm 15V$, $V_{OUT(MAX)} = 9.1\ V_{RMS}$, $f_{MAX} = 20$ kHz, THD $\leq 1\%$

Duplicate the above circuit for stereo

$$f_L = \frac{1}{2\pi R2C1}, \quad f_{LB} = \frac{1}{2\pi R1C1}$$

$$f_H = \frac{1}{2\pi R5C3}, \quad f_{HB} = \frac{1}{2\pi(R1 + 2R7)\,C3}$$

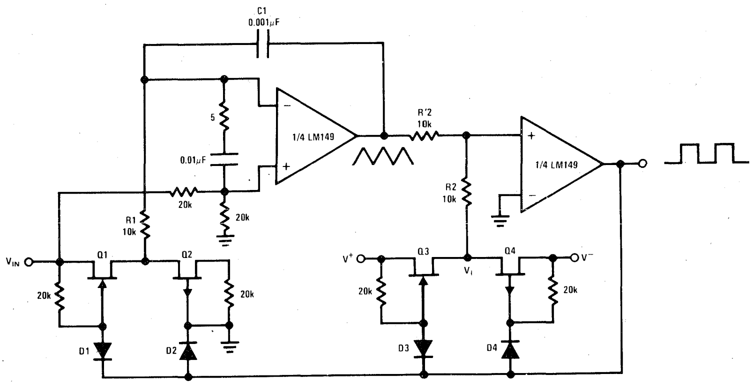
Max Bass Gain $\cong (R1 + R2)/R1$

Max Treble Gain $\cong (R1 + 2R7)/R5$

as shown: $f_L \cong 32$ Hz, $f_{LB} \cong 320$ Hz

$f_H \cong 11$ kHz, $f_{HB} \cong 1.1$ Hz

Triangular, Squarewave Generator



$$f = \frac{K \times V_{IN}}{8V^+C1R1}, \quad K = R2/R'2, \quad \frac{2V_I}{K} \leq 25V, \quad V^+ = V^-, \quad V_S = \pm 15V$$

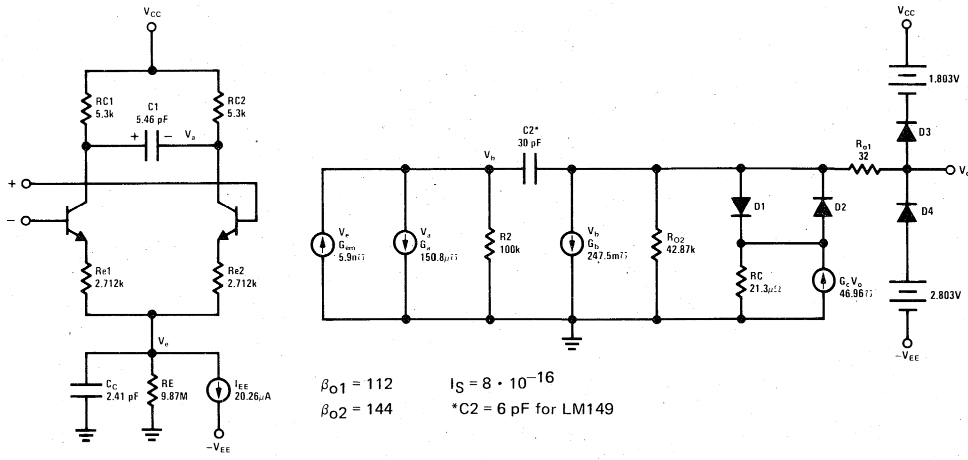
Use LM125 for ±15V supply

The circuit can be used as a low frequency V/F for process control.

Q1, Q3: KE4393, Q2, Q4: P1087E, D1–D4 = 1N914

typical simulation

LM148, LM149, LM741 Macromodel for Computer Simulation



$\beta_{o1} = 112$ $\quad$ $I_S = 8 \cdot 10^{-16}$

$\beta_{o2} = 144$ $\quad$ *C2 = 6 pF for LM149

—For more details, see IEEE Journal of Solid-State Circuits, Vol. SC-9, No. 6, December 1974

Operational Amplifiers/Buffers

LM158/LM258/LM358, LM158A/LM258A/LM358A, LM2904 low power dual operational amplifiers

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

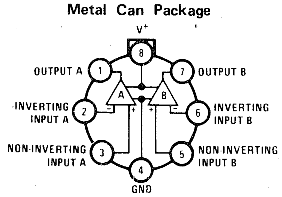
- Eliminates need for dual supplies
- Two internally compensated op amps in a single package
- Allows directly sensing near GND and V_{OUT} also goes to GND
- Compatible with all forms of logic
- Power drain suitable for battery operation
- Pin-out same as LM1558/LM1458 dual operational amplifier

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}

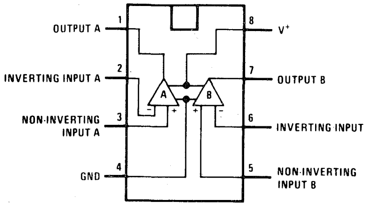
connection diagrams (Top Views)

Metal Can Package



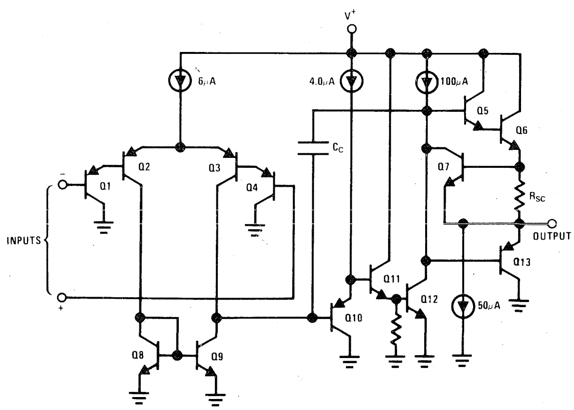
Order Number LM158AH, LM158H, LM258AH, LM258H, LM358AH or LM358H
See Package 11

Dual-In-Line Package



Order Number LM358AN LM358N or LM2904N
See Package 20

schematic diagram (Each Amplifier)



absolute maximum ratings

	LM158/LM258/LM358 LM158A/LM258A/LM358A	LM2904
Supply Voltage, V^+	32 V_{DC} or ±16 V_{DC}	26 V_{DC} or ±13 V_{DC}
Differential Input Voltage	32 V_{DC}	26 V_{DC}
Input Voltage	−0.3 V_{DC} to +32 V_{DC}	−0.3 V_{DC} to +32 V_{DC}
Power Dissipation (Note 1)		
Molded DIP (LM358N)	570 mW	570 mW
Metal Can (LM158H/LM258H/LM358H)	500 mW	
Output Short-Circuit to GND (One Amplifier) (Note 2) $V^+ \leq 15\ V_{DC}$ and $T_A = 25°C$	Continuous	Continuous
Input Current ($V_{IN} < -0.3\ V_{OL}$) (Note 3)	50 mA	
Operating Temperature Range		
LM358	0°C to +70°C	−40°C to +85°C
LM258	−25°C to +85°C	
LM158	−55°C to +125°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 ($V^+ = +5.0\ V_{DC}$, Note 4)

PARAMETER	CONDITIONS	LM158A			LM258A			LM358A			LM158/LM258			LM358			LM2904			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$T_A = 25°C$, (Note 5)		1	2		1	3		2	3		±2	±5		±2	±7		±2	±7	mV_{DC}
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$, $T_A = 25°C$, (Note 6)		20	50		40	80		45	100		45	150		45	250		45	250	nA_{DC}
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, $T_A = 25°C$		2	10		2	15		5	30		±3	±30		±5	±50		±5	±50	nA_{DC}
Input Common-Mode Voltage Range	$V^+ = 30\ V_{DC}$, $T_A = 25°C$ (Note 7)	0		$V^+-1.5$	0		$V^+-1.5$	0		$V^+-1.5$	0		$V^+-1.5$	0		$V^+-1.5$	0		$V^+-1.5$	V_{DC}
Supply Current	$R_L = \infty$, $V_{CC} = 30V$ (LM2904 $V_{CC} = 26V$)		1.5	3		1.5	3		1.5	3		1.5	3		1.5	3		1.5	3	mA_{DC}
	$R_L = \infty$ On All Op Amps Over Full Temperature Range		0.7	1.2		0.7	1.2		0.7	1.2		0.7	1.2		0.7	1.2		0.7	1.2	mA_{DC}
	$T_A = 25°C$																		3	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		50	100		25	100		50	100		25	100			100		V/mV
Output Voltage Swing	$R_L = 2\ k\Omega$, $T_A = 25°C$ (LM2904 $R_L \geq 10\ k\Omega$)										0		$V^+-1.5$	0		$V^+-1.5$	0		$V^+-1.5$	V_{DC}
Common-Mode Rejection Ratio	DC, $T_A = 25°C$	70	85		70	85		65	85		70	85		65	70		50	70		dB
Power Supply Rejection Ratio	DC, $T_A = 25°C$	65	100		65	100		65	100		65	100		65	100		50	100		dB
Amplifier-to-Amplifier Coupling	f = 1 kHz to 20 kHz, $T_A = 25°C$ (Input Referred), (Note 8)		−120			−120			−120			−120			−120			−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		20	40		20	40		20	40		20	40		20	40		mA_{DC}

electrical characteristics (con't) ($V^+ = +5.0\ V_{DC}$, Note 4)

PARAMETER	CONDITIONS	LM158A			LM258A			LM358A			LM158/LM258			LM358			LM2904			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Sink	$V_{IN}^- = 1\ V_{DC}$, $V_{IN} = 0\ V_{DC}$, $V^+ = 15\ V_{DC}$, $T_A = 25°C$	10	20		10	20		10	20		10	20		10	20		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		12	50		12	50		12	50		12	50					μA_{DC}
Short Circuit to Ground	$T_A = 25°C$, (Note 2)		40	60		40	60		40	60		40	60		40	60		40	60	mA_{DC}
Input Offset Voltage	(Note 5)			4			4			5			±7			±9			±10	mV_{DC}
Input Offset Voltage Drift	$R_S = 0\Omega$		7	15		7	15		7	20		7			7			7		$\mu V/°C$
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$			30			30			75			±100			±150		45	±200	nA_{DC}
Input Offset Current Drift			10	200		10	200		10	300		10			10			10		$pA_{DC}/°C$
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$		40	100		40	100		40	200		40	300		40	500		40	500	nA_{DC}
Input Common-Mode Voltage Range	$V^+ = 30\ V_{DC}$, (Note 7)	0		V^+-2	0		V^+-2	0		V^+-2	0		V^+-2	0		V^+-2	0		V^+-2	V_{DC}

Note 1: For operating at high temperatures, the LM358/LM358A, LM2904 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/LM258A and LM158/LM158A 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. Destructive dissipation can result from simultaneous shorts on all amplifiers.

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 $-55°C \le T_A \le +125°C$, unless otherwise stated. With the LM258/LM258A, all temperature specifications are limited to $-25°C \le T_A \le +85°C$, the LM358/LM358A temperature specifications are limited to $0°C \le T_A \le +70°C$, and the LM2904 specifications are limited to $-40°C \le T_A \le +85°C$.

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 $V^+ - 1.5\ V_{DC}$).

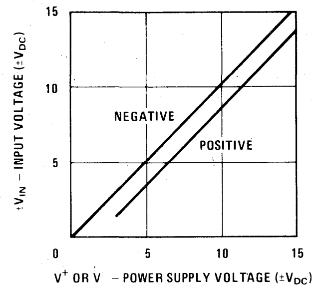
Note 6: The direction of the input current is out of the IC due to the PNP input stage. This current is essentially constant, independent of the state of the output so no loading change exists on the input lines.

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 (+26 V_{DC} for LM2904).

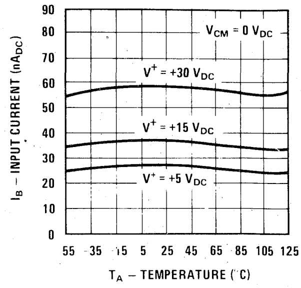
Note 8: Due to proximity of external components, insure that coupling is not originating via stray capacitance between these external parts. This typically can be detected as this type of capacitive increases at higher frequencies.

typical performance characteristics

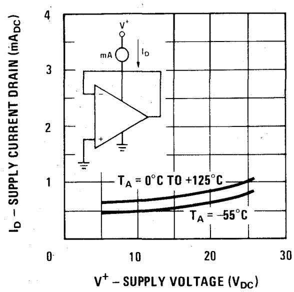
Input Voltage Range



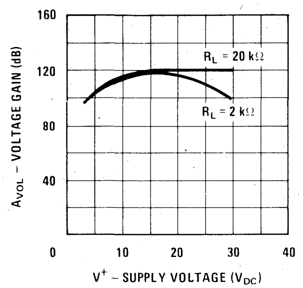
Input Current



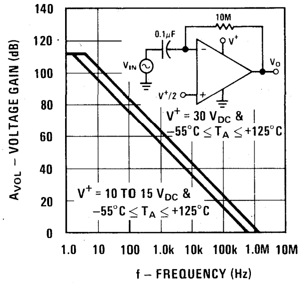
Supply Current



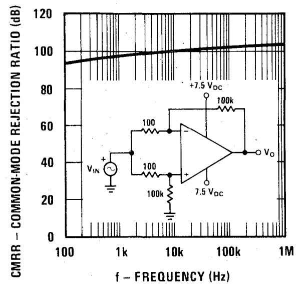
Voltage Gain



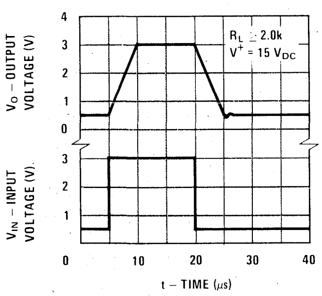
Open Loop Frequency Response



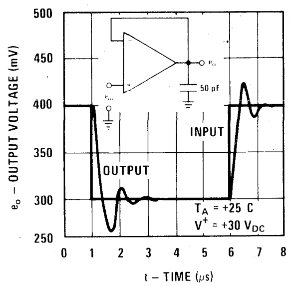
Common Mode Rejection Ratio



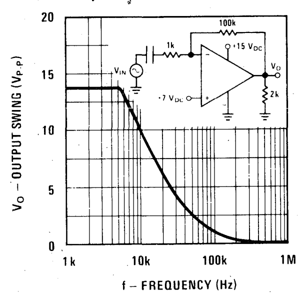
Voltage Follower Pulse Response



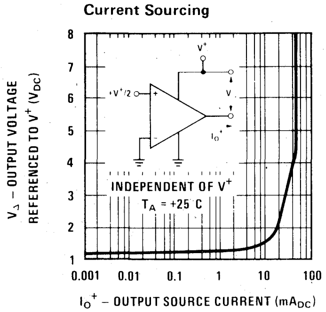
Voltage Follower Pulse Response (Small Signal)



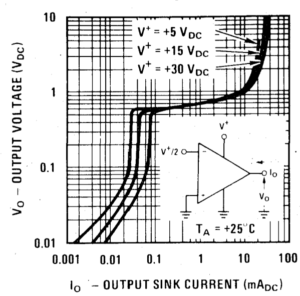
Large Signal Frequency Response



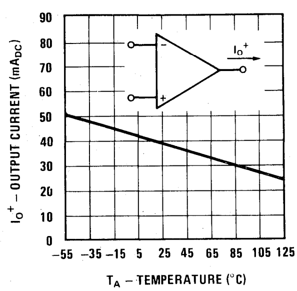
Output Characteristics Current Sourcing



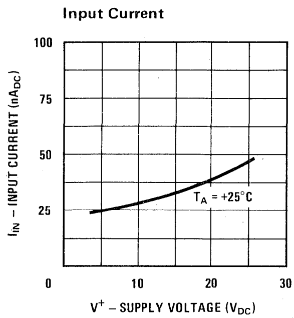
Output Characteristics Current Sinking

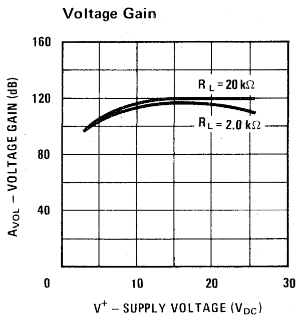


Current Limiting



typical performance characteristics (con't) (LM2902 only)





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 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.

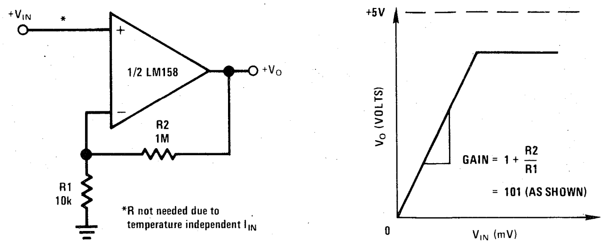
The bias network of the LM158 establishes a drain current which is independent of the magnitude of the power supply voltage over the range of from 3 V_{DC} to 30 V_{DC}.

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.

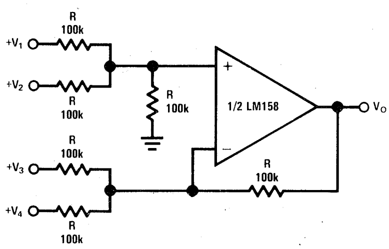
The circuits presented in the section on typical applications emphasize operation on only a single power supply voltage. If complementary power supplies are available, all of the standard op amp circuits can be used. In general, introducing a pseudo-ground (a bias voltage reference of $V^+/2$) will allow 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)

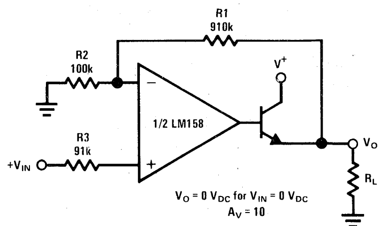


DC Summing Amplifier
(V_{IN}'S $\geq 0\ V_{DC}$ AND $V_O \geq 0\ V_{DC}$)

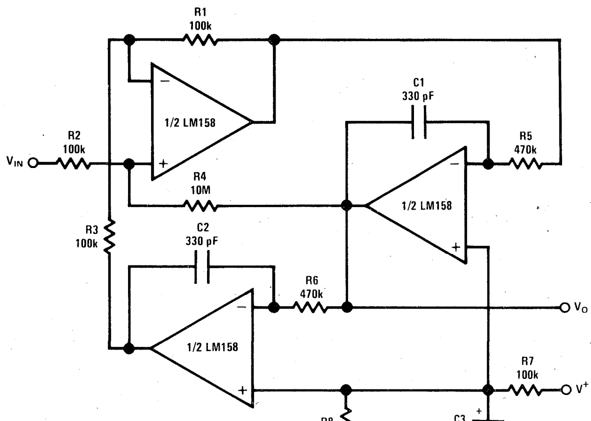


Where: $V_O = V_1 + V_2 - V_3 - V_4$
$(V_1 + V_2) \geq (V_3 + V_4)$ to keep $V_O > 0\ V_{DC}$

Power Amplifier

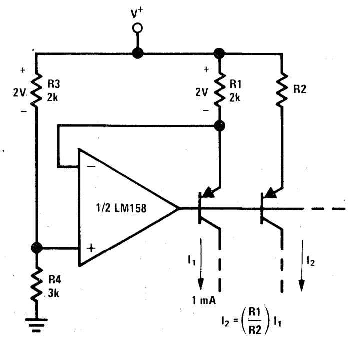


"BI-QUAD" RC Active Bandpass Filter



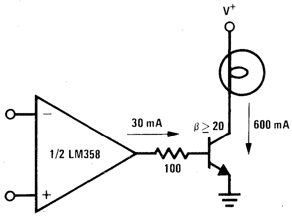
$f_O = 1$ kHz
$Q = 50$
$A_V = 100$ (40 dB)

Fixed Current Sources

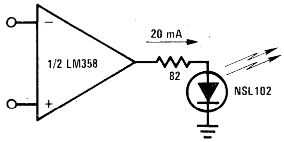


typical single-supply applications (con't) ($V^+ = 5.0\ V_{DC}$)

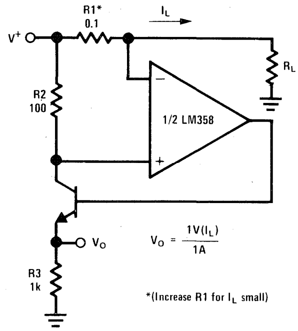
Lamp Driver



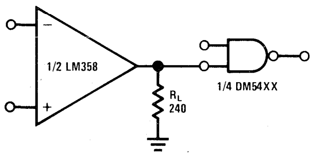
LED Driver



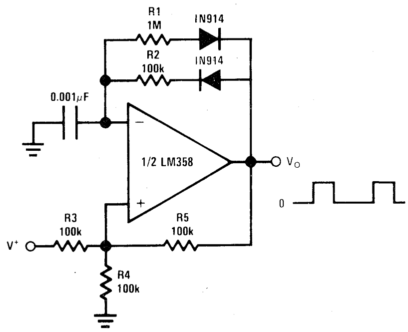
Current Monitor



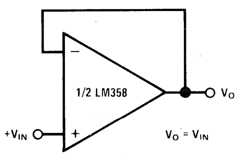
Driving TTL



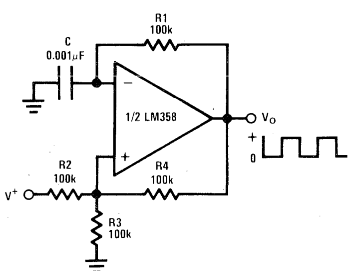
Pulse Generator



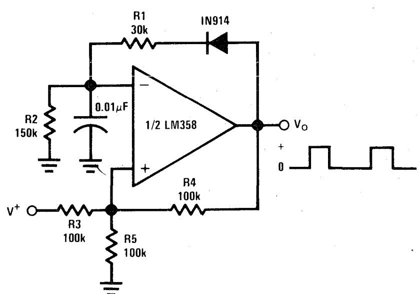
Voltage Follower



Squarewave Oscillator

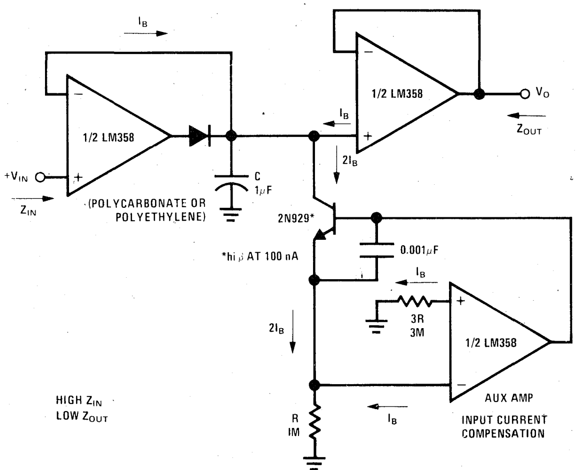


Pulse Generator

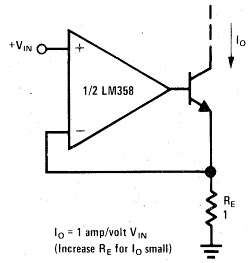


typical single-supply applications (con't) ($V^+ = 5.0\ V_{DC}$)

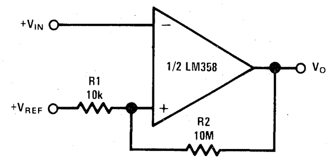
Low Drift Peak Detector



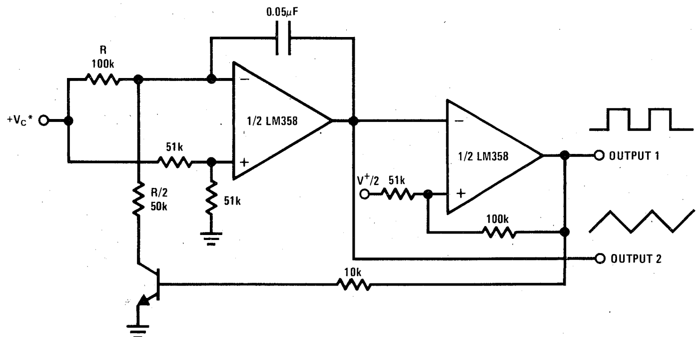
High Compliance Current Sink



Comparator with Hysteresis

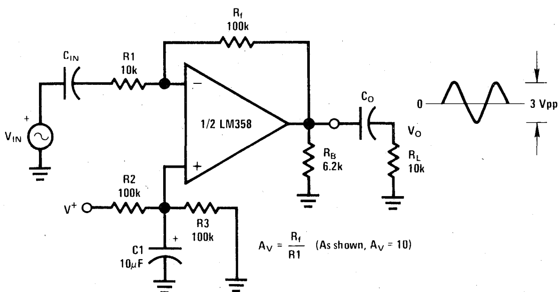


Voltage Controlled Oscillator (VCO)



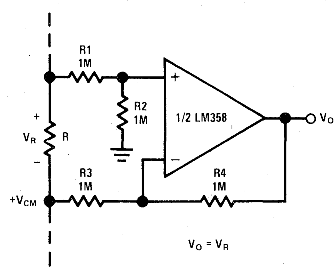
*WIDE CONTROL VOLTAGE RANGE: $0\ V_{DC} \leq V_C \leq 2\ (V^+ - 1.5\ V_{DC})$

AC Coupled Inverting Amplifier



$A_V = \frac{R_f}{R1}$ (As shown, $A_V = 10$)

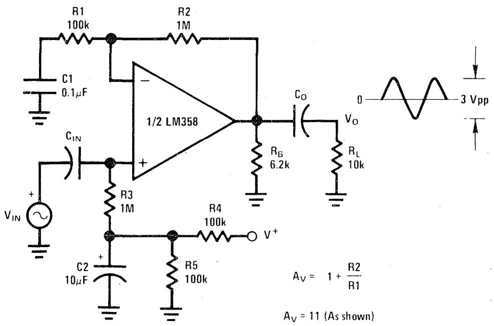
Ground Referencing A Differential Input Signal



$V_O = V_R$

typical single-supply applications (con't) ($V^+ = 5.0\ V_{DC}$)

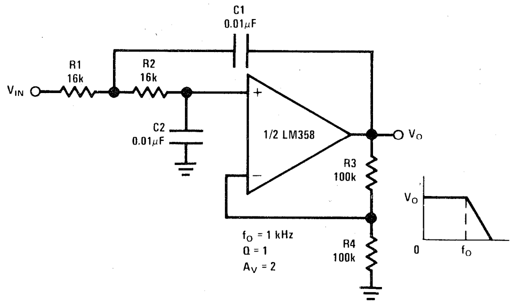
AC Coupled Non-Inverting Amplifier



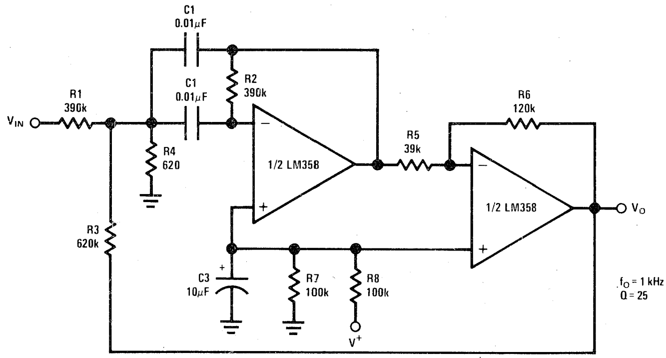
$A_V = 1 + \frac{R2}{R1}$

$A_V = 11$ (As shown)

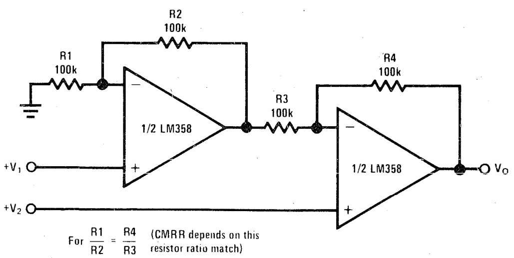
DC Coupled Low-Pass RC Active Filter



Bandpass Active Filter



High Input Z, DC Differential Amplifier

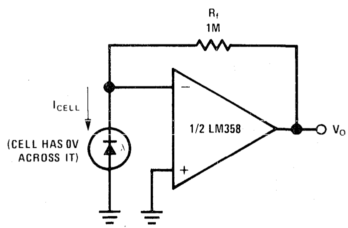


For $\frac{R1}{R2} = \frac{R4}{R3}$ (CMRR depends on this resistor ratio match)

$V_O = 1 + \frac{R4}{R3} \quad (V_2 - V_1)$

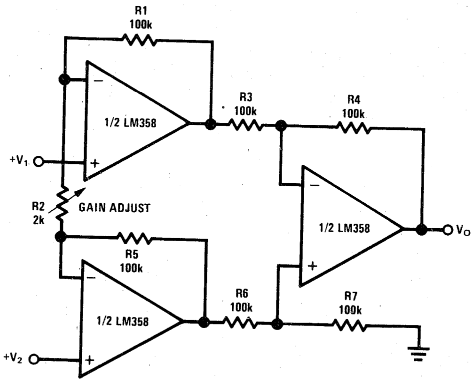
As shown: $V_O = 2(V_2 - V_1)$

Photo Voltaic-Cell Amplifier



typical single-supply applications (con't) ($V^+ = 5.0\ V_{DC}$)

High Input Z Adjustable-Gain DC Instrumentation Amplifier

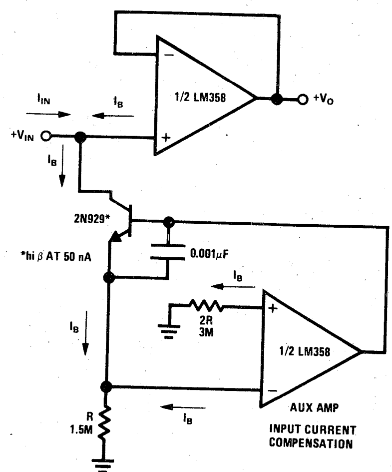


If R1 = R5 & R3 = R4 = R6 = R7 (CMRR depends on match)

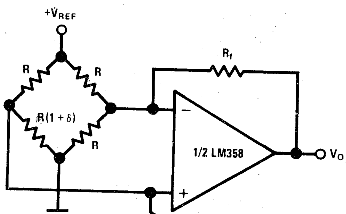
$$V_O = 1 + \frac{2R1}{R2}(V_2 - V_1)$$

As shown $V_O = 101\ (V_2 - V_1)$

Using Symmetrical Amplifiers to Reduce Input Current (General Concept)



Bridge Current Amplifier



For $\delta << 1$ and $R_f >> R$

$$V_O \cong V_{REF}\left(\frac{\delta}{2}\right)\frac{R_f}{R}$$

Operational Amplifiers/Buffers

LM216/LM316, LM216A/LM316A operational amplifiers

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:

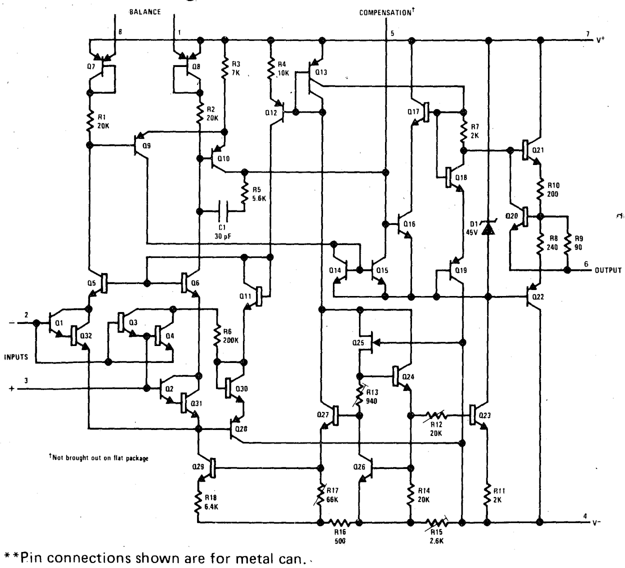
- Guaranteed bias currents as low as 50 pA
- Maximum offset currents down to 15 pA
- Operates from supplies of ±3V to ±20V
- Supply current only 300 μA at ±20V

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.

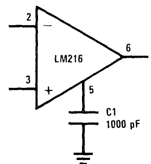
schematic diagram**



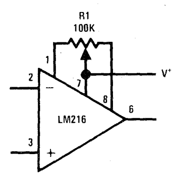
**Pin connections shown are for metal can.

auxiliary circuits**

Overcompensation for Greater Stability Margin

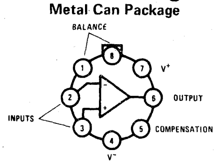


Offset Balancing



connection diagrams

Metal Can Package

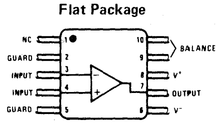


Note: Pin 4 connected to case.

TOP VIEW

Order Number LM216H or LM216AH or LM316H or LM316AH
See Package 11

Flat Package



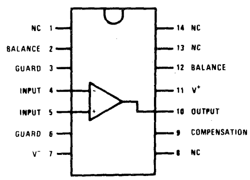
Note: Pin 6 connected to bottom of package.

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 Package



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	LM216A	LM216	LM316A	LM316	UNITS
Input Offset Voltage	$T_A = 25°C$	3	10	3	10	mV
Input Offset Current	$T_A = 25°C$	15	50	15	50	pA
Input Bias Current	$T_A = 25°C$	50	150	50	150	pA
Input Resistance	$T_A = 25°C$	5	1	5	1	GΩ
Supply Current	$T_A = 25°C$	0.6	0.8	0.6	0.8	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = ±15V$ $V_{OUT} = ±10V$, $R_L \geq 10\ k\Omega$	40	20	40	20	V/mV
Input Offset Voltage		6	15	6	15	mV
Input Offset Current		30	100	30	100	pA
Input Bias Current		100	250	100	250	pA
Supply Current	$T_A = T_{MAX}$	0.5		0.5		mA
Large Signal Voltage Gain	$V_S = ±15V$, $V_{OUT} = ±10V$ $R_L \geq 10\ k\Omega$	20	10	30	15	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.

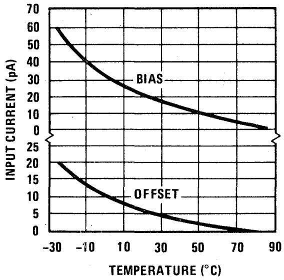
Note 2: The inputs are shunted with back-to-back diodes for overvoltage protection. Therefore, excessive current will flow if a differential input voltage in excess of 1V is applied between the inputs unless some limiting resistance is used.

Note 3: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

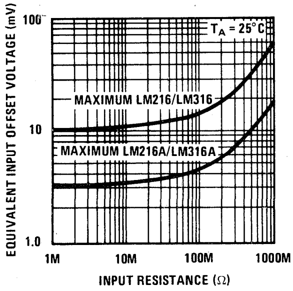
Note 4: These specifications apply for $±5V \leq V_S \leq ±20V$ and $-25°C \leq T_A \leq 85°C$, unless otherwise specified. With the LM316 and LM316A however, all temperature specifications are limited to $0°C \leq T_A \leq 55°C$.

typical performance characteristics

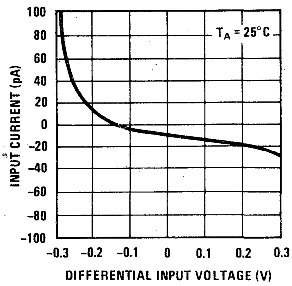
Input Currents



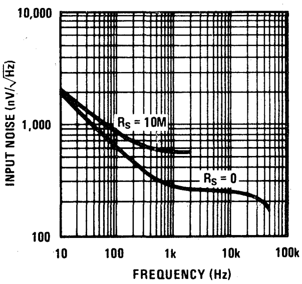
Offset Error



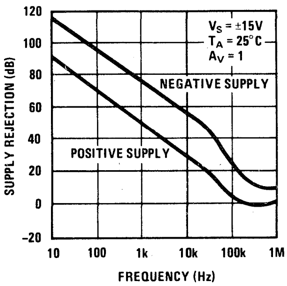
Input Current



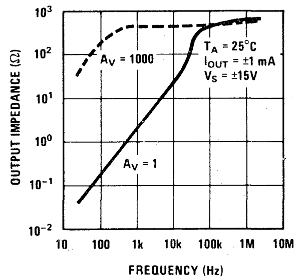
Input Noise Voltage



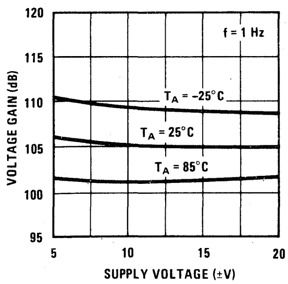
Power Supply Rejection



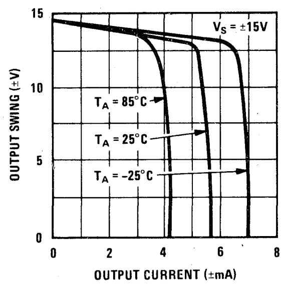
Closed Loop Output Impedance



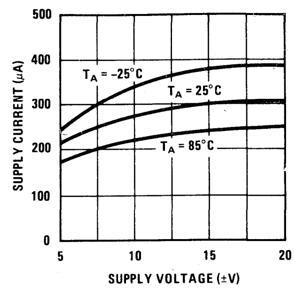
Voltage Gain



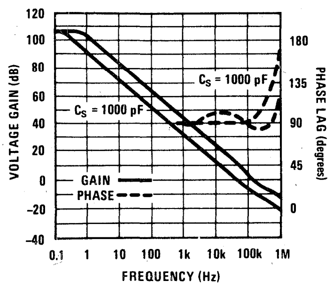
Output Swing



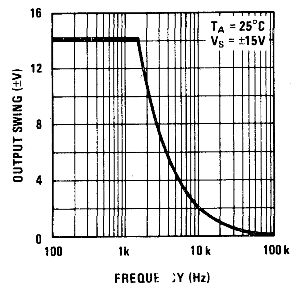
Supply Current



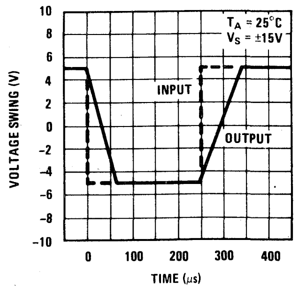
Open Loop Frequency Response



Large Signal Frequency Response



Voltage Follower Pulse Response



Operational Amplifiers/Buffers

LM709/LM709A/LM709C operational amplifier

general description

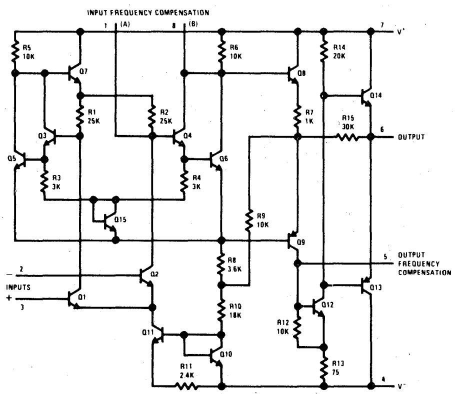
The LM709 series are a monolithic operational amplifier intended for general-purpose applications. Operation is completely specified over the range of voltages commonly used for these devices. The design, in addition to providing high gain, minimizes both offset voltage and bias currents. Further, the 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/LM709A except that it is specified for operation from 0°C to +70°C.

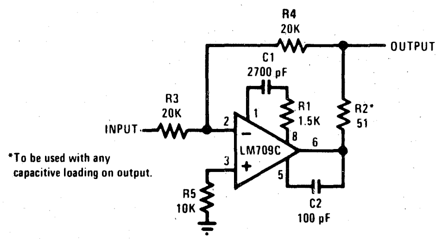
schematic diagram**



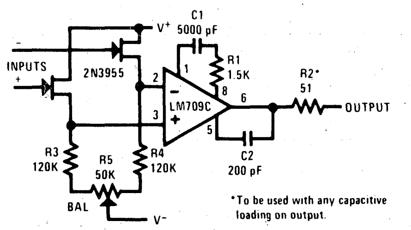
**Pin connections shown are for metal can package.

typical applications**

Unity Gain Inverting Amplifier

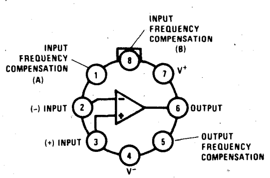


FET Operational Amplifier



connection diagrams

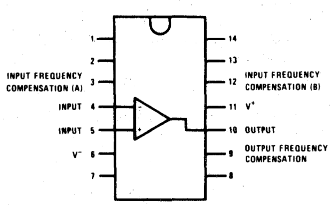
Metal Can Package



Note: Pin 4 connected to case.

Order Number LM709H or LM709CH
See Package 11

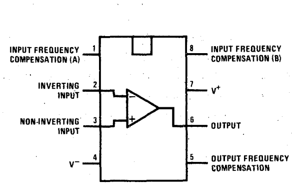
Dual-In-Line Package



Order Number LM709AJ, LM709J or LM709CJ
See Package 16

Order Number LM709CN
See Package 22

Dual-In-Line Package



Order Number LM709CN-8
See Package 20

absolute maximum ratings

	LM709/LM709A	LM709C
Supply Voltage	±18V	±18V
Power Dissipation (Note 1)	300 mW	250 mW
Differential Input Voltage	±5V	±5V
Input Voltage	±10V	±10V
Output Short-Circuit Duration (T_A = 25°C)	5 seconds	5 seconds
	T_{MIN} T_{MAX}	T_{MIN} T_{MAX}
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C
Operating Temperature Range	−55°C to +125°C	0°C to +70°C
Lead Temperature (Soldering, 10 seconds)	300°C	300°C

electrical characteristics (Note 2)

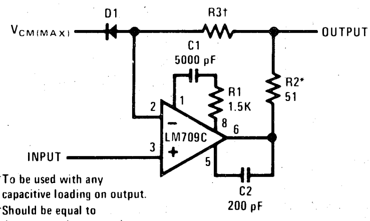
PARAMETER	CONDITIONS	LM709A			LM709			LM709C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	T_A = 25°C, $R_S \leq$ 10 kΩ		0.6	2.0		1.0	5.0		2.0	7.5	mV
Input Bias Current	T_A = 25°C		100	200		200	500		300	1500	nA
Input Offset Current	T_A = 25°C		10	50		50	200		100	500	nA
Input Resistance	T_A = 25°C	350	700		150	400		50	250		kΩ
Output Resistance	T_A = 25°C		150			150			150		Ω
Supply Current	T_A = 25°C, V_S = ±15V		2.5	3.6		2.6	5.5		2.6	6.6	mA
Transient Response	V_{IN} = 20 mV, $C_L \leq$ 100 pF										
Risetime	T_A = 25°C			1.5		0.3	1.0		0.3	1.0	μs
Overshoot				30		10	30		10	30	%
Slew Rate	T_A = 25°C		0.25			0.25			0.25		V/μs
Input Offset Voltage	$R_S \leq$ 10 kΩ			3.0			6.0			10	mV
Average Temperature Coefficient of Input Offset Voltage	R_S = 50Ω, T_A = 25°C to T_{MAX}		1.8	10		3.0			6.0		μV/°C
	R_S = 50Ω, T_A = 25°C to T_{MIN}		1.8	10		6.0			12		μV/°C
	R_S = 10 kΩ, T_A = 25°C to T_{MAX}		2.0	15							
	R_S = 10 kΩ, T_A = 25°C to T_{MIN}		4.8	25							
Large Signal Voltage Gain	V_S = ±15V, $R_L \geq$ 2 kΩ, V_{OUT} = ±10V	25		70	25	45	70	15	45		V/mV
Output Voltage Swing	V_S = ±15V, R_L = 10 kΩ	±12	±14		±12	±14		±12	±14		V
	V_S = ±15V, R_L = 2 kΩ	±10	±13		±10	±13		±10	±13		V
Input Voltage Range	V_S = ±15V	±8.0			±8.0	±10.0		±8.0	±10		V
Common-Mode Rejection Ratio	$R_S \leq$ 10 kΩ	80	110		70	90		65	90		dB
Supply Voltage Rejection Ratio	$R_S \leq$ 10 kΩ		40	100		25	150		25	200	μV/V
Input Offset Current	T_A = T_{MAX}		3.5	50		20	200		75	400	nA
	T_A = T_{MIN}		40	250		100	500		125	750	nA
Input Bias Current	T_A = T_{MIN}		0.3	0.6		0.5	1.5		0.36	2.0	μA
Input Resistance	T_A = T_{MIN}	85	170		40	100		50	250		kΩ

Note 1: For operating at elevated temperatures, the device must be derated based on a 150°C maximum junction temperature for LM709/LM709A and 100°C maximum for LM709C 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-thick, 2-ounce copper conductors (see curve).

Note 2: These specifications apply for −55°C $\leq T_A \leq$ +125°C for LM709/LM709A and 0°C $\leq T_A \leq$ +70°C for LM709C with the following conditions: ±9V $\leq V_S \leq$ ±15V, C1 = 5000 pF, R1 = 1.5k, C2 = 200 pF and R2 = 51Ω.

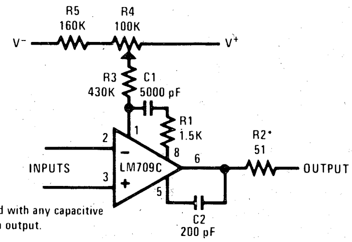
typical applications (con't)

Voltage Follower



*To be used with any capacitive loading on output.
†Should be equal to dc source resistance on input.

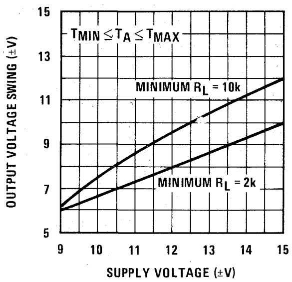
Offset Balancing Circuit



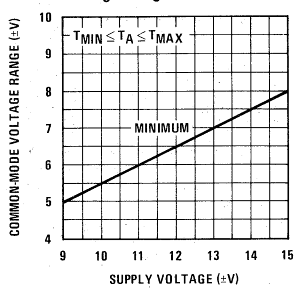
*To be used with any capacitive loading on output.

guaranteed performance characteristics

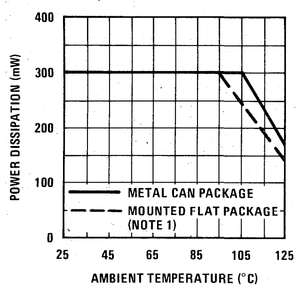
Output Voltage Swing



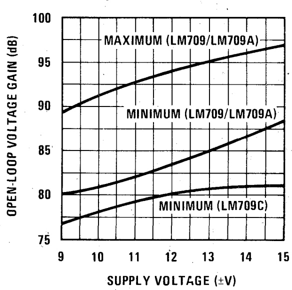
Input Common-Mode Voltage Range



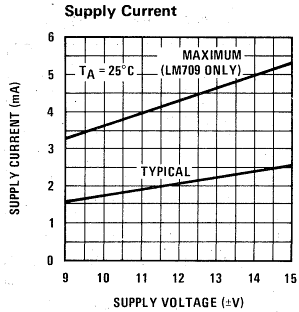
Maximum Power Dissipation



Voltage Gain

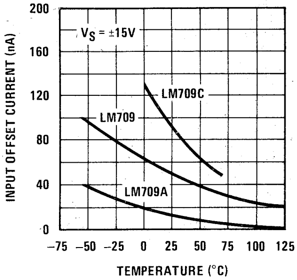


Supply Current

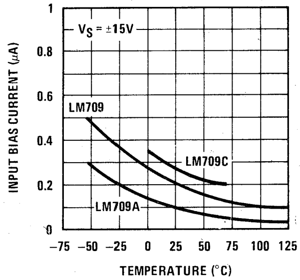


typical performance characteristics

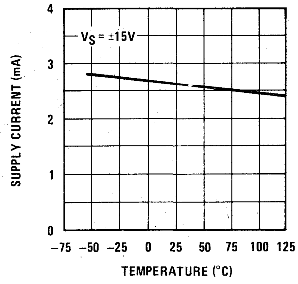
Input Offset Current



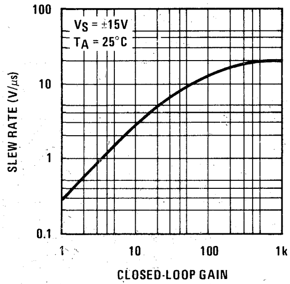
Input Bias Current



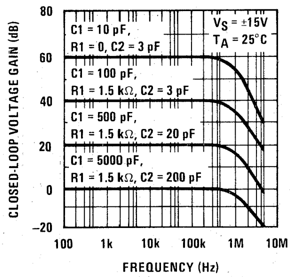
Supply Current



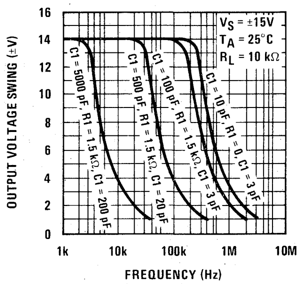
Slew Rate as a Function of Closed-Loop Gain Using Recommended Compensation Networks



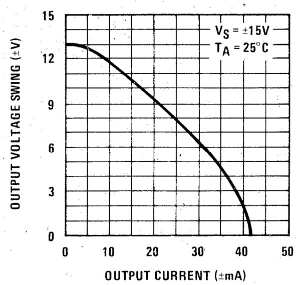
Frequency Response For Various Closed-Loop Gains



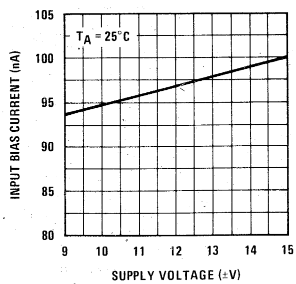
Output Voltage Swing as a Function of Frequency



Output Voltage Swing



Input Bias Current as a Function of Supply Voltage



Operational Amplifiers/Buffers

LM741/LM741A/LM741C/LM741E operational amplifier

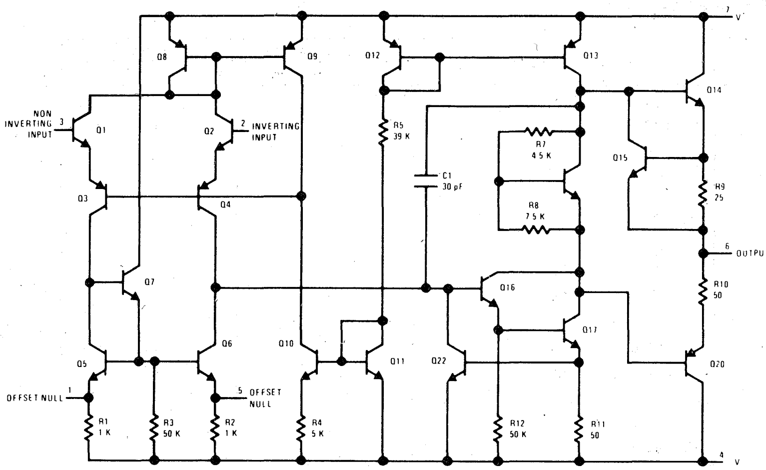
general description

The LM741 series 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.

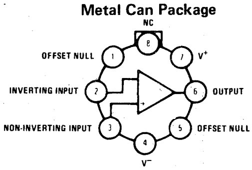
The amplifiers offer many features which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, as well as freedom from oscillations.

The LM741C/LM741E are identical to the LM741/LM741A except that the LM741C/LM741E have their performance guaranteed over a 0°C to +70°C temperature range, instead of −55°C to +125°C.

schematic and connection diagrams (Top Views)



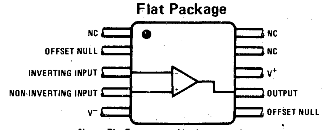
Metal Can Package



Note: Pin 4 connected to case.

Order Number LM741H, LM741AH, LM741CH or LM741EH
See Package 11

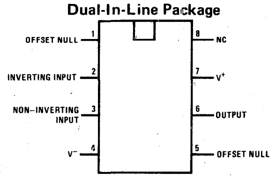
Flat Package



Note: Pin 5 connected to bottom of package.

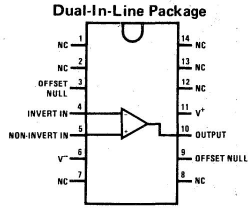
Order Number LM741F or LM741AF
See Package 3

Dual-In-Line Package



Order Number LM741CN or LM741EN
See Package 20
Order Number LM741CJ or LM741EJ
See Package 15

Dual-In-Line Package



Order Number LM741CD, LM741D, LM741AD or LM741ED
See Package 2B
Order Number LM741CN-14
See Package 22
Order Number LM741J-14, LM741AJ-14 LM741CJ-14 or LM741EJ-14
See Package 16

absolute maximum ratings

	LM741A	LM741E	LM741	LM741C
Supply Voltage	±22V	±22V	±22V	±18V
Power Dissipation (Note 1)				
Differential Input Voltage	±30V	±30V	±30V	±30V
Input Voltage (Note 2)	±15V	±15V	±15V	±15V
Output Short Circuit Duration	Indefinite	Indefinite	Indefinite	Indefinite
Operating Temperature Range	−55°C to +125°C	0°C to +70°C	−55°C to +125°C	0°C to +70°C
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C	300°C	300°C	300°C

electrical characteristics

PARAMETER	CONDITIONS	LM741A/LM741E			LM741			LM741C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$T_A = 25°C$										
	$R_S \le 10\ k\Omega$					1.0	5.0		2.0	6.0	mV
	$R_S \le 50\Omega$		0.8	3.0							mV
	$T_{AMIN} \le T_A \le T_{AMAX}$										
	$R_S \le 50\Omega$			4.0							mV
	$R_S \le 10\ k\Omega$						6.0			7.5	mV
Average Input Offset Voltage Drift				15							μV/°C
Input Offset Voltage Adjustment Range	$T_A = 25°C$, $V_S = \pm 20V$	±10				±15			±15		mV
Input Offset Current	$T_A = 25°C$		3.0	30		20	200		20	200	nA
	$T_{AMIN} \le T_A \le T_{AMAX}$			70		85	500			300	nA
Average Input Offset Current Drift				0.5							nA/°C
Input Bias Current	$T_A = 25°C$		30	80		80	500		80	500	nA
	$T_{AMIN} \le T_A \le T_{AMAX}$			0.210			1.5			0.8	μA
Input Resistance	$T_A = 25°C$, $V_S = \pm 20V$	1.0	6.0		0.3	2.0		0.3	2.0		MΩ
	$T_{AMIN} \le T_A \le T_{AMAX}$, $V_S = \pm 20V$	0.5									MΩ
Input Voltage Range	$T_A = 25°C$							±12	±13		V
	$T_{AMIN} \le T_A \le T_{AMAX}$				±12	±13					V
Large Signal Voltage Gain	$T_A = 25°C$, $R_L \ge 2\ k\Omega$										
	$V_S = \pm 20V$, $V_O = \pm 15V$	50									V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$				50	200		20	200		V/mV
	$T_{AMIN} \le T_A \le T_{AMAX}$, $R_L \ge 2\ k\Omega$,										
	$V_S = \pm 20V$, $V_O = \pm 15V$	32									V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$				25			15			V/mV
	$V_S = \pm 5V$, $V_O = \pm 2V$	10									V/mV
Output Voltage Swing	$V_S = \pm 20V$										
	$R_L \ge 10\ k\Omega$	±16									V
	$R_L \ge 2\ k\Omega$	±15									V
	$V_S = \pm 15V$										
	$R_L \ge 10\ k\Omega$				±12	±14		±12	±14		V
	$R_L \ge 2\ k\Omega$				±10	±13		±10	±13		V
Output Short Circuit Current	$T_A = 25°C$	10	25	35		25			25		mA
	$T_{AMIN} \le T_A \le T_{AMAX}$	10		40							mA
Common-Mode Rejection Ratio	$T_{AMIN} \le T_A \le T_{AMAX}$										
	$R_S \le 10\ k\Omega$, $V_{CM} = \pm 12V$				70	90		70	90		dB
	$R_S \le 50\ k\Omega$, $V_{CM} = \pm 15V$	80	95								dB

electrical characteristics (con't)

PARAMETER	CONDITIONS	LM741A/LM741E MIN	LM741A/LM741E TYP	LM741A/LM741E MAX	LM741 MIN	LM741 TYP	LM741 MAX	LM741C MIN	LM741C TYP	LM741C MAX	UNITS
Supply Voltage Rejection Ratio	$T_{AMIN} \le T_A \le T_{AMAX}$, $V_S = \pm 20V$ to $V_S = \pm 5V$										
	$R_S \le 50\Omega$	86	96								dB
	$R_S \le 10\ k\Omega$				77	96		77	96		dB
Transient Response	$T_A = 25°C$, Unity Gain										
Rise Time			0.25	0.8		0.3			0.3		μs
Overshoot			6.0	20		5			5		%
Bandwidth (Note 4)	$T_A = 25°C$	0.437	1.5								MHz
Slew Rate	$T_A = 25°C$, Unity Gain	0.3	0.7			0.5			0.5		V/μs
Supply Current	$T_A = 25°C$					1.7	2.8		1.7	2.8	mA
Power Consumption	$T_A = 25°C$										
	$V_S = \pm 20V$		80	150							mW
	$V_S = \pm 15V$					50	85		50	85	mW
LM741A	$V_S = \pm 20V$										
	$T_A = T_{AMIN}$			165							mW
	$T_A = T_{AMAX}$			135							mW
LM741E	$V_S = \pm 20V$			150							mW
	$T_A = T_{AMIN}$			150							mW
	$T_A = T_{AMAX}$			150							mW
LM741	$V_S = \pm 15V$										
	$T_A = T_{AMIN}$					60	100				mW
	$T_A = T_{AMAX}$					45	75				mW

Note 1: The maximum junction temperature of the LM741/LM741A is 150°C, while that of the LM741C/LM741E 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. The thermal resistance of the dual-in-line package is 100°C/W junction to ambient. 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: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: Unless otherwise specified, these specifications apply for $V_S = \pm 15V$, $-55°C \le T_A \le +125°C$ (LM741/LM741A). For the LM741C/LM741E, these specifications are limited to $0°C \le T_A \le +70°C$.

Note 4: Calculated value from: BW (MHz) = 0.35/Rise Time(μs).

Operational Amplifiers/Buffers

LM747/LM747A/LM747C/LM747E dual operational amplifier

general description

The LM747 series are general purpose dual operational amplifiers. The two amplifiers share a common bias network and power supply leads. Otherwise, their operation is completely independent.

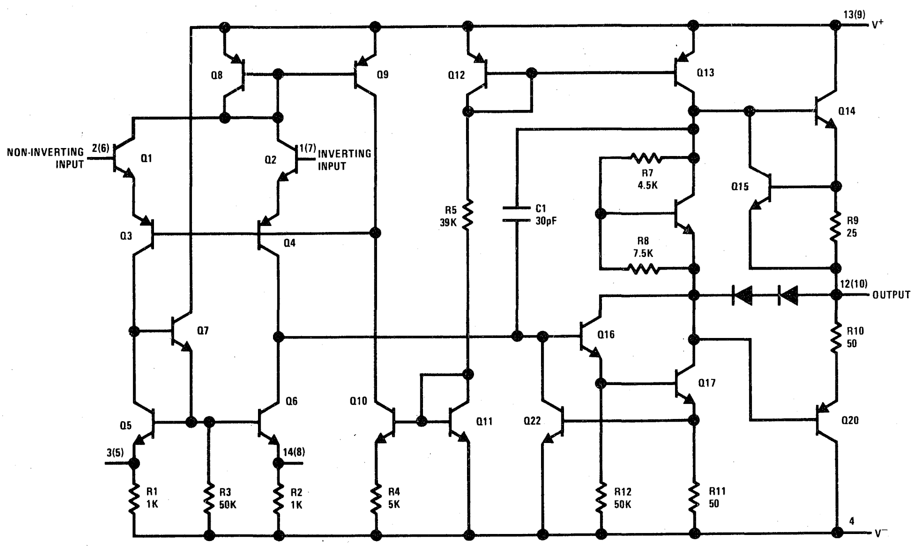
features

- 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/LM747E is identical to the LM747/LM747A except that the LM747C/LM747E 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.

absolute maximum ratings

Supply Voltage	LM747/LM747A	±22V
	LM747C/LM747E	±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/LM747A		−55°C to +125°C
LM747C/LM747E		0°C to +70°C
Storage Temperature Range		−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)		300°C

electrical characteristics

PARAMETER	CONDITIONS	LM747A/LM747E			LM747			LM747C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$T_A = 25°C$										
	$R_S \leq 10\ k\Omega$					1.0	5.0		2.0	6.0	mV
	$R_S \leq 50\Omega$		0.8	3.0							mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
	$R_S \leq 50\Omega$			4.0							mV
	$R_S \leq 10\ k\Omega$						6.0			7.5	mV
Average Input Offset Voltage Drift				15							µV/°C
Input Offset Voltage Adjustment Range	$T_A = 25°C$, $V_S = \pm 20V$	±10				±15			±15		mV
Input Offset Current	$T_A = 25°C$		3.0	30		20	200		20	200	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			70		85	500			300	nA
Average Input Offset Current Drift				0.5							nA/°C
Input Bias Current	$T_A = 25°C$		30	80		80	500		80	500	nA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$			0.210			1.5			0.8	µA
Input Resistance	$T_A = 25°C$, $V_S = \pm 20V$	1.0	6.0		0.3	2.0		0.3	2.0		MΩ
	$T_{AMIN} \leq T_A \leq T_{AMAX}$, $V_S = \pm 20V$	0.5									MΩ
Input Voltage Range	$T_A = 25°C$							±12	±13		V
	$T_{AMIN} \leq T_A \leq T_{AMAX}$				±12	±13					V
Large Signal Voltage Gain	$T_A = 25°C$, $R_L \geq 2\ k\Omega$										
	$V_S = \pm 20V$, $V_O = \pm 15V$	50									V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$				50	200		20	200		V/mV
	$T_{AMIN} \leq T_A \leq T_{AMAX}$, $R_L \geq 2\ k\Omega$,										
	$V_S = \pm 20V$, $V_O = \pm 15V$	32									V/mV
	$V_S = \pm 15V$, $V_O = \pm 10V$				25			15			V/mV
	$V_S = \pm 5V$, $V_O = \pm 2V$	10									V/mV
Output Voltage Swing	$V_S = \pm 20V$										
	$R_L \geq 10\ k\Omega$	±16									V
	$R_L \geq 2\ k\Omega$	±15									V
	$V_S = \pm 15V$										
	$R_L \geq 10\ k\Omega$				±12	±14		±12	±14		V
	$R_L \geq 2\ k\Omega$				±10	±13		±10	±13		V
Output Short Circuit Current	$T_A = 25°C$	10	25	35		25			25		mA
	$T_{AMIN} \leq T_A \leq T_{AMAX}$	10		40							mA
Common-Mode Rejection Ratio	$T_{AMIN} \leq T_A \leq T_{AMAX}$										
	$R_S \leq 10\ k\Omega$, $V_{CM} = \pm 12V$				70	90		70	90		dB
	$R_S \leq 50\ k\Omega$, $V_{CM} = \pm 15V$	80	95								dB

electrical characteristics (con't)

PARAMETER	CONDITIONS	LM747A/LM747E			LM747			LM747C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Supply Voltage Rejection Ratio	$T_{AMIN} \leq T_A \leq T_{AMAX}$, $V_S = \pm 20V$ to $V_S = \pm 5V$										
	$R_S \leq 50\Omega$	86	96								dB
	$R_S \leq 10\ k\Omega$				77	96		77	96		dB
Transient Response	$T_A = 25°C$, Unity Gain										
Rise Time			0.25	0.8		0.3			0.3		μs
Overshoot			6.0	20		5			5		%
Bandwidth (Note 4)	$T_A = 25°C$	0.437	1.5								MHz
Slew Rate	$T_A = 25°C$, Unity Gain	0.3	0.7			0.5			0.5		V/μs
Supply Current	$T_A = 25°C$					1.7	2.8		1.7	2.8	mA
Power Consumption	$T_A = 25°C$										
	$V_S = \pm 20V$		80	150							mW
	$V_S = \pm 15V$					50	85		50	85	mW
LM747A	$V_S = \pm 20V$										
	$T_A = T_{AMIN}$			165							mW
	$T_A = T_{AMAX}$			135							mW
LM747E	$V_S = \pm 20V$			150							mW
	$T_A = T_{AMIN}$			150							mW
	$T_A = T_{AMAX}$			150							mW
LM747	$V_S = \pm 15V$										
	$T_A = T_{AMIN}$					60	100				mW
	$T_A = T_{AMAX}$					45	75				mW

Note 1: The maximum junction temperature of the LM747/LM747A is 150°C, while that of the LM747C/LM747E 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.

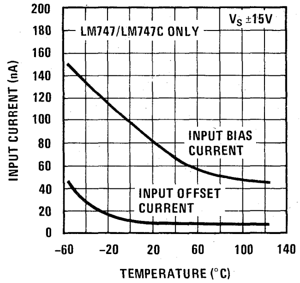
Note 3: These specifications apply for $\pm 5V \leq V_S \leq \pm 20V$ and $-55°C \leq T_A \leq 125°C$ for the LM747A and $0°C \leq T_A \leq 70°C$ for the LM747E unless otherwise specified. The LM741 and LM741C are specified for $V_S = \pm 15V$ and $-55°C \leq T_A \leq 125°C$ and $0°C \leq T_A \leq 70°C$, respectively, unless otherwise specified.

Note 4: Calculated value from: 0.35/Rise Time (μs).

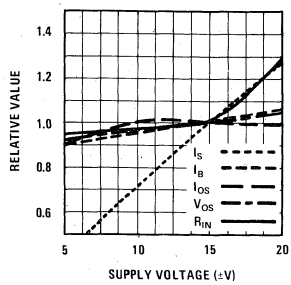
Note 5: The positive supply current for LM7471A, LM747-1, LM747-1C and LM747-1E are guaranteed to be less than or equal to one-half the maximum value indicated.

typical performance characteristics

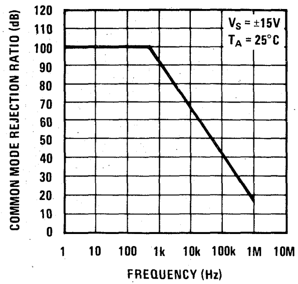
Input Bias and Offset Currents vs Ambient Temperature



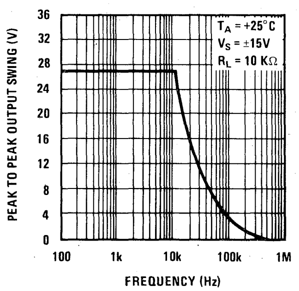
DC Parameters vs Supply Voltage



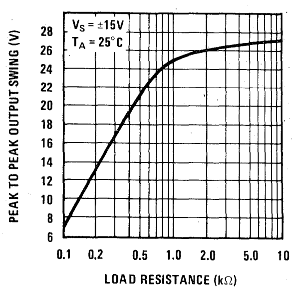
Common Mode Rejection Ratio vs Frequency



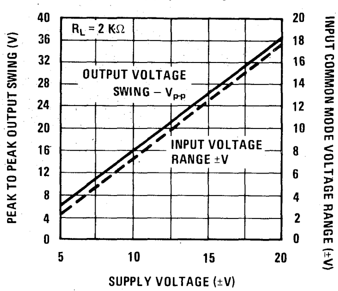
Output Voltage Swing vs Frequency



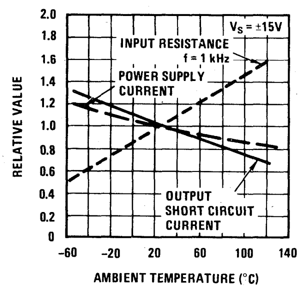
Output Voltage Swing vs Load Resistance



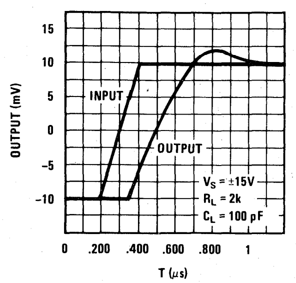
Output Swing and Input Range vs Supply Voltage



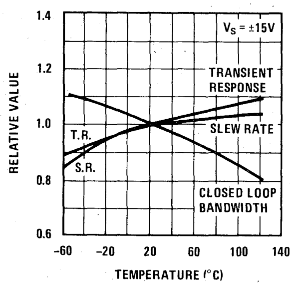
Normalized DC Parameters vs Ambient Temperature



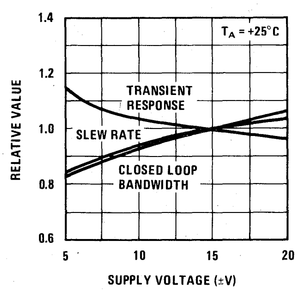
Transient Response



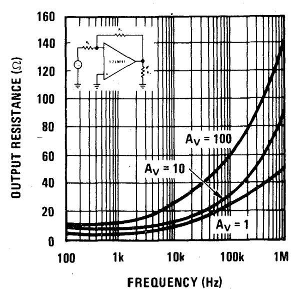
Frequency Characteristics vs Ambient Temperature



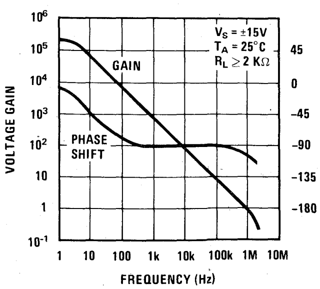
Frequency Characteristics vs Supply Voltage



Output Resistance vs Frequency



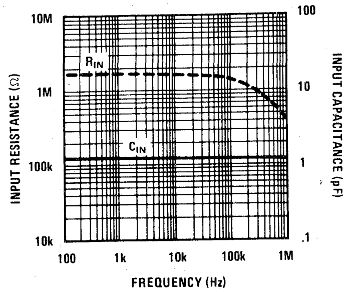
Open Loop Transfer Characteristics vs Frequency



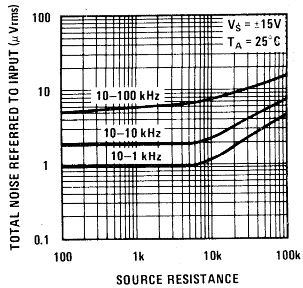
3

typical performance characteristics (con't)

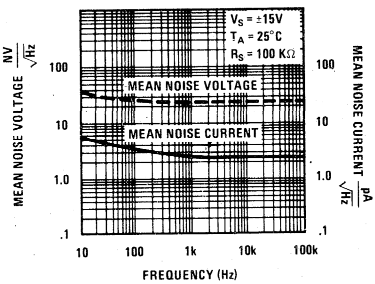
Input Resistance and Input Capacitance vs Frequency



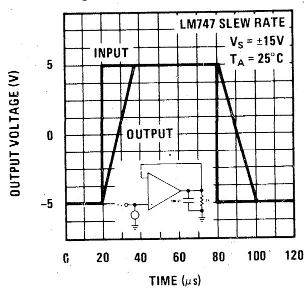
Broadband Noise for Various Bandwidths



Input Noise Voltage and Current vs Frequency

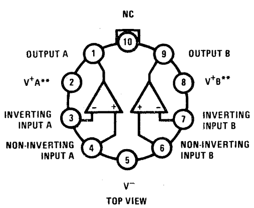


Voltage Follower Large Signal Pulse Response



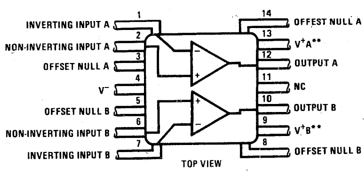
connection diagrams

Metal Can Package



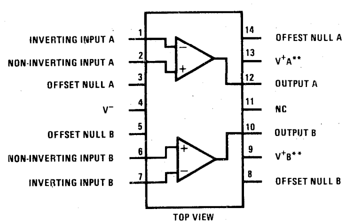
Order Number LM747AH, LM747H, LM747EH, LM747CH, LM747-1AH, LM747-1H, LM747-1EH or LM747-1CH
See Package 14

Flat Package



Order Number LM747F, LM747CF
See Package 4

Dual-In-Line Package



Order Number LM747AD, LM747D, LM747ED, LM747CD, LM747-1AD, LM747-1D, LM747-1ED or LM747-1CD
See Package 2B

Order Number LM747AJ, LM747J, LM747EJ, LM747CJ, LM747-1AJ, LM747-1J, LM747-1EJ, LM747-1CJ
See Package 16

Order Number LM747EN, LM747CN, LM747-1EN or LM747-1CN
See Package 22

**V^+A and V^+B are internally connected.

Operational Amplifiers/Buffers

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:

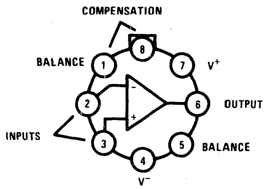
- Frequency compensation with a single 30 pF capacitor
- Operation from ±5V to ±20V
- Low current drain: 1.8 mA at ±20V
- Continuous short-circuit protection
- Operation as a comparator with differential inputs as high as ±30V
- No latch-up when common mode range is exceeded.
- Same pin configuration 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

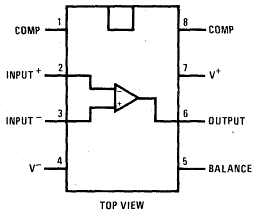
Metal Can Package



Note: Pin 4 connected to case.

Order Number LM748H or LM748CH
See Package 11

Dual-In-Line Package

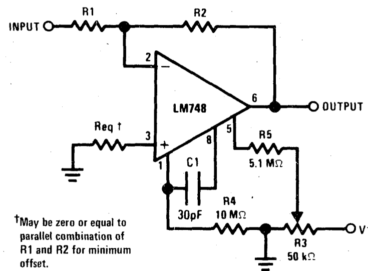


Order Number LM748CN
See Package 20

Order Number LM748J or LM748CJ
See Package 15

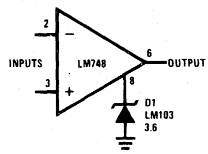
typical applications

Inverting Amplifier with Balancing Circuit

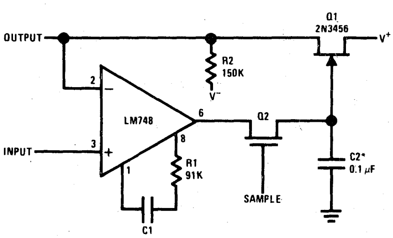


†May be zero or equal to parallel combination of R1 and R2 for minimum offset.

Voltage Comparator for Driving DTL or TTL Integrated Circuits

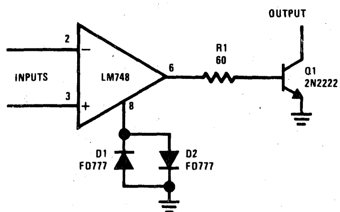


Low Drift Sample and Hold



*Polycarbonate-dielectric capacitor.

Voltage Comparator for Driving RTL Logic or High Current Driver



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	$T_A = 25°C$, $R_S \leq 10\ k\Omega$		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	$T_A = 25°C$, $V_S = \pm 15V$ $V_{OUT} = \pm 10V$, $R_L \geq 2\ k\Omega$	50	160		V/mV
Input Offset Voltage	$R_S \leq 10\ k\Omega$			6.0	mV
Average Temperature Coefficient of Input Offset Voltage	$R_S \leq 50\Omega$ $R_S \leq 10\ k\Omega$		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	$V_S = \pm 15V$, $V_{OUT} = \pm 10V$ $R_L \geq 2\ K\Omega$	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	$R_S \leq 10\ k\Omega$	70	90		dB
Supply Voltage Rejection Ratio	$R_S \leq 10\ k\Omega$	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).

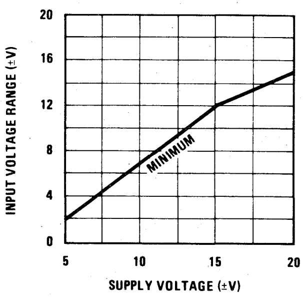
Note 2: For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: Continuous short circuit is allowed for case temperatures to +125°C and ambient temperatures to +70°C.

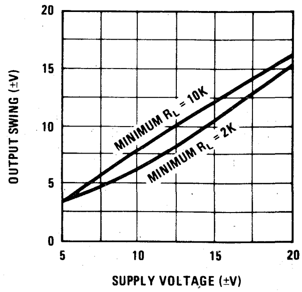
Note 4: These specifications apply for $\pm 5V \leq V_S \leq +15V$ and $-55°C \leq T_A \leq 125°C$, unless otherwise specified. With the LM748C, however, all temperature specifications are limited to $0°C \leq T_A \leq 70°C$.

guaranteed performance characteristics (Note 4)

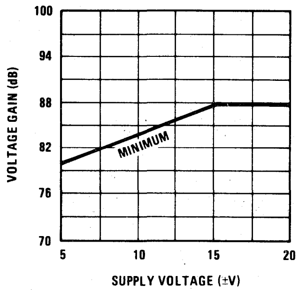
Input Voltage Range



Output Swing

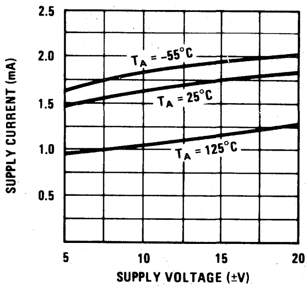


Voltage Gain

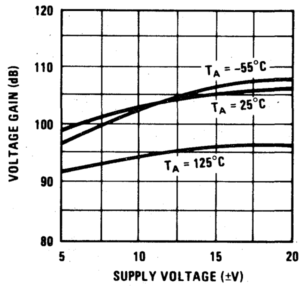


typical performance characteristics

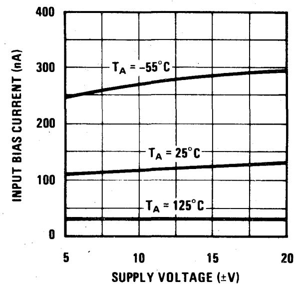
Supply Current



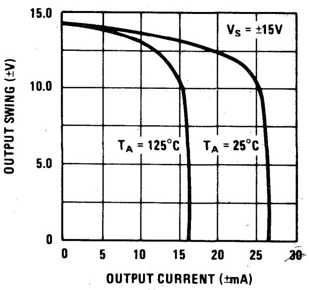
Voltage Gain



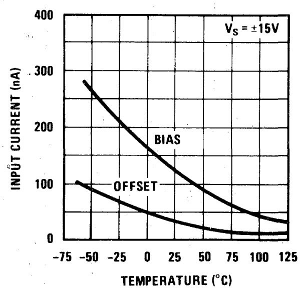
Input Bias Current



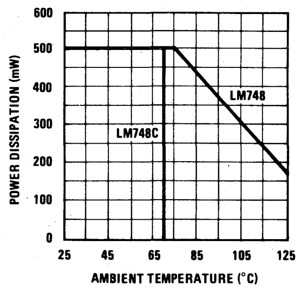
Current Limiting



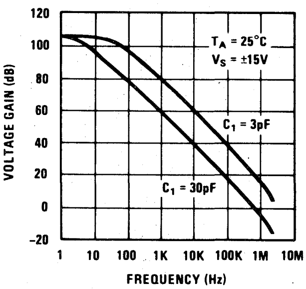
Input Current



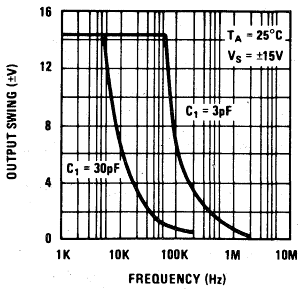
Maximum Power Dissipation



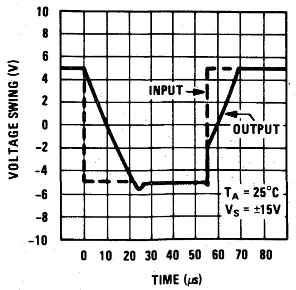
Open Loop Frequency Response



Large Signal Frequency Response



Voltage Follower Pulse Response



3

Operational Amplifiers/Buffers

LM1558/LM1458 dual operational amplifier

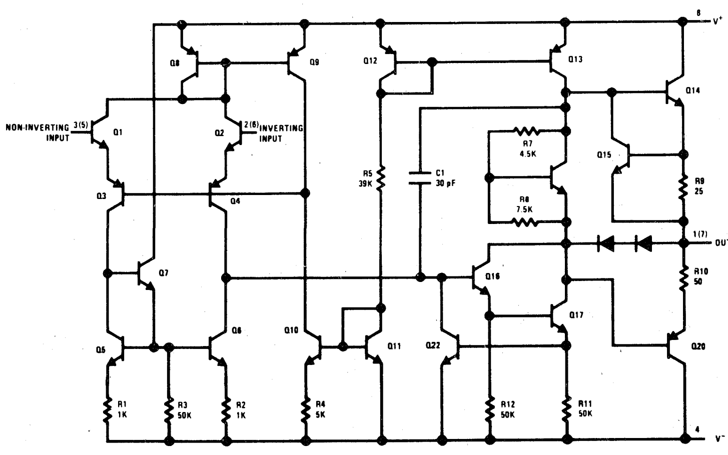
general description

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

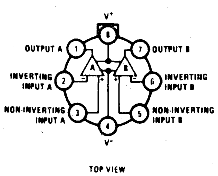
The LM1458 is identical to the LM1558 except that the LM1458 has its specifications guaranteed over the temperature range from 0°C to 70°C instead of –55°C to +125°C.

schematic and connection diagrams



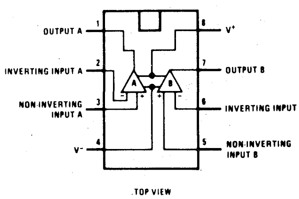
Note: Numbers in parentheses are pin numbers for amplifier B.

Metal Can Package



Order Number LM1558H or LM1458H
See Package 11

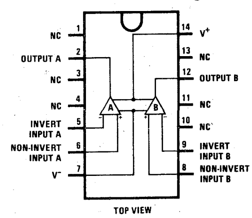
Dual-In-Line Package



Order Number LM1558J or LM1458J
See Package 15

Order Number LM1458N
See Package 20

Dual-In-Line Package



Order Number LM1458N-14
See Package 22

absolute maximum ratings

Supply Voltage LM1558	±22V
LM1458	±18V
Power Dissipation (Note 1) LM1558H/LM1458H	500 mW
LM1458N	400 mW
Differential Input Voltage	±30V
Input Voltage (Note 2)	±15V
Output Short-Circuit Duration	Indefinite
Operating Temperature Range LM1558	−55°C to 125°C
LM1458	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	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	$T_A = 25°C$, $V_S = \pm15V$		3.0	5.0		3.0	5.6	mA
Large Signal Voltage Gain	$T_A = 25°C$, $V_S = \pm15V$, $V_{OUT} = \pm10V$, $R_L \geq 2\ k\Omega$	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	$V_S = \pm15V$, $V_{OUT} = \pm10V$, $R_L \geq 2\ k\Omega$	25			15			V/mV
Output Voltage Swing	$V_S = \pm15V$, $R_L = 10\ k\Omega$	±12	±14		±12	±14		V
	$R_L = 2\ k\Omega$	±10	±13		±10	±13		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 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 $V_S = \pm15V$ 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 $V_S = \pm15V$.

Operational Amplifiers/Buffers

LM1900/LM2900/LM3900, LM3301, LM3401 quad amplifiers

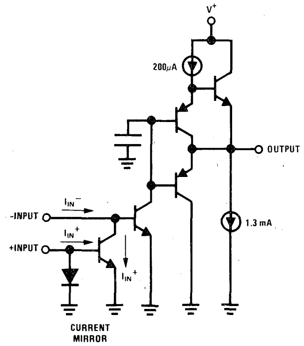
general description

The LM1900 series 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

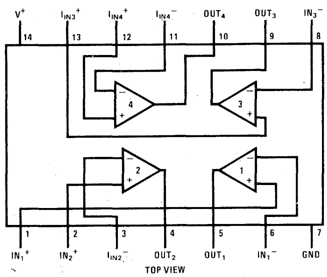
- Wide single supply voltage range or dual supplies — $4\ V_{DC}$ to $36\ V_{DC}$; $\pm 2\ V_{DC}$ to $\pm 18\ V_{DC}$
- Supply current drain independent of supply voltage
- Low input biasing current — 30 nA
- High open-loop gain — 70 dB
- Wide bandwidth — 2.5 MHz (Unity Gain)
- Large output voltage swing — $(V^+ - 1)$ Vp-p
- Internally frequency compensated for unity gain
- Output short-circuit protection

schematic and connection diagrams

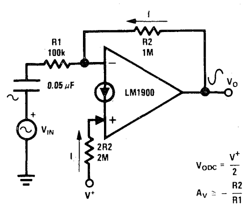


Order Number LM1900D or LM2900D
See Package 1
Order Number LM1900J or LM2900J
See Package 16
Order Number LM2900N, LM3900N, LM3301N or LM3401N
See Package 22

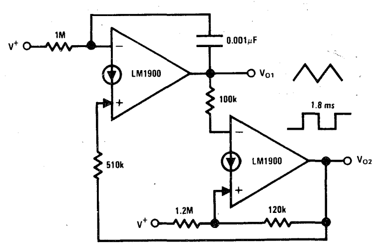
Dual-In-Line and Flat Package



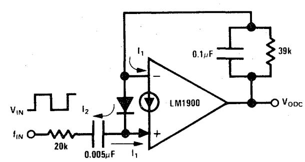
typical applications ($V^+ = 15\ V_{DC}$)



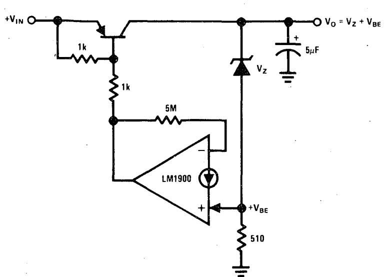
Inverting Amplifier



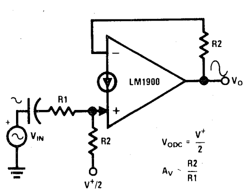
Triangle/Square Generator



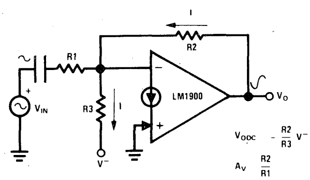
Frequency-Doubling Tachometer



Low $V_{IN} - V_{OUT}$ Voltage Regulator



Non-Inverting Amplifier



Negative Supply Biasing

absolute maximum ratings

	LM1900	LM2900/LM3900	LM3301	LM3401
Supply Voltage	36 V_{DC} ±18 V_{DC}	32 V_{DC} ±16 V_{DC}	28 V_{DC} ±14 V_{DC}	18 V_{DC} ±9 V_{DC}
Power Dissipation (T_A = 25°C) (Note 1)				
Cavity DIP	900 mW	900 mW		
Flat Pack	800 mW	800 mW		
Molded DIP	570 mW	570 mW	570 mW	570 mW
Input Currents, I_{IN}^+ or I_{IN}^-	20 mA_{DC}	20 mA_{DC}	20 mA_{DC}	20 mA_{DC}
Output Short-Circuit Duration – One Amplifier T_A = 25°C (See Application Hints)	Continuous	Continuous	Continuous	Continuous
Operating Temperature Range	−55°C to +125°C		−40°C to +85°C	0°C to +75°C
LM2900		−40°C to +85°C		
LM3900		0°C to +70°C		
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C	300°C	300°C	300°C

electrical characteristics (Note 6)

PARAMETER	CONDITIONS	LM1900			LM2900			LM3900			LM3301			LM3401			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Open Loop																	
Voltage Gain														800			V/mV
Voltage Gain	T_A = 25°C, f = 100 Hz	2	3		1.2	2.8		1.2	2.8		1.2	2.8		1.2	2.8		V/mV
Input Resistance	T_A = 25°C, Inverting Input		1			1			1			1		0.1	1		MΩ
Output Resistance			8			8			8			8			8		kΩ
Unity Gain Bandwidth	T_A = 25°C, Inverting Input		2.5			2.5			2.5			2.5			2.5		MHz
Input Bias Current	T_A = 25°C, Inverting Input		25	100		30	200		30	200		30	300		30	300	nA
	Inverting Input															500	nA
Slew Rate	T_A = 25°C, Positive Output Swing		0.5			0.5			0.5			0.5			0.5		V/µs
	T_A = 25°C, Negative Output Swing		20			20			20			20			20		V/µs
Supply Current	T_A = 25°C, R_L = ∞ On All Amplifiers		6.2	12		6.2	10		6.2	10		6.2	10		6.2	10	mA_{DC}
Output Voltage Swing	T_A = 25°C, R_L = 2k, V_{CC} = 15.0 V_{DC}																
V_{OUT} High	I_{IN}^- = 0, I_{IN}^+ = 0	13.5	14.2		13.5			13.5			13.5			13.5			V_{DC}
V_{OUT} Low	I_{IN}^- = 10µA, I_{IN}^+ = 0		0.09	0.2		14.2	0.2		14.2	0.2		14.2	0.2		14.2	0.2	V_{DC}
V_{OUT} High	I_{IN}^- = 0, I_{IN}^+ = 0 R_L = ∞, V_{CC} = 30 V_{DC}	28.0	29.5			0.09			0.09			0.09			0.09		V_{DC}
Output Current Capability	T_A = 25°C																
Source		10	15		6	18		6	10		5	18		5	10		mA_{DC}
Sink	(Note 2)	1.0	1.3		0.5	1.3		0.5	1.3		0.5	1.3		0.5	1.3		mA_{DC}
I_{SINK}	V_{OL} = 1V, I_{IN} = 5µA	4	5			5			5			5			5		mA_{DC}

electrical characteristics (con't) (Note 6)

PARAMETER	CONDITIONS	LM1900			LM2900			LM3900			LM3301			LM3401			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Power Supply Rejection	$T_A = 25°C$, f = 100 Hz	50	70			70			70			70			70		dB
Mirror Gain	@ 20μA (Note 3)	0.95	1.0	1.05	0.90	1.0	1.1	0.90	1.0	1.1	0.90	1	1.10	0.90	1	1.10	μA/μA
	@ 200μA (Note 3)	0.95	1.0	1.05	0.90	1.0	1.1	0.90	1.0	1.1	0.90	1	1.10	0.90	1	1.10	μA/μA
ΔMirror Gain	@ 20μA To 200μA (Note 3)		1	2		2	5		2	5		2	5		2	5	%
Mirror Current	(Note 4)		10	500		10	500		10	500		10	500		10	500	μA_{DC}
Negative Input Current	$T_A = 25°C$ (Note 5)		1.0			1.0			1.0			1.0			1.0		mA_{DC}
Voltage Gain	f = 100 Hz	800															V/mV
Input Bias Current	Inverting Input			150													nA

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.

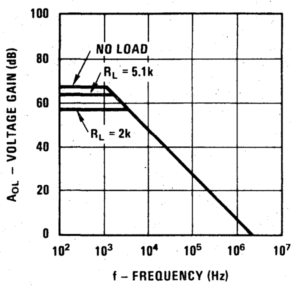
Note 4: Input V_{BE} match between the non-inverting and the inverting inputs occurs for a mirror current (non-inverting input current) of approximately 10μA. This is therefore a typical design center for many of the application circuits.

Note 5: Clamp transistors are included on the IC to prevent the input voltages from swinging below ground more than approximately −0.3 V_{DS}. 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.

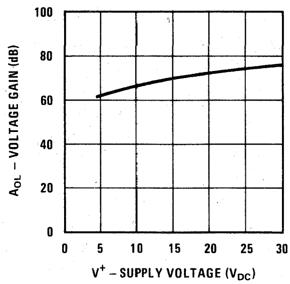
Note 6: These specs apply for $-55°C \leq T_A \leq +125°C$, unless otherwise stated.

typical performance characteristics

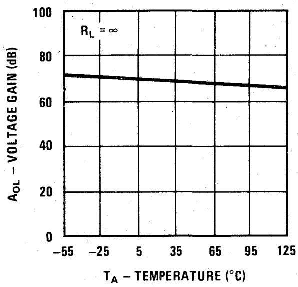
Open Loop Gain



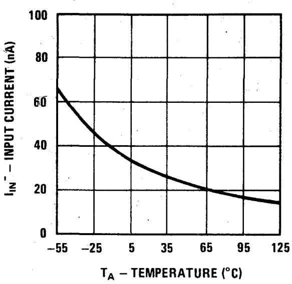
Voltage Gain



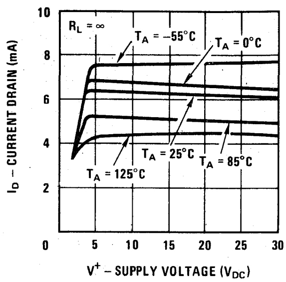
Voltage Gain



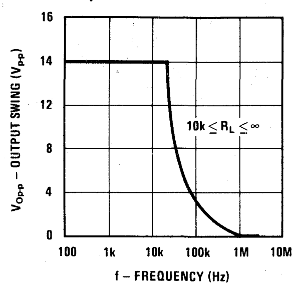
Input Current



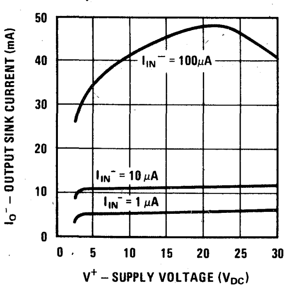
Supply Current



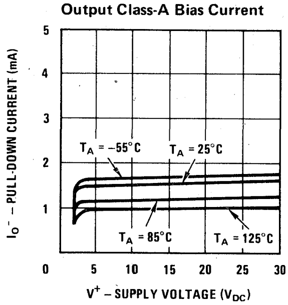
Large Signal Frequency Response



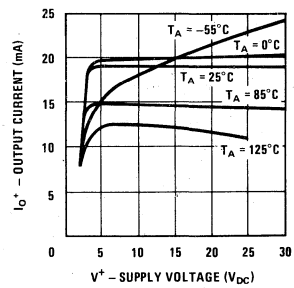
Output Sink Current



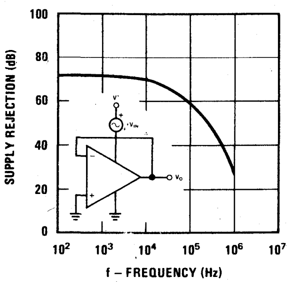
Output Class-A Bias Current



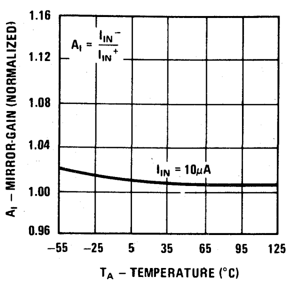
Output Source Current



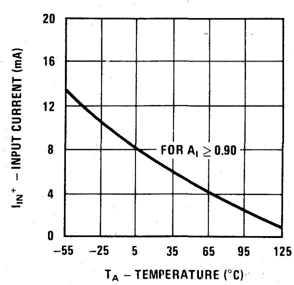
Supply Rejection



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.

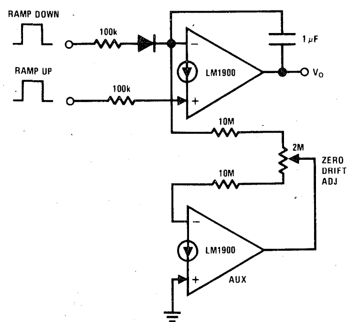
Output short circuits either to ground or to the positive power supply should be of short time duration. Units can be destroyed, not as a result of the short circuit current causing metal fuzing, but rather due to the large increase in IC chip dissipation which will cause eventual failure due to excessive junction temperatures. For example, when operating from a well-regulated +5 V_{DC} 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.

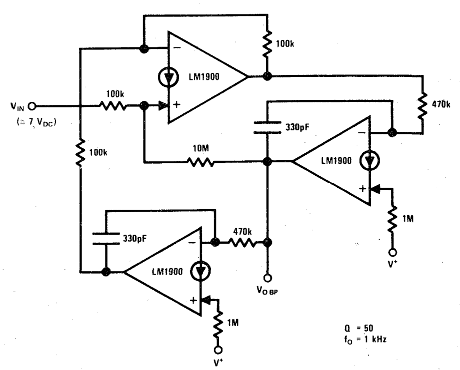
Operation of this amplifier can be best understood by noticing that input currents are differenced at the inverting-input terminal and this difference current then flows through the external feedback resistor to produce the output voltage. Common-mode current biasing is generally useful to allow operating 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 V_{DC} 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 100μA.

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 both with 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)

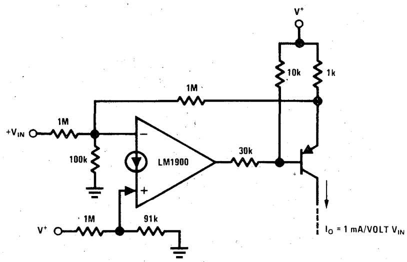


Low-Drift Ramp and Hold Circuit

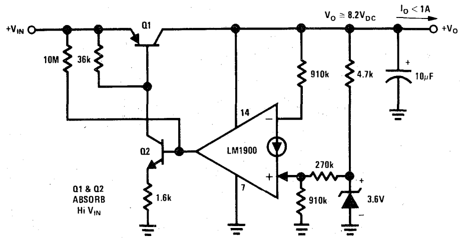


Bi-Quad Active Filter
(2nd Degree State-Variable Network)

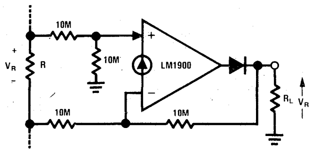
typical applications (con't)



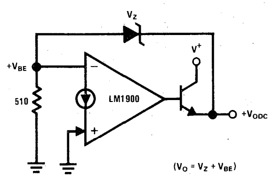
Voltage-Controlled Current Source (Transconductance Amplifier)



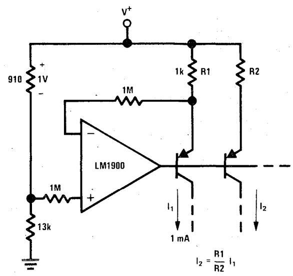
Hi V_{IN}, Lo $(V_{IN} - V_O)$ Self-Regulator



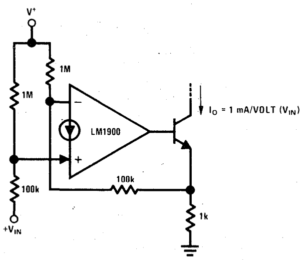
Ground-Referencing a Differential Input Signal



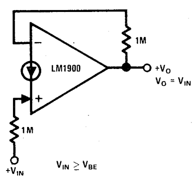
Voltage Regulator



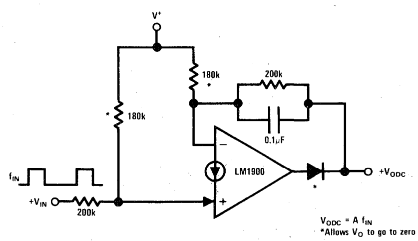
Fixed Current Sources



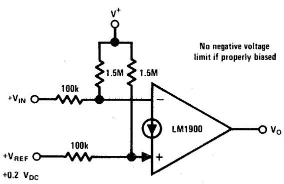
Voltage-Controlled Current Sink (Transconductance Amplifier)



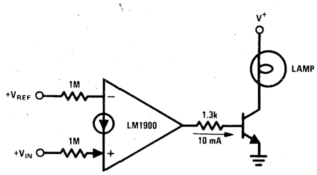
Buffer Amplifier



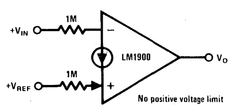
Tachometer



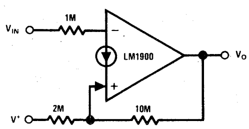
Low-Voltage Comparator



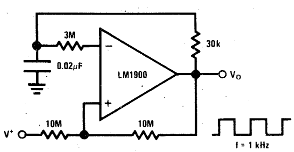
Power Comparator



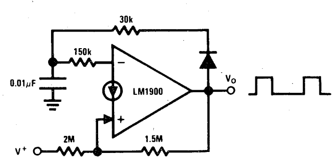
Comparator



Schmitt-Trigger



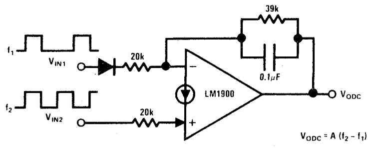
Square-Wave Oscillator



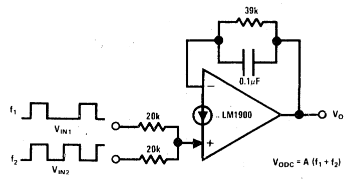
Pulse Generator

3

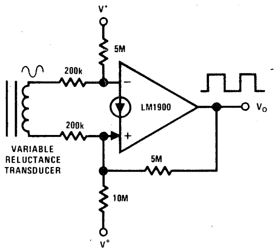
typical applications (con't)



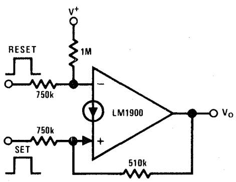
Frequency Differencing Tachometer



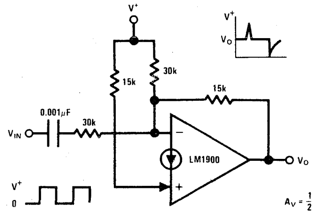
Frequency Averaging Tachometer



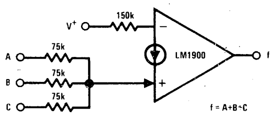
Squaring Amplifier (W/Hysteresis)



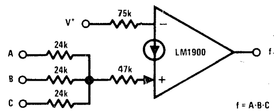
Bi-Stable Multivibrator



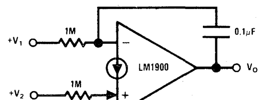
Differentiator (Common-Mode Biasing Keeps Input at $+V_{BE}$)



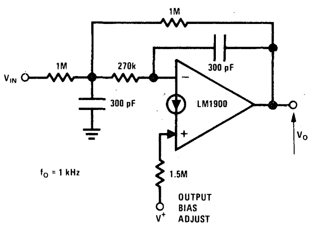
"OR" Gate



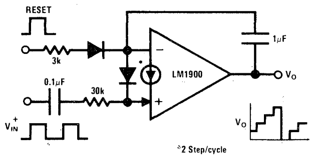
"AND" Gate



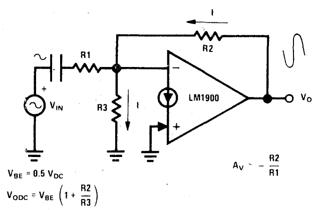
Difference Integrator



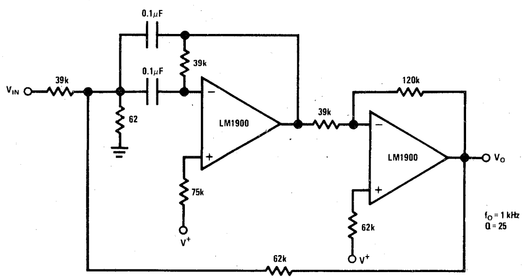
Low Pass Active Filter



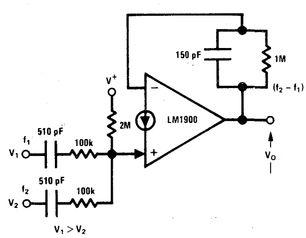
Staircase Generator



V_{BE} Biasing

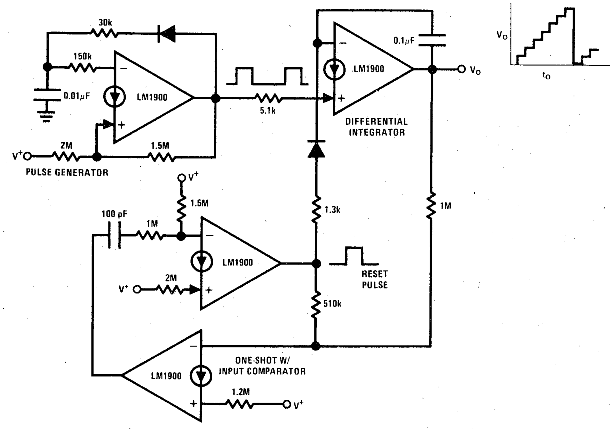


Bandpass Active Filter

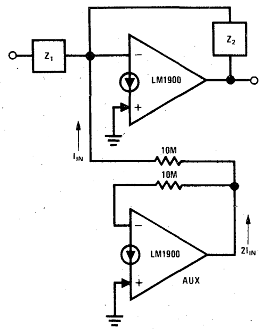


Low-Frequency Mixer

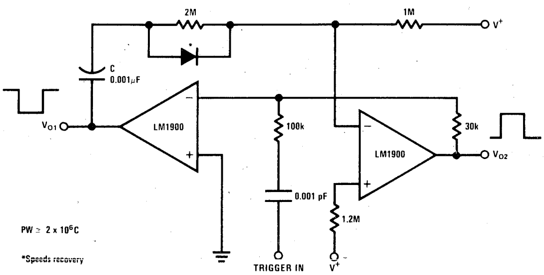
typical applications (con't)



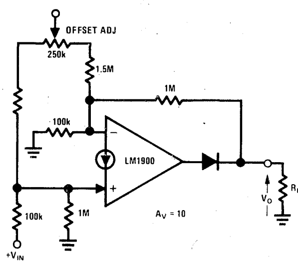
Free-Running Staircase Generator/Pulse Counter



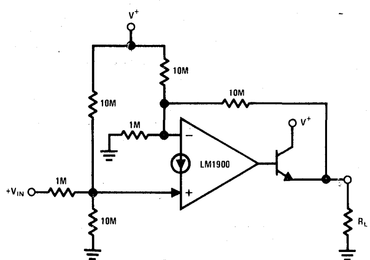
Supplying I_{IN} with Aux. Amp (to Allow Hi-Z Feedback Networks)



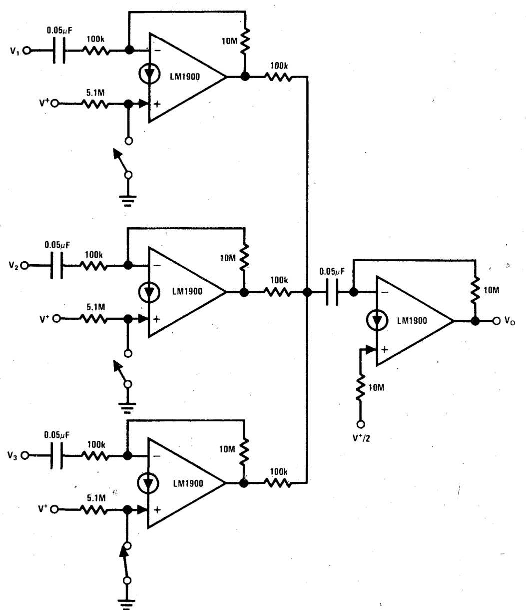
One-Shot Multivibrator



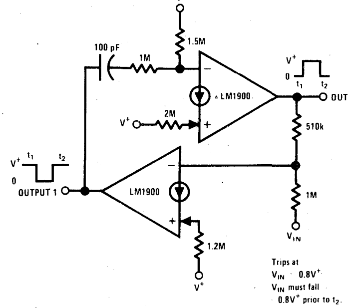
Non-Inverting DC Gain to (0,0)



Power Amplifier

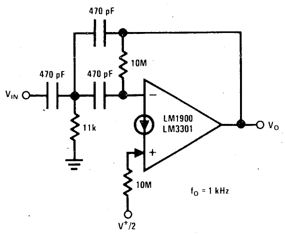


Channel Selection by DC Control (or Audio Mixer)

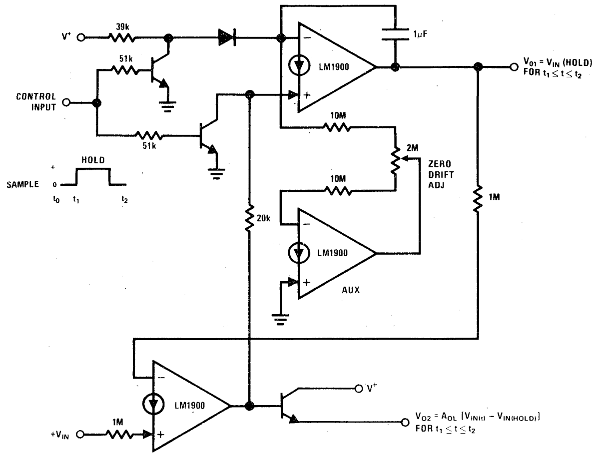


One-Shot with DC Input Comparator

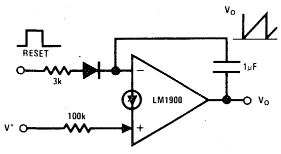
typical applications (con't)



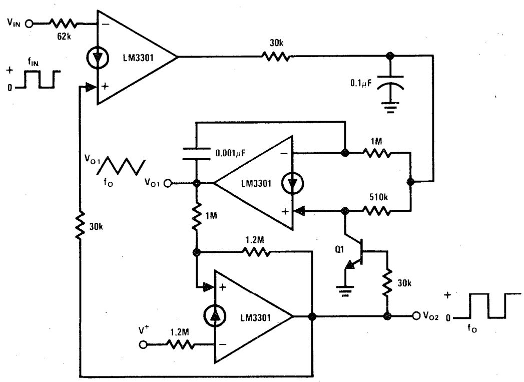
High Pass Active Filter



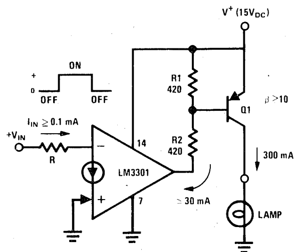
Sample-Hold and Compare with New $+V_{IN}$



Sawtooth Generator

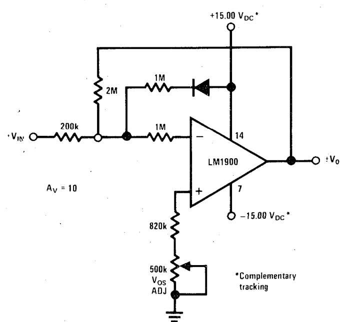


Phase-locked Loop

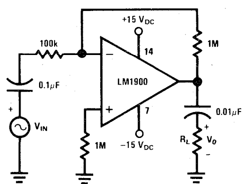


Boosting to 300 mA Loads

split-supply applications ($V^+ = +15\ V_{DC}$ & $V^- = -15\ V_{DC}$)



Non-Inverting DC Gain



AC Amplifier

Operational Amplifiers/Buffers

LM4250/LM4250C programmable operational amplifier

general description

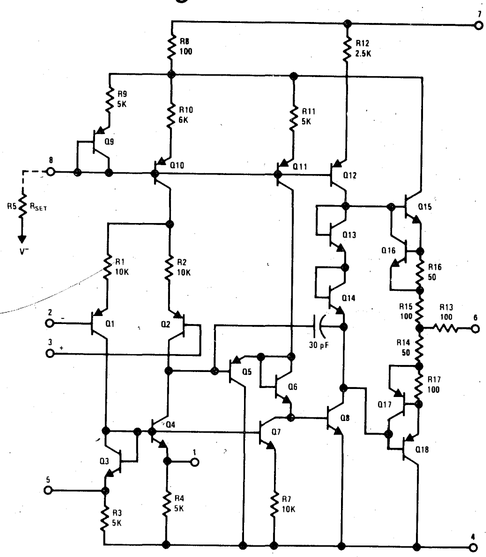
The LM4250 and LM4250C are extremely versatile programmable monolithic operational amplifiers. A single external master bias current setting resistor programs the input bias current, input offset current, quiescent power consumption, slew rate, input noise, and the gain-bandwidth product. The device is a truly general purpose operational amplifier.

features

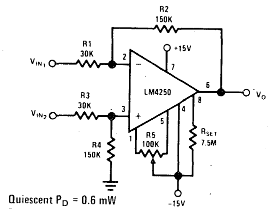
- ±1V to ±18V power supply operation
- 3 nA input offset current
- Standby power consumption as low as 500 nW
- No frequency compensation required
- Programmable electrical characteristics
- Offset Voltage nulling capability
- Can be powered by two flashlight batteries
- Short circuit protection

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.

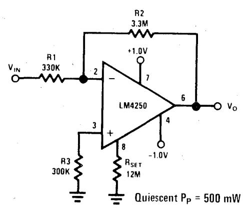
schematic diagrams



typical applications



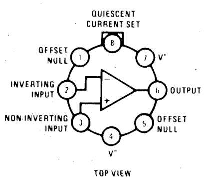
X5 Difference Amplifier



500 Nano-Watt X10 Amplifier

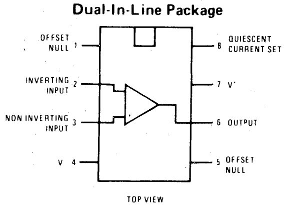
connection diagrams

Metal Can Package



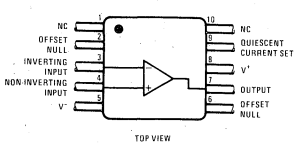
Order Number LM4250H or LM4250CH
See Package 11

Dual-In-Line Package



Order Number LM4250CN
See Package 20
Order Number LM4250J
or LM4250CJ
See Package 15

Flat Package



Order Number LM4250F
See Package 3

absolute maximum ratings

Supply Voltage	±18V	Output Short-Circuit Duration		Indefinite
Power Dissipation (Note 1)	500 mW	Operating Temperature Range	LM4250	$-55°C \leq T_A \leq 125°C$
Differential Input Voltage	±30V		LM4250C	$0°C \leq T_A \leq 70°C$
Input Voltage (Note 2)	±15V	Storage Temperature Range		−65°C to 150°C
I_{SET} Current	150 µA	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 ≤ T_A ≤ 70°C unless otherwise specified)

PARAMETERS	CONDITIONS	$V_S = \pm1.5V$, $I_{SET} = 1\ \mu A$ MIN	$I_{SET} = 1\ \mu A$ MAX	$I_{SET} = 10\ \mu A$ MIN	$I_{SET} = 10\ \mu A$ 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	$V_S = \pm15V$, $I_{SET} = 1\ \mu A$ MIN	$I_{SET} = 1\ \mu A$ MAX	$I_{SET} = 10\ \mu A$ MIN	$I_{SET} = 10\ \mu A$ 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

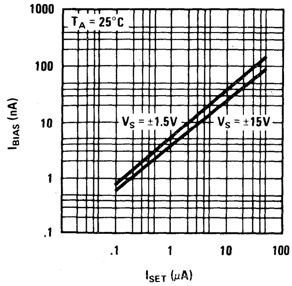
resistor biasing

Set Current Setting Resistor to V^-

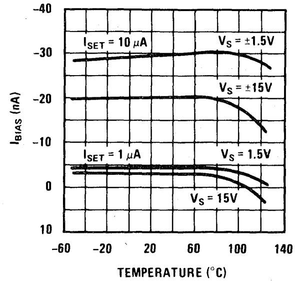
	I_{SET}				
V_S	0.1 μA	0.5 μA	1.0 μA	5 μA	10 μA
±1.5V	25.6 MΩ	5.04 MΩ	2.5 MΩ	492 kΩ	244 kΩ
±3.0V	55.6 MΩ	11.0 MΩ	5.5 MΩ	1.09 MΩ	544 kΩ
±6.0V	116 MΩ	23.0 MΩ	11.5 MΩ	2.29 MΩ	1.14 MΩ
±9.0V	176 MΩ	35.0 MΩ	17.5 MΩ	3.49 MΩ	1.74 MΩ
±12.0V	236 MΩ	47.0 MΩ	23.5 MΩ	4.69 MΩ	2.34 MΩ
±15.0V	296 MΩ	59.0 MΩ	29.5 MΩ	5.89 MΩ	2.94 MΩ

typical performance characteristics

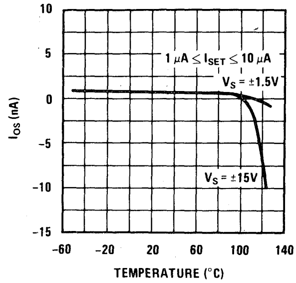
Input Bias Current vs I_{SET}



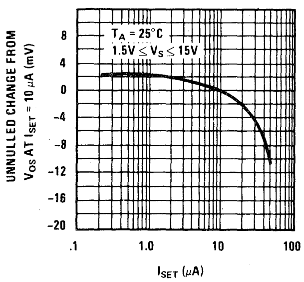
Input Bias Current vs Temperature



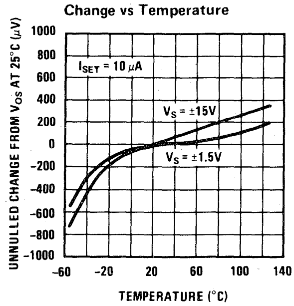
Input Offset Current vs Temperature



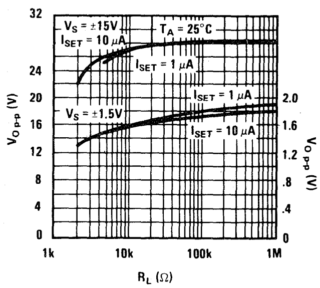
Unnulled Input Offset Voltage Change vs I_{SET}



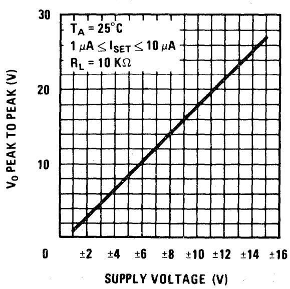
Unnulled Input Offset Voltage Change vs Temperature



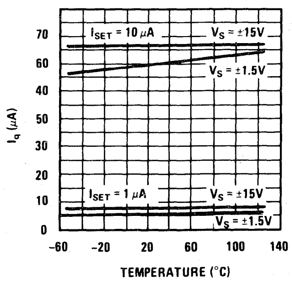
Peak to Peak Output Voltage Swing vs Load Resistance



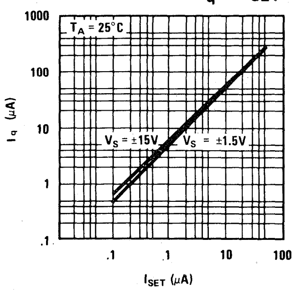
Peak to Peak Output Voltage Swing vs Supply Voltage



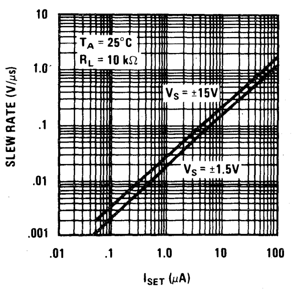
Quiescent Current (I_q) vs Temperature



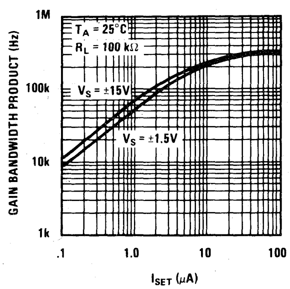
Quiescent Current (I_q) vs I_{SET}



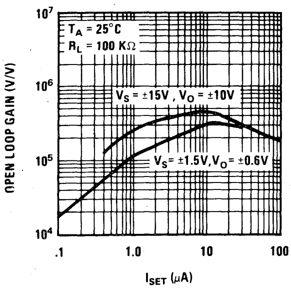
Slew Rate vs I_{SET}



Gain Bandwidth Product vs I_{SET}

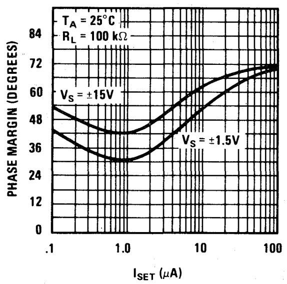


Open Loop Voltage Gain vs I_{SET}

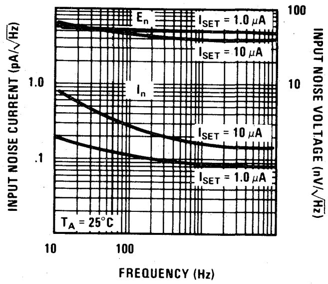


typical performance characteristics (con't)

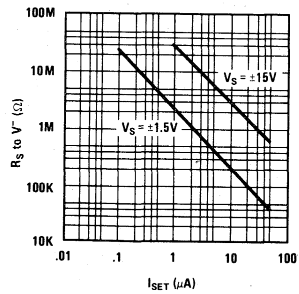
Phase Margin vs I_{SET}



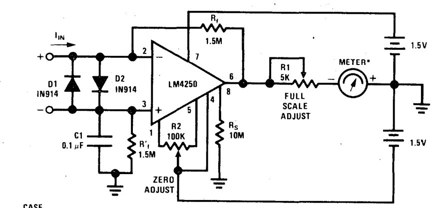
Input Noise Current (I_n) and Voltage (E_n) vs Frequency



R_{SET} vs I_{SET}



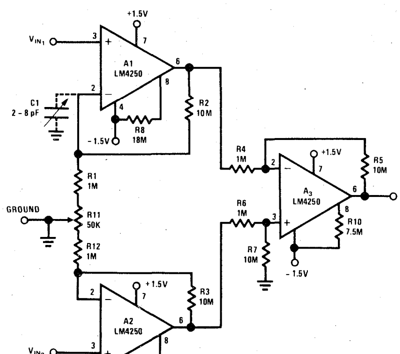
typical applications (con't)



Quiescent P_D = 1.8 μW

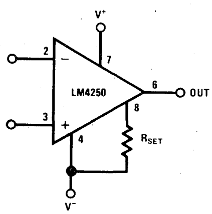
*Meter movement (0 – 100 μA, 2 kΩ) marked for 0 – 100 nA full scale.

Floating Input Meter Amplifier
100 Nano-Ampere Full Scale

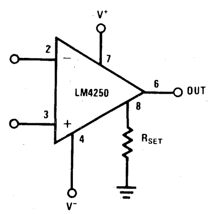


Note 1: Quiescent P_D = 10 μW.
Note 2: R2, R3, R4, R5, R6, and R7 are 1% resistors.
Note 3: R11 and C1 are for DC and AC common mode rejection adjustments.

X100 Instrumentation Amplifier 10 μW



R_{SET} Connected to V^-

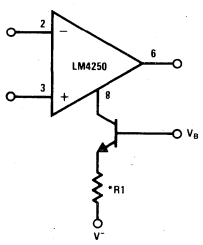


R_{SET} Connected to Ground

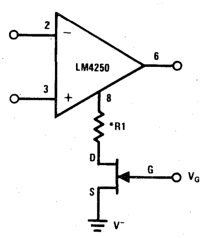
I_{SET} EQUATIONS:

$$I_{SET} \approx \frac{V^+ + |V^-| - 0.5}{R_{SET}}$$ where R_{SET} is connected to V^-.

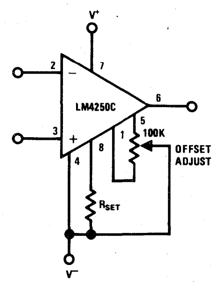
$$I_{SET} \approx \frac{V^+ - 0.5}{R_{SET}}$$ where R_{SET} is connected to ground.



Transistor Current Source Biasing



FET Current Source Biasing

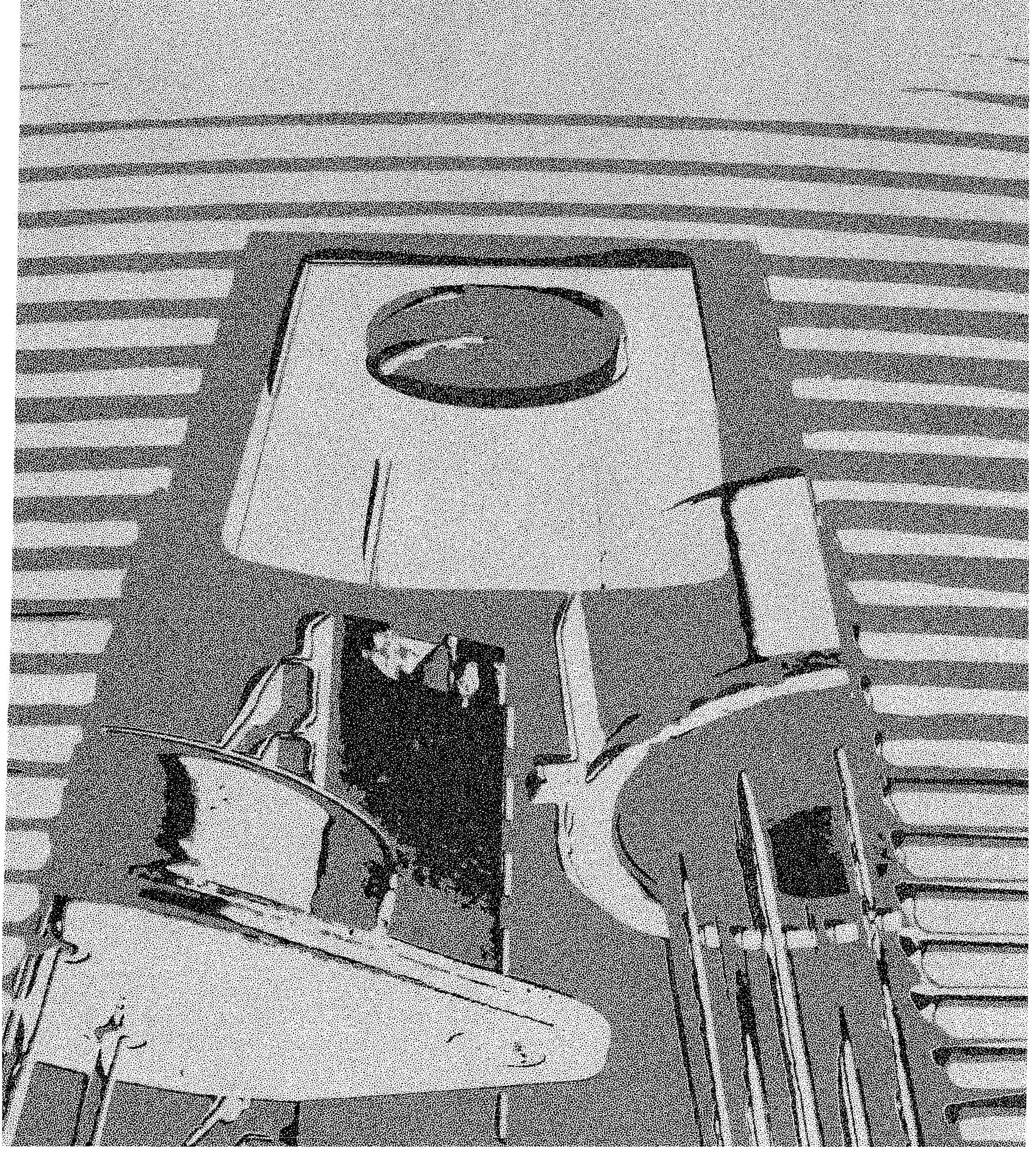


Offset Null Circuit

*R1 limits I_{SET} maximum

3

National Semiconductor
INSTRUMENTATION AMPLIFIERS
Section 4



Instrumentation Amplifiers

Section Contents

*Product added to this Data Book since last printing.

4

Definition of Terms

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 common-mode 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 =

$$\frac{(V2^2 + V3^2 + V4^2 + \ldots)^{1/2}\,(100\%)}{V1}$$

where V1 is the rms amplitude of the fundamental and V2, V3, V4, . . . are the rms amplitudes of the individual harmonics.

Input Bias Current: The average of the two input currents.

Input Common-Mode Voltage Range: The range of voltages on the input terminals for which the amplifier is operational. Note that the specifications are not guaranteed over the full common-mode voltage range unless specifically stated.

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.

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.

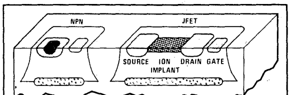
Supply Current: The current required from the power supply to operate the amplifier with no load and the output midway between the supplies.

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).

Instrumentation Amplifiers



BI-FET Technology

LF152/LF252/LF352 FET input instrumentation amplifier

general description

The LF152 series is the first monolithic JFET input instrumentation amplifier. The well-matched high voltage JFET input devices provide very high input impedance and extremely low bias currents, making the LF152 ideal in applications where high source impedances are encountered.

The LF152 very accurately amplifies a differential input signal and rejects common-mode signal and noise. It is not an op amp, but operates with an internal closed loop gain connection which allows good linearity with no external feedback. The LF152 eliminates the need for extremely precise resistor matching to obtain high common-mode rejection (CMR) and provides high input impedance as compared to the use of conventional op amps connected as a difference amplifier.

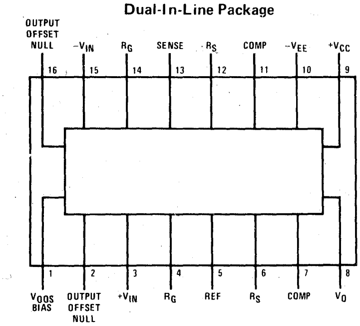
The LF152 utilizes internal differential current feedback eliminating the need for precision external feedback components. The amplifier gain can be easily adjusted from 1 to 1000 by changing the value of a single resistor. The transfer function for the LF152 is highly accurate because it has a very low initial gain error and non-linearity. The bandwidth and slew rate are externally controlled and the sense input and device output are pinned out separately for added versatility.

features

- JFET inputs
- High input impedance — $2 \times 10^{12}\Omega$
- Low bias currents — 3 pA
- Low noise currents — 0.01 pA rms
- Low gain nonlinearity — 0.02%
- High common-mode rejection ratio (G = 100) — 110 dB min
- Single resistor gain adjust
- External compensation for extended gain and frequency ranges
- Both input and output offset adjust capability to allow a change of gain without rezeroing
- Low supply current — 1 mA

connection diagram

Dual-In-Line Package



Order Number LF152D, LF252D or LF352D
See Package 26

simplified schematic

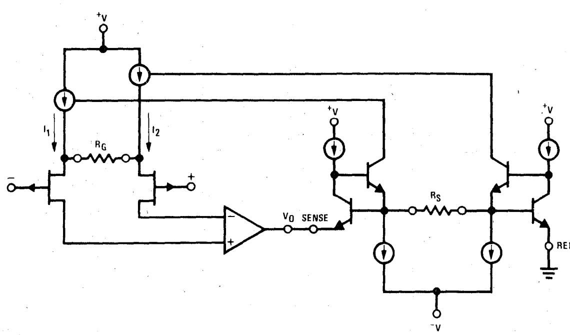


FIGURE 1

typical circuit

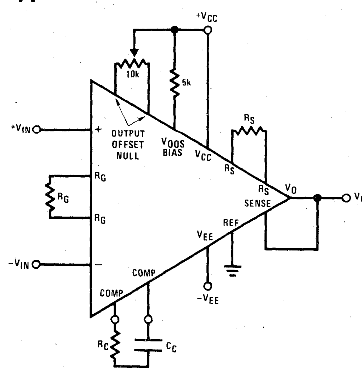


FIGURE 2

absolute maximum ratings

	LF152	LF252	LF352
Supply Voltage	±22V	±18V	±18V
Differential Input Voltage	±44V	±36V	±36V
Input Voltage Range	±22V	±18V	±18V
Output Short Circuit Duration	Continuous	Continuous	Continuous
Power Dissipation and Thermal Resistance (Note 1)			
Cavity DIP (D) P_D (25°C)	900 mW	900 mW	900 mW
θ_{jA}	100°C/W	100°C/W	100°C/W
Maximum Junction Temperature	+150°C	+110°C	+100°C
Operating Temperature Range	$-55°C \leq T_A \leq +125°C$	$-25°C \leq T_A \leq +85°C$	$0°C \leq T_A \leq +70°C$
Storage Temperature Range	$-65°C \leq T_A \leq +150°C$	$-65°C \leq T_A \leq +150°C$	$-65°C \leq T_A \leq +150°C$
Lead Temperature (Soldering, 60 seconds)	300°C	300°C	300°C

dc electrical characteristics (Notes 2 and 3)

PARAMETER		CONDITIONS	LF152			LF252/LF352			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
G_R	Gain Range	$R_C = 160\Omega$, $C_C = 0.002\mu F$	1		1000	1		1000	
G	Gain Equation	$G = R_S/R_G$							
G_E	Error From Gain Equation	$T_A = 25°C$, G = 1–100, R_L = 10k		0.05	0.1		0.05	0.2	%
G_{NL}	Gain Nonlinearity	$T_A = 25°C$, G = 1–100, R_L = 10k		0.02	0.05		0.02	0.1	%
$\Delta G/\Delta T$	Gain Temperature Coefficient			3			3		ppm/°C
V_O	Output Voltage Range	R_L = 2k	±10			±10			V
R_O	Output Resistance	$T_A = 25°C$, G = 1		1.2			1.5		Ω
V_{IN}	Input Voltage Range		±10	±12		±10	±12		V
I_B	Input Bias Current	$T_A = 25°C$		3	20		3	40	pA
				3	20		0.2	3	nA
I_{IO}	Input Offset Current	$T_A = 25°C$		0.5	10		0.5	20	pA
				0.3	2.0		0.05	0.6	nA
R_{IN}	Input Resistance	$T_A = 25°C$							
	Differential			2×10^{12}			2×10^{12}		Ω
	Common-Mode			2×10^{12}			2×10^{12}		Ω
C_{IN}	Input Capacitance	$T_A = 25°C$							
	Differential			2.5			2.5		pF
	Common-Mode			5.0			5.0		pF
CMRR	Common-Mode Rejection	G = 1	75	85		65	80		dB
	(RTI) (Note 4)	G = 10	95	105		85	100		dB
		G = 100	110	125		100	120		dB
		G = 1000	115	125		105	120		dB
V_{IOS}	Input Offset Voltage	$T_A = 25°C$		8	15		15	30	mV
$\Delta V_{IOS}/\Delta T$	Temperature Coefficient			10			10		µV/°C
$\Delta V_{IOS}/\Delta V_S$	Supply Sensitivity			100			200		µV/V
V_{OOS}	Output Offset Voltage	$T_A = 25°C$			200			400	mV
$\Delta V_{OOS}/\Delta T$	Temperature Coefficient			600			600		µV/°C
$\Delta V_{OOS}/\Delta V_S$	Supply Sensitivity			400			800		µV/V
I_{REF}	Reference Current			15			20		µA
R_{REF}	Reference Input Resistance			500			250		MΩ
I_S	Supply Current	$T_A = 25°C$		0.7	1.5		1.2	1.8	mA

ac electrical characteristics (Notes 2 and 3)

PARAMETER		CONDITIONS	LF152			LF252/LF352			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
e_n	Noise Voltage (RTI) (Note 5)	$T_A = 25°C$							
		0.1 Hz – 10 Hz		1.3+670/G			1.3+670/G		μVp-p
		10 Hz – 10 kHz		8+450/G			8+450/G		μVrms
i_n	Noise Current (RTI) (Note 5)	$T_A = 25°C$, 10 Hz – 10 kHz		0.01			0.01		pArms
GBW	Small Signal Bandwidth	$T_A = 25°C$, ±3 dB							
		G = 1		140			140		kHz
		G = 10		50			50		kHz
		G = 100		30			30		kHz
		G = 1000		7			7		kHz
		$T_A = 25°C$, ±1% Flatness							
		G = 1		5			5		kHz
		G = 10		4			4		kHz
		G = 100		2			2		kHz
		G = 1000		1.5			1.5		kHz
PBW	Full-Power Bandwidth			25			25		kHz
SR	Slew Rate			1			1		V/μs
t_s	Settling Time 0.1%	$T_A = 25°C$							
		G = 1		15			15		μs
		G = 10		15			15		μs
		G = 100		40			40		μs
		G = 1000		200			200		μs

Note 1: The maximum power dissipation for these devices must be derated at elevated temperatures and is dictated by $T_{j\,MAX}$, θ_{jA}, and the ambient temperature, T_A. The maximum available power dissipation at any temperature is $P_D = (T_{J\,MAX} - T_A)/\theta_{jA}$ or the 25°C $P_{D\,MAX}$, whichever is less.

Note 2: These specifications apply for $V_S = \pm15V$ and over the absolute maximum operating temperature range ($T_L \le T_A \le T_H$) unless otherwise noted. Parameters are specified for $R_C = 160\Omega$, $C_C = 0.002\mu F$, and a proper layout such as the PC board in *Figure 7*, which is laid out for *Figure 2 and Figure 4*.

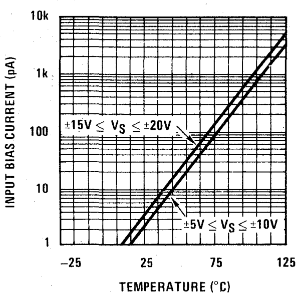
Note 3: If V_{OOS} adjust is not used, pins 1, 2 and 16 **MUST** be shorted to V_{CC}.

Note 4: Referred to input (RTI). May be referred to output by subtracting gain in dB.

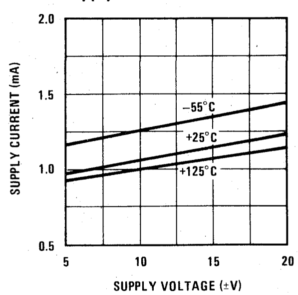
Note 5: Referred to input (RTI). May be referred to output by multiplying by gain G.

typical performance characteristics

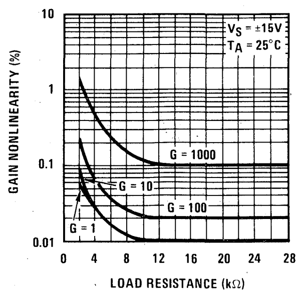
Input Bias Current



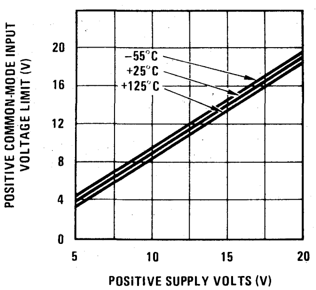
Supply Current



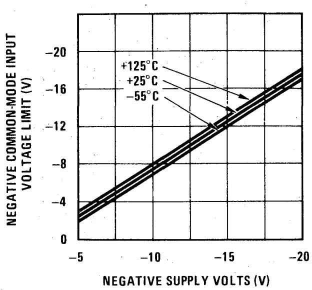
Gain Nonlinearity



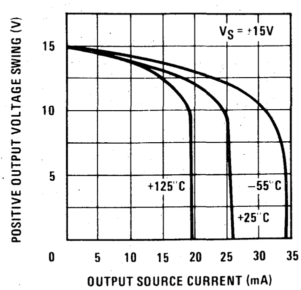
Positive Common-Mode Input Voltage Limit



Negative Common-Mode Input Voltage Limit

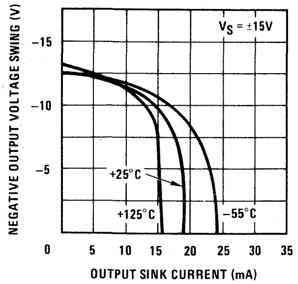


Positive Current Limit

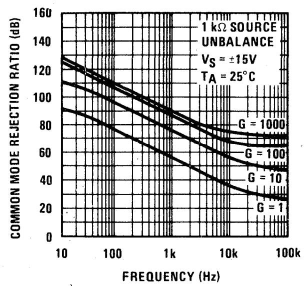


typical performance characteristics (con't)

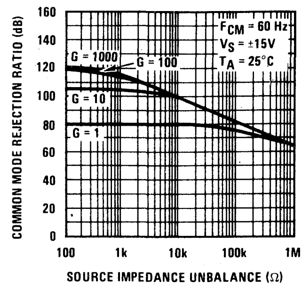
Negative Current Limit



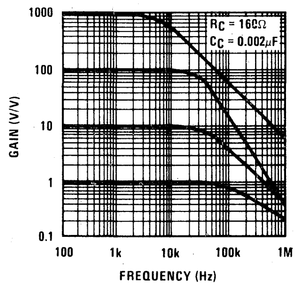
Common-Mode Rejection Ratio (RTI)



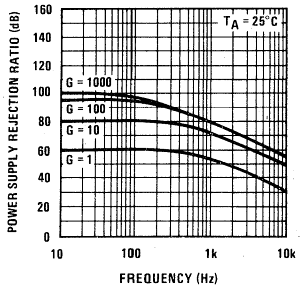
Common-Mode Rejection Ratio (RTI)



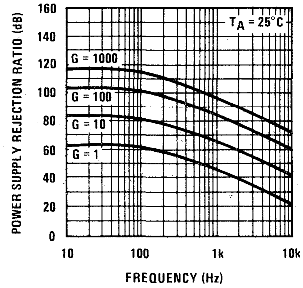
Frequency Response



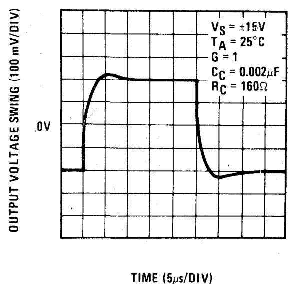
Positive Power Supply Rejection Ratio (RTI)



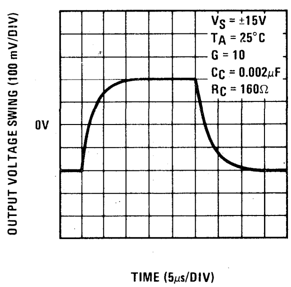
Negative Power Supply Rejection Ratio (RTI)



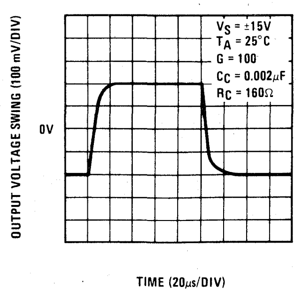
Small Signal Pulse Response (G = 1)



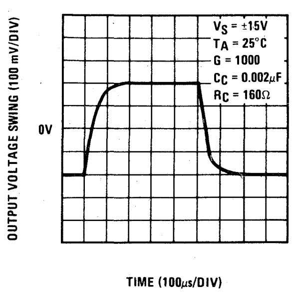
Small Signal Pulse Response (G = 10)



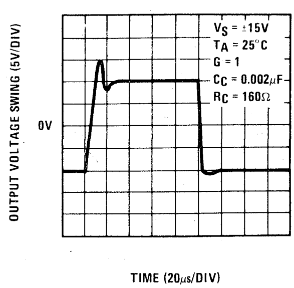
Small Signal Pulse Response (G = 100)



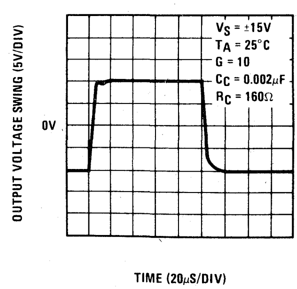
Small Signal Pulse Response (G = 1000)



Large Signal Pulse Response (G = 1)

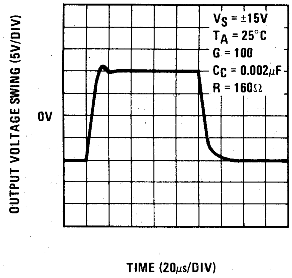


Large Signal Pulse Response (G = 10)

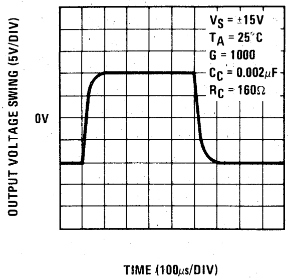


typical performance characteristics (con't)

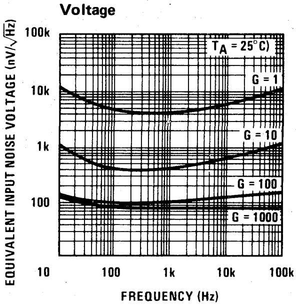
Large Signal Pulse Response (G = 100)



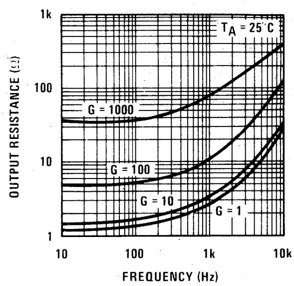
Large Signal Pulse Response (G = 1000)



Equivalent Input Noise Voltage



Output Resistance



application hints

BASIC OPERATION

The LF152 is a monolithic JFET input differential current feedback instrumentation amplifier. The BI-FET process used to fabricate the LF152 makes it possible to take advantage of JFETs throughout the design. In the simplified schematic of *Figure 1,* the differential input voltage is impressed across resistor R_G via the input JFETs, while the difference between the sense and reference voltages is impressed across the resistor R_S. The gain of the amplifier is determined by the ratio of resistor R_S to resistor R_G ($G = R_S/R_G$). (For clarity let's follow a signal through the amplifier:)

In *Figure 1,* let $R_G = R_S = 1$ MΩ, the (−) input be grounded, and the (+) input be 1V; the output should be 1V. The 1V signal applied developes 1μA through R_G from right to left and unbalances the current drive to the second stage amplifier. The additional current driven into the (+) input of the second stage amplifier causes the output to increase. As V_O increases, the sense input voltage increases and the left side of R_S also increases. When the sense input has risen 1V, 1μA will flow through R_S from left to right and, thus, subtract 1μA from I_1. An opposite action simultaneously occurs in I2 which brings the currents into the second stage and thus the system back into balance.

The LF152 series is designed to optimize key parameters in instrumentation amplifiers. The device has very high common-mode rejection, low gain non-linearity, extremely low bias currents and very high input impedance.

INPUTS

The P-channel JFET input devices of the LF152 series provide very low bias currents and very high input impedances.

The maximum differential input voltage is independent of the supply voltages, however, neither of the input voltages should be allowed to exceed the negative supply, as this will cause large currents to flow, which can result in a destroyed unit.

Exceeding the negative voltage range on either input will cause a reversal of phase to the output and force the amplifier output to the corresponding high or low state. Exceeding the negative input voltage range on both inputs will force the amplifier output to a high state. Exceeding the positive input voltage range on a single input will not change the phase of the output; however, gain linearity will degrade. If both inputs exceed the positive input voltage range, the output of the amplifier will be forced to a high state.

The common-mode slew rate of the inputs should be limited to 5V/μs to insure low input bias currents.

application hints (con't)

USING THE SENSE, REFERENCE, AND OUTPUT PINS

The sense input and the output of the device are pinned out separately to allow increased flexibility in system designs (see applications). The reference input allows biasing of the output voltage, from +10V to −10V. The ac input resistance of both the sense and reference inputs is unusually high because their input currents are forced to be constant with voltage (typically 20μA).

The maximum linear output swing is determined by the magnitude of resistor R_S:

$$|V_{O\,MAX}| = 10\mu A\ (R_S)$$

If the output of the amplifier is to be abruptly changed more than 6V, a PNP transistor should be connected, as shown in *Figure 3*, to prevent the slew rate of the output from exceeding the slew rate of the sense stage. If this precaution is not taken, the base-emitter junction of the input transistor in the sense stage will transiently break down and its β will degrade, resulting in a permanent negative shift in output offset voltage.

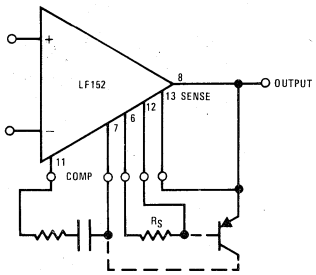


FIGURE 3. Large Signal Transient Suppression

OFFSET VOLTAGE

Because of the two stage design of the instrumentation amplifier, there are two independent contributors to offset voltage (V_{OS}). The output offset (V_{OOS}) is independent of gain while the input offset (V_{IOS}) is multiplied by the gain of the amplifier to the output.

$$V_{OS} = V_{IOS}\ (G) + V_{OOS}$$

The output offset of the LF152 can be adjusted as shown in *Figure 2*. In addition, the LF152 features input offset adjust which is not common to monolithic instrumentation amplifiers and is normally available only on expensive modules. The simple adjust scheme shown in *Figure 5* has only a slight increase in non-linearity compared to that of *Figure 4* and is recommended for most applications. Nulling both input and output offset makes the overall offset zero, independent of gain.

The output offset is affected by adjustment of the input offset. For every mV of input offset adjust, the output offset will change by approximately 32 mV. Adjustment of the output offset has no effect on the input offset, so it should always be done last.

Offset adjustment changes the temperature coefficient of the V_{OS} drift. The typical input offset drift of the unadjusted device is −10μV/°C. If the input offset is adjusted, the V_{IOS} drift increases by approximately

$$V_{IOS}\ \text{drift} \approx -10\mu V/^{\circ}C + 2\mu V/^{\circ}C/(\text{mV of adjustment})$$

The V_{OOS} drift will be improved by output offset adjust because the magnitudes of the current sources adjusted become less sensitive to V_{BE} variations. If V_{OOS} adjust is not used, pins 1, 2 and 16 must be shorted to the positive supply for circuit operation.

OFFSET VOLTAGE ADJUSTMENT PROCEDURE

For gains less than 100, only output offset adjustment is needed. For gains greater than 100, input offset adjust is usually necessary since the input offset voltage amplified to the output may be out of the range of the output offset adjust. Input offset adjust is also needed if zero overall offset is desired while varying the amplifier gain.

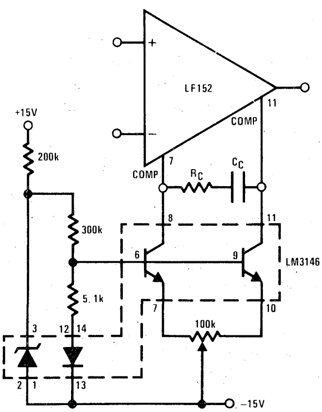


FIGURE 4. Input Offset Adjust

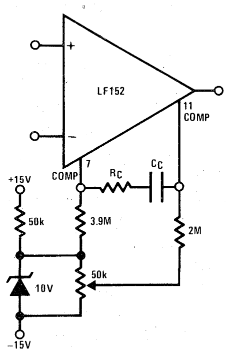


FIGURE 5. Simple Input Offset Adjust

application hints (con't)

To adjust the input offset, the following procedure should be used:

The effective input offset voltage appears directly across R_G when both inputs are connected to ground, and can be measured by a voltmeter referenced to ground. This offset error across R_G can be zeroed by the input offset adjustment circuit shown in *Figure 4 or 5.* The remaining error at the output is strictly due to the output offset voltage which can then be nulled out with the circuit shown in *Figure 2.* The amplifier is now offset nulled independent of gain.

COMPENSATION

The variable bandwidth and slew rate of the LF152 are controlled by an RC network between the compensation pins of the amplifier as shown in *Figure 2.* R_C and C_C may be varied for optimum operating characteristics in a particular application.

Layout of accompanying circuitry may influence the value of this RC network. The lead lengths to resistors R_S and R_G should be minimized and the capacitance from these nodes should also be minimized for optimum frequency response. If $R_C = 160\Omega$ and $C_C = 0.002\mu F$ in the printed circuit board of *Figure 7*, the amplifier will be compensated for all gains from 1 to 1000. Gains from 0.1 to 10,000 may be obtained with different compensation.

GAIN ERROR AND NONLINEARITY

Gain error of the LF152 is the error between the average slope of the transfer function compared to the slope of R_S/R_G. In the LF152, the small gain error is essentially constant with gain and may be nulled out by trimming R_S.

Of the existing monolithic instrumentation amplifiers, the LF152 is among the lowest in gain nonlinearity error. Gain nonlinearity is the curvature of the transfer function from the theoretically perfect function as shown in *Figure 6.*

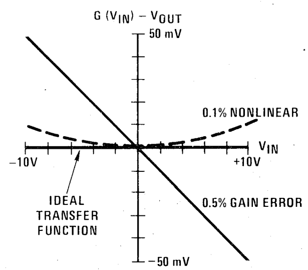


FIGURE 6. Gain Error and Nonlinearity

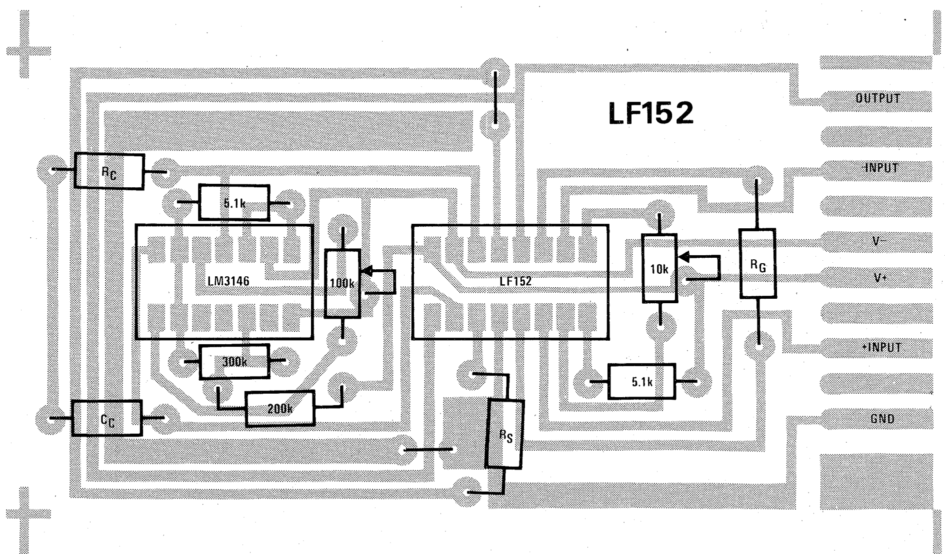
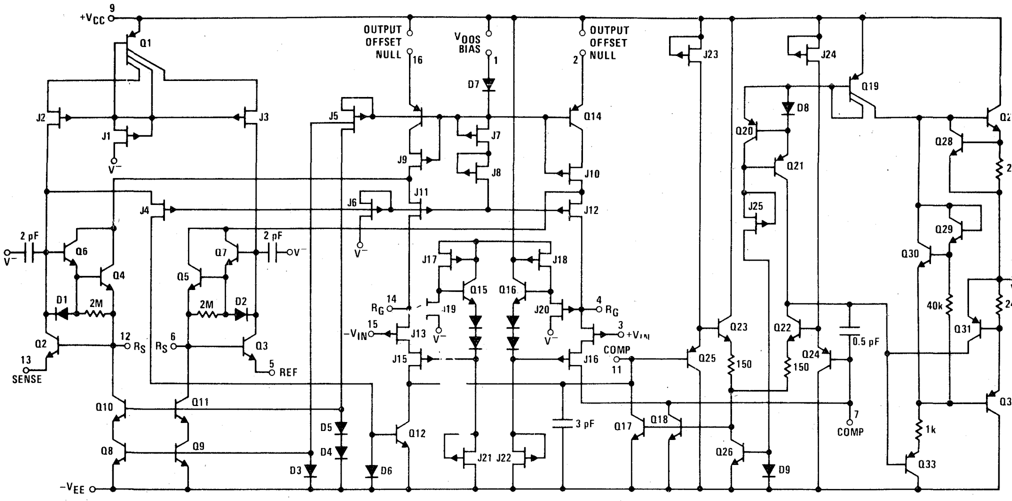


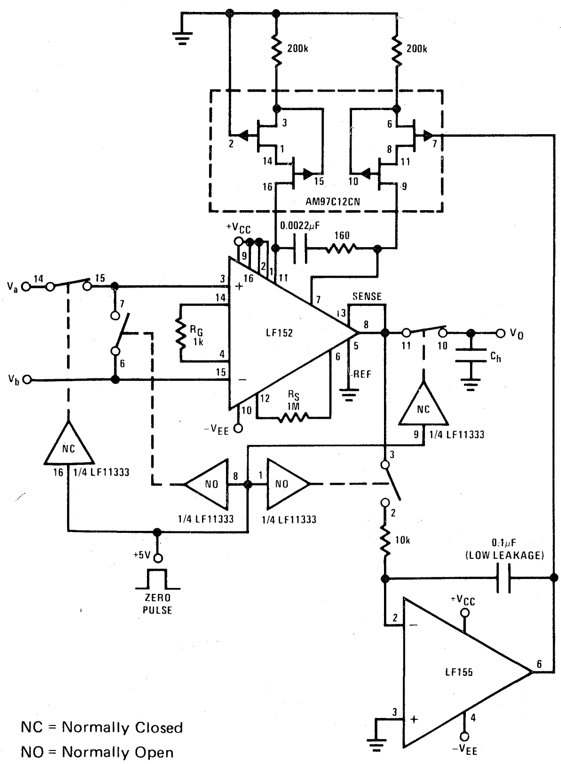
FIGURE 7. PC Layout (Bottom View)

detailed schematic



typical applications

Automatic V_{IOS} Adjust ($G \geq 100$)

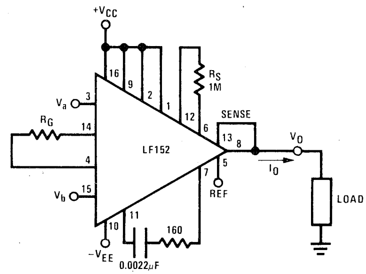


NC = Normally Closed

NO = Normally Open

Minimum pulse width to drive V_O to zero is 400μs.

General Purpose Instrumentation Amplifier



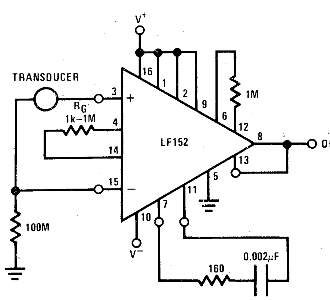
$$V_O = (V_a - V_b)\ \frac{R_S}{R_G} + V_{REF}$$

For $\frac{R_S}{R_G} = 1$

$V_O = V_a + V_{REF} - V_b$

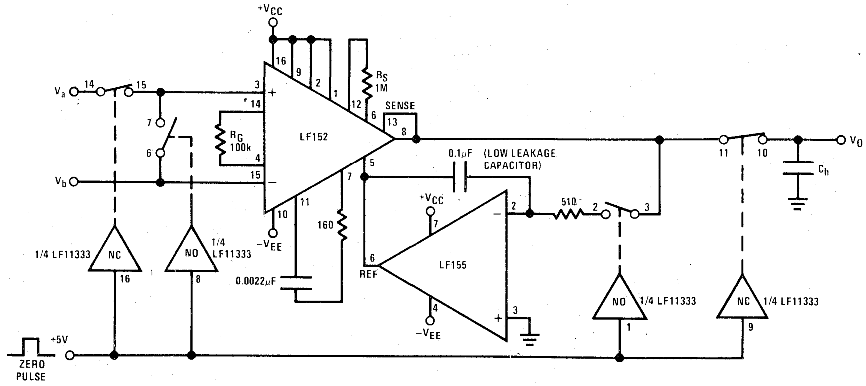
I_O SOURCE OR SINK $\leq$ 5 mA

Isolated Sensor



typical applications (con't)

Automatic V_{OOS} Adjust (For $G \leq 100$)

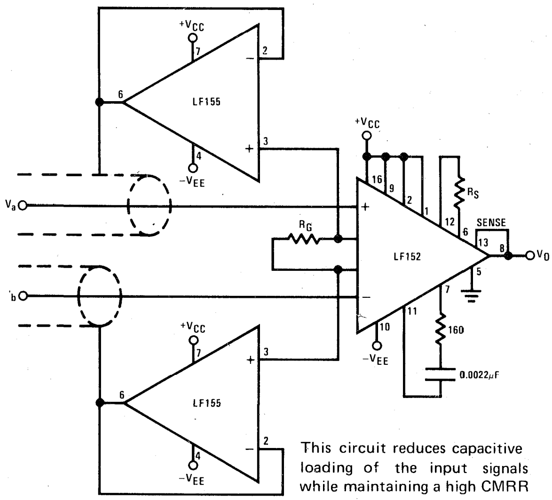


Minimum pulse width to drive V_O to zero is 450μs

NC = Normally Closed

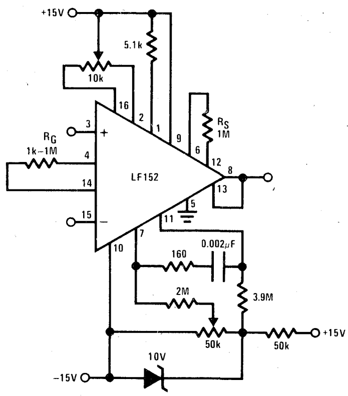
NO = Normally Open

AC Active Guard Drive

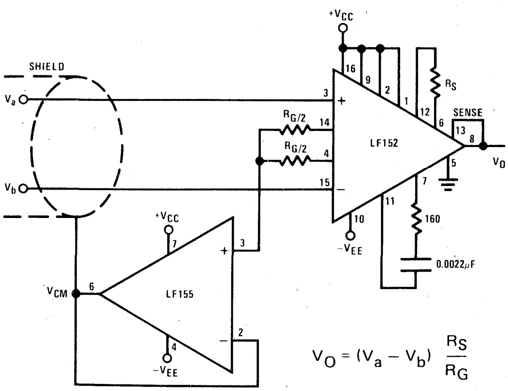


This circuit reduces capacitive loading of the input signals while maintaining a high CMRR

Typical Circuit with Full Offset Adjust



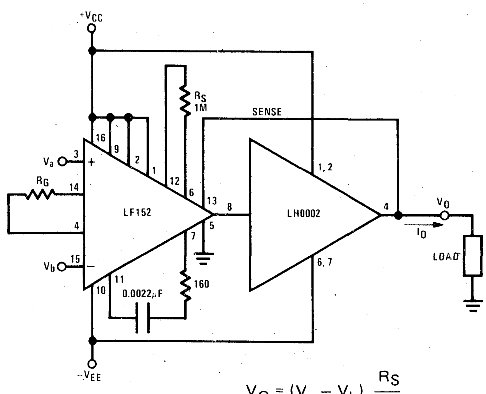
Active Guard Drive



$$V_O = (V_a - V_b)\ \frac{R_S}{R_G}$$

(This circuit reduces the degradation of CMRR caused by the capacitance of shielded cable.)

Output Current Boost



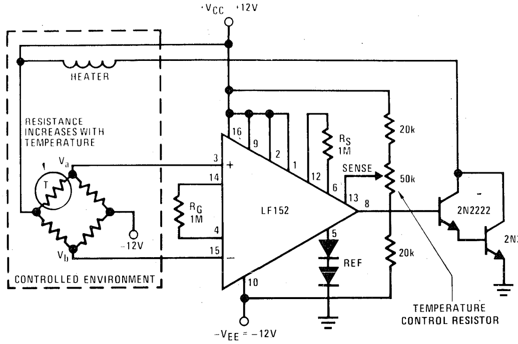
$$V_O = (V_a - V_b)\ \frac{R_S}{R_G}$$

I_O SOURCE OR SINK ≤ 95 mA

4

typical applications (con't)

Temperature Control Circuit

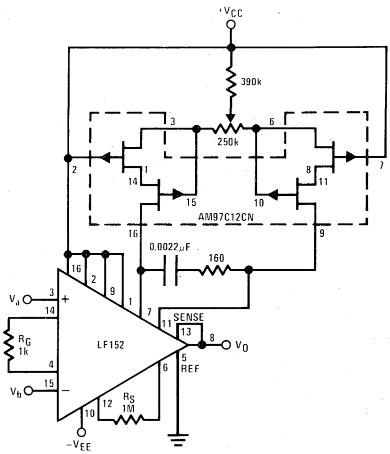


Under balanced conditions, $V_{SENSE} - V_{REF}$ appears across R_S, $V_a - V_b$ appears across R_G and $I_{RG} = I_{RS}$.

$$\frac{V_a - V_b}{R_G} = \frac{V_{SENSE}}{R_S} \text{ or } V_a - V_b = V_{SENSE} \frac{R_G}{R_S}$$

V_{SENSE} is fixed by the temperature control resistor and R_G/R_S is constant. The LF152 is used as a comparator with a feedback loop closed through the heater and the temperature dependent resistor. If $V_a - V_b > V_{SENSE}\ R_G/R_S$. The output goes high turning "ON" the heater. If $V_a - V_b < V_{SENSE}\ R_G/R_S$. The output goes low turning "OFF" the heater.

Alternate Input Offset (V_{IOS}) Adjust Scheme



definition of terms

G **Closed loop gain.** $G = R_S/R_G$

G_E **Gain error.** A rotational error of the transfer function about the origin.

G_{NL} **Gain nonlinearity.** Curvature of the transfer function.

V_{OS} **Offset voltage.** Voltage offset of the transfer function at the origin $V_{OS} = V_{IOS}(G) + V_{OOS}$

Instrumentation Amplifiers

LH0020/LH0020C* high gain instrumentation operational amplifier

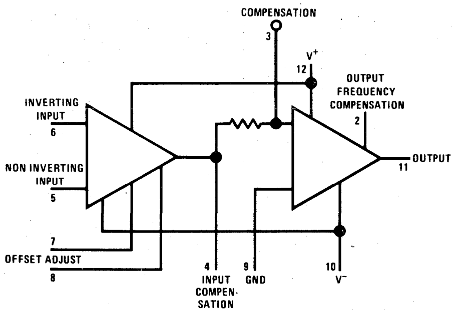
general description

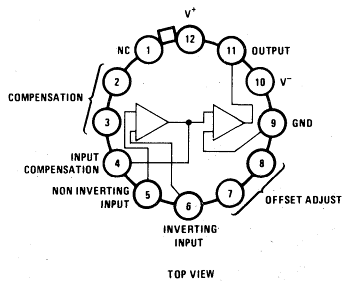
The LH0020/LH0020C is a general purpose operational amplifier designed to source and sink 50 mA output currents. In addition to its high output capability, the LH0020/LH0020C exhibits excellent open loop gain, typically in excess of 100 dB. The parameters of the LH0020 are guaranteed over the temperature range of −55°C to +125°C and ±5V $\leqslant V_S \leqslant$ ±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

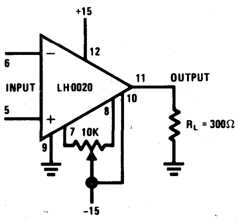




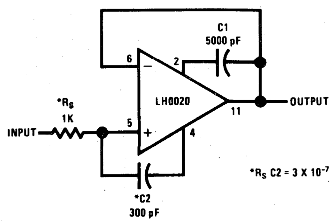
Order Number LH0020G or LH0020CG
See Package 6

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	$V_S = \pm 15V$	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	$V_S = \pm 15V$, $R_L = 300\Omega$, $V_O = \pm 10V$	25	100	300		25	50	150		V/mV
	$V_S = \pm 15V$, $R_L = 300\Omega$, $V_O = \pm 10V$	−55 to +125	50			0 to 85	30			V/mV
Output Voltage Swing	$V_S = \pm 15V$, $R_L = 300\Omega$	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	$V_S = \pm 15V$, $R_L = 0\Omega$	25		100	130	25	25	120	140	mA
Input Voltage Range	$V_S = \pm 15V$	−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 $\pm 5V \leq V_S \leq \pm 22V$ for the LH0020, $\pm 5V \leq V_S \leq \pm 18V$ for the LH0020C, pin 9 grounded, and a 5000 pF capacitor between pins 2 and 3, unless otherwise specified.

Instrumentation Amplifiers

LH0036/LH0036C instrumentation amplifier

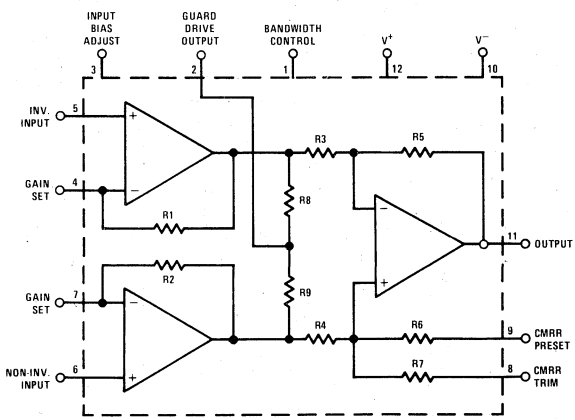
general description

The LH0036/LH0036C 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 LH0036 is specified for operation over the −55°C to +125°C temperature range and the LH0036C is specified for operation over the −25°C to +85°C temperature range.

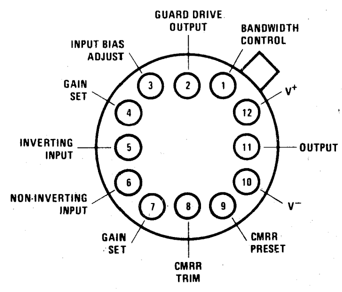
features

- 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 LH0036 or LH0036C
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		0.5	1.0		1.0	2.0	mV
	R_S = 1.0kΩ			2.0			3.0	mV
Output Offset Voltage (V_{OOS})	R_S = 1.0kΩ, T_A = 25°C		2.0	5.0		5.0	10	mV
	R_S = 1.0kΩ			6.0			12	mV
Input Offset Voltage Tempco ($\Delta V_{IOS}/\Delta T$)	$R_S \leq 1.0k\Omega$		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		2.5			6.0		mV
	A_V = 10		0.7			1.5		mV
	A_V = 100		0.52			1.05		mV
	A_V = 1000		0.502			1.005		mV
Input Bias Current (I_B)	T_A = 25°C		40	100		50	125	nA
				150			200	nA
Input Offset Current (I_{OS})	T_A = 25°C		10	40		20	50	nA
				80			100	nA
Small Signal Bandwidth	A_V = 1.0, R_L = 10kΩ		350			350		kHz
	A_V = 10, R_L = 10kΩ		35			35		kHz
	A_V = 100, R_L = 10kΩ		3.5			3.5		kHz
	A_V = 1000, R_L = 10kΩ		350			350		Hz
Full Power Bandwidth	V_{IN} = ±10V, R_L = 10k, A_V = 1		5.0			5.0		kHz
Input Voltage Range	Differential	±10	±12		±10	±12		V
	Common Mode	±10	±12		±10	±12		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		1.0	2.5		1.0	5.0	mV/V
	$\pm 5.0V \leq V_S \leq \pm 15V$, A_V = 100		0.05	0.25		0.10	0.50	mV/V
CMRR	A_V = 1.0 DC to		1.0	2.5		2.5	5.0	mV/V
	A_V = 10 100 Hz		0.1	0.25		0.25	0.50	mV/V
	A_V = 100 ΔR_S = 1.0k		50	100		50	100	μV/V
Output Voltage	V_S = ±15V, R_L = 10kΩ,	±10	±13.5		±10	±13.5		V
	V_S = ±1.5V, R_L = 100kΩ	±0.6	±0.8		±0.6	±0.8		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		3.8			3.8		μs
	A_V = 100		180			180		μs

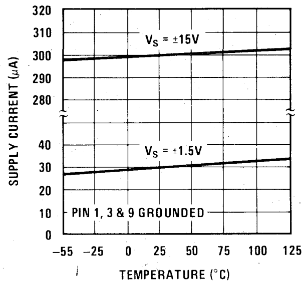
Note 1: Unless otherwise specified, all specifications apply for V_S = ±15V, Pins 1, 3, and 9 grounded, −25°C to +85°C for the LH0036C and −55°C to +125°C for the LH0036.

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

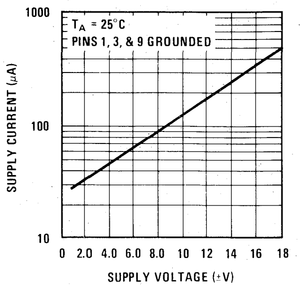
Note 3: The maximum junction temperature is 150°C. For operation at elevated temperature derate the G package on a thermal resistance of 90°C/W, above 25°C.

typical performance characteristics

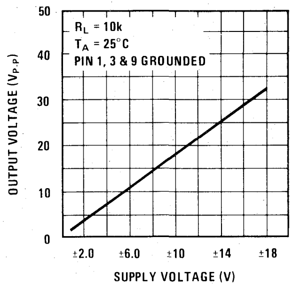
Supply Current vs Temperature



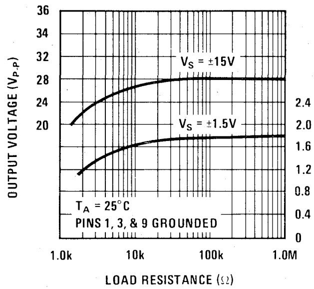
Supply Current vs Supply Voltage



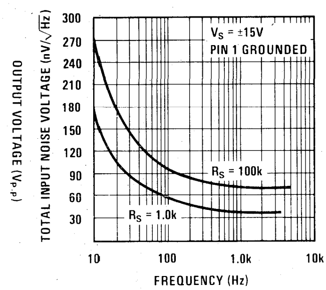
Output Voltage Swing vs Supply Voltage



Peak to Peak Output Voltage Swing vs R_L

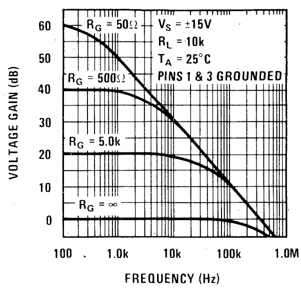


Total Input Noise Voltage* vs Frequency

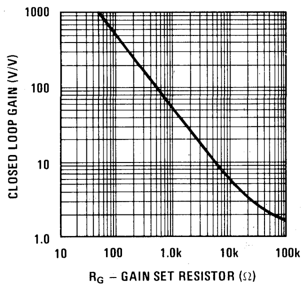


*Noise voltage includes contribution from source resistance

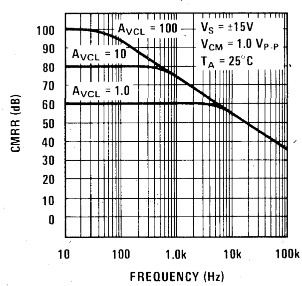
Closed Loop Voltage Gain vs Frequency



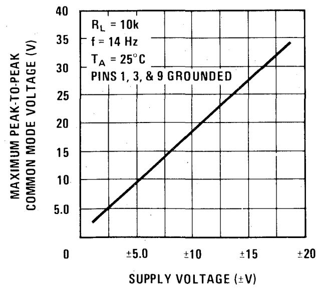
Closed Loop Voltage Gain



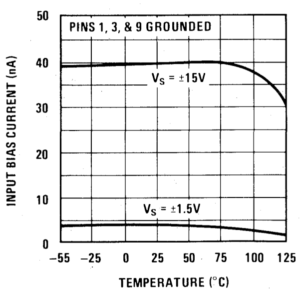
CMRR vs Frequency



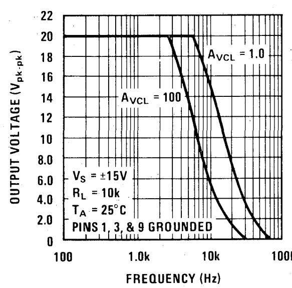
Common Mode Voltage vs Supply Voltage



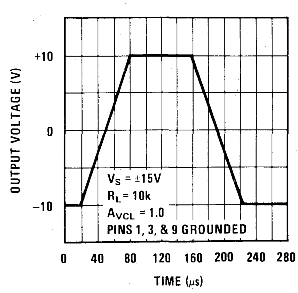
Input Bias Current



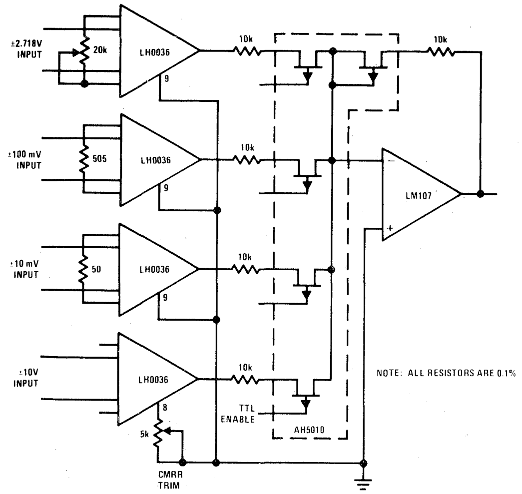
Output Voltage Swing vs Frequency



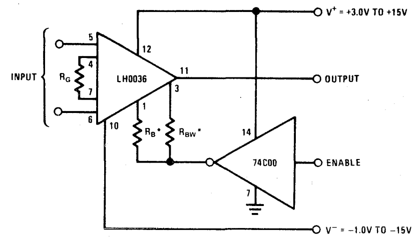
Large Signal Pulse Response



typical applications

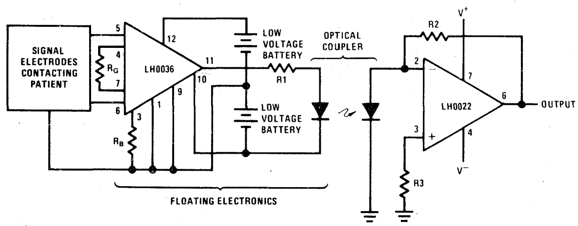


Pre MUX Signal Conditioning

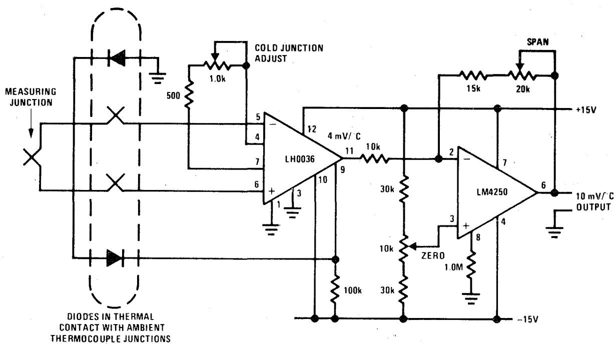


*R_{BW} AND R_B ARE OPTIONAL BANDWIDTH AND INPUT BIAS CURRENT CONTROLLING RESISTORS.

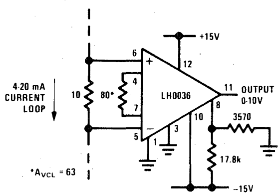
Instrumentation Amplifier with Logic Controlled Shut-Down



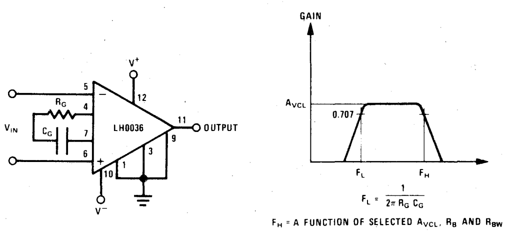
Isolation Amplifier for Medical Telemetry



Thermocouple Amplifier with Cold Junction Compensation



Process Control Interface



High Pass Filter

applications information

THEORY OF OPERATION

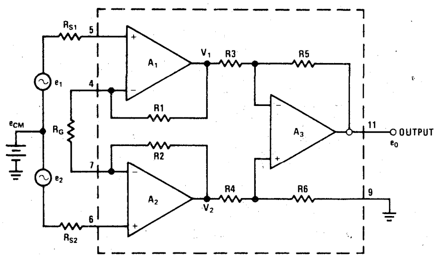


FIGURE 1. Simplified LH0036

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:

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

By similar analysis V_2 is seen to be:

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

For R1 = R2:

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

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

$$e_0 = (1)(V_2 - V_1) = (e_2 - e_1)\left[1 + \left(\frac{2R1}{R_G}\right)\right] \qquad (4)$$

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:

$$A_{VCL} = \frac{e_0}{e_2 - e_1} = 1 + \frac{50k}{R_G} \qquad (5a)$$

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:

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

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}.

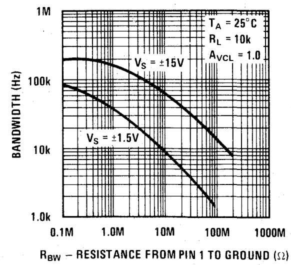


FIGURE 2. Bandwidth vs R_{BW}

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}.

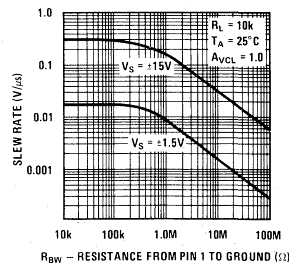


FIGURE 3. Output Slew Rate vs R_{BW}

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.

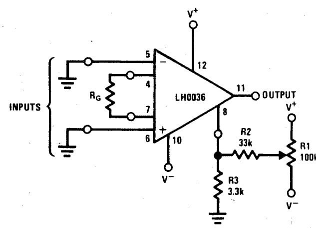


FIGURE 4. V_{OS} Adjustment Circuit

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

4

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.

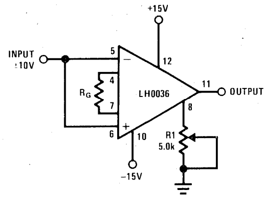


FIGURE 5. CMRR Adjustment Circuit

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.

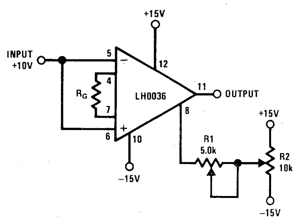


FIGURE 6. Combined CMRR, V_{OS} Adjustment Circuit

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.

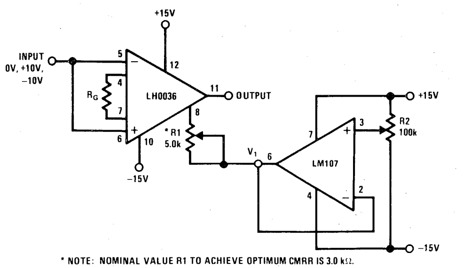


FIGURE 7. Improved V_{OS}, CMRR Nulling Circuit

AC CMRR Considerations

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

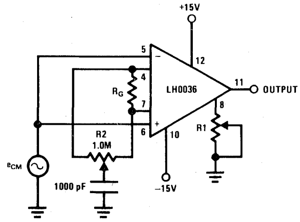


FIGURE 8. Improved AC CMRR Circuit

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.

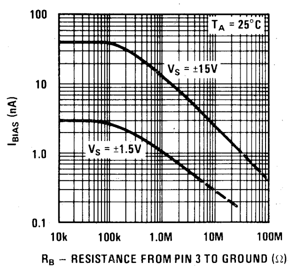


FIGURE 9. Input Bias Current as a Function of R_B

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

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

applications information (con't)

or

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

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)

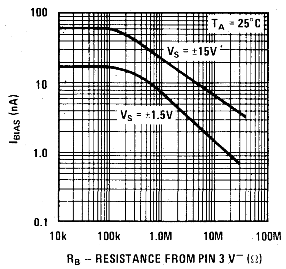


FIGURE 10. Input Bias Current as a Function of R_B

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.

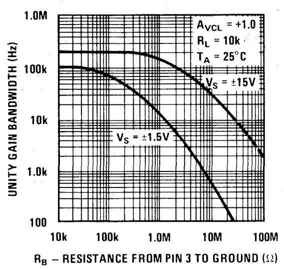


FIGURE 11. Unity Gain Bandwidth as a Function of R_B

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.

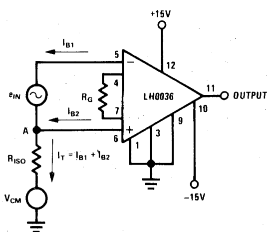


FIGURE 12. Bias Current Return Path

In a typical application, V_S = ±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 MΩ, the voltage at point A exceeds the +12V common range of the device. Clearly, for R_{ISO} = ∞, 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:

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

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.

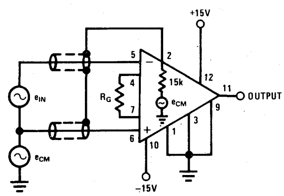


FIGURE 13. Use of Guard

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.

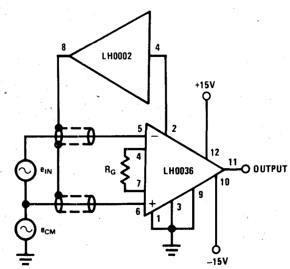


FIGURE 14. Guard Pin With Buffer

Instrumentation Amplifiers

LM121/LM221/LM321, LM121A/LM221A/LM321A precision preamplifiers

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 50 better than standard op amps alone. Further, the added dc gain of the LM121 decreases the closed loop gain error.

The LM121 series 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.

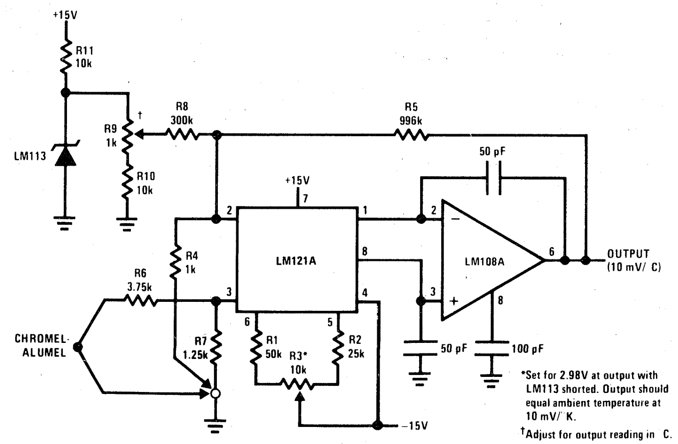
features

- Guaranteed drift of LM121A series — 0.2μV/°C
- Guaranteed drift of LM121 series — 1μV/°C
- 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 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.

typical applications



Thermocouple Amplifier with Cold Junction Compensation

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	
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 seconds)	300°C

electrical characteristics (Note 4) LM121, LM221, LM321

PARAMETER	CONDITIONS	LM121, LM221 MIN	LM121, LM221 TYP	LM121, LM221 MAX	LM321 MIN	LM321 TYP	LM321 MAX	UNITS
Input Offset Voltage	$T_A = 25°C$, $6.4k \le R_{SET} \le 70k$			0.7			1.5	mV
Input Offset Current	$T_A = 25°C$,							
	$R_{SET} = 70k$			1			2	nA
	$R_{SET} = 6.4k$			10			20	nA
Input Bias Current	$T_A = 25°C$,							
	$R_{SET} = 70k$			10			18	nA
	$R_{SET} = 6.4k$			100			180	nA
Input Resistance	$T_A = 25°C$,							
	$R_{SET} = 70k$	4			2			MΩ
	$R_{SET} = 6.4k$	0.4			0.2			MΩ
Supply Current	$T_A = 25°C$, $R_{SET} = 70k$			1.5			2.2	mA
Input Offset Voltage	$6.4k \le R_{SET} \le 70k$			1.0			2.5	mV
Input Bias Current	$R_{SET} = 70k$			30			28	nA
	$R_{SET} = 6.4k$			300			280	nA
Input Offset Current	$R_{SET} = 70k$			3			4	nA
	$R_{SET} = 6.4k$			30			40	nA
Input Offset Current Drift	$R_{SET} = 70k$		3			3		pA/°C
Average Temperature Coefficient of Input Offset Voltage	$R_S \le 200\Omega$, $6.4k \le R_{SET} \le 70k$ Offset Voltage Nulled			1			1	μV/°C
Long Term Stability			5			5		μV/yr
Supply Current				2.5			3.5	mA
Input Voltage Range	$V_S = \pm 15V$, (Note 5)							
	$R_{SET} = 70k$	±13			±13			V
	$R_{SET} = 6.4k$	+7, −13			+7, −13			V
Common-Mode Rejection Ratio	$R_{SET} = 70k$	120			114			dB
	$R_{SET} = 6.4k$	114			114			dB
Supply Voltage Rejection Ratio	$R_{SET} = 70k$	120			114			dB
	$R_{SET} = 6.4k$	114			114			dB
Voltage Gain	$T_A = 25°C$, $R_{SET} = 70k$, $R_L > 3\ M\Omega$	16			12			V/V
Noise	$R_{SET} = 70k$, $R_{SOURCE} = 0$		8			8		$nV/\sqrt{Hz}$

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 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 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 $\pm 5 \le V_S \le \pm 20V$ and $-55°C \le T_A \le +125°C$, unless otherwise specified. With the LM221, however, all temperature specifications are limited to $-25°C \le T_A \le +85°C$, and for the LM321 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.

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) LM121A, LM221A, LM321A

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	$V_S = \pm15V$, (Note 5)							
	$R_{SET} = 70k$	±13			±13			V
	$R_{SET} = 6.4k$	+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	$T_A = 25°C$, $R_{SET} = 70k$, $R_L > 3 M\Omega$	16	20		12	20		V/V
Noise	$R_{SET} = 70k$, $R_{SOURCE} = 0$		8			8		$nV/\sqrt{Hz}$

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 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 $\pm5 \leq V_S \leq \pm20V$ 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 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 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 LM121 SERIES

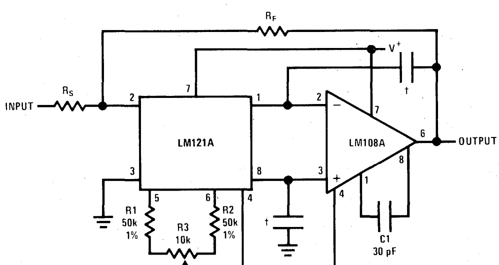
$$\text{Gain } A_V \approx \frac{1.2 \times 10^6}{R_{SET}}$$

Null Pot Value should be 10% of R_{SET}

$$\text{Operating Current} \approx \frac{2 \times 0.65V}{R_{SET}}$$

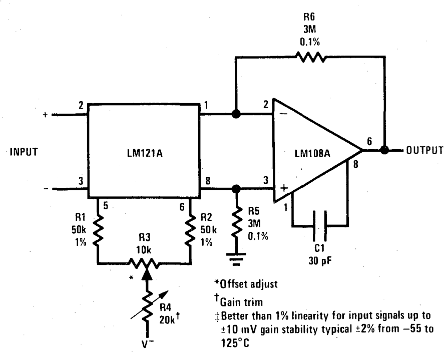
$$\text{Positive Common-Mode Limit} \approx V^+ - \left[0.6 - \frac{0.65V \times 50k}{R_{SET}}\right]$$

typical applications



*Offset adjust.
†See table for frequency compensation.

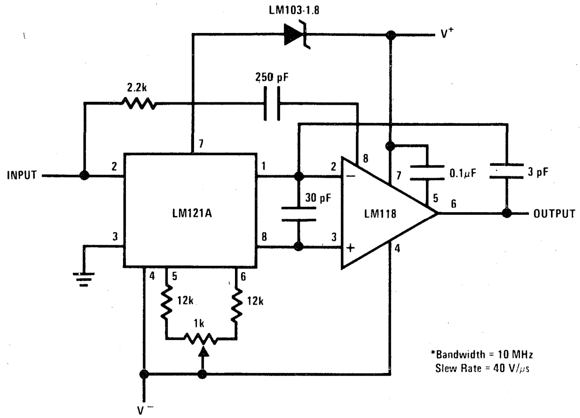
FIGURE 1. Low Drift Op Amp Using the LM121A as a Preamp



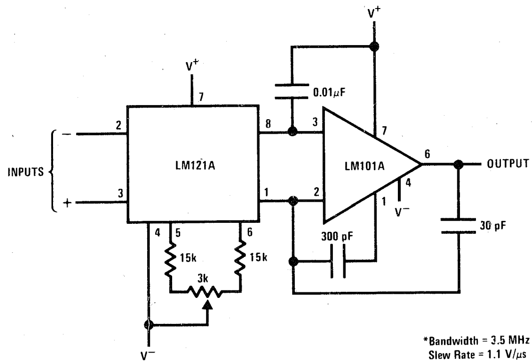
*Offset adjust
†Gain trim
‡Better than 1% linearity for input signals up to ±10 mV gain stability typical ±2% from −55 to 125°C
Match of R5 and R6 effect power supply rejection

Gain of 1000 Instrumentation Amplifier‡

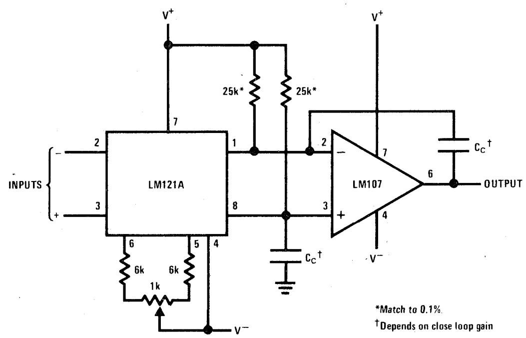
typical applications (con't)



High Speed* Inverting Amplifier with Low Drift



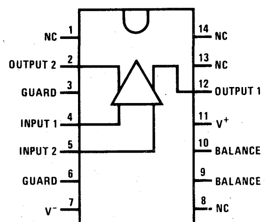
Medium Speed* General Purpose Amplifier



Increased Common-Mode Range at High Operating Currents

connection diagrams

Dual-In-Line Package

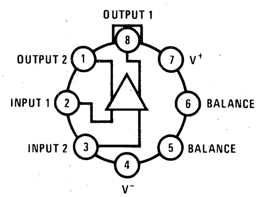


NOTE: Pin 7 connected to bottom of package.

TOP VIEW

Order Number LM121D, LM221D, LM321D, LM121AD, LM221AD or LM321AD
See Package 1

Metal Can Package



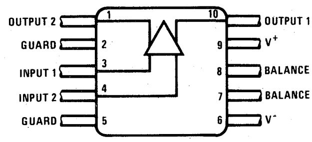
Note: Pin 4 connected to case.

TOP VIEW

Order Number LM121H, LM221H, LM321H, LM121AH, LM221AH or LM321AH
See Package 11

Note: Outputs are inverting from the input of the same number.

Flat Package

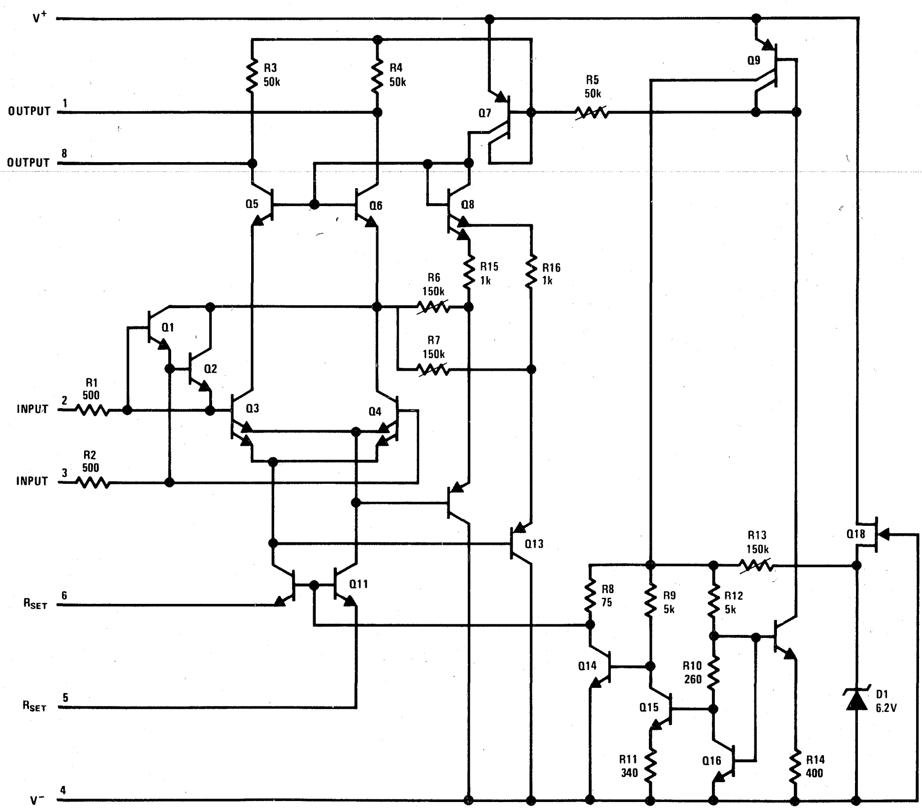


NOTE: Pin 6 connected to bottom of package.

TOP VIEW

Order Number LM121F, LM221F, LM321F, LM121AF, LM221AF or LM321AF
See Package 3

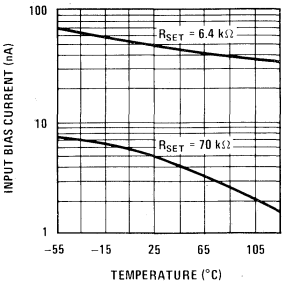
schematic diagram*



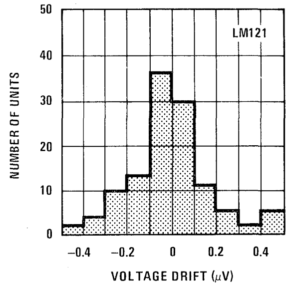
*Pin connections shown on schematic diagram and typical applications are for TO-5 package.

typical performance characteristics

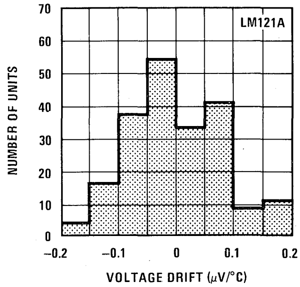
Input Bias Current



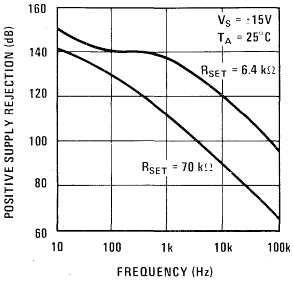
Distribution of Offset Voltage Drift (Nulled)



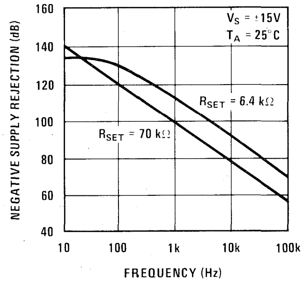
Distribution of Offset Voltage Drift (Nulled)



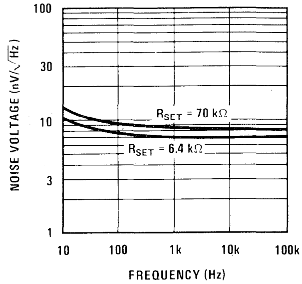
Positive Power Supply Rejection



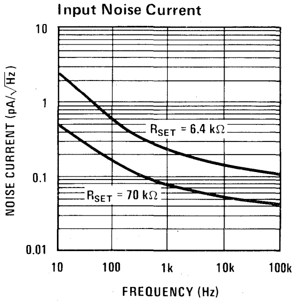
Negative Power Supply Rejection



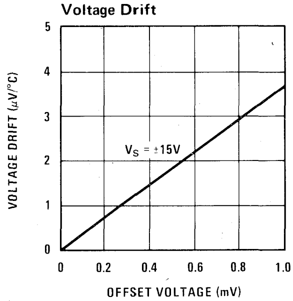
Input Noise Voltage



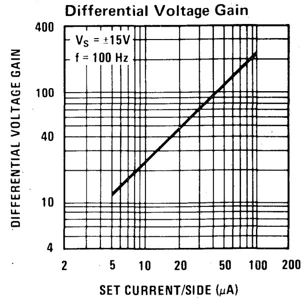
Input Noise Current



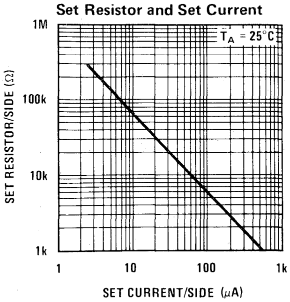
Voltage Drift



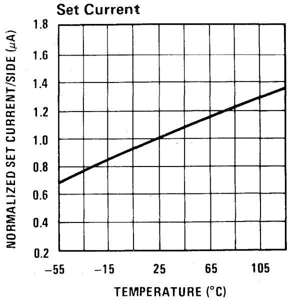
Differential Voltage Gain



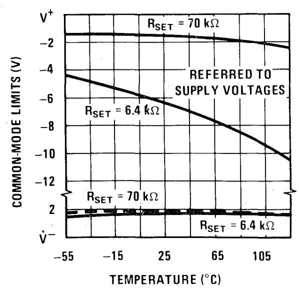
Set Resistor and Set Current



Set Current

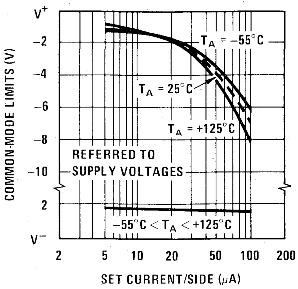


Common-Mode Limits

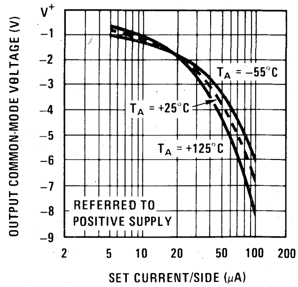


typical performance characteristics (con't)

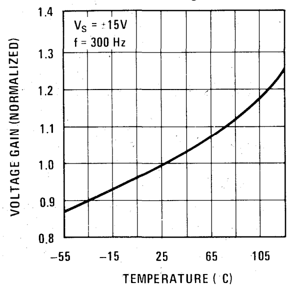
Common-Mode Limits



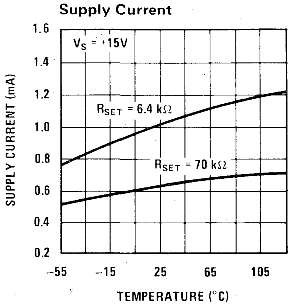
Output Common-Mode Voltage



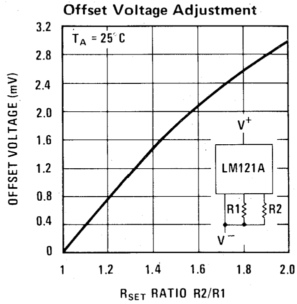
Differential Voltage Gain



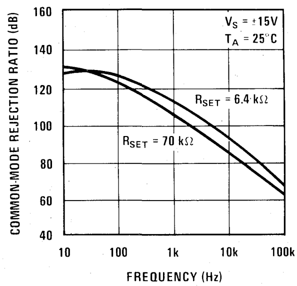
Supply Current



Offset Voltage Adjustment



Common-Mode Rejection Ratio



4

Instrumentation Amplifiers

LM725/LM725A/LM725C instrumentation operational amplifier

general description

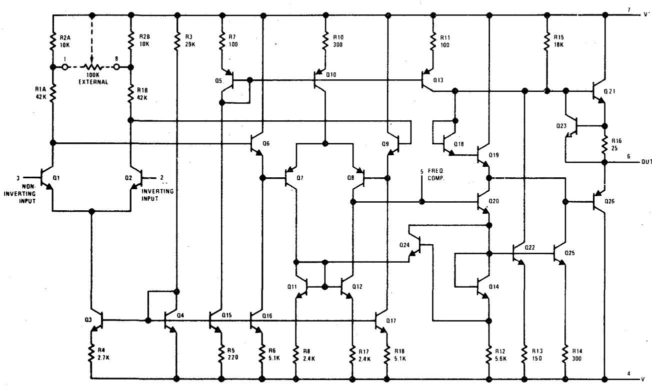
The LM725/LM725A/LM725C are operational amplifiers featuring superior performance in applications where low noise, low drift, and accurate closed-loop gain are required. With high common mode rejection and offset null capability, it is especially suited for low level instrumentation applications over 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.

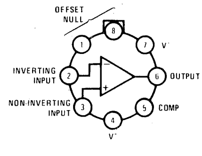
features

- 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/√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

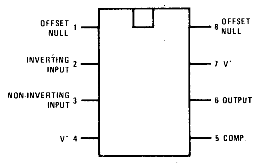


Metal Can Package



Order Number LM725H or LM725AH or LM725CH
See Package 11

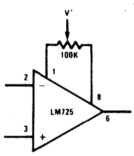
Dual-In-Line Package



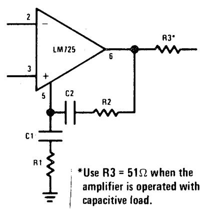
Order Number LM725CN
See Package 20

auxiliary circuits

Voltage Offset Null Circuit



Frequency Compensation Circuit

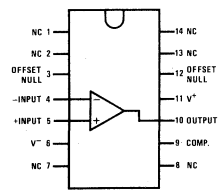


*Use R3 = 51Ω when the amplifier is operated with capacitive load.

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[illegible]	.0[illegible]

Dual-In-Line Package



Order Number LM725D
See Package 1
Order Number LM725J-14, LM725AJ-14 or LM725CJ-14
See Package 16

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
Lead Temperature (Soldering, 10 sec)	300°C

Operating Temperature Range	$T_{A(MIN)}$		$T_{A(MAX)}$
LM725	−55°C	to	+125°C
LM725A	−55°C	to	+125°C
LM725C	0°C	to	+70°C

electrical characteristics (Note 3)

PARAMETER	CONDITIONS	LM725A			LM725			LM725C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage (Without External Trim)	T_A = 25°C, $R_S \le$ 10 kΩ			0.5		0.5	1.0		0.5	2.5	mV
Input Offset Current	T_A = 25°C		2.0	5.0		2.0	20		2.0	35	nA
Input Bias Current	T_A = 25°C		42	80		42	100		42	125	nA
Input Noise Voltage	T_A = 25°C										
	f_o = 10 Hz		15			15			15		nV/√Hz
	f_o = 100 Hz		9.0			9.0			9.0		nV/√Hz
	f_o = 1 kHz		8.0			8.0			8.0		nV/√Hz
Input Noise Current	T_A = 25°C										
	f_o = 10 Hz		1.0			1.0			1.0		pA/√Hz
	f_o = 100 Hz		0.3			0.3			0.3		pA/√Hz
	f_o = 1 kHz		0.15			0.15			0.15		pA/√Hz
Input Resistance	T_A = 25°C		1.5			1.5			1.5		MΩ
Input Voltage Range	T_A = 25°C	±13.5	±14		±13.5	±14		±13.5	±14		V
Large Signal Voltage Gain	T_A = 25°C, $R_L \ge$ 2 kΩ, V_{OUT} = ±10V	1000	3000		1000	3000		250	3000		V/mV
Common-Mode Rejection Ratio	T_A = 25°C, $R_S \le$ 10 kΩ	120			110	120		94	120		dB
Power Supply Rejection Ratio	T_A = 25°C, $R_S \le$ 10 kΩ		2.0	5.0		2.0	10	2.0	35		μV/V
Output Voltage Swing	T_A = 25°C,										
	$R_L \ge$ 10 kΩ	±12.5	±13.5		±12	±13.5		±12	±13.5		V
	$R_L \ge$ 2 kΩ	±12.0	±13.5		±10	±13.5		±10	±13.5		V
Power Consumption	T_A = 25°C		80	105		80	105		80	150	mW
Input Offset Voltage (Without External Trim)	$R_S \le$ 10 kΩ			0.7			1.5			3.5	mV
Average Input Offset Voltage Drift (Without External Trim)	R_S = 50Ω			2.0		2.0	5.0			2.0	μV/°C
Average Input Offset Voltage Drift (With External Trim)	R_S = 50Ω		0.6	1.0		0.6			0.6		μV/°C
Input Offset Current	$T_A = T_{MAX}$		1.2	4.0		1.2	20		1.2	35	nA
	$T_A = T_{MIN}$		7.5	18.0		7.5	40		4.0	50	nA
Average Input Offset Current Drift			35	90		35	150		10		pA/°C
Input Bias Current	$T_A = T_{MAX}$		20	70		20	100			125	nA
	$T_A = T_{MIN}$		80	180		80	200			250	nA
Large Signal Voltage Gain	$R_L \ge$ 2 kΩ, $T_A = T_{MAX}$	1,000,000			1,000,000			125,000			V/V
	$R_L \ge$ 2 kΩ, $T_A = T_{MIN}$	500,000			250,000			125,000			V/V
Common-Mode Rejection Ratio	$R_S \le$ 10 kΩ	110			100				115		dB
Power Supply Rejection Ratio	$R_S \le$ 10 kΩ			8.0			20		20		μV/V
Output Voltage Swing	$R_L \ge$ 2 kΩ	±12			±10			±10			V

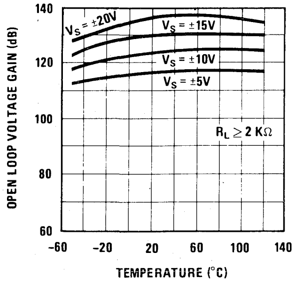
Note 1: Derate at 150°C/W for operation at ambient temperatures above 75°C.

Note 2: For supply voltages less than ±22V, the absolute maximum input voltage is equal to the supply voltage.

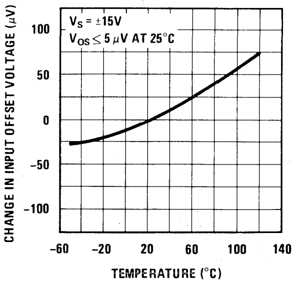
Note 3: These specifications apply for V_S = ±15V unless otherwise specified.

typical performance characteristics

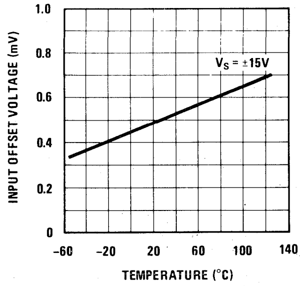
Open Loop Voltage Gain vs Temperature for Various Supply Voltages



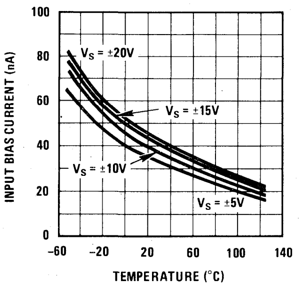
Nulled Input Offset Voltage vs Temperature



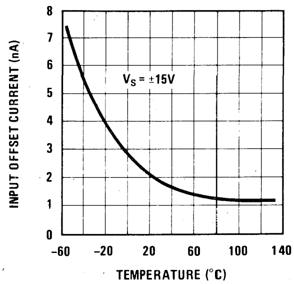
Unnulled Input Offset Voltage vs Temperature



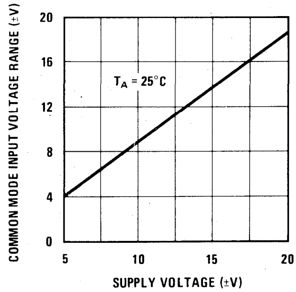
Input Bias Current vs Temperature



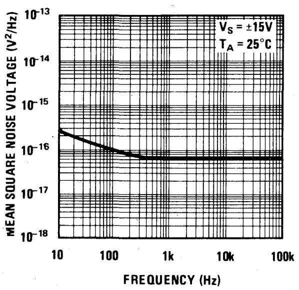
Input Offset Current vs Temperature



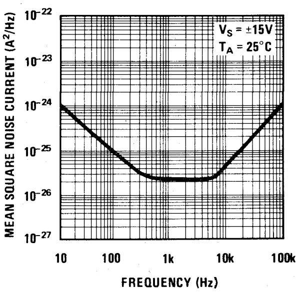
Common Mode Input Voltage vs Supply Voltage



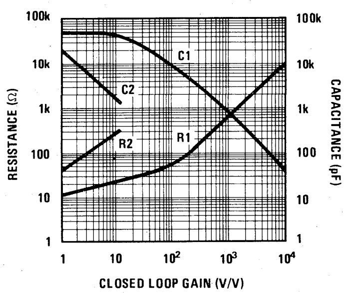
Input Noise Voltage vs Frequency



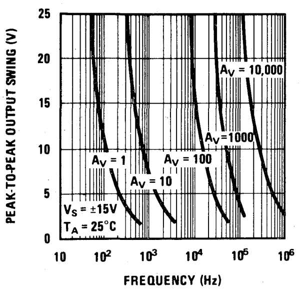
Input Noise Current vs Frequency



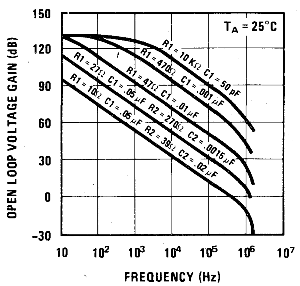
Values for Suggested Compensation Networks for Various Closed Loop Voltage Gains



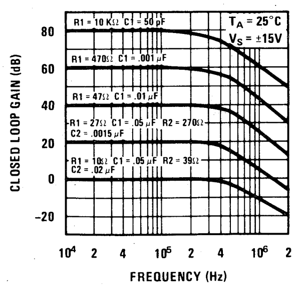
Output Voltage Swing vs Frequency for Recommended Compensation Networks



Open Loop Voltage Gain vs Frequency Using Recommended Compensation Networks

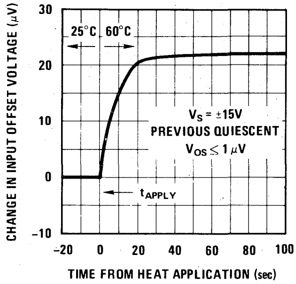


Frequency Response for Various Closed-Loop Gains Using Recommended Compensation Networks

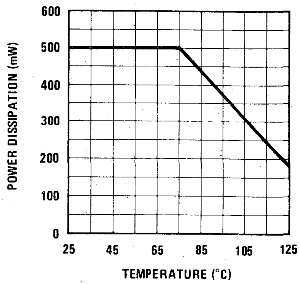


typical performance characteristics (con't)

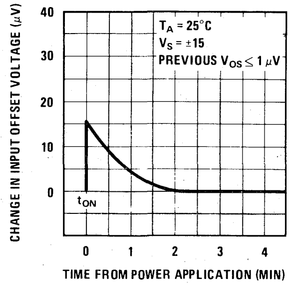
Change in Input Offset Voltage Due to Thermal Shock vs Time



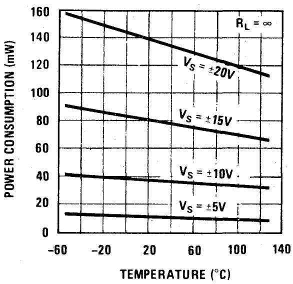
Absolute Maximum Power Dissipation vs Ambient Temperature



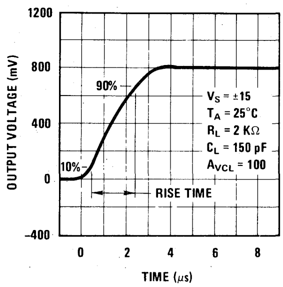
Stabilization Time of Input Offset Voltage from Power Turn-On



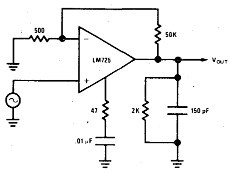
Power Consumption vs Temperature



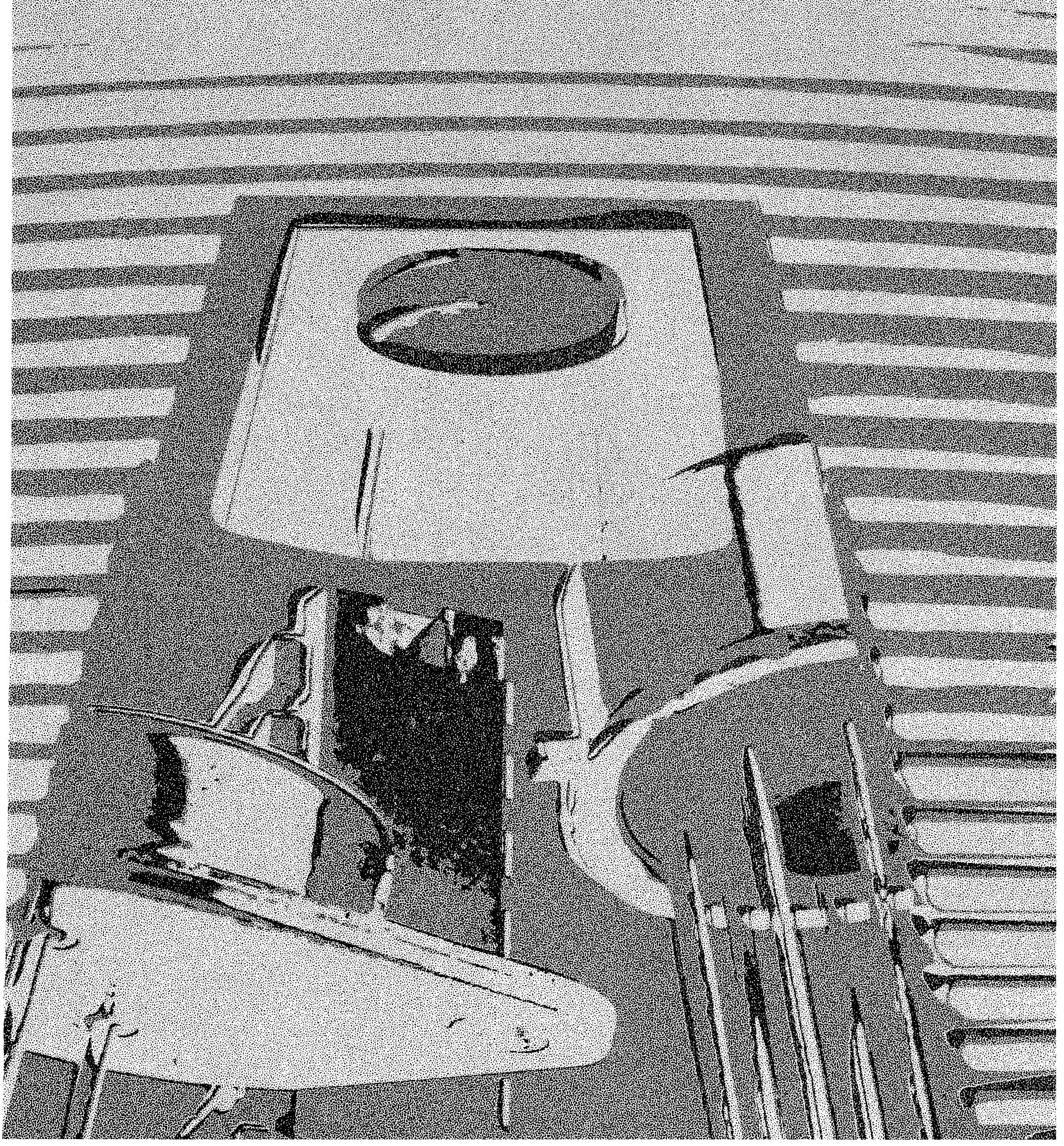
Transient Response



Transient Response Test Circuit



National Semiconductor
VOLTAGE COMPARATORS
Section 5



Voltage Comparators

Section Contents

*Product added to this Data Book since last printing.

Voltage Comparator Guide

Device	Temperature Range*	DTL/TTL Fanout	Supply Voltage Typ (V)	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.	Single comparator with strobe, high speed and sensitivity, large fanout
LM206	Industrial	10	$V^- = -3$	20	3	2	40 max	40k	TO-5 F.P.	
LM306	Commercial	10	To −12	25	5	5	40 max	40k	TO-5 F.P.	
LF111	Military	2	36	0.05	0.000025	4	200	200k	TO-5 DIP F.P.	FET front-end inputs
LF211	Industrial	2	36	0.05	0.000025	4	200	200k	TO-5 DIP F.P.	
LF311	Commercial	2	36	0.15	0.000075	10	200	200k	TO-5 DIP F.P.	
LM111	Military	5	±15	0.1	0.04	0.7	200	200k	TO-5 DIP F.P.	Single, with strobe, will work from single supply, low bias current
LH2111 Dual (Note 1)	Military	5	±15	0.1	0.04	0.7	200	200k	TO-5 DIP F.P.	
LM211	Industrial	5	To 5	0.1	0.04	0.7	200	200k	To-5 DIP F.P.	
LH2211 Dual (Note 1)	Industrial	5	To 5	0.1	0.04	0.7	200	200k	TO-5 DIP F.P.	
LM311	Commercial	5	And GND	0.25	0.06	2	200	200k	TO-5 DIP F.P.	
LH2311 Dual (Note 1)	Commercial	5	And GND	0.25	0.06	2	200	200k	TO-5 DIP F.P.	
LM119	Military	2 (Each Side)	±15	0.5	0.075	4	80	40k	TO-5 DIP F.P.	High speed dual comparator
LM219	Industrial	2 (Each Side)	To 5	0.5	0.075	4	80	40k	TO-5 DIP F.P.	
LM319	Commercial	2 (Each Side)	And GND	1	0.2	8	80	40k	TO-5 DIP	
LM139 Quad	Military	1	±1	0.1	0.025	5	1.3μs	200k	DIP F.P.	Quad comparator designed for single supply operation; input common mode range includes ground
LM239 Quad	Industrial	1	To ±18	0.25	0.050	5	1.3μs	200k	DIP	
LM339 Quad	Commercial	1	Or From	0.25	0.050	5	1.3μs	200k	DIP	
LM139A Quad	Military	1	2	0.1	0.025	2	1.3μs	200k	DIP F.P.	Low offset voltage Quad comparator with DTL/TTL logic levels
LM239A Quad	Industrial	1	To 36	0.25	0.050	2	1.3μs	200k	DIP	
LM339A Quad	Commercial	1	And GND	0.25	0.050	2	1.3μs	200k	DIP	
LM160	Military	2	±4.5	10	2	2	16	3k	TO-5 DIP F.P.	Very high speed, outputs compatible with DTL/TTL logic levels
LM260	Industrial	2	To	10	2	2	16	3k	TO-5 DIP	
LM360	Commercial	2	±6.5	15	4	4	16	3k	TO-5 DIP	
LM161 (LM529)	Military	2	±5	10	2	2	12	3k	TO-5 DIP F.P.	Very high speed, with individual strobes, DTL/TTL compatible
LM261	Industrial	2	To ±15	10	2	2	12	3k	TO-5 DIP	
LM361 (LM529C)	Commercial	2	And 5	15	4	4	12	3k	TO-5 DIP	
LM193	Military	1	±1	0.1	0.025	5	1.3μs	200k	TO-5	Dual comparator designed for single supply operation; input common-mode range includes ground
LM293	Industrial	1	To ±18	0.25	0.050	5	1.3μs	200k	TO-5	
LM393	Commercial	1	Or From	0.25	0.050	5	1.3μs	200k	TO-5, DIP	
LM193A	Military	1	2	0.1	0.025	2	1.3μs	200k	TO-5	Low offset voltage dual comparator with DTL/TTL logic levels
LM293A	Industrial	1	To 36	0.25	0.050	2	1.3μs	200k	TO-5	
LM393A	Commercial	1	And Gnd	0.25	0.050	2	1.3μs	200k	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 Dual	Military	1	$V^+ = 12$	75	10	3.5	40	1500	TO-5	Dual differential, common output, individual strobes
LM711C Dual	Commercial	1	$V^- = -6$	100	15	5	40	1500	TO-5 DIP	
LM1514 Dual	Military	1	$V^+ = 14$	20	3	3	30	1250	DIP	Dual LM710 with separate strobes, individual outputs
LM1414 Dual	Commercial	1	$V^- = -7$	25	5	4	30	1000	DIP	
LM2901 Quad	Industrial	1	±1 (2V) to ±18 (36)	0.25	0.05	7	1.3	200k	DIP	Quad comparator designed for single supply operation; input common-mode range includes ground
LM2903	Automotive	1	±1 (2V) to ±18 (36)	0.25	0.050	7	1.3μs	2[illegible]k	DIP	Dual comparator designed for single supply operation; input common-mode range includes ground

Note 1: Dual version of device. †Response time is specified for 100 mV step input with 5 mV overdrive.

*Military: −55°C to +125°C; Industrial: −25°C to +85°C; Commercial: 0°C to +70°C; Automotive: −40°C to +85°C

5

Definition of Terms

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.

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.

Voltage Comparators

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.

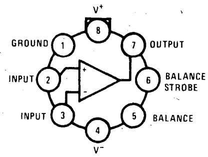
Further, the LF111 can be used in place of the LM111 eliminating errors due to input currents.

advantages

- Eliminates input current errors
- Interchangeable with LM111
- No need for input current buffering

connection diagrams*

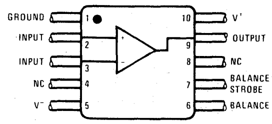
Metal Can Package



NOTE: Pin 4 connected to case.
TOP VIEW

Order Number LF111H, LF211H or LF311H
See Package 11

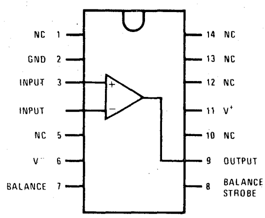
Flat Package



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

Order Number LF111F, LF211F or LF311F
See Package 3

Dual-In-Line Package

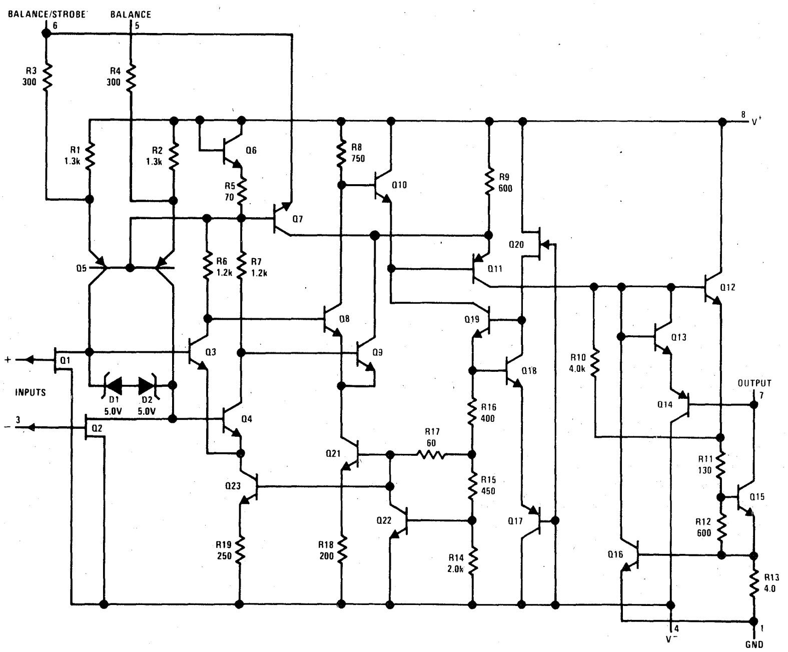


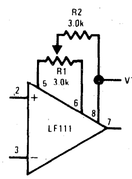
Note: Pin 6 connected to bottom of package.
TOP VIEW

Order Number LF111D, LF211D or LF311D
See Package 1

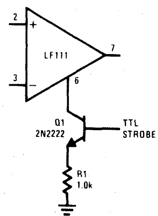
*Pin connections shown on schematic diagram and typical applications are for TO-5 package.

schematic diagram and auxiliary circuits

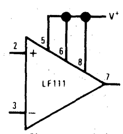




Offset Balancing



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	$V^+ \geq 4.5$V, 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)	$T_A = 25°C$, $R_S \le 50k$		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	$V_{IN} \le -10$ 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	$V_{IN} \ge 10$ mV, $V_{OUT} = 35V$, $T_A = 25°C$		0.2	10	nA
Input Offset Voltage (Note 4)	$R_S \le 50k$			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	$V^+ \ge 4.5V$, $V^- = 0$ $V_{IN} \le -10$ mV, $I_{SINK} \le 8.0$ 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.

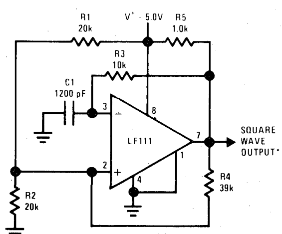
Note 3: These specifications apply for $V_S = \pm 15V$ and $-55°C \le T_A \le +125°C$ for the LF111, unless otherwise stated. With the LF211, however, all temperature specifications are limited to $-25°C \le T_A \le +85°C$ and for the LF311 $0°C \le T_A \le +70°C$. The offset voltage, offset current 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.

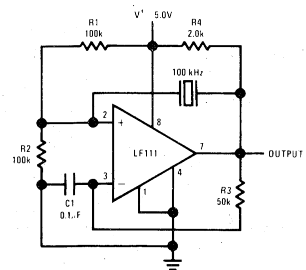
Note 6: For input voltages greater than 15V above the negative supply the bias and offset currents will increase—see typical performance curves.

typical applications



*TTL or DTL fanout of two.

100 kHz Free Running Multivibrator

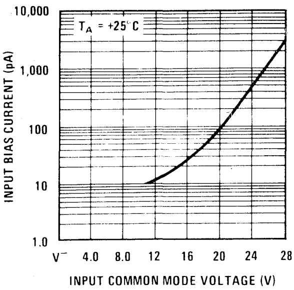


Crystal Oscillator

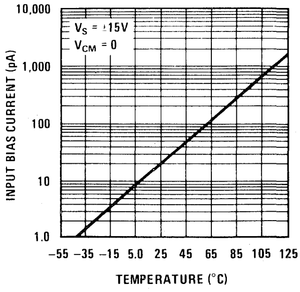
5

typical performance

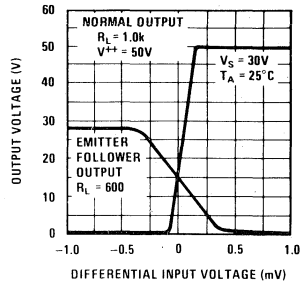
Input Bias Current vs Common Mode



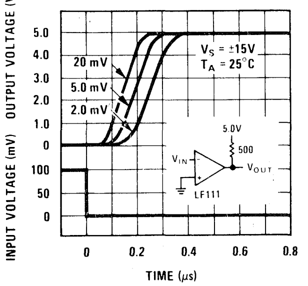
Input Bias Current vs Temperature



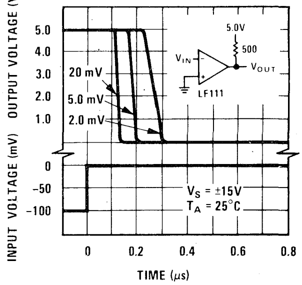
Transfer Function



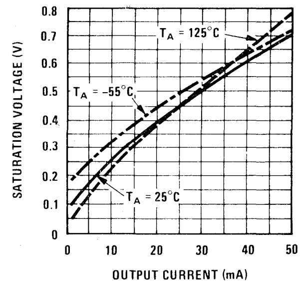
Response Time for Various Input Overdrives



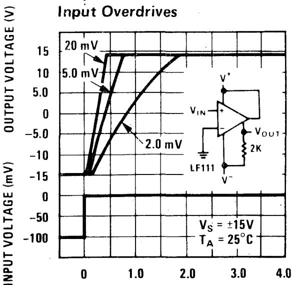
Response Time for Various Input Overdrives



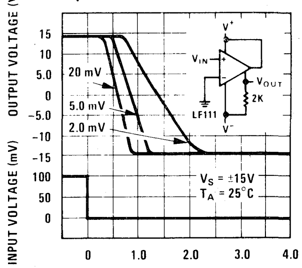
Output Saturation Voltage



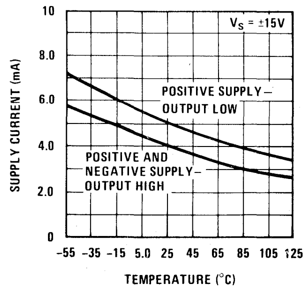
Response Time for Various Input Overdrives



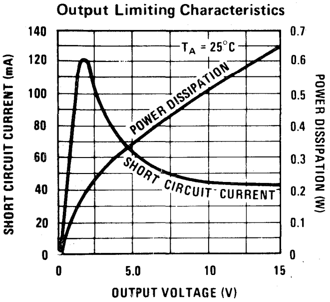
Response Time for Various Input Overdirves



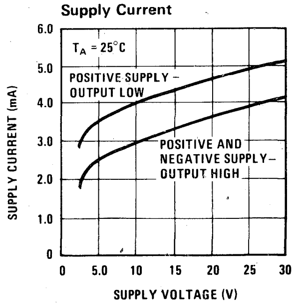
Supply Current



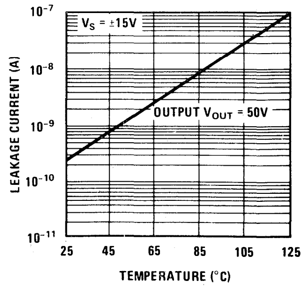
Output Limiting Characteristics



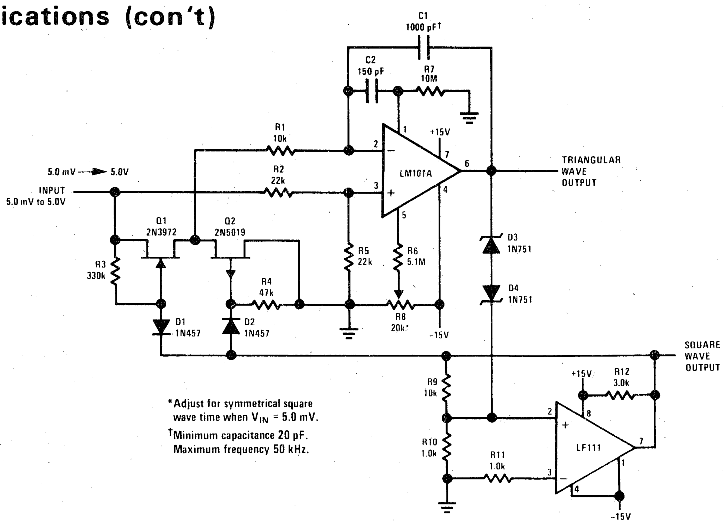
Supply Current



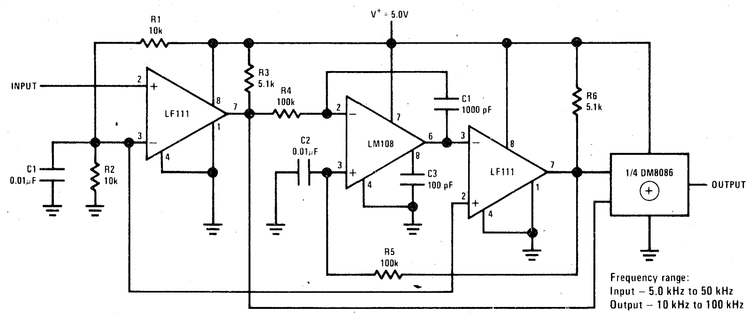
Leakage Currents



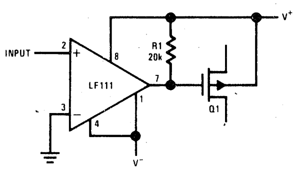
typical applications (con't)



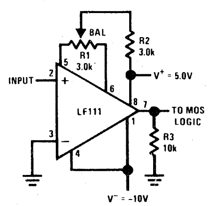
10 Hz to 10 kHz Voltage Controlled Oscillator



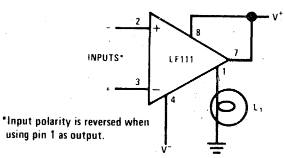
Frequency Doubler



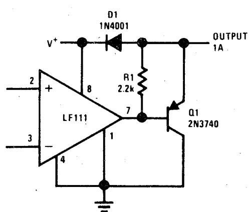
Zero Crossing Detector Driving MOS Switch



Zero Crossing Detector Driving MOS Logic

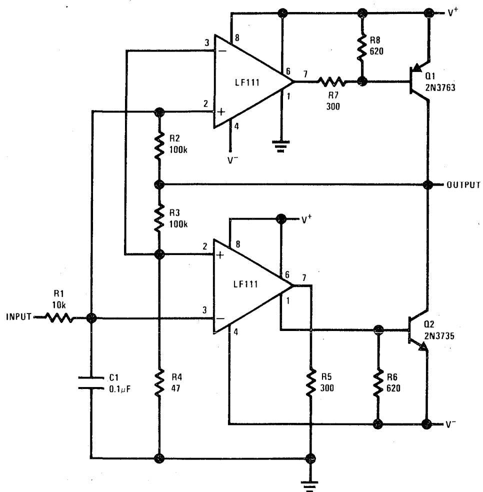


Driving Ground-Referred Load

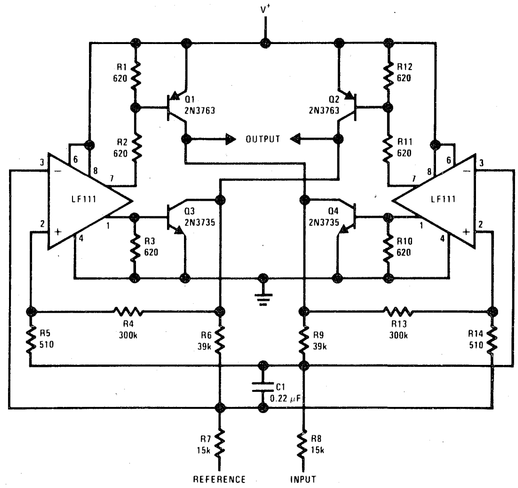


Comparator and Solenoid Driver

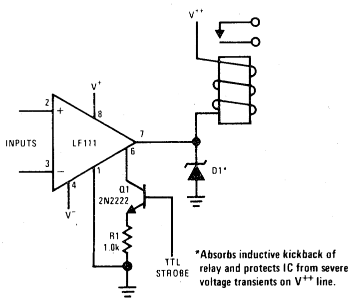
typical applications (con't)



Switching Power Amplifier

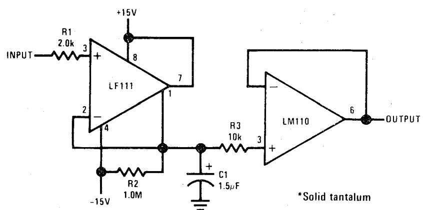


Switching Power Amplifier



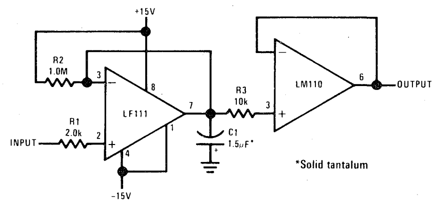
*Absorbs inductive kickback of relay and protects IC from severe voltage transients on V^{++} line.

Relay Driver with Strobe



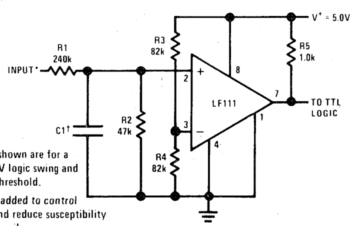
*Solid tantalum

Positive Peak Detector



*Solid tantalum

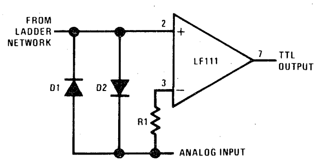
Negative Peak Detector



*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



Using Clamp Diodes to Improve Response

Voltage Comparators

LH2111/LH2211/LH2311 dual voltage comparator

general description

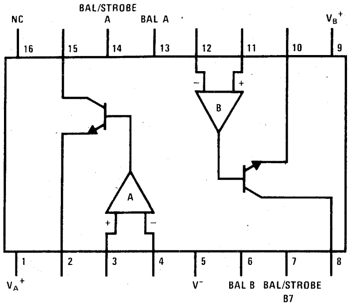
The LH2111 series of dual voltage comparators are two LM111 type comparators in a single hermetic package. Featuring all the same performance characteristics of the single, these duals offer in addition closer thermal tracking, lower weight, reduced insertion cost and smaller size than two singles. For 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

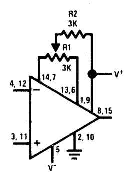
connection diagram



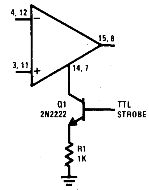
Order Number LH2111D or LH2211D or LH2311D
See Package 2

Order Number LH2111F or LH2211F or LH2311F
See Package 5

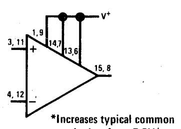
auxiliary circuits



Offset Balancing

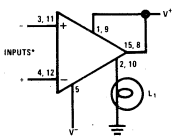


Strobing

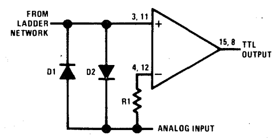


*Increases typical common mode slew from 7.0V/μs to 18V/μs.

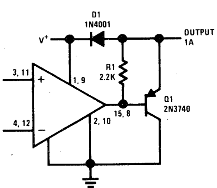
Increasing Input Stage Current*



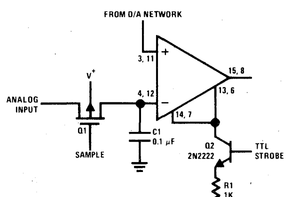
Driving Ground-Referred Load



Using Clamp Diodes to Improve Responses

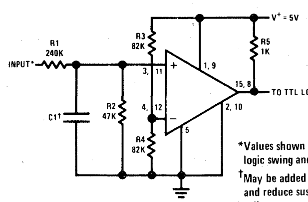


Comparator and Solenoid Driver



*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 Short Circuit Duration	10 sec
Output to Negative Supply Voltage ($V_{OUT} - V^-$)	50V	Operating Temperature Range LH2111	−55°C to 125°C
Ground to Negative Supply Voltage (GND − V^-)	30V	LH2211	−25°C to 85°C
Differential Input Voltage	±30V	LH2311	0°C to 70°C
Input Voltage (Note 1)	±15V	Storage Temperature Range	−65°C to 150°C
Power Dissipation (Note 2)	500 mW	Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics – each side (Note 3)

PARAMETER	CONDITIONS	LIMITS LH2111	LIMITS LH2211	LIMITS LH2311	UNITS
Input Offset Voltage (Note 4)	$T_A = 25°C$, $R_S \le 50k$	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	$V_{IN} \le -5$ 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	$V_{IN} \ge 5$ mV, $V_{OUT} = 35V$ $T_A = 25°C$	10	10	50	nA Max
Input Offset Voltage (Note 4)	$R_S \le 50k$	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	$V^+ \ge 4.5V$, $V^- = 0$ $V_{IN} \le -5$ mV, $I_{SINK} \le 8$ 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 $-55°C \le T_A \le 125°C$ for the LH2111, $-25°C \le T_A \le 85°C$ for the LH2211, and $0°C \le T_A \le 70°C$ 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

LM106/LM206/LM306 voltage comparator

general description

The LM106 series 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.

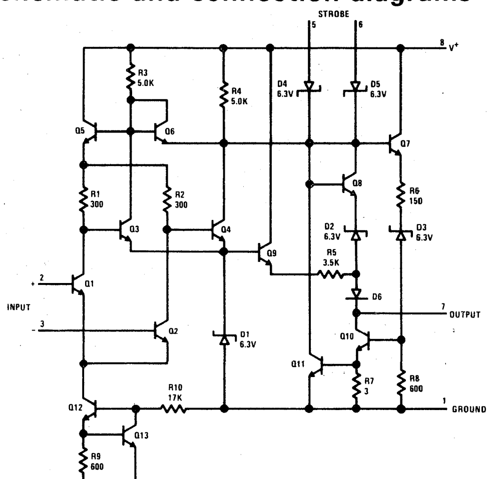
The devices have short-circuit protection which limits the inrush current when it is used to drive incandescent lamps, in addition to preventing damage from accidental shorts to the positive supply. The speed is equivalent to that of an LM710. However, they are even faster where buffers and additional logic circuitry can be eliminated by the increased flexibility of the LM106 series. 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. The LM306 is specified for operation over 0°C to +70°C temperature range.

features

- Improved accuracy
- 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

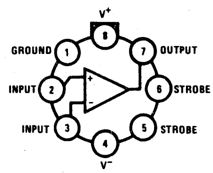
schematic and connection diagrams **



**Pin connections shown are for TO-5 package.

Metal Can

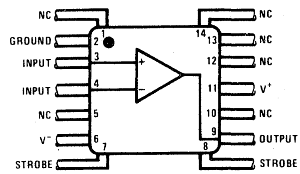
TOP VIEW



Note: Pin 4 connected to case.

Order Number LM106H, LM206H or LM306H
See Package 11

Flat Package



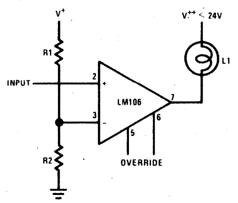
Note: Pin 6 connected to bottom of package.

TOP VIEW

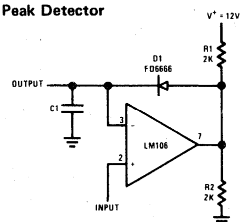
Order Number LM106F or LM206F
See Package 4

typical applications **

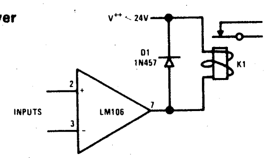
Level Detector and Lamp Driver



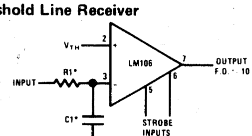
Fast Response Peak Detector



Relay Driver



Adjustable Threshold Line Receiver



*Optional for response time control.

absolute maximum ratings

Positive Supply Voltage	15V
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 seconds
Operating Temperature Range	T_{MIN} T_{MAX}
LM106	−55°C to +125°C
LM206	−25°C to +85°C
LM306	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	LM106/LM206			LM306			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	(Note 3)		0.5	2.0		1.6	5.0	mV
Input Offset Current	(Note 3)		0.7	3.0		1.8	5.0	μA
Input Bias Current			10	20		16	25	μA
Response Time	$R_L = 390\Omega$ to 5V $C_L = 15$ pF, (Note 4)		28	40		28	40	ns
Saturation Voltage	$V_{IN} \leq -5$ mV, $I_{OUT} = 100$ mA		1.0	1.5				V
	$V_{IN} \leq -7$ mV, $I_{OUT} = 100$ mA					0.8	2.0	V
Output Leakage Current	$V_{IN} \geq 5$ mV, $8V \leq V_{OUT} \leq 24V$		0.02	1.0				μA
	$V_{IN} \geq 7$ mV, $8V \leq V_{OUT} \leq 24V$					0.02	2.0	μA
The following specifications apply for $T_{MIN} \leq T_A \leq T_{MAX}$ (Note 5)								
Input Offset Voltage	(Note 3)			3.0			6.5	mV
Average Temperature Coefficient of Input Offset Voltage			3.0	10		5	20	μV/°C
Input Offset Current	$T_L \leq T_A \leq 25°C$, (Note 3)		1.8	7.0		2.4	7.5	μA
	$25°C \leq T_A \leq T_H$		0.25	3.0			5.0	μA
Average Temperature Coefficient of Input Offset Current	$25°C \leq T_A \leq T_H$		5.0	25		15	50	nA/°C
	$T_L \leq T_A \leq 25°C$		15	75		24	100	nA/°C
Input Bias Current	$T_L \leq T_A \leq 25°C$			45		25	40	μA
	$25°C \leq T_A \leq T_H$			20			25	μA
Input Voltage Range	$-7V \geq V^- \geq -12V$	±5.0			±5.0			V
Differential Input Voltage Range		±5.0			±5.0			V
Saturation Voltage	$V_{IN} \leq -5$ mV, $I_{OUT} = 50$ mA $V_{IN} \leq -8$ mV For LM306			1.0			1.0	V
Saturation Voltage	$V_{IN} \leq -5$ mV, $I_{OUT} = 16$ mA $V_{IN} \leq -8$ mV For LM306			0.4			0.4	V
Positive Output Level	$V_{IN} \geq 5$ mV, $I_{OUT} = -400\mu A$ $V_{IN} \geq 8$ mV For LM306	2.5		5.5	2.5		5.5	V
Output Leakage Current	$V_{IN} \geq 5$ mV, $8V \leq V_{OUT} \leq 24V$ $V_{IN} \geq 8$ mV For LM306 $T_L \leq T_A \leq 25°C$			1.0			2.0	μA
	$25°C < T_A \leq T_H$			100			100	μA
Strobe Current	$V_{STROBE} = 0.4V$		−1.7	−3.2		−1.7	−3.2	mA
Strobe "ON" Voltage		0.9	1.4		0.9	1.4		V
Strobe "OFF" Voltage	$I_{SINK} \leq 16$ mA		1.4	2.2		1.4	2.2	V
Positive Supply Current	$V_{IN} = -5$ mV $V_{IN} = -8$ mV For LM306		5.5	10		5.5	10	mA
Negative Supply Current			−1.5	−3.6		−1.5	−3.6	mA

Note 1: The maximum junction temperature of LM106 is 150°C, LM206 is 110°C, LM306 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.

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.

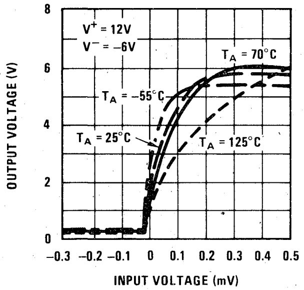
Note 3: The offset voltages and offset currents given are the maximum values required to drive the output down to 0.5V or up to 4.4V (0.5V or up to 4.8V for the LM306). Thus, these parameters actually define an error band and take into account the worst-case effects of voltage gain, specified supply 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.

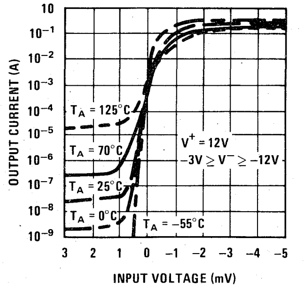
Note 5: All currents into device pins are considered positive.

typical performance characteristics

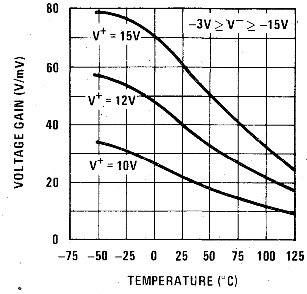
Transfer Function



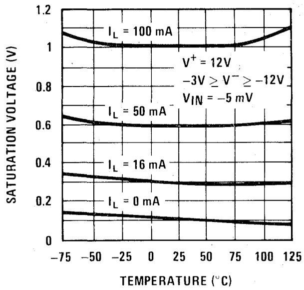
Transconductance



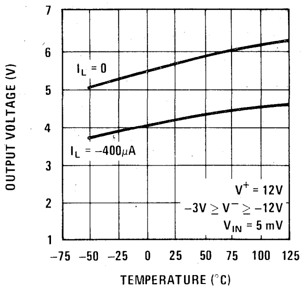
Voltage Gain



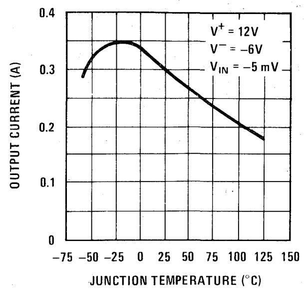
Saturation Voltage



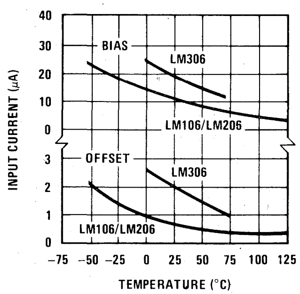
Positive Output Level



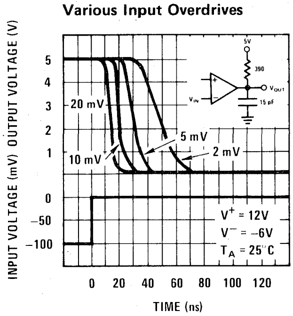
Short Circuit Output Current



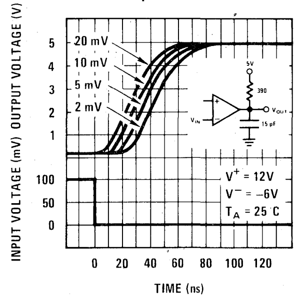
Input Current



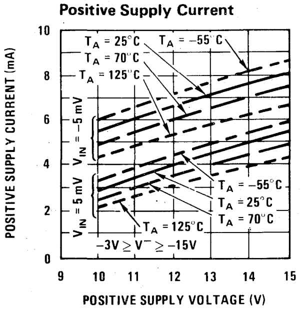
Response Time For Various Input Overdrives



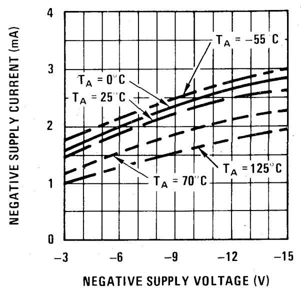
Response Time For Various Input Overdrives



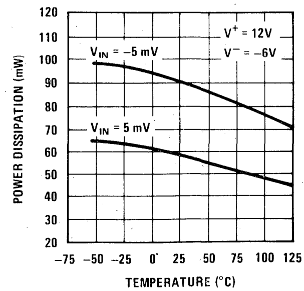
Positive Supply Current



Negative Supply Current



Power Consumption



Voltage Comparators

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:

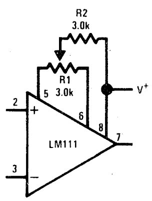
- Operates from single 5V supply
- Input current: 150 nA max. over temperature
- Offset current: 20 nA max. over temperature
- Differential input voltage range: ±30V
- Power consumption: 135 mW at ±15V

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.

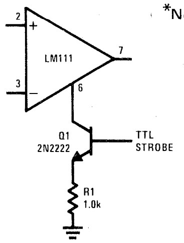
The LM211 is identical to the LM111, except that its performance is specified over a −25°C to 85°C temperature range instead of −55°C to 125°C.

auxiliary circuits*

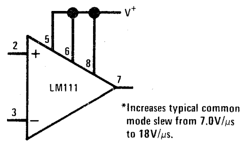
*Note: Pin connections shown on schematic diagram and typical applications are for TO-5 package.



Offset Balancing

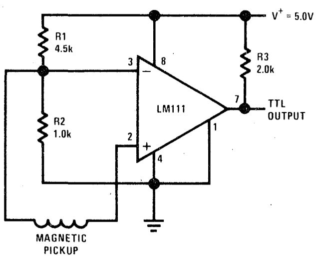


Strobing

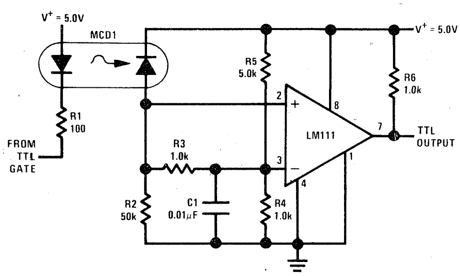


Increasing Input Stage Current*

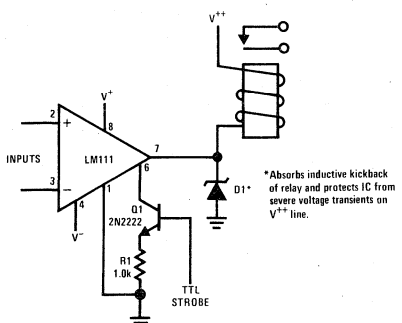
typical applications*



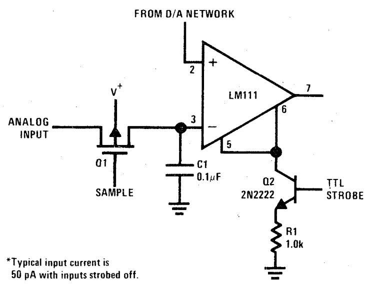
Detector for Magnetic Transducer



Digital Transmission Isolator



Relay Driver with Strobe



Strobing off Both Input* and Output Stages

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, $V_{OUT} = 35V$ $T_A = 25°C$, $I_{STROBE} = 3$ mA		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.

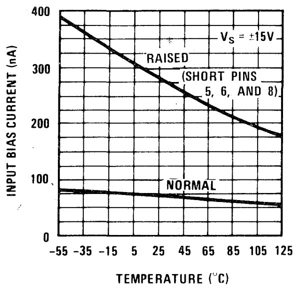
Note 3: These specifications apply for $V_S = \pm15V$ and $-55°C \leq T_A \leq 125°C$, unless otherwise stated. With the LM211, however, all temperature specifications are limited to $-25°C \leq T_A \leq 85°C$. The offset voltage, offset current and bias current specifications apply for any supply voltage 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.

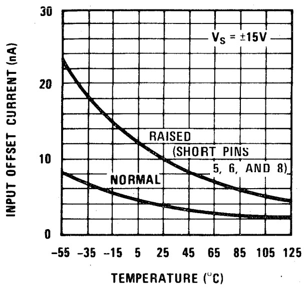
Note 5: The response time specified (see definitions) is for a 100 mV input step with 5 mV overdrive.

typical performance characteristics

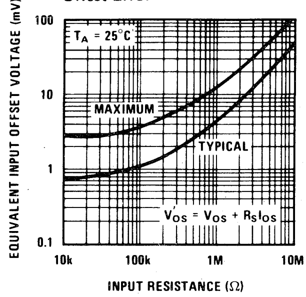
Input Bias Current



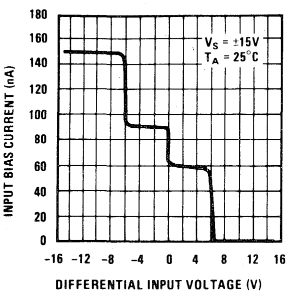
Input Offset Current



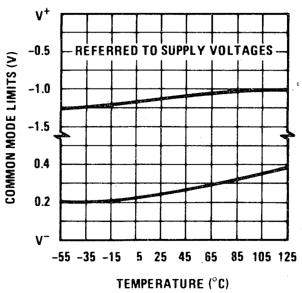
Offset Error



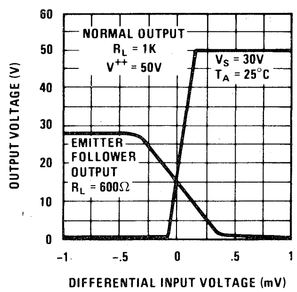
Input Characteristics



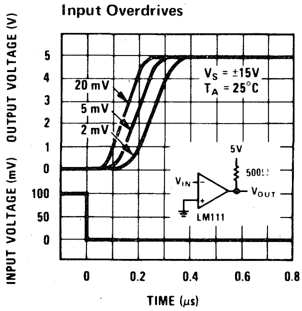
Common Mode Limits



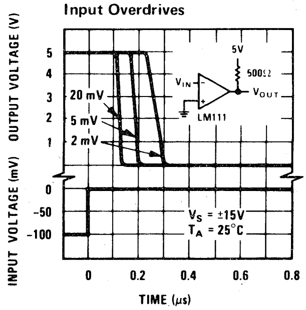
Transfer Function



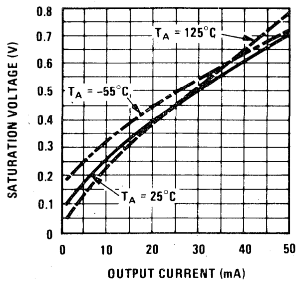
Response Time for Various Input Overdrives



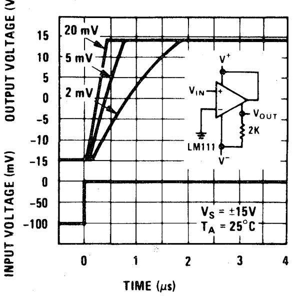
Response Time for Various Input Overdrives



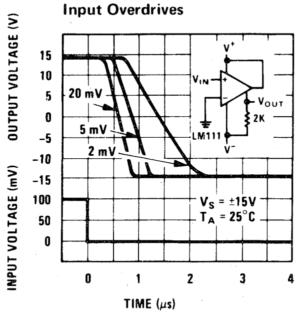
Output Saturation Voltage



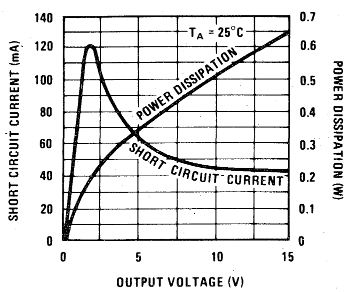
Response Time for Various Input Overdrives



Response Time for Various Input Overdrives

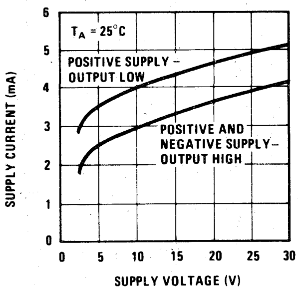


Output Limiting Characteristics

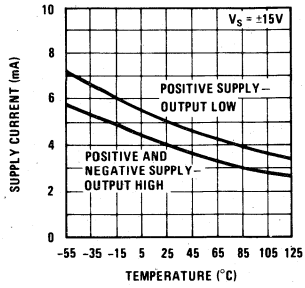


typical performance characteristics (con't)

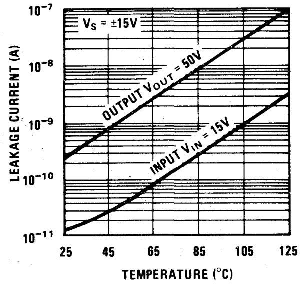
Supply Current



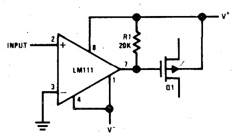
Supply Current



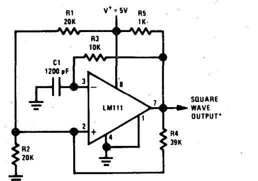
Leakage Currents



typical applications (con't)

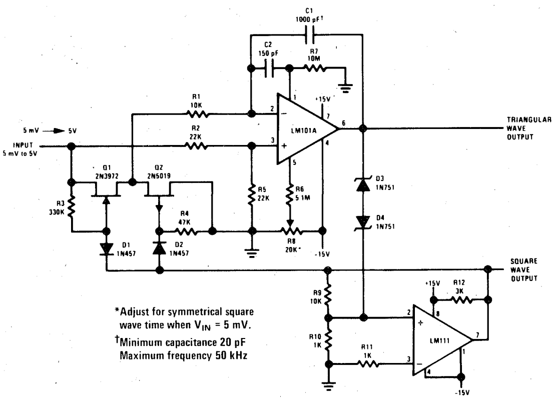


Zero Crossing Detector Driving MOS Switch



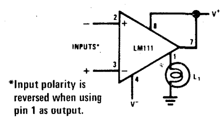
*TTL or DTL fanout of two.

100 kHz Free Running Multivibrator



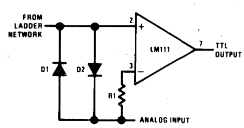
*Adjust for symmetrical square wave time when V_{IN} = 5 mV.
†Minimum capacitance 20 pF Maximum frequency 50 kHz

10 Hz to 10 kHz Voltage Controlled Oscillator

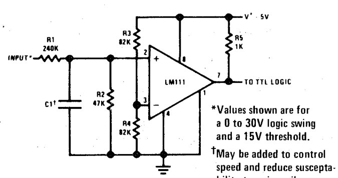


*Input polarity is reversed when using pin 1 as output.

Driving Ground-Referred Load

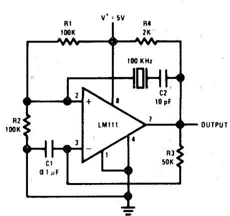


Using Clamp Diodes to Improve Response

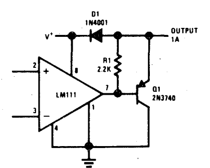


*Values shown are for a 0 to 30V logic swing and a 15V threshold.
†May be added to control speed and reduce susceptability to noise spikes.

TTL Interface with High Level Logic

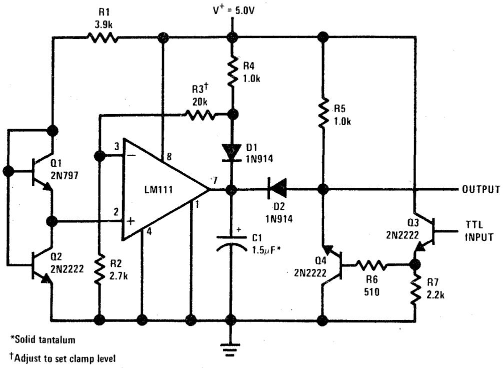


Crystal Oscillator

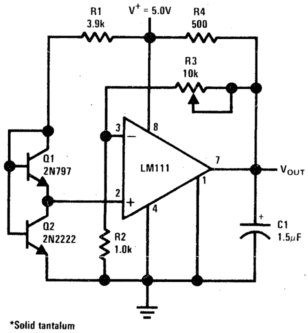


Comparator and Solenoid Driver

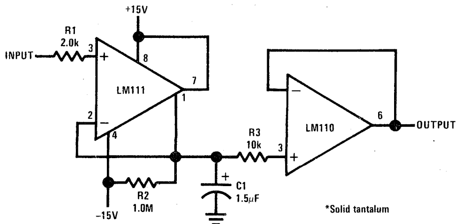
typical applications (con't)



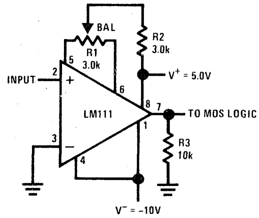
Precision Squarer



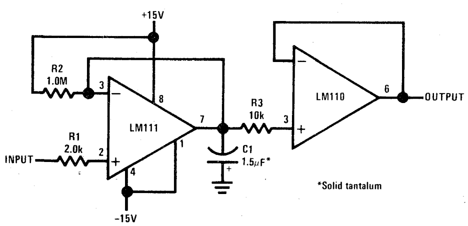
Low Voltage Adjustable Reference Supply



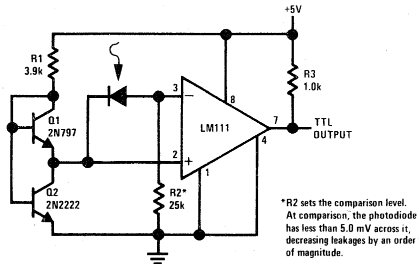
Positive Peak Detector



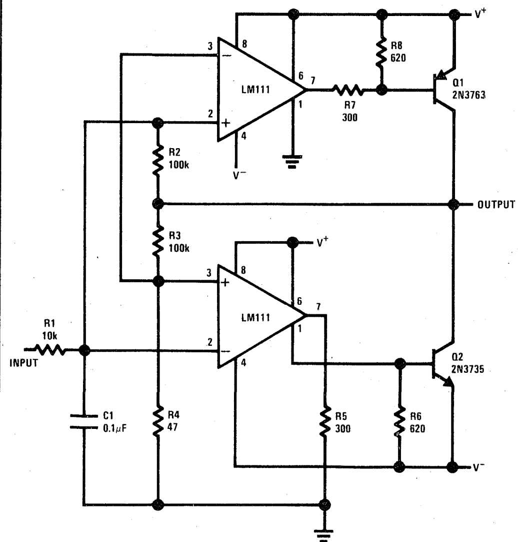
Zero Crossing Detector driving MOS logic



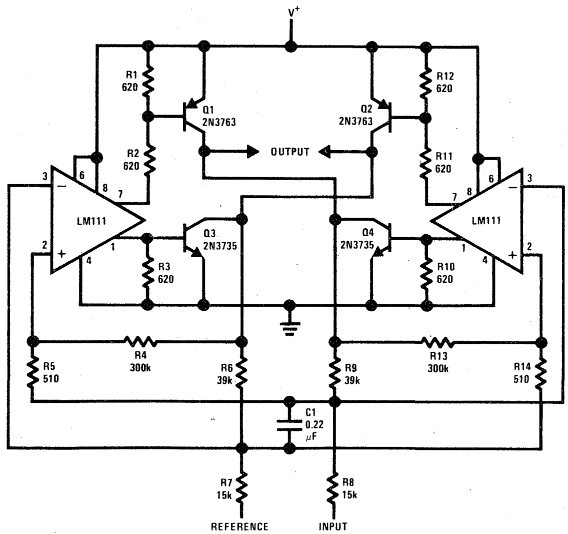
Negative Peak Dectector



Precision Photodiode Comparator

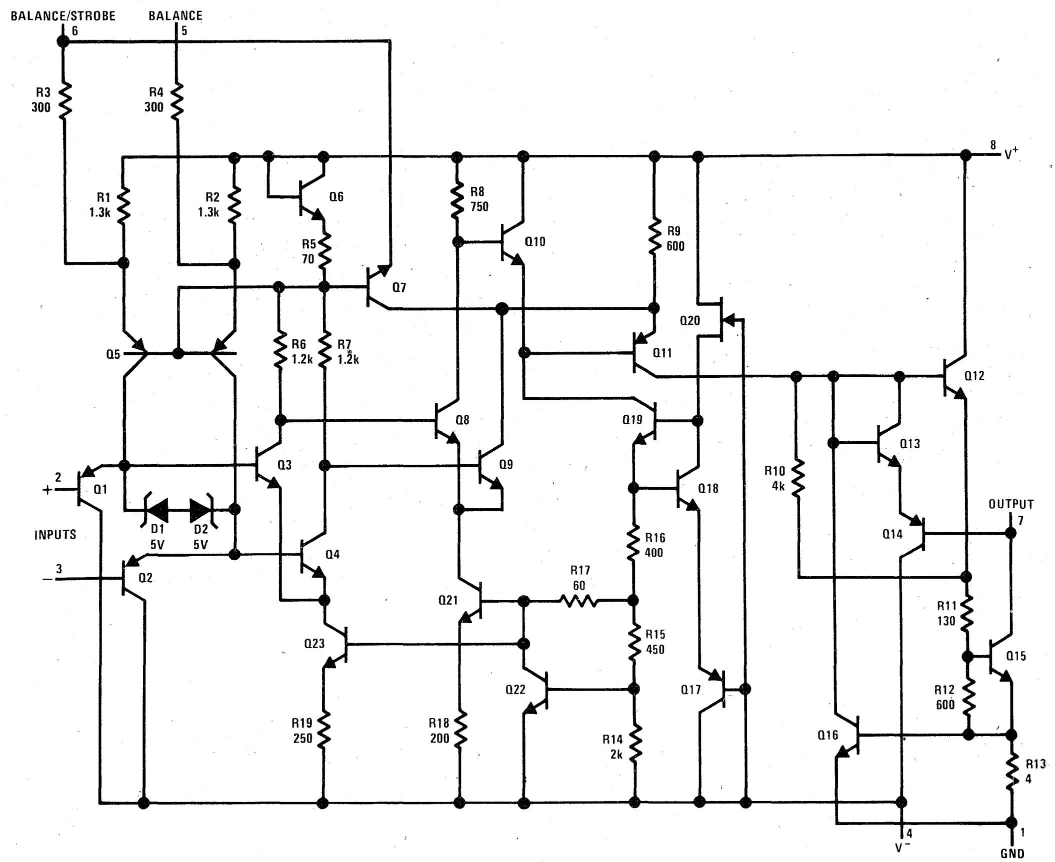


Switching Power Amplifier



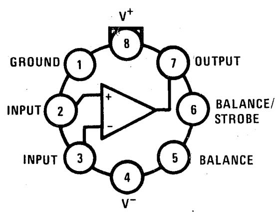
Switching Power Amplifier

schematic diagram



connection diagrams*

Metal Can Package

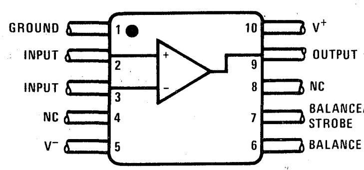


NOTE: Pin 4 connected to case.

TOP VIEW

Order Number
LM111H or LM211H
See Package 11

Flat Package

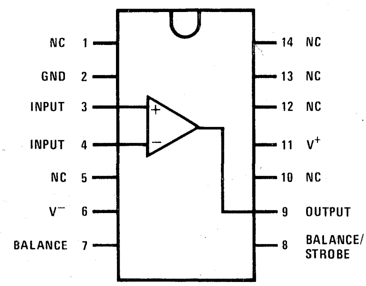


NOTE: Pin 5 connected to bottom of package.

TOP VIEW

Order Number
LM111F or LM211F
See Package 3

Dual-In-Line Package



Note: Pin 6 connected to bottom of package.

TOP VIEW

Order Number
LM111D or LM211D
See Package 1

**Order Number LM111J
or LM211J
See Package 16**

*Pin connections shown are for metal can.

Voltage Comparators

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.

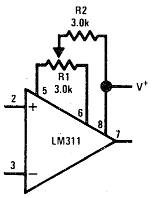
features

- 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

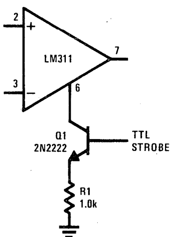
Both the input and the output of the LM311 can be isolated from system ground, and the output can drive loads referred to ground, the positive supply or the negative supply. Offset balancing and strobe capability are provided and outputs can be wire OR'ed. Although slower than the LM306 and LM710C (200 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.

auxiliary circuits*

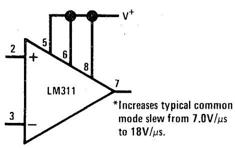
*Note: Pin connections shown on schematic diagram and typical applications are for TO-5 package.



Offset Balancing

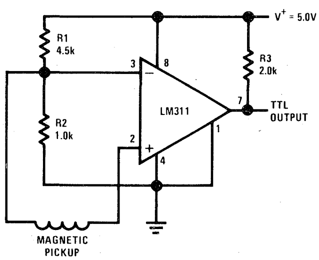


Strobing

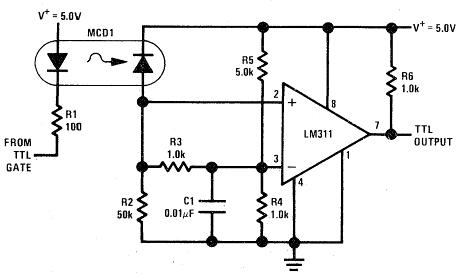


Increasing Input Stage Current*

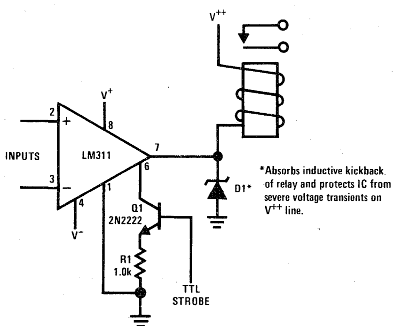
typical applications*



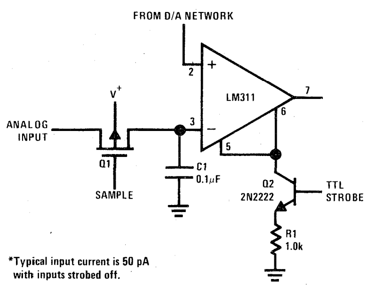
Detector for Magnetic Transducer



Digital Transmission Isolator



Relay Driver with Strobe



Strobing off Both Input* and Output Stages

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)	$T_A = 25°C$, $R_S \le 50K$		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	$V_{IN} \le -10$ 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	$V_{IN} \ge 10$ mV, $V_{OUT} = 35V$ $T_A = 25°C$, $I_{STROBE} = 3$ mA		0.2	50	nA
Input Offset Voltage (Note 4)	$R_S \le 50K$			10	mV
Input Offset Current (Note 4)				70	nA
Input Bias Current				300	nA
Input Voltage Range			±14		V
Saturation Voltage	$V^+ \ge 4.5V$, $V^- = 0$ $V_{IN} \le -10$ mV, $I_{SINK} \le 8$ 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 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.

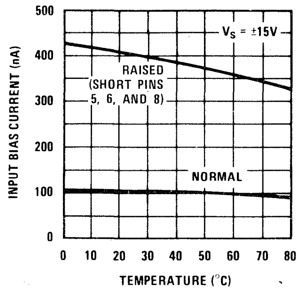
Note 3: These specifications apply for $V_S = \pm15V$ and $0°C < T_A < 70°C$, unless otherwise specified. The offset voltage, offset current and bias current specifications apply for any supply voltage from a single 5V supply up to ±15V supplies.

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.

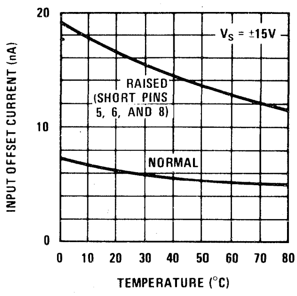
Note 5: The response time specified (see definitions) is for a 100 mV input step with 5 mV overdrive.

typical performance characteristics

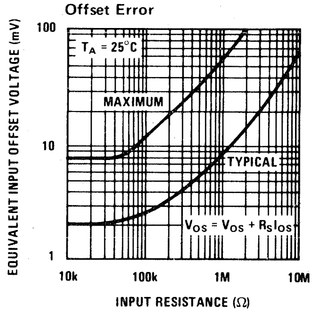
Input Bias Current



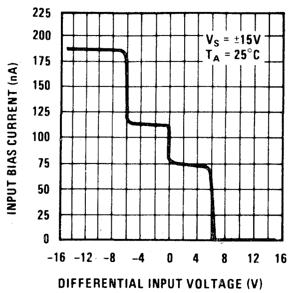
Input Offset Current



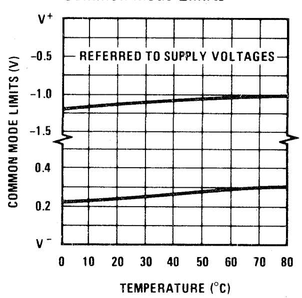
Offset Error



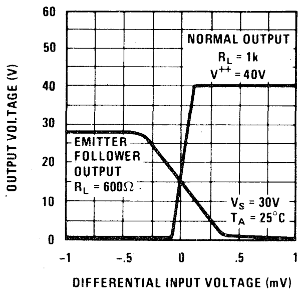
Input Characteristics



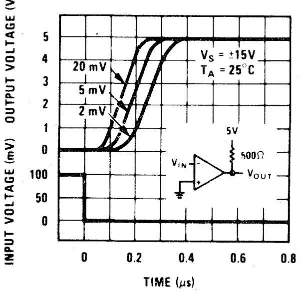
Common Mode Limits



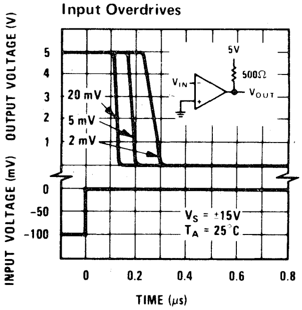
Transfer Function



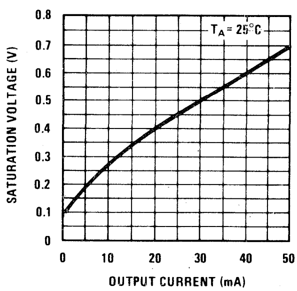
Response Time for Various Input Overdrives



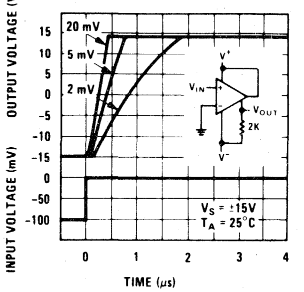
Response Time for Various Input Overdrives



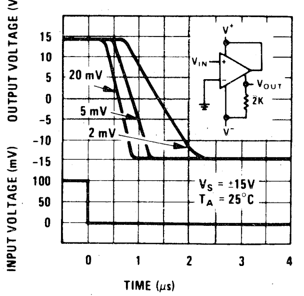
Output Saturation Voltage



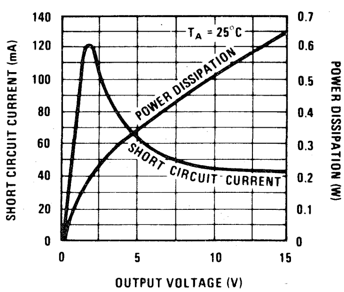
Response Time for Various Input Overdrives



Response Time for Various Input Overdrives

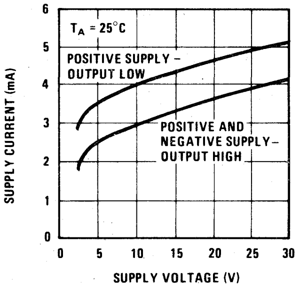


Output Limiting Characteristics

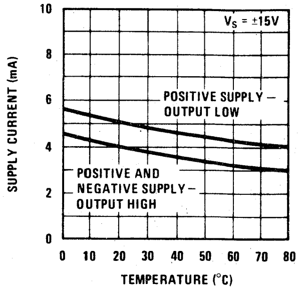


typical performance characteristics (con't)

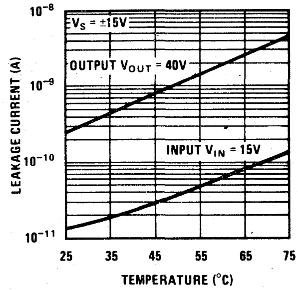
Supply Current



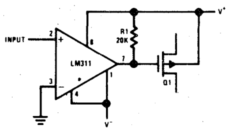
Supply Current



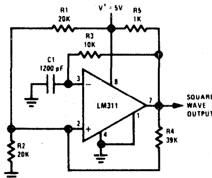
Leakage Currents



typical applications

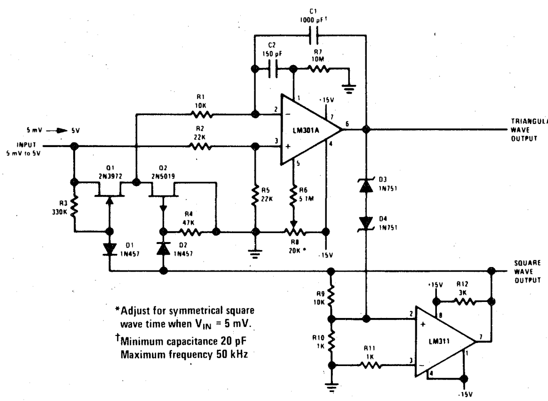


Zero Crossing Detector Driving MOS Switch



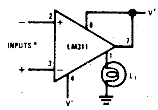
*TTL or DTL fanout of two.

100 kHz Free Running Multivibrator



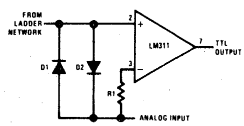
*Adjust for symmetrical square wave time when V_{IN} = 5 mV.
†Minimum capacitance 20 pF Maximum frequency 50 kHz

10 Hz to 10 kHz Voltage Controlled Oscillator

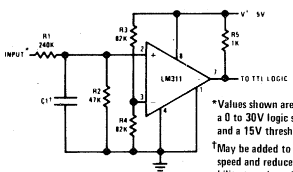


*Input polarity is reversed when using pin 1 as output.

Driving Ground-Referred Load

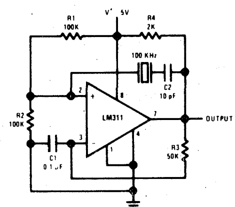


Using Clamp Diodes to Improve Response

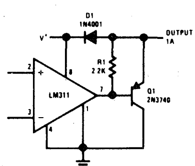


*Values shown are for a 0 to 30V logic swing and a 15V threshold.
†May be added to control speed and reduce susceptability to noise spikes.

TTL Interface with High Level Logic

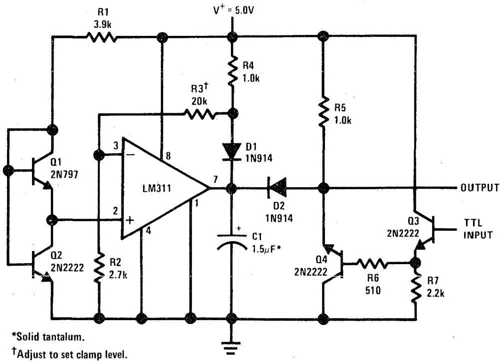


Crystal Oscillator



Comparator and Solenoid Driver

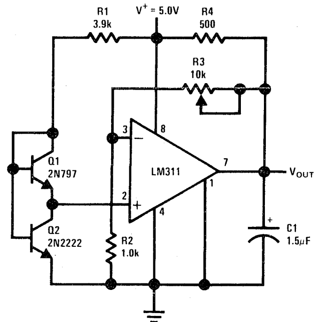
typical applications (con't)



*Solid tantalum.

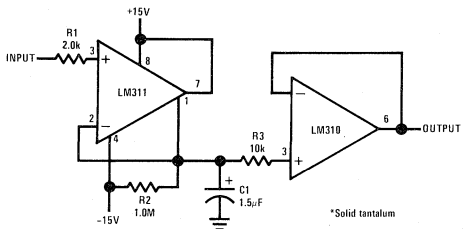
†Adjust to set clamp level.

Precision Squarer



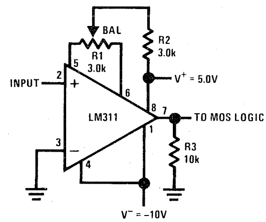
*Solid tantalum

Low Voltage Adjustable Reference Supply

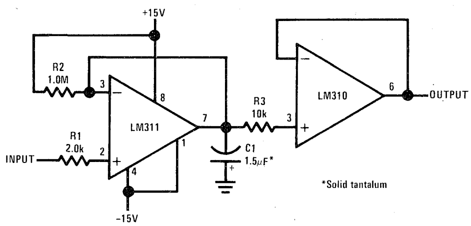


*Solid tantalum

Positive Peak Detector

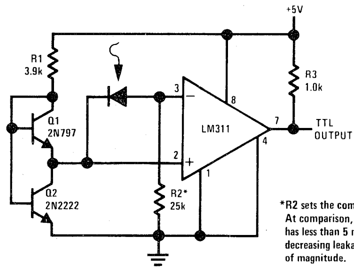


Zero Crossing Detector driving MOS logic



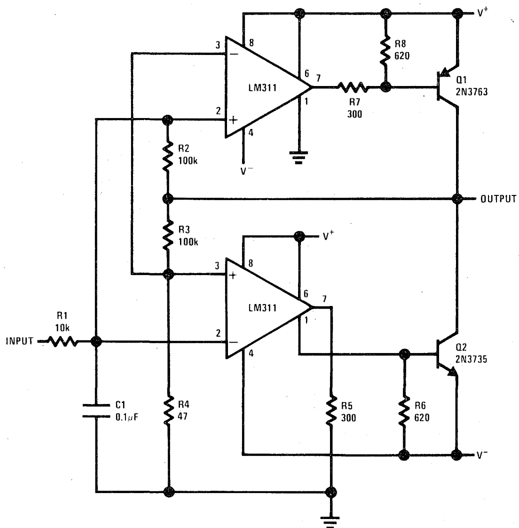
*Solid tantalum

Negative Peak Dectector

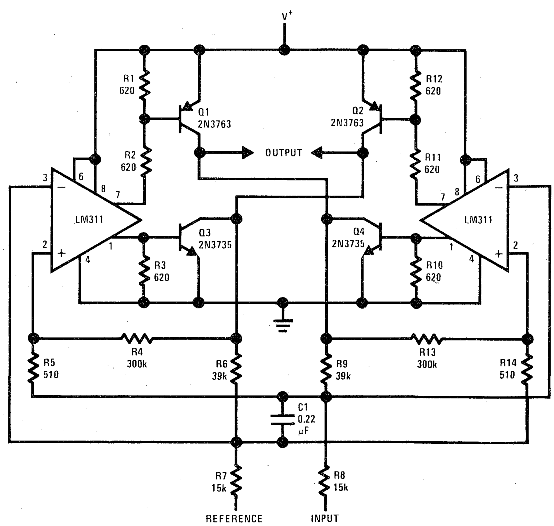


*R2 sets the comparison level. At comparison, the photodiode has less than 5 mV across it, decreasing leakages by an order of magnitude.

Precision Photodiode Comparator

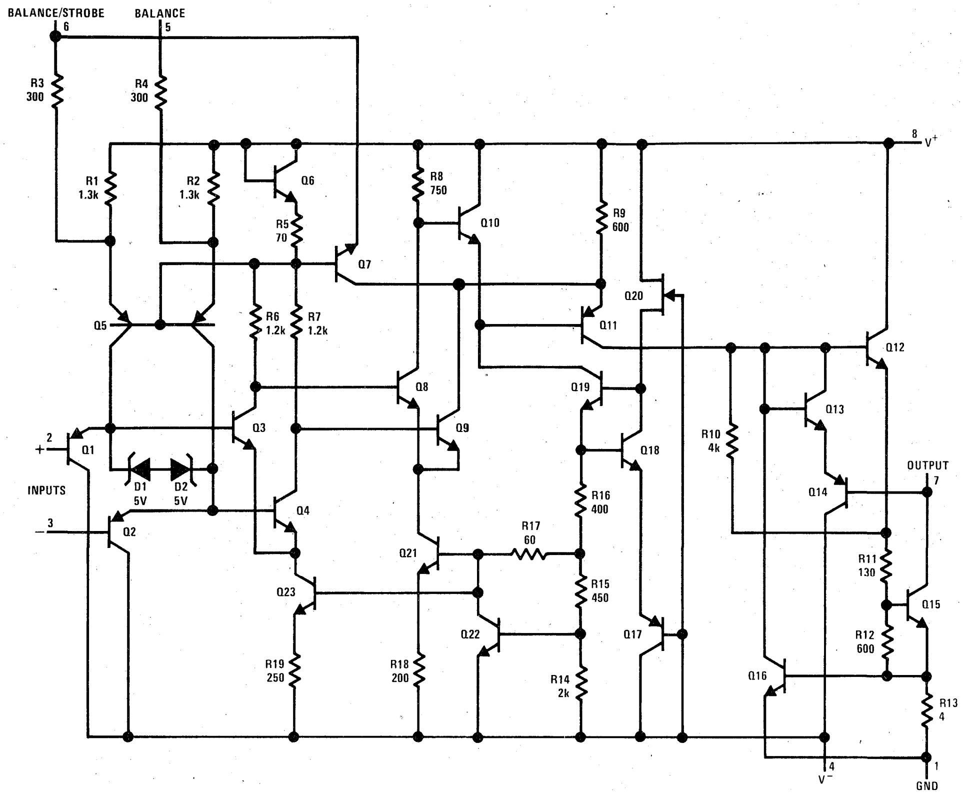


Switching Power Amplifier



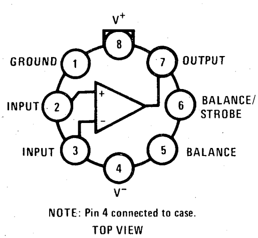
Switching Power Amplifier

schematic diagram



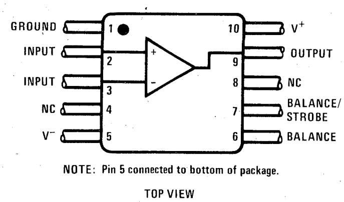
connection diagrams *

Metal Can Package



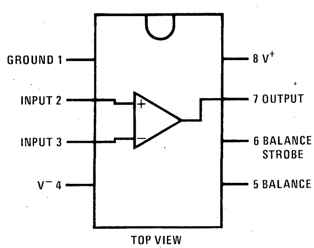
Order Number LM311H
See Package 11

Flat Package



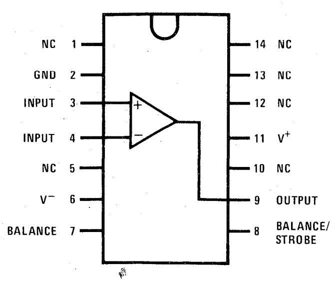
Order Number LM311F
See Package 3

Dual-In-Line Package



Order Number LM311N
See Package 20
Order Number LM311J-8
See Package 15

Dual-In-Line Package



Note: Pin 6 connected to bottom of package.

Order Number LM311D
See Package 1
Order Number LM311N-14
See Package 22
Order Number LM311J
See Package 16

*Pin connections shown on schematic diagram and typical applications are for TO-5 package.

Voltage Comparators

LM119/LM219/LM319 high speed dual comparator

general description

The LM119 series 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:

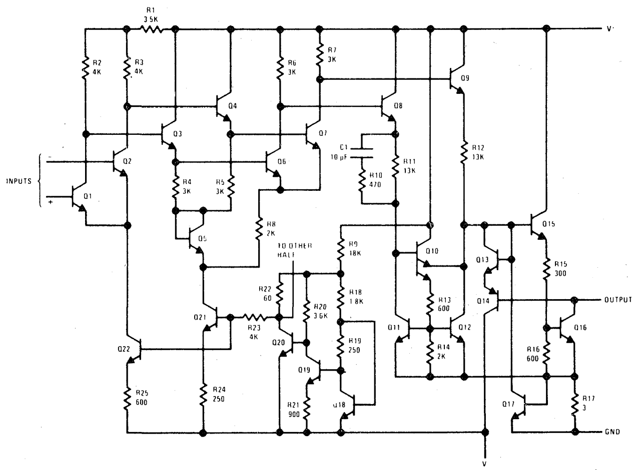
features

- 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

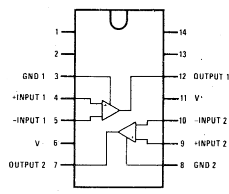
Although designed primarily for applications requiring operation from digital logic supplies, the LM119 series are fully specified for power supplies up to ±15V. It features faster response than the LM111 at the expense of higher power dissipation. However, the high speed, wide operating voltage range and low package count make the LM119 much more versatile than older devices like the LM711.

The LM119 is specified from −55°C to +125°C, the LM219 is specified from −25°C to +85°C, and the LM319 is specified from 0°C to +70°C.

schematic and connection diagrams



Dual-In-Line-Package



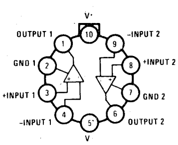
TOP VIEW

Order Number LM119D, LM219D or LM319D
See Package 1

Order Number LM319N
See Package 22

Order Number LM119J, LM219J or LM319J
See Package 16

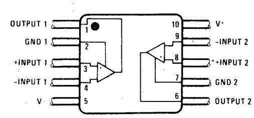
Metal Can Package



TOP VIEW

Order Number LM119H, LM219H or LM319H
See Package 12

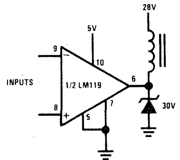
Flat Package



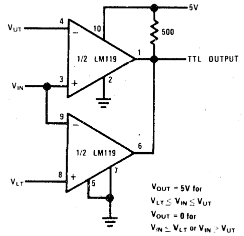
TOP VIEW

Order Number LM119F, LM219F or LM319F
See Package 3

typical applications



Relay Driver



Window Detector

absolute maximum ratings LM119/LM219

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 LM119	−55°C to 125°C
Ground to Positive Supply Voltage	18V	LM219	−25°C to 85°C
Differential Input Voltage	±5V	Storage Temperature Range	−65°C to 150°C
Input Voltage (Note 1)	±15V	Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics (Note 3)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Offset Voltage (Note 4)	$T_A = 25°C$, $R_S \leq 5k$		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	$V_{IN} \leq -5$ mV, $I_{OUT} = 25$ mA $T_A = 25°C$		0.75	1.5	V
Output Leakage Current	$V_{IN} \geq 5$ mV, $V_{OUT} = 35V$ $T_A = 25°C$		0.2	2	μA
Input Offset Voltage (Note 4)	$R_S \leq 5k$			7	mV
Input Offset Current (Note 4)				100	nA
Input Bias Current				1000	nA
Input Voltage Range	$V_S = \pm15V$ $V^+ = 5V$, $V^- = 0$	 1	±13 	 3	V V
Saturation Voltage	$V^+ \geq 4.5V$, $V^- = 0$ $V_{IN} \leq -6$ mV, $I_{SINK} \leq 3.2$ mA $T_A \geq 0°C$ $T_A \leq 0°C$		 0.23 	 0.4 0.6	 V V
Output Leakage Current	$V_{IN} \geq 5$ 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 $-55°C \leq T_A \leq 125°C$, unless otherwise stated. With the LM219, 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.

absolute maximum ratings LM319

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 LM319	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)	$T_A = 25°C$, $R_S \leq 5k$		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)	$T_A = 25°C$ $V_S = \pm15V$		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	$V_S = \pm15V$ $V^+ = 5V$, $V^- = 0$	 1	±13	 3	V 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	$T_A = 25°C$ $V_S = \pm15V$		8	12.5	mA
Negative Supply Current	$T_A = 25°C$ $V_S = \pm15V$		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.

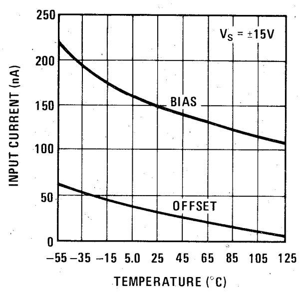
Note 3: These specifications apply for $V_S = \pm15V$ and $0°C \leq T_A \leq 70°C$, unless otherwise stated. The offset voltage, offset current and bias current specifications apply for any supply voltage from a single 5V supply up to ±15V supplies.

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.

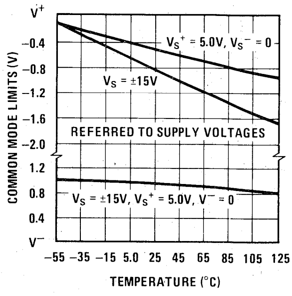
Note 5: The response time specified is for a 100 mV input step with 5 mV overdrive.

typical performance characteristics LM119/LM219

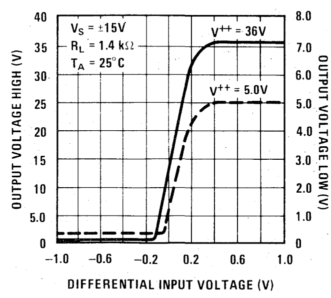
Input Currents



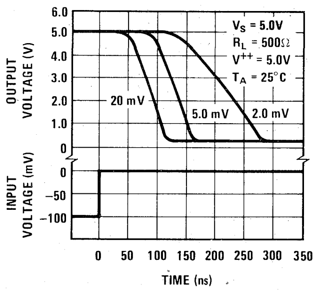
Common Mode Limits



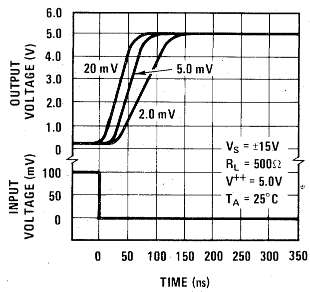
Transfer Function



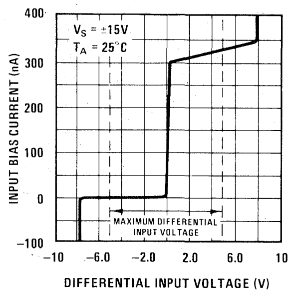
Response Time for Various Input Overdrives



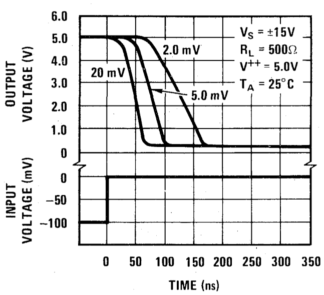
Response Time for Various Input Overdrives



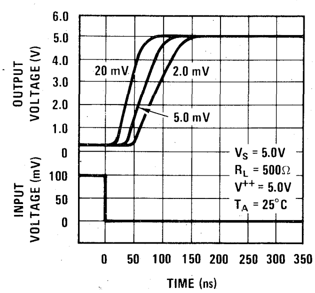
Input Characteristics



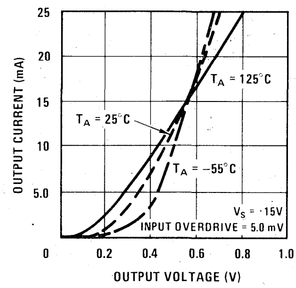
Response Time for Various Input Overdrives



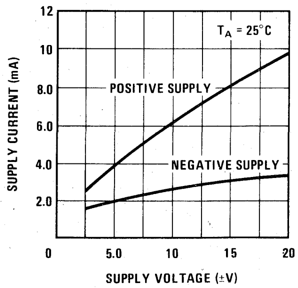
Response Time for Various Input Overdrives



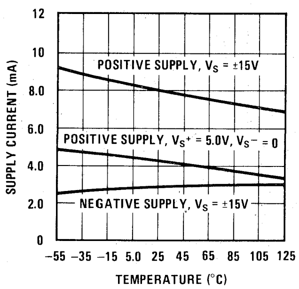
Output Saturation Voltage



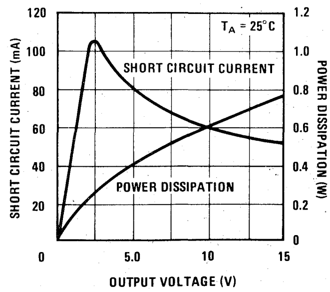
Supply Current



Supply Current

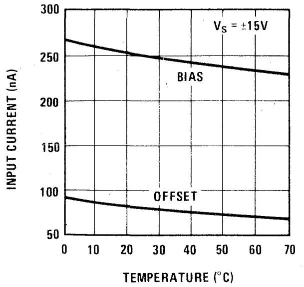


Output Limiting Characteristics

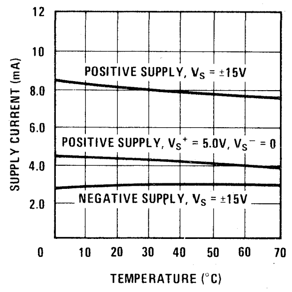


typical performance characteristics LM319

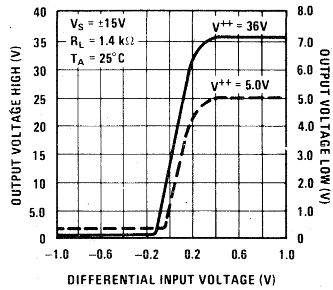
Input Currents



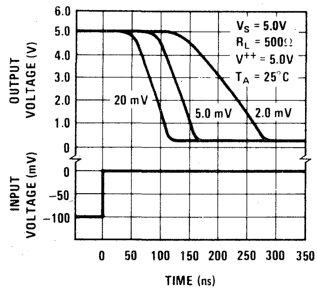
Supply Currents



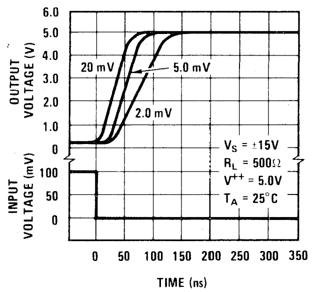
Transfer Function



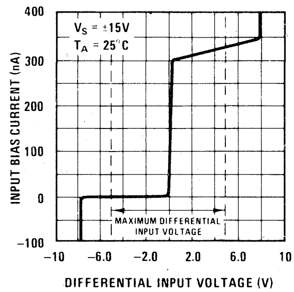
Response Time for Various Input Overdrives



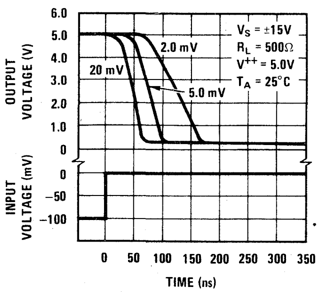
Response Time for Various Input Overdrives



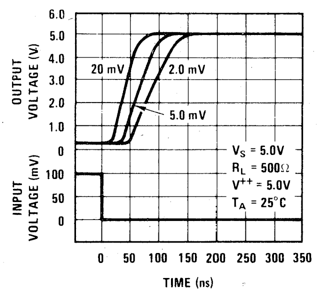
Input Characteristics



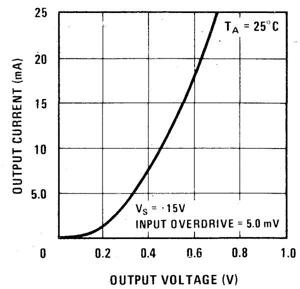
Response Time for Various Input Overdrives



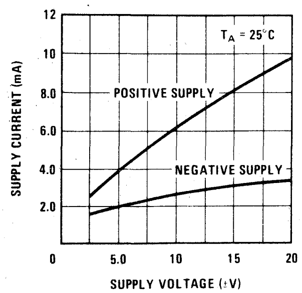
Response Time for Various Input Overdrives



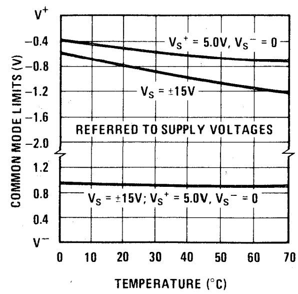
Output Saturation Voltage



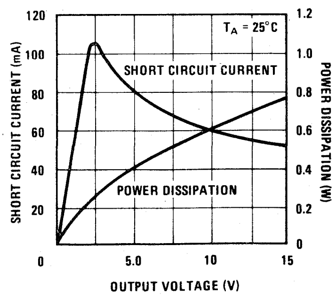
Supply Current



Common Mode Limits



Output Limiting Characteristics



Voltage Comparators

LM139/LM239/LM339, LM139A/LM239A/LM339A, LM2901, LM3302 low power low offset voltage quad comparators

general description

The LM139 series consists of four independent precision voltage comparators with an offset voltage specification as low as 2 mV max for all four comparators. These 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, they will directly interface with MOS logic— where the low power drain of the LM339 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

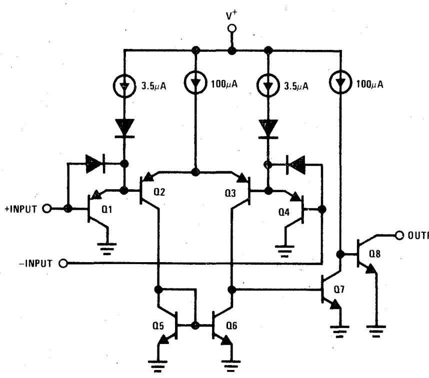
features

- Wide single supply voltage range or dual supplies

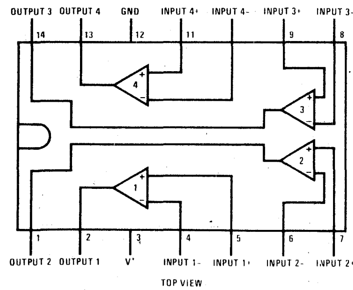
LM139 series,	2 V_{DC} to 36 V_{DC} or
LM139A series, LM2901	±1 V_{DC} to ±18 V_{DC}
LM3302	2 V_{DC} to 28 V_{DC}
	or ±1 V_{DC} to ±14 V_{DC}

- Very low supply current drain (0.8 mA) — independent of supply voltage (2 mW/comparator at +5 V_{DC})
- Low input biasing current — 25 nA
- Low input offset current — ±5 nA; and offset voltage — ±3 mV
- Input common-mode voltage range includes gnd
- Differential input voltage range equal to the power supply voltage
- Low output saturation voltage — 250 mV at 4 mA
- Output voltage compatible with TTL, DTL, ECL, MOS and CMOS logic systems

schematic and connection diagrams



Dual-In-Line and Flat Package



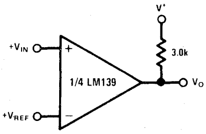
Order Number LM139D, LM139AD, LM239D or LM239AD
See Package 1

Order Number LM139J, LM139AJ, LM239J, LM239AJ, LM339J, LM339AJ, LM2901J or LM3302J
See Package 16

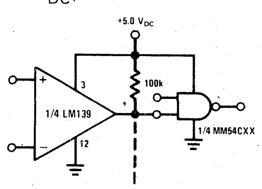
Order Number LM139F, LM139AF, LM239F or LM239AF
See Package 4

Order Number LM339N, LM339AN, LM2901N or LM3302N
See Package 22

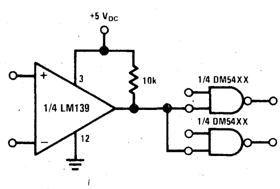
typical applications ($V^+ = 5.0\ V_{DC}$)



Basic Comparator



Driving CMOS



Driving TTL

absolute maximum ratings

	LM139/LM239/LM339 LM139A/LM239A/LM339A LM2901	LM3302
Supply Voltage, V^+	36 V_{DC} or ±18 V_{DC}	28 V_{DC} or ±14 V_{DC}
Differential Input Voltage	36 V_{DC}	28 V_{DC}
Input Voltage	−0.3 V_{DC} to +36 V_{DC}	−0.3 V_{DC} to +28 V_{DC}
Power Dissipation (Note 1)		
Molded DIP	570 mW	570 mW
Cavity DIP	900 mW	
Flat Pack	800 mW	
Output Short-Circuit to GND, (Note 2)	Continuous	Continuous
Input Current ($V_{IN} < -0.3\ V_{DC}$), (Note 3)	50 mA	50 mA
Operating Temperature Range		−40°C to +85°C
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	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C	300°C

electrical characteristics ($V^+ = 5\ V_{DC}$, Note 4)

PARAMETER	CONDITIONS	LM139A			LM239A, LM339A			LM139			LM239, LM339			LM2901			LM3302			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$T_A = 25°C$, (Note 9)		±1.0	±2.0		±1.0	±2.0		±2.0	±5.0		±2.0	±5.0		±2.0	±7.0		±3	±20	mV_{DC}
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$ with Output in Linear Range, $T_A = 25°C$, (Note 5)		25	100		25	250		25	100		25	250		25	250		25	500	nA_{DC}
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$, $T_A = 25°C$		±3.0	±25		±5.0	±50		±3.0	±25		±5.0	±50		±5	±50		±3	±100	nA_{DC}
Input Common-Mode Voltage Range	$T_A = 25°C$, (Note 6)	0		$V^+-1.5$	0		$V^+-1.5$	0		$V^+-1.5$	0		$V^+-1.5$	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		0.8	2.0		0.8	2.0		0.8	1.0		0.8	2	mA_{DC}
	$R_L = \infty$, $V^+ = 30V$, $T_A = 25°C$														1	2.5				mA_{DC}
Voltage Gain	$R_L \geq 15\ k\Omega$, $V^+ = 15\ V_{DC}$ (To Support Large V_O Swing), $T_A = 25°C$	50	200		50	200			200			200		25	100		2	30		V/mV
Large Signal Response Time	V_{IN} = TTL Logic Swing, V_{REF} = 1.4 V_{DC}, $V_{RL} = 5\ V_{DC}$, $R_L = 5.1\ k\Omega$, $T_A = 25°C$		300			300			300			300			300			300		ns
Response Time	$V_{RL} = 5\ V_{DC}$, $R_L = 5.1\ k\Omega$, $T_A = 25°C$, (Note 7)		1.3			1.3			1.3			1.3			1.3			1.3		μs
Output Sink Current	$V_{IN(-)} \geq 1\ V_{DC}$, $V_{IN(+)} = 0$, $V_O \leq 1.5\ V_{DC}$, $T_A = 25°C$	6.0	16		6.0	16		6.0	16		6.0	16		6.0	16		2.0	16		mA_{DC}
Saturation Voltage	$V_{IN(-)} \geq 1\ V_{DC}$, $V_{IN(+)} = 0$, $I_{SINK} \leq 4\ mA$, $T_A = 25°C$		250	400		250	400		250	400		250	400			400		250	500	mV_{DC}
Output Leakage Current	$V_{IN(+)} \geq 1\ V_{DC}$, $V_{IN(-)} = 0$, $V_O = 5\ V_{DC}$, $T_A = 25°C$		0.1			0.1			0.1			0.1			0.1			0.1		nA_{DC}

electrical characteristics (con't)

PARAMETER	CONDITIONS	LM139A			LM239A, LM339A			LM139			LM239, LM339			LM2901			LM3302			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	(Note 9)			4.0			4.0			9.0			9.0		9	15			40	mV_{DC}
Input Offset Current	$I_{IN(+)} - I_{IN(-)}$			±100			±150			±100			±150		50	200			300	nA_{DC}
Input Bias Current	$I_{IN(+)}$ or $I_{IN(-)}$ with Output in Linear Range			300			400			300			400		200	500			1000	nA_{DC}
Input Common-Mode Voltage Range		0		$V^+-2.0$	0		$V^+-2.0$	0		$V^+-2.0$	0		$V^+-2.0$	0		$V^+-2.0$	0		$V^+-2.0$	V_{DC}
Saturation Voltage	$V_{IN(-)} \geq 1\ V_{DC}$, $V_{IN(+)} = 0$, $I_{SINK} \leq 4$ mA			700			700			700			700		400	700			700	mV_{DC}
Output Leakage Current	$V_{IN(+)} \geq 1\ V_{DC}$, $V_{IN(-)} = 0$, $V_O = 30\ V_{DC}$			1.0			1.0			1.0			1.0			1.0			1.0	μA_{DC}
Differential Input Voltage	Keep all V_{IN}'s $\geq 0\ V_{DC}$ (or V^-, if used), (Note 8)			V^+			V^+			36			36	0		V^+			V_{CC}	V_{DC}

Note 1: For operating at high temperatures, the LM339/LM339A, LM2901, LM3302 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 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 $V^+ = 5\ V_{DC}$ and $-55°C \leq T_A \leq +125°C$, unless otherwise stated. With the LM239/LM239A, all temperature specifications are limited to $-25°C \leq T_A \leq +85°C$, the LM339/LM339A temperature specifications are limited to $0°C \leq T_A \leq +70°C$, and the LM2901, LM3302 temperature range is $-40°C \leq T_A \leq +85°C$.

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 mV overdrive. For larger overdrive signals 300 ns can be obtained, see typical performance characteristics section.

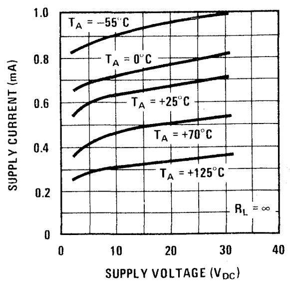
Note 8: Positive excursions of input voltage may exceed the power supply level. As long as the other voltage remains within the common-mode range, the comparator will provide a proper output state. The low input voltage state must not be less than $-0.3\ V_{DC}$ (or $0.3\ V_{DC}$ below the magnitude of the negative power supply, if used).

Note 9: At output switch point, $V_O \cong 1.4\ V_{DC}$, $R_S = 0\Omega$ with V^+ from $5\ V_{DC}$; and over the full input common-mode range ($0\ V_{DC}$ to $V^+ -1.5\ V_{DC}$).

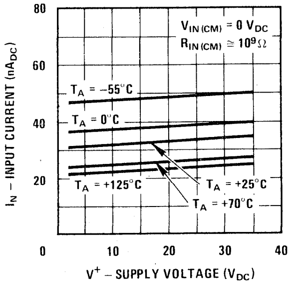
Note 10: For input signals that exceed V_{CC}, only the overdriven comparator is affected. With a 5V supply, V_{IN} should be limited to 25V max, and a limiting resistor should be used on all inputs that might exceed the positive supply.

typical performance characteristics LM139/LM239/LM339, LM139A/LM239A/LM339A, LM3302

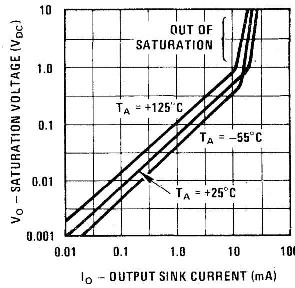
Supply Current



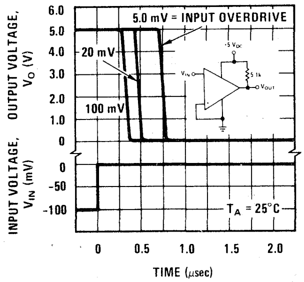
Input Current



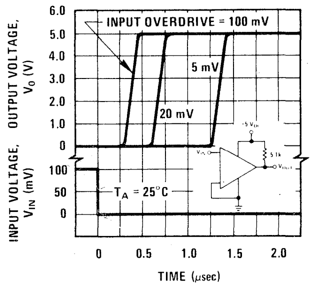
Output Saturation Voltage



Response Time for Various Input Overdrives – Negative Transition

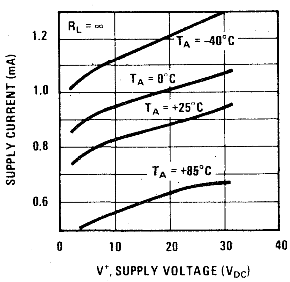


Response Time for Various Input Overdrives – Positive Transition

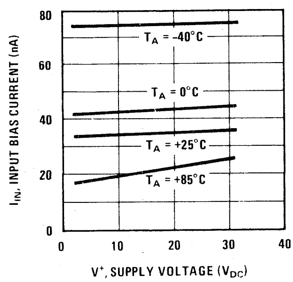


typical performance characteristics LM2901

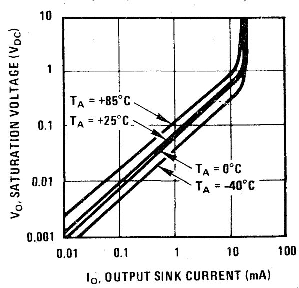
Supply Current



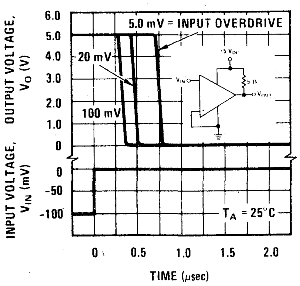
Input Current



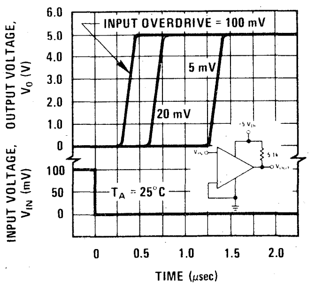
Output Saturation Voltage



Response Time for Various Input Overdrives–Negative Transition



Response Time for Various Input Overdrives–Positive Transition



application hints

The LM139 series are high gain, wide bandwidth devices 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 $< 10\ k\Omega$ 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.

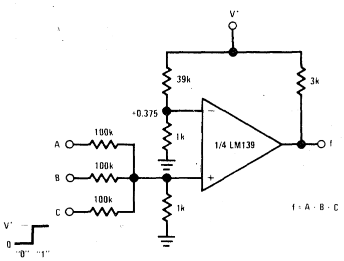
The bias network of the LM139 series establishes a drain current which is independent of the magnitude of the power supply voltage over the range of from 2 V_{DC} to 30 V_{DC}.

It is usually unnecessary to use a bypass capacitor across the power supply line.

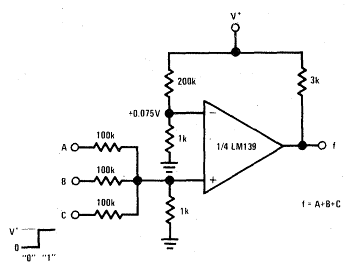
The differential input voltage may be larger than V^+ without damaging the device. Protection should be provided to prevent the input voltages from going negative more than $-0.3\ V_{DC}$ (at 25°C). An input clamp diode can be used as shown in the applications section.

The output of the LM139 series 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 mV) allows the output to clamp essentially to ground level for small load currents.

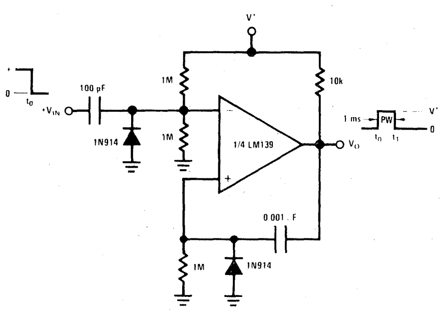
typical applications ($V^+ = 15\ V_{DC}$)



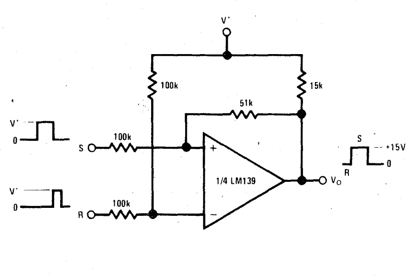
AND Gate



OR Gate

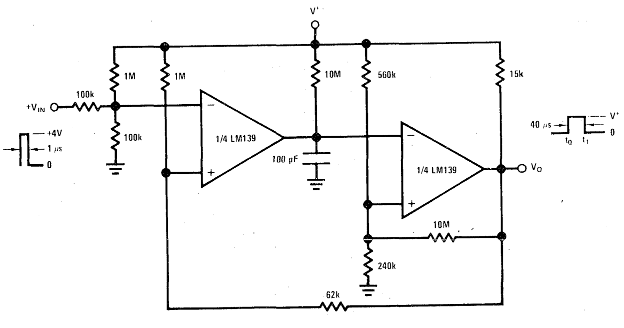


One-Shot Multivibrator

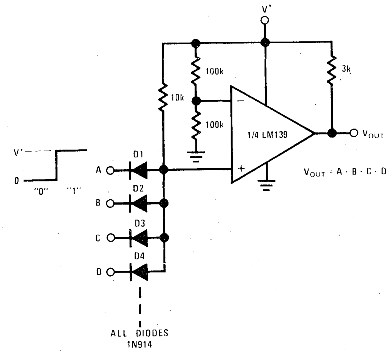


Bi-Stable Multivibrator

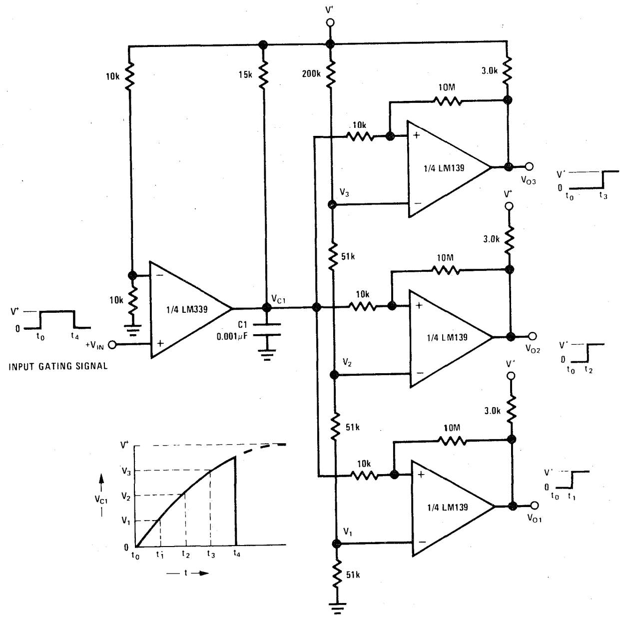
typical applications (con't) ($V^+ = 15\ V_{DC}$)



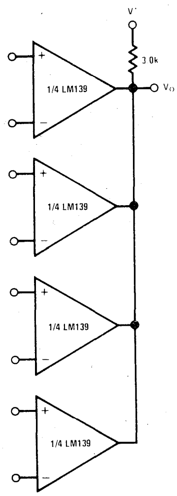
One-Shot Multivibrator with Input Lock Out



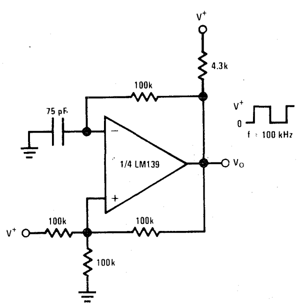
Large Fan-in AND Gate



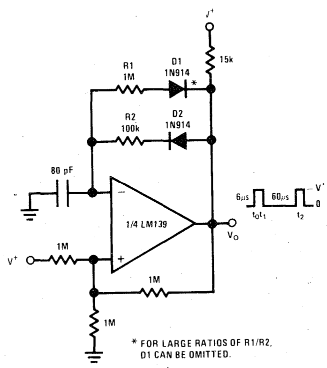
Time Delay Generator



ORing the Outputs

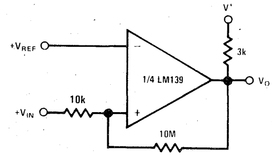


Squarewave Oscillator

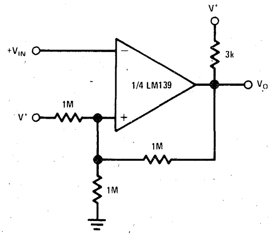


Pulse Generator

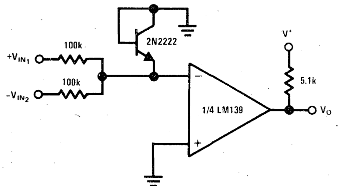
typical applications (con't) ($V^{+} = 5\ V_{DC}$)



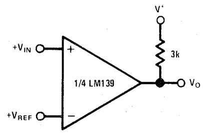
Non-Inverting Comparator with Hysteresis



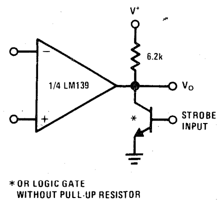
Inverting Comparator with Hysteresis



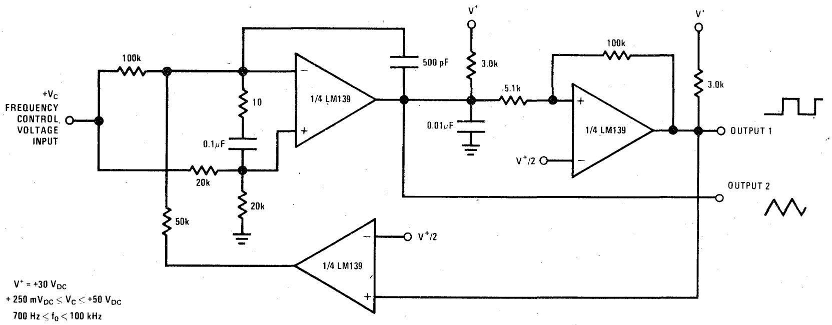
Comparing Input Voltages of Opposite Polarity



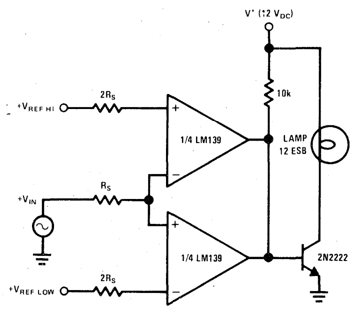
Basic Comparator



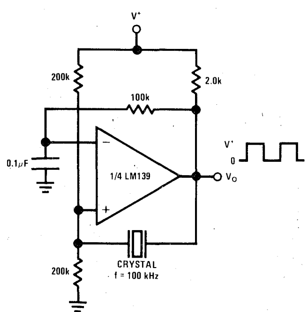
Output Strobing



Two-Decade High-Frequency VCO

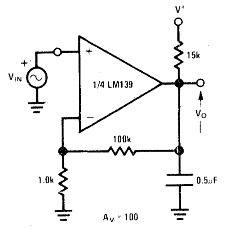


Limit Comparator

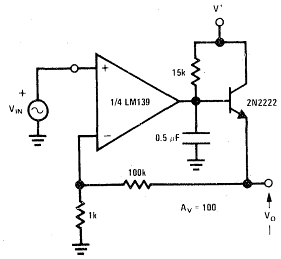


Crystal Controlled Oscillator

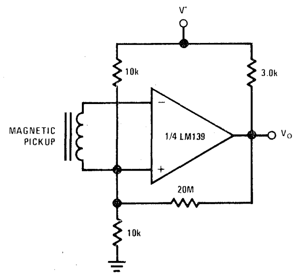
typical applications (con't) ($V^+ = 5\ V_{DC}$)



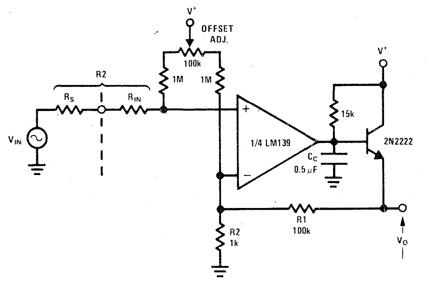
Low Frequency Op Amp



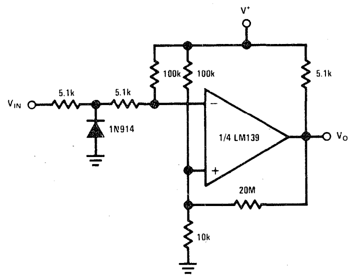
Low Frequency Op Amp ($V_O = 0V$ for $V_{IN} = 0V$)



Transducer Amplifier

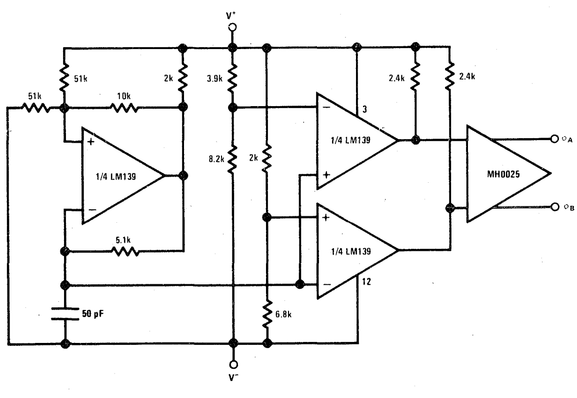


Low Frequency Op Amp with Offset Adjust

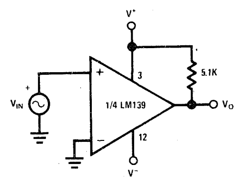


Zero Crossing Detector (Single Power Supply)

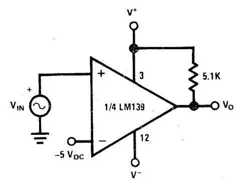
split-supply applications ($V^+ = +15\ V_{DC}$ and $V^- = -15\ V_{DC}$)



MOS Clock Driver



Zero Crossing Detector



Comparator With a Negative Reference

Voltage Comparators

LM160/LM260/LM360 high speed differential comparator

general description

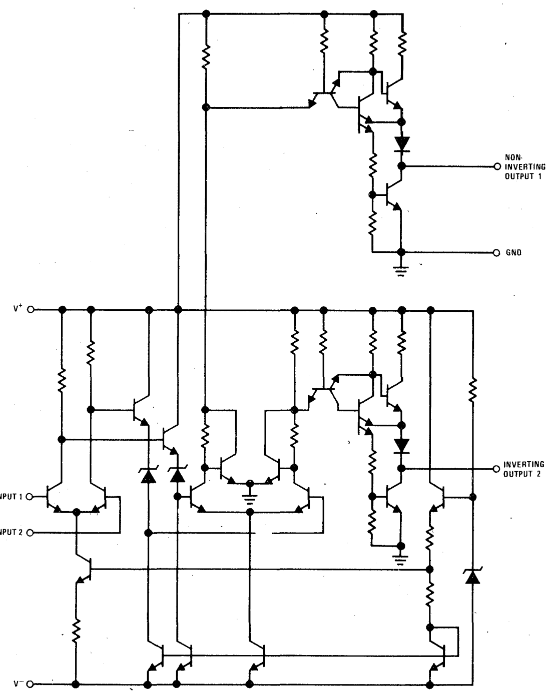
The LM160/LM260/LM360 is a very high speed differential input, complementary TTL output voltage comparator with improved characteristics over the μA760/μA760C, for which it is a pin-for-pin replacement. The device has been optimized for greater speed, input impedance and fan-out, and lower input offset 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.

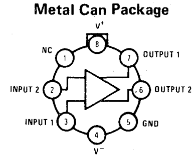
features

- 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



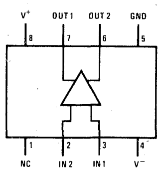
Metal Can Package



TOP VIEW

Order Number LM160H, LM260H or LM360H
See Package 11

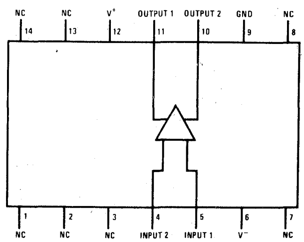
Dual-In-Line Package



TOP VIEW

Order Number LM360N-8
See Package 20

Dual-In-Line and Flat Packages



TOP VIEW

Order Number LM160D, LM260D or LM360D
See Package 1

Order Number LM360N-14
See Package 22

Order Number LM160F
See Package 4

Order Number LM160J-14, LM260J-14
or LM360J-14
See Package 16

absolute maximum ratings

Positive Supply Voltage	+8V
Negative Supply Voltage	−8V
Peak Output Current	20 mA
Differential Input Voltage	±5V
Input Voltage	$V^+ \geq V_{IN} \geq V^-$
Operating Temperature Range	
LM160	−55°C to +125°C
LM260	−25°C to +85°C
LM360	0°C to +70°C
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	$T_A = 25°C$, $V_S = \pm 5V$ (Note 1)		13	25	ns
	$T_A = 25°C$, $V_S = \pm 5V$ (Note 2)		12	20	ns
	$T_A = 25°C$, $V_S = \pm 5V$ (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	$V_S = \pm 6.5V$	±4	±4.5		V
Differential Input Voltage Range		±5			V
Output High Voltage (Either Output)	$I_{OUT} = -320\mu A$, $V_S = \pm 4.5V$	2.4	3		V
Output Low Voltage (Either Output)	$I_{SINK} = 6.4$ mA		.25	.4	V
Positive Supply Current	$V_S = \pm 6.5V$		18	32	mA
Negative Supply Current	$V_S = \pm 6.5V$		−9	−16	mA

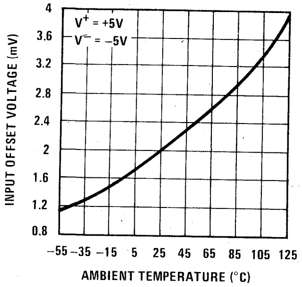
Note 1: Response time measured from the 50% point of a 30 mV_{P-P} 10 MHz sinusoidal input to the 50% point of the output.

Note 2: Response time measured from the 50% point of a 2 V_{P-P} 10 MHz sinusoidal input to the 50% point of the output.

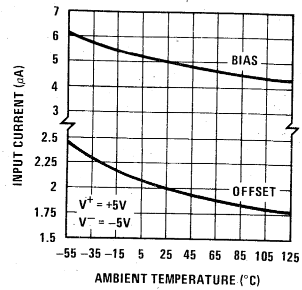
Note 3: Response time measured from the start of a 100 mV input step with 5 mV overdrive to the time when the output crosses the logic threshold.

typical performance characteristics

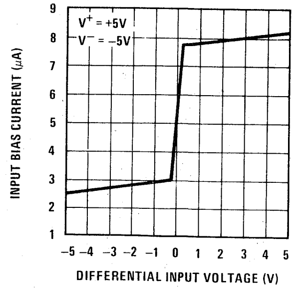
Offset Voltage



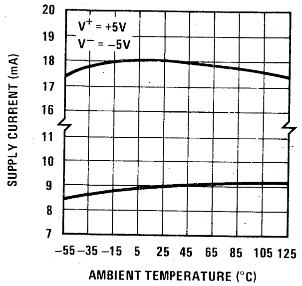
Input Currents vs Ambient Temperature



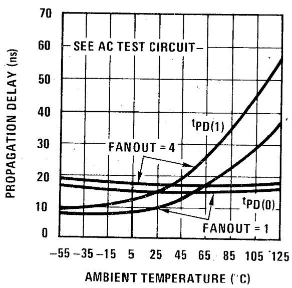
Input Characteristics



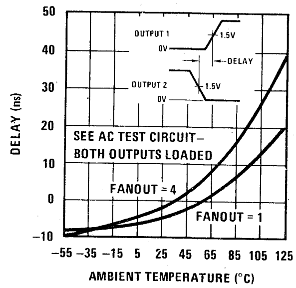
Supply Current vs Ambient Temperature



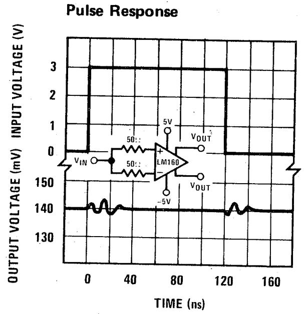
Propagation Delay vs Ambient Temperature



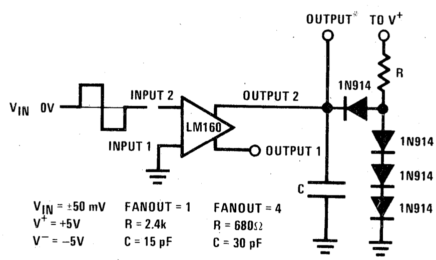
Delay of Output 1 With Respect to Output 2 vs Ambient Temperature



Common-Mode Pulse Response



AC Test Circuit



5

Voltage Comparators

LM161/LM261/LM361 high speed differential comparators

general description

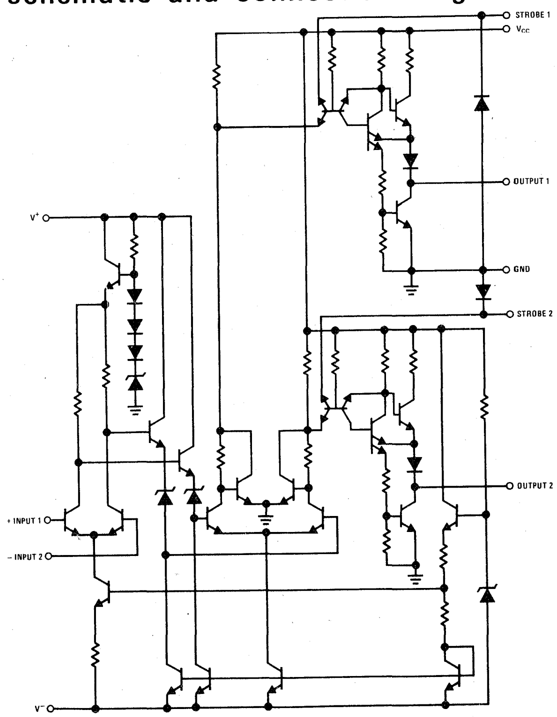
The LM161/LM261/LM361 is a very high speed differential input, complementary TTL output voltage comparator with improved characteristics over the SE529/NE529 for which it is a pin-for-pin replacement. The device has been optimized for greater speed performance and lower input offset voltage. Typically 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.

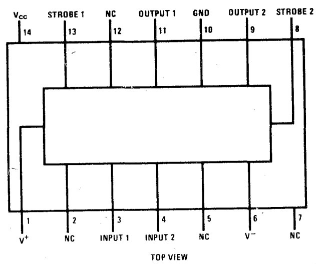
features

- 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

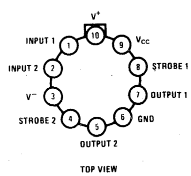


Dual-In-Line and Flat Package



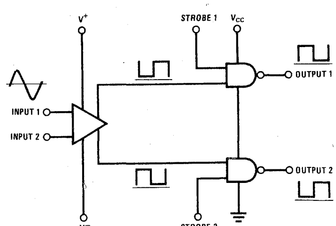
Order Number LM161D, LM261D or LM361D
See Package 1
Order Number LM161F
See Package 4
Order Number LM161J, LM261J or LM361J
See Package 16
Order Number LM361N
See Package 22

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	T_{MIN} T_{MAX}
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

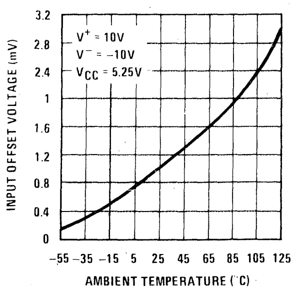
	MIN	TYP	MAX
Supply Voltage V^+			
LM161/LM261	5V		15V
LM361	5V		15V
Supply Voltage V^-			
LM161/LM261	−6V		−15V
LM361	−6V		−15V
Supply Voltage V_{CC}			
LM161/LM261	4.5V	5V	5.5V
LM361	4.75V	5V	5.25V

electrical characteristics (V^+ = +10V, V_{CC} = +5V, V^- = −10V, $T_{MIN} \leq T_A \leq T_{MAX}$, unless noted)

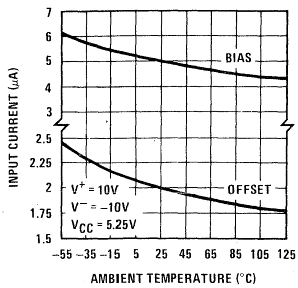
PARAMETER	CONDITIONS	LIMITS						UNITS
		LM161/LM261			LM361			
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage			1	3		1	5	mV
Input Bias Current	T_A = 25°C		5			10		µA
				20			30	µA
Input Offset Current	T_A = 25°C		2			2		µA
				3			5	µA
Voltage Gain	T_A = 25°C		3			3		V/mV
Input Resistance	T_A = 25°C, 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, $-55°C \leq T_A \leq 125°C$			4.5				mA
Supply Current I^+	V^+ = 10V, V^- = −10V, V_{CC} = 5.25V, $0°C \leq T_A \leq 70°C$						5	mA
Supply Current I^-	V^+ = 10V, V^- = −10V, V_{CC} = 5.25V, $55°C \leq T_A \leq 125°C$			10				mA
Supply Current I^-	V^+ = 10V, V^- = −10V, V_{CC} = 5.25V, $0°C \leq T_A \leq 70°C$						10	mA
Supply Current I_{CC}	V^+ = 10V, V^- = −10V, V_{CC} = 5.25V, $-55°C \leq T_A \leq 125°C$			18				mA
Supply Current I_{CC}	V^+ = 10V, V^- = −10V, V_{CC} = 5.25V, $0°C \leq T_A \leq 70°C$						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

typical performance characteristics

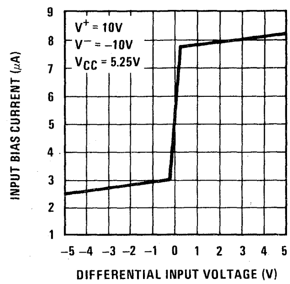
Offset Voltage



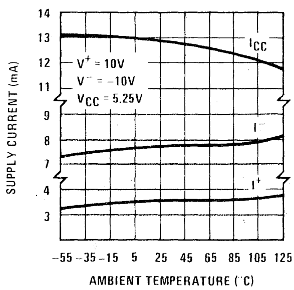
Input Currents vs Ambient Temperature



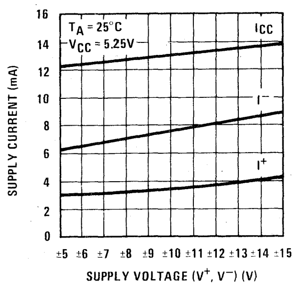
Input Characteristics



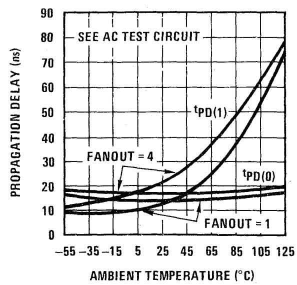
Supply Current vs Ambient Temperature



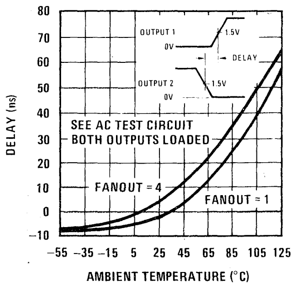
Supply Current vs Supply Voltage



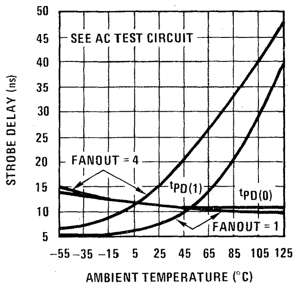
Propagation Delay vs Ambient Temperature



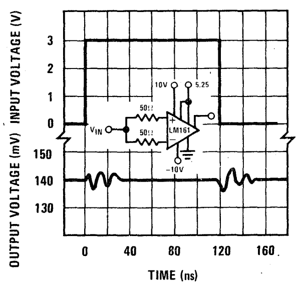
Delay of Output 1 With Respect to Output 2 vs Ambient Temperature



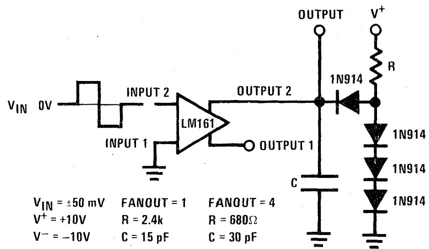
Strobe Delay vs Ambient Temperature



Common-Mode Pulse Response



AC Test Circuit



V_{IN} = ±50 mV	FANOUT = 1	FANOUT = 4
V^+ = +10V	R = 2.4k	R = 680Ω
V^- = −10V	C = 15 pF	C = 30 pF
V_{CC} = 5.25V		

Voltage Comparators

LM193/LM293/LM393, LM193A/LM293A/LM393A, LM2903 low power low offset voltage dual comparators

general description

The LM193 series consists of two independent precision voltage comparators with an offset voltage specification as low as 2.0 mV max for two 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 LM193 series was designed to directly interface with TTL and CMOS. When operated from both plus and minus power supplies, the LM193 series will directly interface with MOS logic where their low power drain is a distinct advantage over standard comparators.

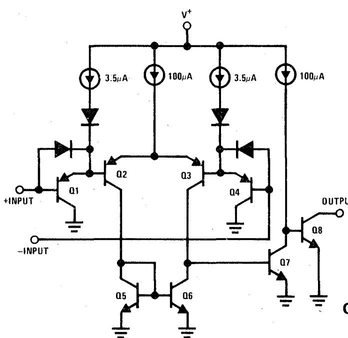
advantages

- High precision comparators
- Reduced V_{OS} drift over temperature
- Eliminates need for dual supplies
- Allows sensing near ground
- Compatible with all forms of logic
- Power drain suitable for battery operation

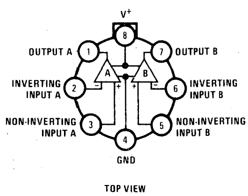
features

- 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: 25 nA
- Low input offset current: ±5 nA
  and maximum 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: 250 mV at 4 mA
- Output voltage compatible with TTL, DTL, ECL, MOS and CMOS logic systems

schematic and connection diagrams

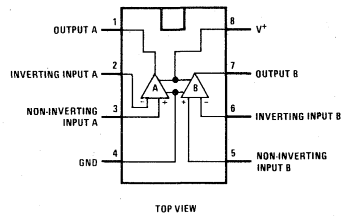


Metal Can Package



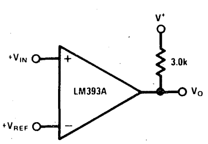
Order Number LM193H, LM193AH, LM293H, LM293AH, LM393H or LM393AH
See Package 11

Dual-In-Line Package

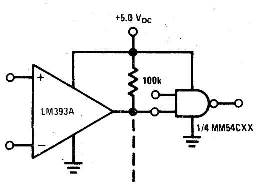


Order Number LM393N, LM393AN or LM2903N
See Package 20

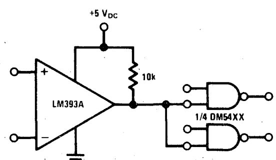
typical applications ($V^+ = 5.0\ V_{DC}$)



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	570 mW
Metal Can	900 mW
Output Short-Circuit to Ground, (Note 2)	Continuous
Input Current ($V_{IN} < -0.3\ V_{DC}$), (Note 3)	50 mA
Operating Temperature Range	
LM393/LM393A	0°C to +70°C
LM293/LM293A	−25°C to +85°C
LM193/LM193A	−55°C to +125°C
LM2903	−40°C to +85°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics ($V^+ = 5\ V_{DC}$) (Note 4)

PARAMETER	CONDITIONS	LM193A			LM293A, LM393A			LM193			LM293, LM393			LM2903			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$T_A = 25°C$, (Note 9)		±1.0	±2.0		±1.0	±2.0		±1.0	±5.0		±1.0	±5.0		±2.0	±7.0	mV_{DC}
Input Bias Current	I_{IN+} or I_{IN-} with Output In Linear Range, $T_A = 25°C$, (Note 5)		25	100		25	250		25	100		25	250		25	250	nA_{DC}
Input Offset Current	$I_{IN+} - I_{IN-}$, $T_A = 25°C$		±3.0	±25		±5.0	±50		±3.0	±25		±5.0	±50		±5.0	±50	nA_{DC}
Input Common-Mode Voltage Range	$T_A = 25°C$, (Note 6)	0		$V^+-1.5$	0		$V^+-1.5$	0		$V^+-1.5$	0		$V^+-1.5$	0		$V^+-1.5$	V_{DC}
Supply Current	$R_L = \infty$ on All Comparators, $T_A = 25°C$		0.8	1		0.8	1		0.8	1		0.8	1		0.8	1.0	mA_{DC}
	$R_L = \infty$ on All Amps, $V^+ = 30\ V_{DC}$		1	2.5		1	2.5			2.5			2.5		1	2.5	mA_{DC}
Voltage Gain	$R_L \geq 15\ k\Omega$, $T_A = 25°C$, $V^+ = 15\ V_{DC}$ (To Support Large V_O Swing)	50	200		50	200		50	200		50	200		25	100		$V/\mu V$
Large Signal Response Time	V_{IN} = TTL Logic Swing, $V_{REF} = 1.4\ V_{DC}$ $V_{RL} = 5\ V_{DC}$, $R_L = 5.1\ k\Omega$, $T_A = 25°C$		300			300			300			300			300		ns
Response Time	$V_{RL} = 5\ V_{DC}$, $R_L = 5.1\ k\Omega$, $T_A = 25°C$, (Note 7)		1.3			1.3			1.3			1.3			1.5		μs
Output Sink Current	$V_{IN-} \geq 1\ V_{DC}$, $V_{IN+} = 0$, $V_O \leq 1.5\ V_{DC}$, $T_A = 25°C$	6.0	16		6.0	16		6.0	16		6.0	16		6	16		mA_{DC}
Saturation Voltage	$V_{IN-} \geq 1\ V_{DC}$, $V_{IN+} = 0$, $I_{SINK} \leq 4$ mA, $T_A = 25°C$		250	400		250	400		250	400		250	400			400	mV_{DC}
Output Leakage Current	$V_{IN} = 0$, $V_{IN+} \geq 1\ V_{DC}$, $V_O = 5\ V_{DC}$, $T_A = 25°C$		0.1			0.1			0.1			0.1			1		nA_{DC}

electrical characteristics (con't)

PARAMETER	CONDITIONS	LM193A			LM293A, LM393A			LM193			LM293, LM393			LM2903			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	(Note 9)			4.0			4.0			9			9		9	15	mV_{DC}
Input Offset Current	$I_{IN+} - I_{IN-}$			±100			±150			±100			±150		50	200	nA_{DC}
Input Bias Current	I_{IN+} or I_{IN-} with Output in Linear Range			300			400			300			400		200	500	nA_{DC}
Input Common-Mode Voltage Range		0		V^+–2.0	0		V^+–2.0	0		V^+–2.0	0		V^+–2.0	0		V^+–20	V_{DC}
Saturation Voltage	$V_{IN-} \geq 1\ V_{DC}$, $V_{IN+} = 0$, $I_{SINK} \leq 4$ mA,			700			700			700			700		400	700	mV_{DC}
Output Leakage Current	$V_{IN-} = 0$, $V_{IN+} \geq 1\ V_{DC}$, $V_O = 30\ V_{DC}$,			1.0			1.0			1.0			1.0			1.0	μA
Differential Input Voltage	Keep All V_{IN}'s $\geq 0\ V_{DC}$ (or V^-, if Used), (Note 8)			V^+			V^+			V^+			V^+			V^+	V_{DC}

Note 1: For operating at high temperatures, the LM393/LM393A and LM2903 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 LM193/LM193A/LM293/LM293A 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 $V^+ = 5\ V_{DC}$ and $-55°C \leq T_A \leq +125°C$, unless otherwise stated. With the LM293/LM293A all temperature specifications are limited to $-25°C \leq T_A \leq +85°C$ and the LM393/LM393A temperature specifications are limited to $0°C \leq T_A \leq +70°C$. The LM2903 is limited to $-40°C \leq T_A \leq +85°C$.

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 mV overdrive. For larger overdrive signals 300 ns can be obtained, see typical performance characteristics section.

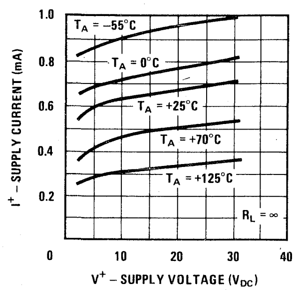
Note 8: Positive excursions of input voltage may exceed the power supply level. As long as the other voltage remains within the common-mode range, the comparator will provide a proper output state. The low input voltage state must not be less than $-0.3\ V_{DC}$ (or 0.3 V_{DC} below the magnitude of the negative power supply, 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^+ –1.5 V_{DC}).

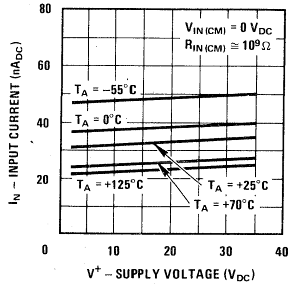
Note 10: For input signals that exceed V_{CC}, only the overdriven comparator is affected. With a 5V supply, V_{IN} should be limited to 25V max, and a limiting resistor should be used on all inputs that might exceed the positive supply.

typical performance characteristics LM193/LM293/LM393, LM193A/LM293A/LM393A

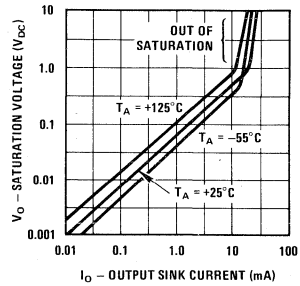
Supply Current



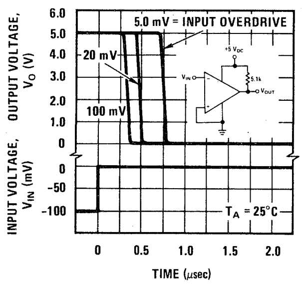
Input Current



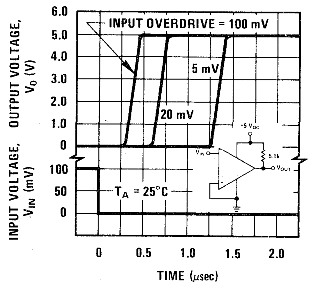
Output Saturation Voltage



Response Time for Various Input Overdrives — Negative Transition

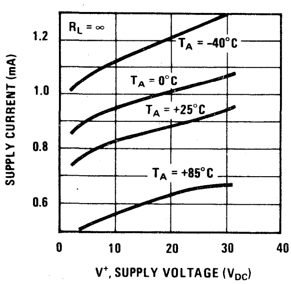


Response Time for Various Input Overdrives — Positive Transition

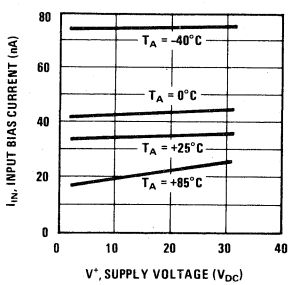


typical performance characteristics LM2903

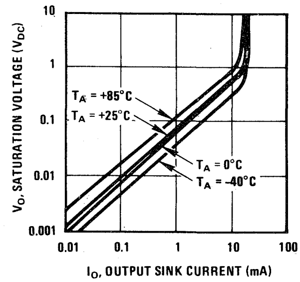
Supply Current



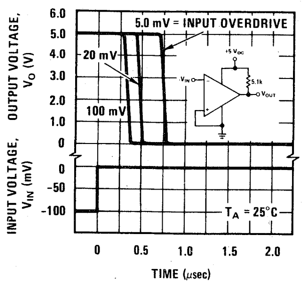
Input Current



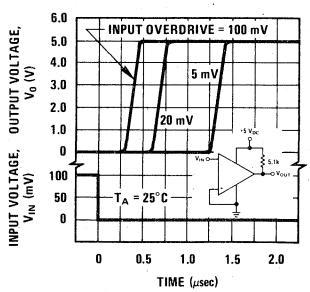
Output Saturation Voltage



Response Time for Various Input Overdrives—Negative Transition



Response Time for Various Input Overdrives—Positive Transition



application hints

The LM193 series are high gain, wide bandwidth devices 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.

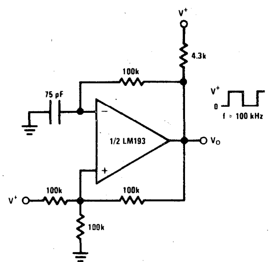
The bias network of the LM193 series establishes a drain current which is independent of the magnitude of the power supply voltage over the range of from 2.0 V_{DC} to 30 V_{DC}.

It is usually unnecessary to use a bypass capacitor across the power supply line.

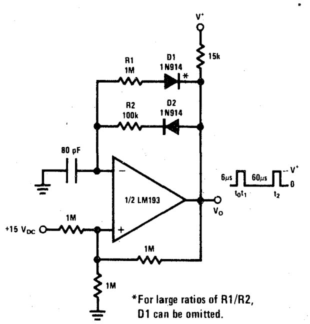
The differential input voltage may be larger than V^+ without damaging the device (see Note 8). Protection should be provided to prevent the input voltages from going negative more than −0.3 V_{DC} (at 25°C). An input clamp diode can be used as shown in the applications section.

The output of the LM193 series 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 LM193 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.

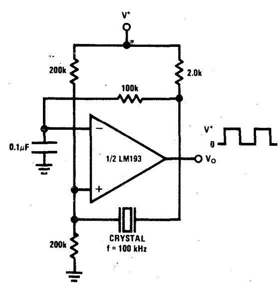
typical applications (con't) (V^+ = 15 V_{DC})



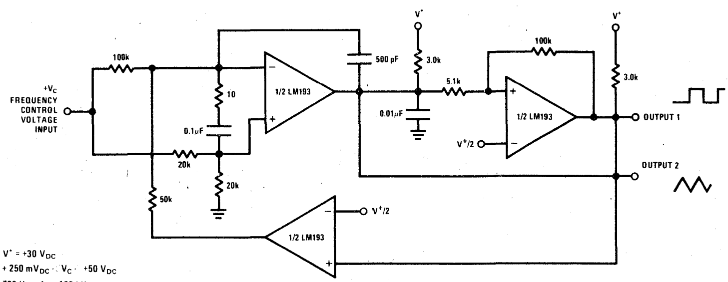
Squarewave Oscillator



Pulse Generator



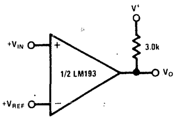
Crystal Controlled Oscillator



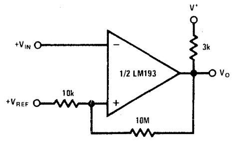
V^+ = +30 V_{DC}
+250 $mV_{DC} \le V_C \le$ +50 V_{DC}
700 Hz $\le f_o \le$ 100 kHz

Two-Decade High-Frequency VCO

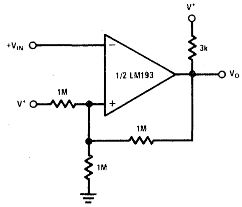
typical applications (con't) ($V^+ = 15\ V_{DC}$)



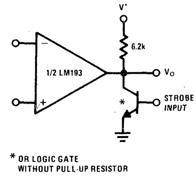
Basic Comparator



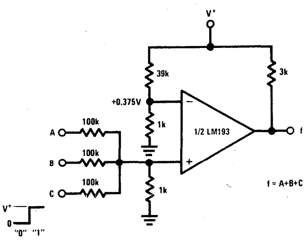
Non-Inverting Comparator with Hysteresis



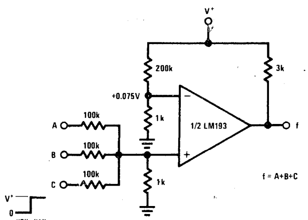
Inverting Comparator with Hysteresis



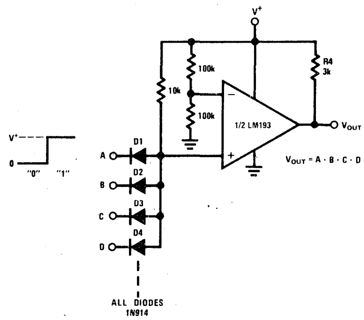
Output Strobing



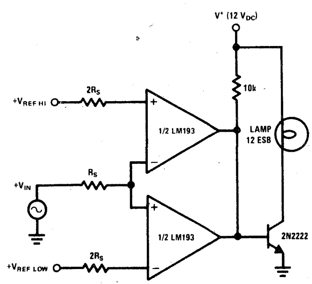
AND Gate



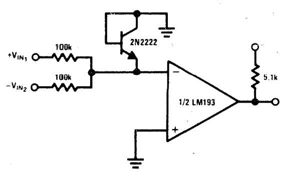
OR Gate



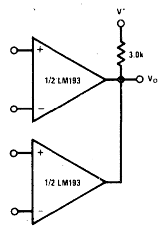
Large Fan-in AND Gate



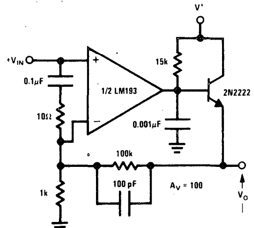
Limit Comparator



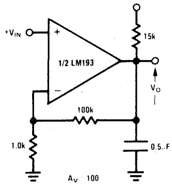
Comparing Input Voltages of Opposite Polarity



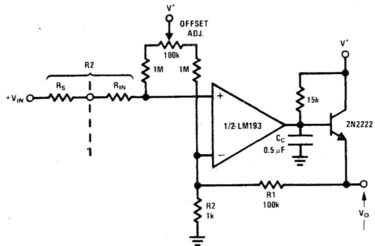
ORing the Outputs



Improved Op Amp

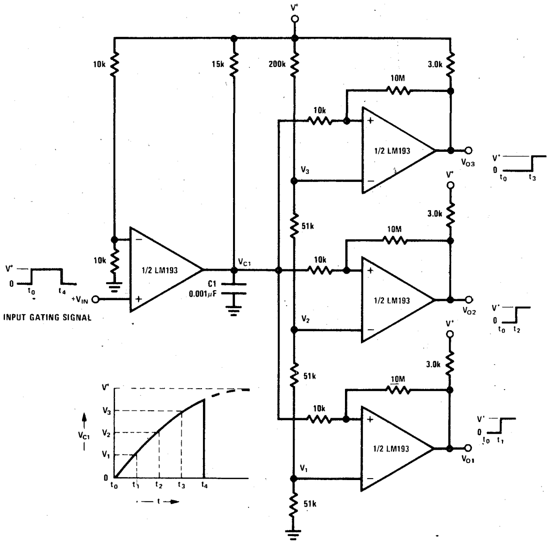


Low Frequency Op Amp

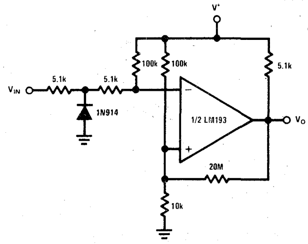


Low Frequency Op Amp with Offset Adjust

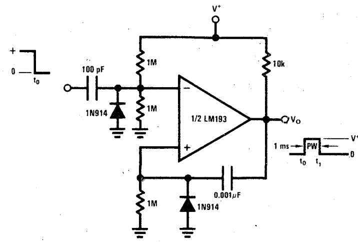
typical applications (con't) ($V^+ = 15\ V_{DC}$)



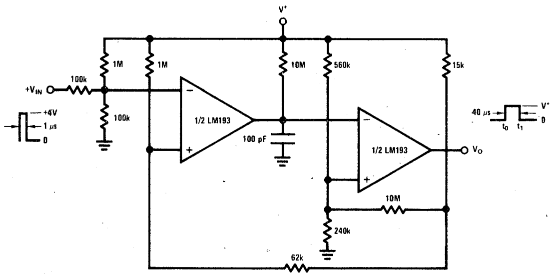
Time Delay Generator



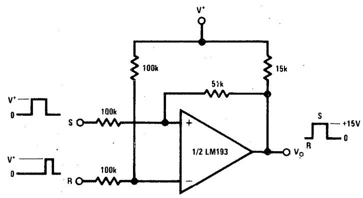
Zero Crossing Detector (Single Power Supply)



One-Shot Multivibrator

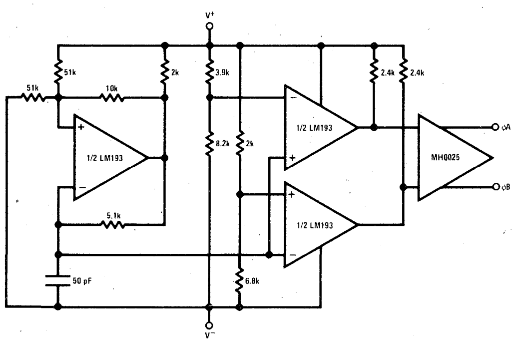


One-Shot Multivibrator with Input Lock Out

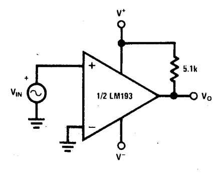


Bi-Stable Multivibrator

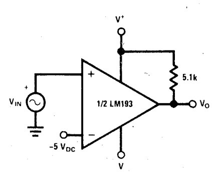
split-supply applications ($V^+ = +15\ V_{DC}$ and $V^- = -15\ V_{DC}$)



MOS Clock Driver



Zero Crossing Detector



Comparator With a Negative Reference

Voltage Comparators

LM710/LM710C voltage comparator

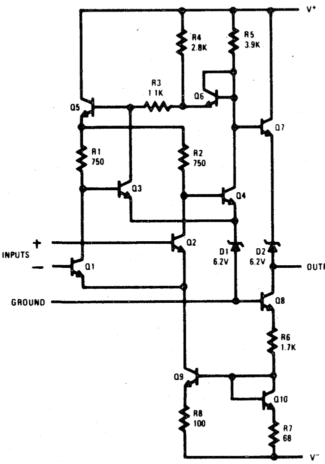
general description

The LM710 series are a high-speed voltage comparators 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.

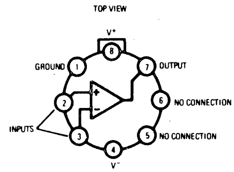
The device is built on a single silicon chip which insures low offset and thermal drift. The use of a minimum number of stages along with minority-carrier lifetime control (gold doping) makes the circuit much faster than operational amplifiers in saturating comparator applications. In fact, the low stray 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 series are useful as pulse height discriminators, voltage comparators in high-speed A/D converters or go, no-go detectors in automatic test equipment. They also have applications in digital systems as an adjustable-threshold line receiver or an interface between logic types. In addition, the low cost of the units suggests it for applications replacing relatively simple discrete component circuitry.

schematic* and connection diagrams



Metal Can Package

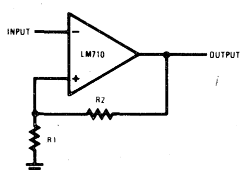


Note: Pin 4 connected to case.

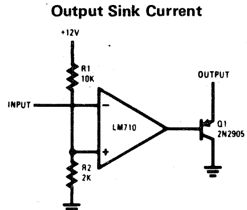
Order Number LM710H or LM710CH
See Package 11

typical applications*

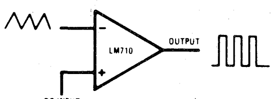
Schmitt Trigger



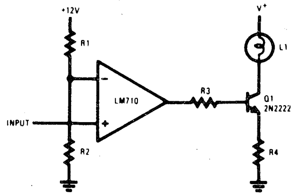
Line Receive With Increased Output Sink Current



Pulse Width Modulator



Level Detector With Lamp Driver



*Pin connections shown are for metal can.

absolute maximum ratings

Positive Supply Voltage	+14V
Negative Supply Voltage	−7V
Peak Output Current	10 mA
Output Short Circuit Duration	10 seconds
Differential Input Voltage	±5V
Input Voltage	±7V
Power Dissipation	
TO-99, (Note 1)	300 mW
Flat Package, (Note 2)	200 mW

	T_{MIN} T_{MAX}
Operating Temperature Range	
LM710	−55°C to +125°C
LM710C	0°C to +70°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 60 seconds)	300°C

electrical characteristics (Note 3)

PARAMETER	CONDITIONS	LM710			LM710C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$R_S \le 200\Omega$, V_{CM} = 0V, T_A = 25°C		0.6	2.0		1.6	5.0	mV
Input Offset Current	V_{OUT} = 1.4V, T_A = 25°C		0.75	3.0		1.8	5.0	μA
Input Bias Current	T_A = 25°C		13	20		16	25	μA
Voltage Gain	T_A = 25°C	1250	1700		1000	1500		
Output Resistance	T_A = 25°C		200			200		Ω
Output Sink Current	V_{OUT} = 0, T_A = 25°C							
	$\Delta V_{IN} \ge 5$ mV	2.0	2.5					mA
	$\Delta V_{IN} \ge 10$ mV				1.6	2.5		mA
Response Time	T_A = 25°C, (Note 4)		40			40		ns
Input Offset Voltage	$R_S \le 200\Omega$, V_{CM} = 0V			3.0			6.5	mV
Average Temperature Coefficient of Input Offset Voltage	$T_{MIN} \le T_A \le T_{MAX}$ $R_S \le 50\Omega$		3.0	10		5.0	20	μV/°C
Input Offset Current	$T_A = T_{A\,MAX}$		0.25	3.0			7.5	μA
	$T_A = T_{A\,MIN}$		1.8	7.0			7.5	μA
Average Temperature Coefficient of Input Offset Current	$25°C \le T_A \le T_{MAX}$		5.0	25		15	50	nA/°C
	$T_{MIN} \le T_A \le 25°C$		15	75		24	100	nA/°C
Input Bias Current	$T_A = T_{MIN}$		27	45		25	40	μA
Input Voltage Range	V^- = −7V	±5.0			±5.0			V
Common-Mode Rejection Ratio	$R_S \le 200\Omega$	80	100		70	98		dB
Differential Input Voltage Range		±5.0			±5.0			V
Voltage Gain		1000			800			V/V
Positive Output Level	$-5\text{ mA} \le I_{OUT} \le 0$							
	$V_{IN} \ge 5$ mV	2.5	3.2	4.0				V
	$V_{IN} \ge 10$ mV				2.5	3.2	4.0	V
Negative Output Level	$V_{IN} \ge 5$ mV	−1.0	−0.5	0				V
	$V_{IN} \ge 10$ mV				−1.0	−0.5	0	V
Output Sink Current	$V_{IN} \ge 5$ mV, V_{OUT} = 0							
	T_A = 125°C	0.5	1.7					mA
	T_A = −55°C	1.0	2.3					mA
	$V_{IN} \ge 10$ mV, V_{OUT} = 0							
	$0°C \le T_A \le +70°C$				0.5			mA
Positive Supply Current	$V_{IN} \ge 5$ mV		5.2	9.0				mA
	$V_{IN} \ge 10$ mV					5.2	9.0	mA
Negative Supply Current	$V_{IN} \ge 5$ mV		4.6	7.0				mA
	$V_{IN} \ge 10$ mV					4.6	7.0	mA
Power Consumption	I_{OUT} = 0							
	$V_{IN} \ge 5$ mV		90	150				mW
	$V_{IN} \ge 10$ mV						150	mW

Note 1: Rating applies for case temperatures to 125°C for LM710 and to 70°C for LM710C; derate linearly at 5.6 mW/°C for ambient temperatures above 105°C.

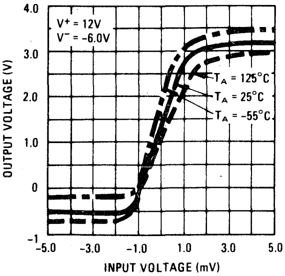
Note 2: Derate linearly at 4.4 mW/°C for ambient temperatures above 100°C.

Note 3: These specifications apply for V^+ = 12V, V^- = −6V, $-55°C \le T_A \le +125°C$ for LM710 and $0°C \le T_A \le +70°C$ for LM710C 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 1V at 125°C for LM710 and 1.5V at 0°C, 1.4V at 25°C and 1.2V at 70°C for LM710C.

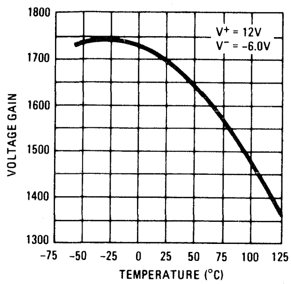
Note 4: The response time specified (see definitions) is a 100 mV input step with 5 mV overdrive (LM710) or a 10 mV overdrive (LM710C).

typical performance characteristics

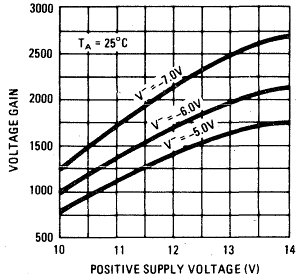
Transfer Function



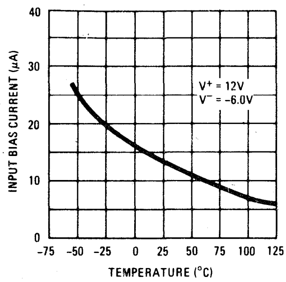
Voltage Gain



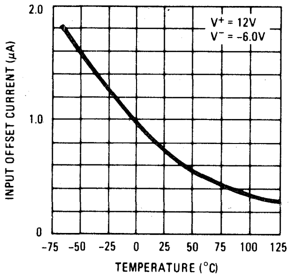
Voltage Gain



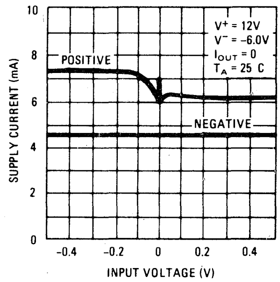
Input Bias Current



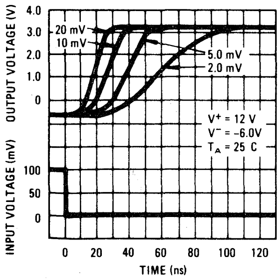
Input Offset Current



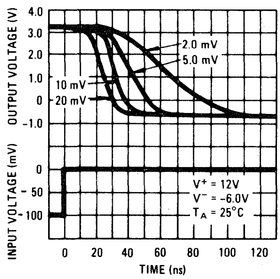
Supply Current



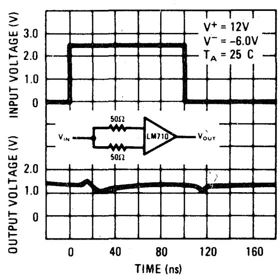
Response Time For Various Input Overdrives



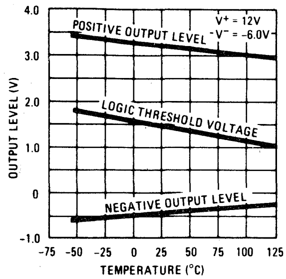
Response Time For Various Input Overdrives



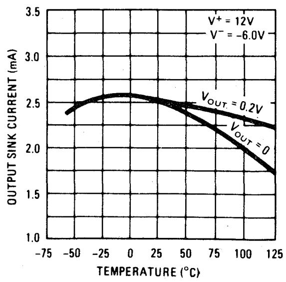
Common Mode Pulse Response



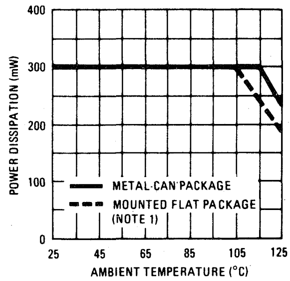
Output Voltage Level



Output Sink Current



Maximum Power Dissipation



Voltage Comparators

LM711/LM711C dual comparator

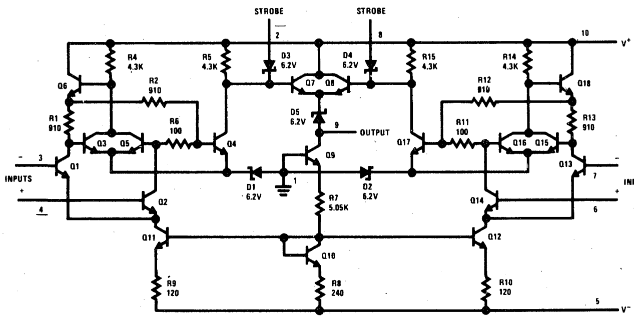
general description

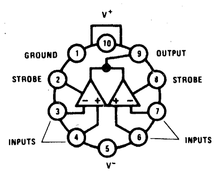
The LM711 series contains two voltage comparators with separate differential inputs, a common output and provision for strobing each side independently. Similar to the LM710, the device features low offset and thermal drift, a large input voltage range, low power consumption, fast recovery from large overloads and compatibility with most integrated logic circuits.

With the addition of an external resistor network, the LM711 series 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 series are 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. With operation specified over a 0°C to +70°C temperature range.

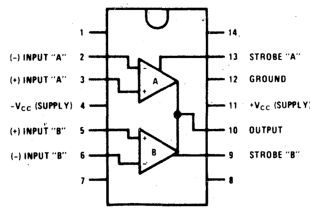
schematic** and connection diagrams





Note: Pin 5 connected to case.

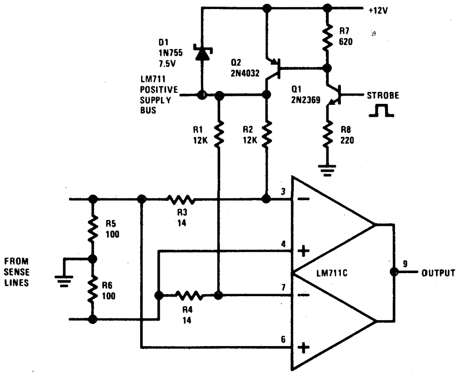
Order Number LM711H or LM711CH
See Package 14



Order Number LM711CN
See Package 22

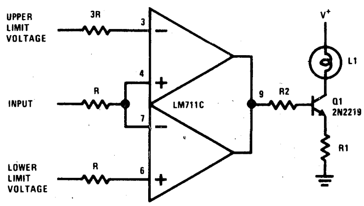
typical applications**

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.

absolute maximum ratings

Positive Supply Voltage	+14V
Negative Supply Voltage	−7V
Peak Output Current	25 mA
Differential Input Voltage	±5V
Input Voltage	±7V
Strobe Voltage	0 to +6V
Internal Power Dissipation (Note 1)	300 mW

Operating Temperature Range	T_{MIN} T_{MAX}
LM711	−55°C to +125°C
LM711C	0°C to +70°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)	LM711			LM711C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage	$R_S \leq 200\Omega$, V_{CM} = 0		1.0	3.5		1.0	5.0	mV
	$R_S \leq 200\Omega$, $-5V \leq V_{CM} \leq +5V$		1.0	5.0		1.0	7.5	mV
Input Offset Current			0.5	10.0		0.5	15	μA
Input Bias Current			25	75		25	100	μA
Voltage Gain		750	1500		700	1500		
Response Time (Note 3)			40			40		ns
Strobe Release Time			12			12		ns
Input Voltage Range	V^- = 7V	±5.0			±5.0			V
Differential Input Voltage Range		±5.0			±5.0			V
Output Resistance			200			200		Ω
Positive Output Level	$V_{IN} \geq$ 10 mV		4.5	5.0		4.5	5.0	V
Loaded Positive Output Level	$V_{IN} \geq$ 10 mV, I_{OUT} = −5 mA	2.5	3.5		2.5	3.5		V
Negative Output Level	$V_{IN} \leq$ −10 mV	−1.0		0	−1.0	−0.5	0	V
Strobed Output Level	$V_{STROBE} \leq$ 0.3V	−1.0		0	−1.0		0	V
Output Sink Current	$V_{IN} \leq$ −10 mV, $V_{OUT} \geq 0$	0.5	0.8		0.5	0.8		mA
Strobe Current	V_{STROBE} = 100 mV		1.2	2.5		1.2	2.5	mA
Positive Supply Current	$V_{IN} \leq$ −10 mV		8.6			8.6		mA
Negative Supply Current			3.9			3.9		mA
Power Consumption			130	200		130	230	mW
The following specifications apply for $T_{MIN} \leq T_A \leq T_{MAX}$:								
Input Offset Voltage	$R_S \leq 200\Omega$, V_{CM} = 0			4.5			6.0	mV
	$R_S \leq 200\Omega$			6.0			10	mV
Input Offset Current				20			25	μA
Input Bias Current				150			150	μA
Average Temperature Coefficient of Input Offset Voltage			5.0			5.0		μV/°C
Voltage Gain		500			500			

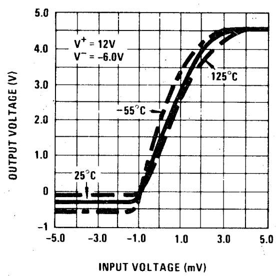
Note 1: Rating applies for case temperatures to 125°C; derate linearly at 5.6 mW/°C for ambient temperatures above 105°C.

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 1V at 125°C.

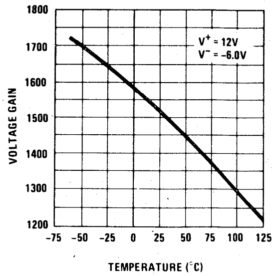
Note 3: The response time specified is for a 100 mV input step with 5 mV overdrive (see definitions).

typical performance characteristics

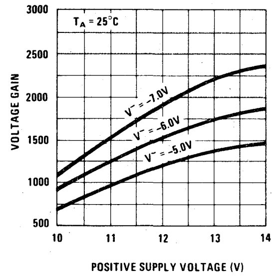
Transfer Function



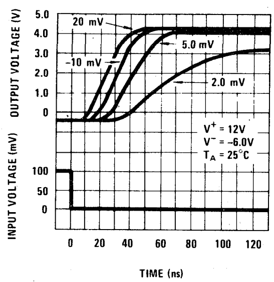
Voltage Gain



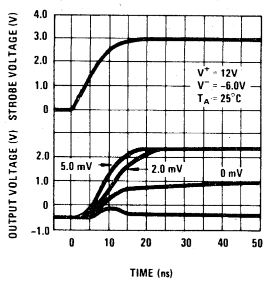
Voltage Gain



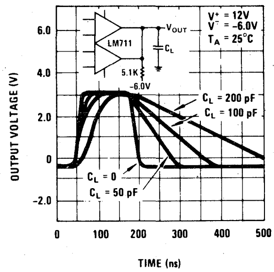
Response Time for Various Input Overdrives



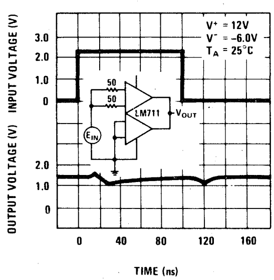
Strobe Release Time for Various Input Overdrives



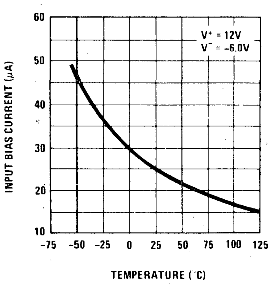
Output Pulse Stretching With Capacitive Loading



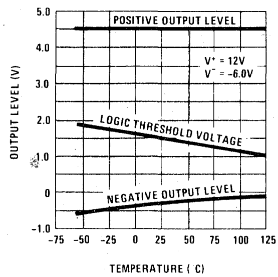
Common Mode Pulse Response



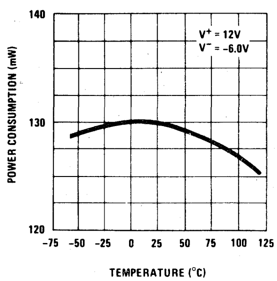
Input Bias Current



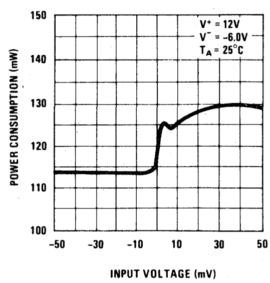
Output Voltage Level



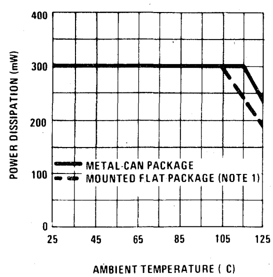
Power Consumption



Power Consumption



Maximum Power Dissipation



Voltage Comparators

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.

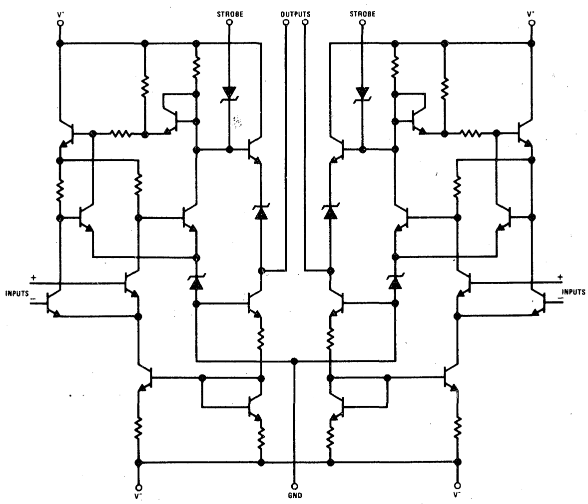
The LM1514/LM1414 is useful as a variable threshold Schmitt trigger, a pulse height discriminator, a voltage comparator in high-speed A-D converters, a memory sense amplifier or a high noise immunity line receiver. The output of the comparator is compatible with all integrated logic forms. The LM1514/LM1414 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.

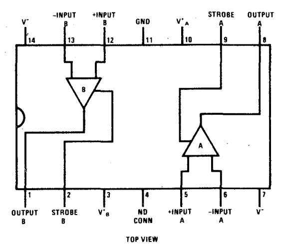
features

- 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 diagrams



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 MIN	LM1514 TYP	LM1514 MAX	LM1414 MIN	LM1414 TYP	LM1414 MAX	UNITS
Input Offset Voltage	$R_S \leq 200\Omega$, $V_{CM} = 0V$, $V_{OUT} = 1.4V$		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	$R_S \leq 200\Omega$, $V^- = -7.0V$	80	100		70	100		dB
Positive Output Voltage	$V_{IN} \geq 7.0$ mV, $0 \leq I_{OUT} \leq -5.0$ mA	2.5	3.2	4.0	2.5	3.2	4.0	V
Negative Output Voltage	$V_{IN} \leq -7.0$ mV	-1.0	-0.5	0	-1.0	-0.5	0	V
Strobed Output Voltage	$V_{STROBE} \leq 0.3V$	-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	$V_{IN} \leq -7$ mV			18			18	mA
Negative Supply Current	$V_{IN} \leq -7$ mV			-14			-14	mA
Power Consumption			180	300		180	300	mW
Response Time	(Note 3)		30			30		ns
LM1514/LM1414: The following apply for $T_L \leq T_A \leq T_H$ (Note 4) unless otherwise specified								
Input Offset Voltage	$R_S \leq 200\Omega$, $V_{OUT} = 1.8V$ 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	$V_{IN} \leq -9.0$ mV, $V_{OUT} \geq 0V$	2.8	4.0		1.6	2.5		mA

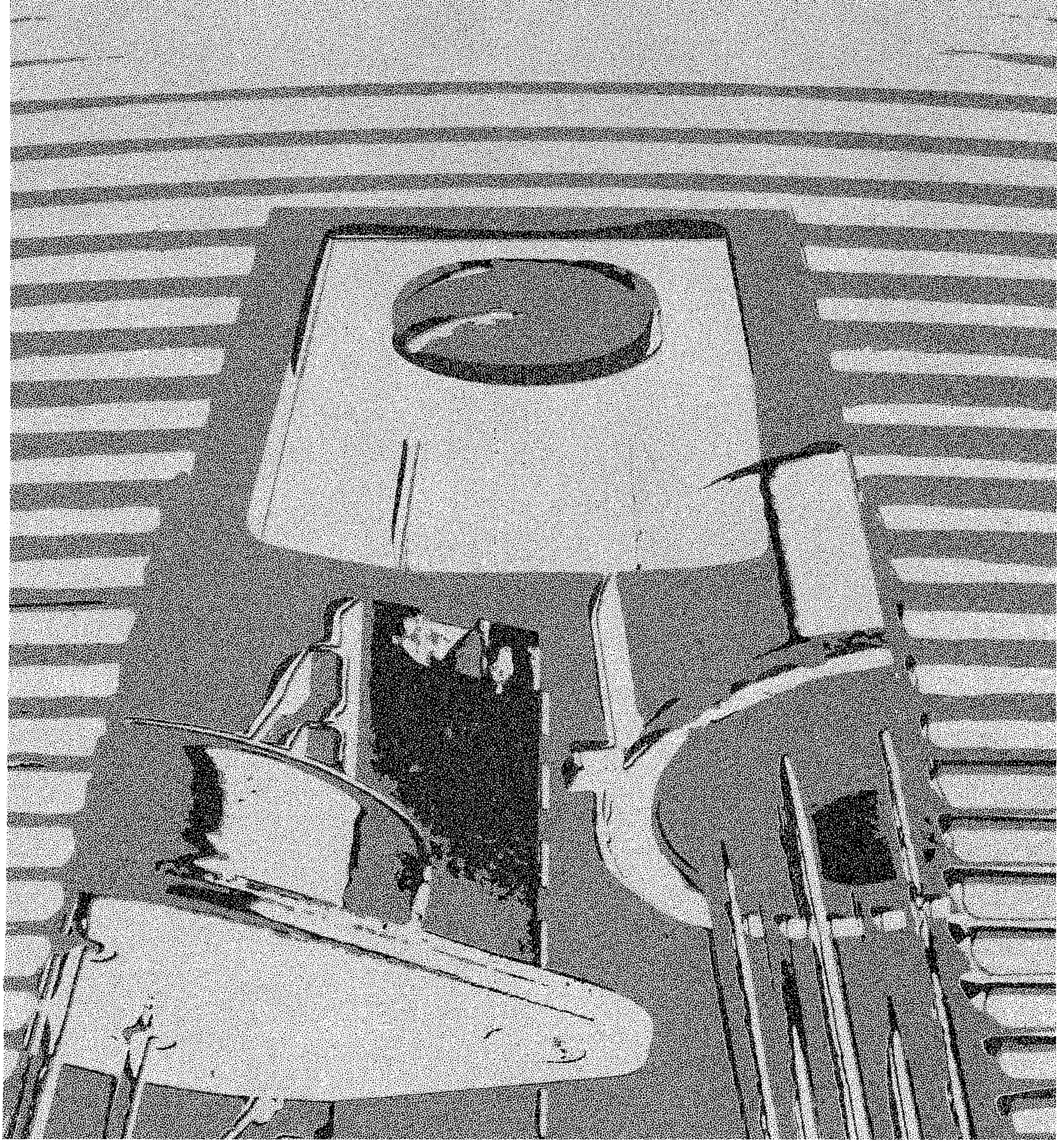
Note 1: Voltage values are with respect to network ground terminal. Positive current is defined as current into the referenced pin.

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, $T_L = 0°C$, $T_H = +70°C$.

National Semiconductor
ANALOG SWITCHES
Section 6



Analog Switches

Section Contents

*Product added to this Data Book since last printing.

Definition of Terms

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 transition 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.

Analog Switches

AH0014/AH0014C* DPDT, AH0015/AH0015C quad SPST, AH0019/AH0019C* dual DPST-TTL/DTL compatible MOS analog switches

general description

This series of 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.

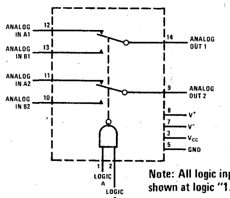
features

- 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.

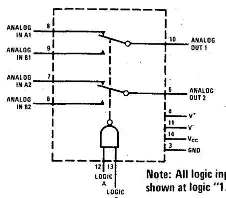
The AH0014, AH0015 and AH0019 are specified for operation over the −55°C to +125°C military temperature range. The AH0014C, AH0015C and AH0019C are specified for operation over the −25°C to +85°C temperature range.

block and connection diagrams



Note: All logic inputs shown at logic "1."

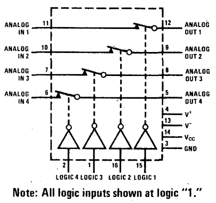
Order Number AH0014F or AH0014CF
See Package 4



Note: All logic inputs shown at logic "1."

Order Number AH0014D or AH0014CD
See Package 1

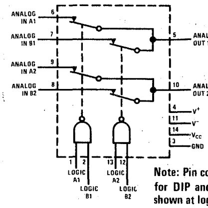
Quad SPST



Note: All logic inputs shown at logic "1."

Order Number AH0015D or AH0015CD
See Package 2

Dual DPST

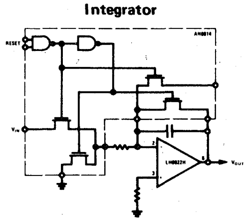


Note: Pin connections are identical for DIP and Flatpack. All logic inputs shown at logic "1."

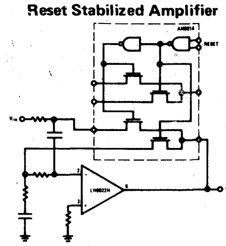
Order Number AH0019F or AH0019CF
See Package 4
Order Number AH0019D or AH0019CD
See Package 1

typical applications

Integrator



Reset Stabilized Amplifier



*Previously called NH0014/NH0014C and NH0019/NH0019C

6

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.

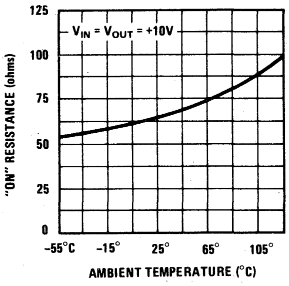
Note 2: All typical values are measured at T_A = 25°C with V_{CC} = 5.0V. V^+ = +10V, V^- = −22V.

Note 3: Current measured is drawn from V_{CC} supply.

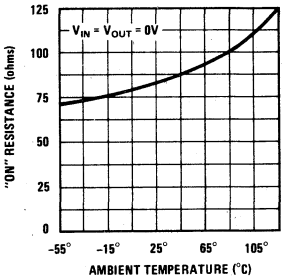
Note 4: All analog switch pins except measurement pin are tied to V^+.

analog switch characteristics (Note 2)

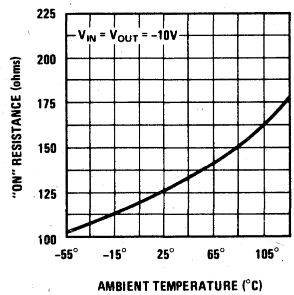
R_{ON} vs Temperature



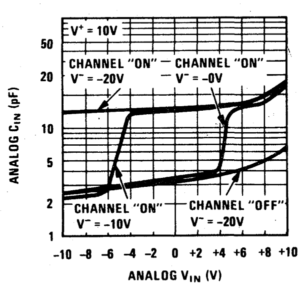
R_{ON} vs Temperature



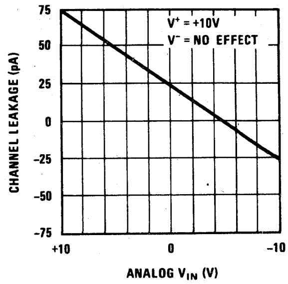
R_{ON} vs Temperature



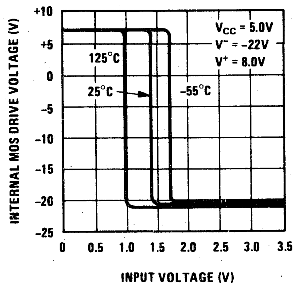
C_{IN} vs V_{IN}



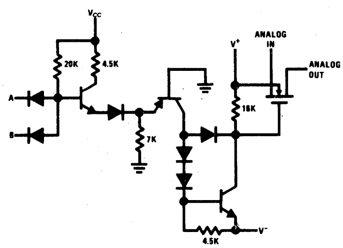
Leakage vs V_{IN} (Channel "OFF")



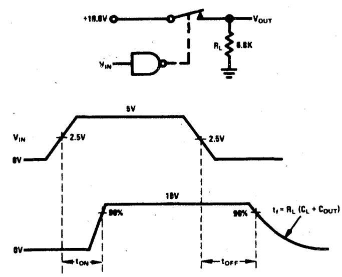
Driver Gate V_{IN} vs V_{OUT}



Schematic (Single Driver Gate and MOS Switch Shown)

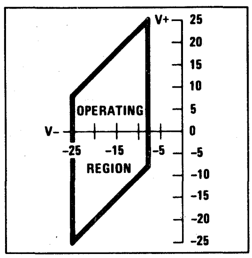


Analog Switching Time Test Circuit



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.



Analog Switches

AH0120, AH0130, AH0140, AH0150, AH0160 series analog switches

general description

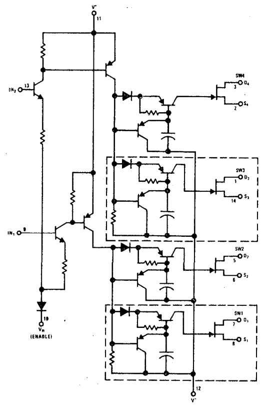
The AH0100 series represents a complete family of junction FET analog switches. The inherent flexibility of the family allows the designer to tailor the device selection to the particular application. Switch configurations available include dual DPST, dual SPST, DPDT, and SPDT. $r_{ds(ON)}$ ranges from 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.

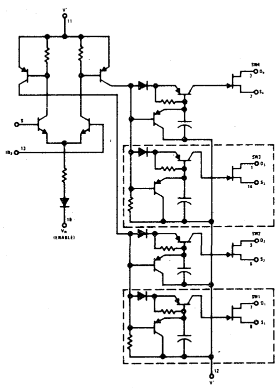
schematic diagrams

DUAL DPST and DUAL SPST



Note: Dotted line portions are not applicable to the dual SPST.

DPDT (diff.) and SPDT (diff.)

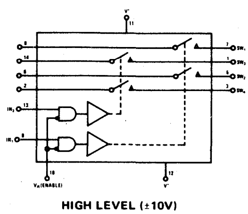


Note: Dotted line portions are not applicable to the SPDT (differential).

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.

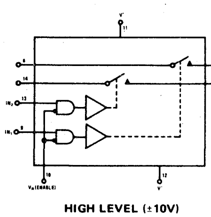
DUAL DPST



HIGH LEVEL (±10V)
AH0140 (10Ω)
AH0129 (30Ω)
AH0126 (80Ω)

MEDIUM LEVEL (±7.5V)
AH0153 (15Ω)
AH0154 (50Ω)

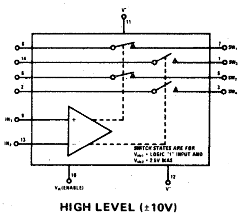
DUAL SPST



HIGH LEVEL (±10V)
AH0141 (10Ω)
AH0133 (30Ω)
AH0134 (80Ω)

MEDIUM LEVEL (±7.5V)
AH0151 (15Ω)
AH0152 (50Ω)

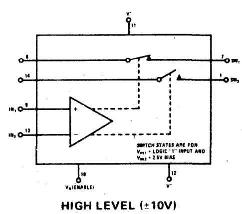
DPDT (Diff)



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	DUAL SPST	DPDT (DIFF)	SPDT (DIFF)	CONDITIONS: $V^+ = 12.0V$, $V^- = -18.0V$, $V_R = 0.0V$		LIMITS: TYP	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	$V_D = 10V$, $I_D = 1$ mA	$T_A = 25°C$	45	80	Ω
							Over Temp. Range		150	Ω
Switch ON Resistance	$r_{ds(ON)}$	AH0129	AH0133	AH0139	AH0144	$V_D = 10V$, $I_D = 1$ mA	$T_A = 25°C$	25	30	Ω
							Over Temp. Range		60	Ω
Switch ON Resistance	$r_{ds(ON)}$	AH0140	AH0141	AH0145	AH0146	$V_D = 10V$, $I_F = 1$ mA	$T_A = 25°C$	8	10	Ω
							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)

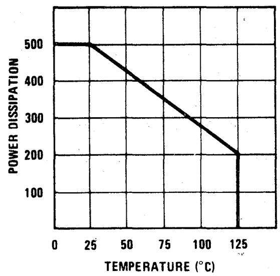
PARAMETER	SYMBOL	DEVICE TYPE				CONDITIONS		LIMITS		UNITS
		DUAL DPST	DUAL SPST	DUAL DPDT	SPDT (DIFF)	$V^+ = +15.0V$, $V^- = -15V$, $V_R = 0V$		TYP	MAX	
Logic "1" Input Current	$I_{IN(ON)}$	All Circuits				Note 2	$T_A = 25°C$	20	60	μA
							Over Temp. Range		120	μA
Logic "0" Input Current	$I_{IN(OFF)}$	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 $T_A = 25°C$.

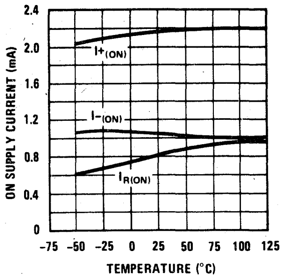
Note 2: For the DPST and Dual DPST, the ON condition is for $V_{IN} = 2.5V$; the OFF condition is for $V_{IN} = 0.8V$. For the differential switches and SW1 and 2 ON, $V_{IN2} = 2.5V$, $V_{IN1} = 3.0V$. For SW3 and 4 ON, $V_{IN2} = 2.5V$, $V_{IN1} = 2.0V$.

typical performance characteristics

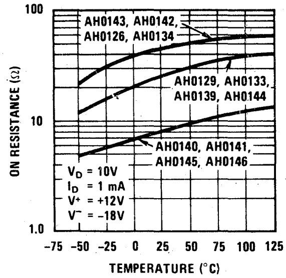
Power Dissipation vs Temperature



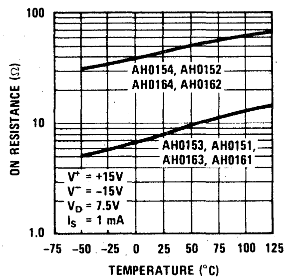
ON Supply Current vs Temperature



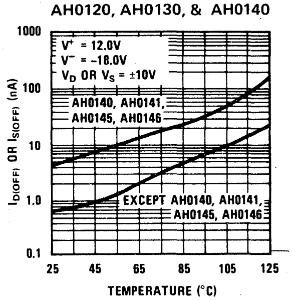
$r_{ds(ON)}$ vs Temperature AH0120 thru AH0140 Series



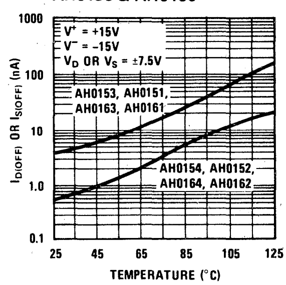
$r_{ds(ON)}$ vs Temperature AH0150/AH0160 Series



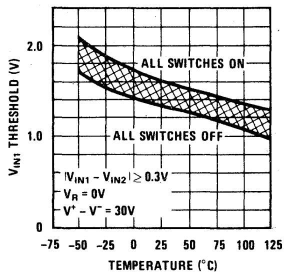
Leakage Current vs Temperature AH0120, AH0130, & AH0140



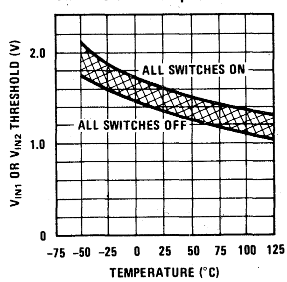
Leakage Current vs Temperature AH0150 & AH0160



Single Ended Switch Input Threshold vs Temperature

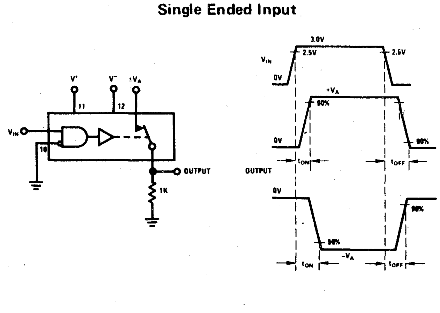


Differential Switch Input Threshold vs Temperature

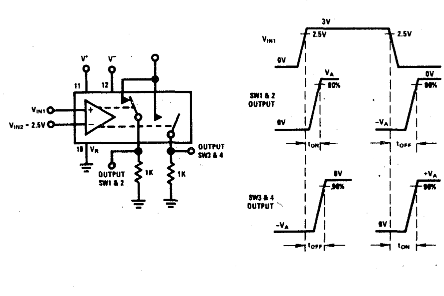


switching time test circuits

Single Ended Input



Differential Input



applications information

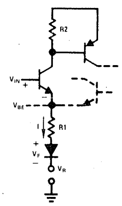
1. INPUT LOGIC COMPATIBILITY

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.

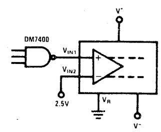
3. DIFFERENTIAL INPUT CONSIDERATIONS

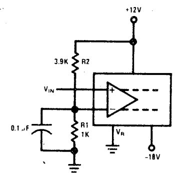
The differential switch driver is essentially a differential amplifier. The input requirements for proper operation are:

$$|V_{IN1} - V_{IN2}| \geq 0.3V$$

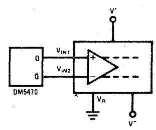
$$2.5 \leq (V_{IN1} \text{ or } V_{IN2}) - V_R \leq 5V$$

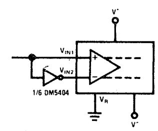
The differential driver may be furnished by a DC level as shown below. The level may be derived from a voltage divider to V^+ or the 5V V_{CC} of the DTL logic. In order to assure proper operation, the divider should be "stiff" with respect to I_{IN2}. Bypassing R1 with a 0.1 μF disc capacitor will prevent degradation of t_{ON} and t_{OFF}.



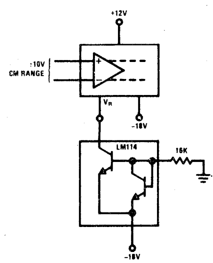


Alternatively, the differential driver may be driven from a TTL flip-flop or inverter.





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:

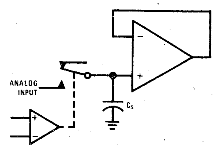
$$V_A \leq V^+ - V_{SAT} - V_{BE} - 1.0V \text{ or}$$

$$V_A \leq V^+ - 2.0V \text{ or } V^+ \geq V_A + 2.0V$$

For the standard high level switches, $V_A = 12 - 2.0V = +10V$.

5. SWITCHING TRANSIENTS

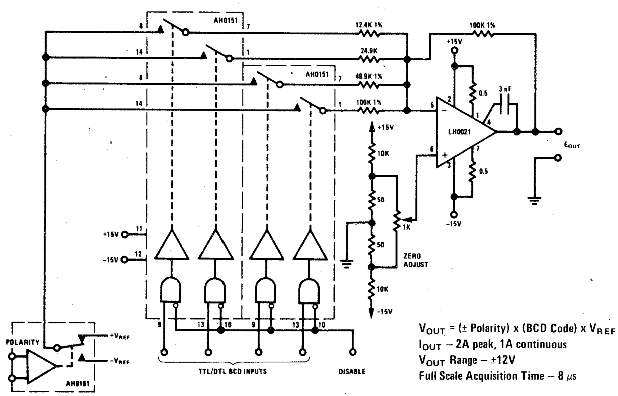
Due to charge stored in the gate-to-source and gate-to-drain capacitances of the FET switch, transients may appear in the output during switching. This is particularly true during the OFF to ON transition. The magnitude and duration of the transient may be minimized by making source and load impedance 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.

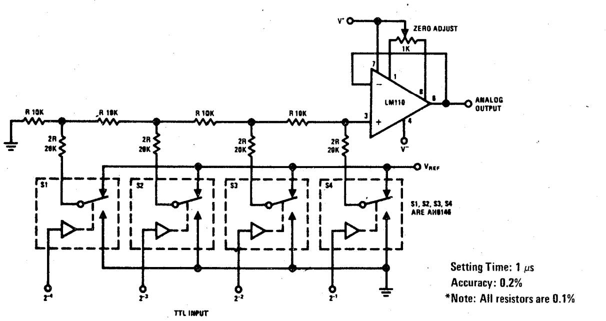
typical applications

Programmable One Amp Power Supply



V_{OUT} = (± Polarity) x (BCD Code) x V_{REF}
I_{OUT} – 2A peak, 1A continuous
V_{OUT} Range – ±12V
Full Scale Acquisition Time – 8 μs

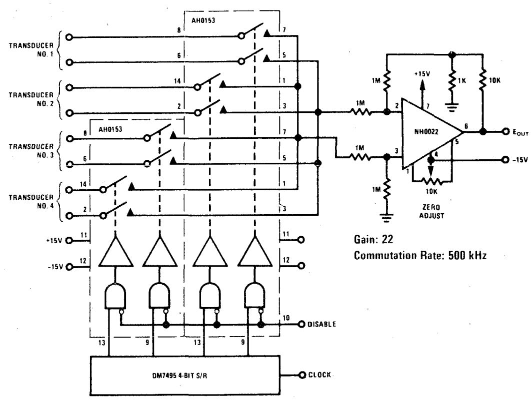
Four to Ten Bit D to A Converter (4 Bits Shown)



Setting Time: 1 μs
Accuracy: 0.2%
*Note: All resistors are 0.1%

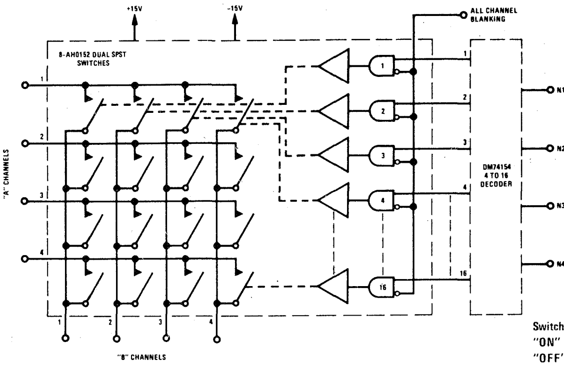
typical applications (con't)

Four Channel Differential Transducer Commutator



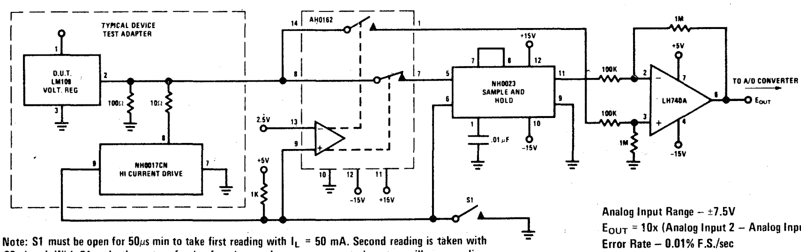
Gain: 22
Commutation Rate: 500 kHz

4 x 4 Cross Point Analog Switch



Switching Time – 800 ns
"ON" Resistance – 45Ω
"OFF" Resistance – 10^{10}Ω

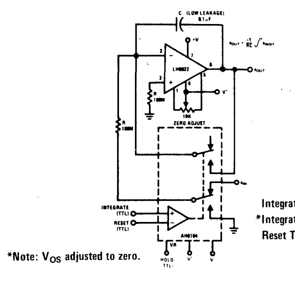
Delta Measurement System for Automatic Linear Circuit Tester



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

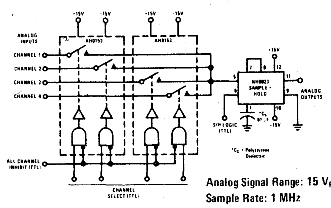
Precision Long Time Constant Integrator with Reset



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

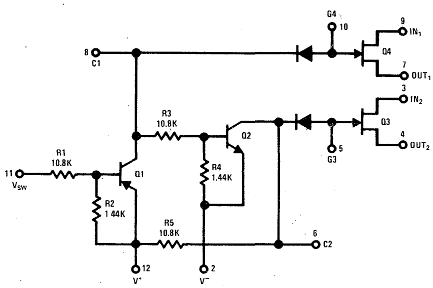
AH2114/AH2114C DPST analog switch general description

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:

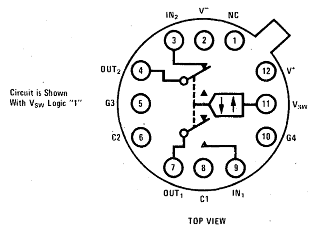
- Low ON resistance, typically 75Ω
- High OFF resistance, typically 10^{11}Ω
- Large output voltage swing, typically ±10V
- Powered from standard op-amp supply voltages of ±15V
- Input signals in excess of 1 MHz
- Turn-ON and turn-OFF times typically 1 μs

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

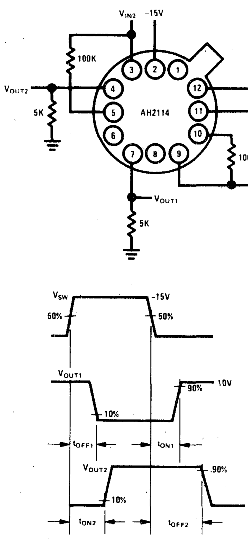


FIGURE 1.

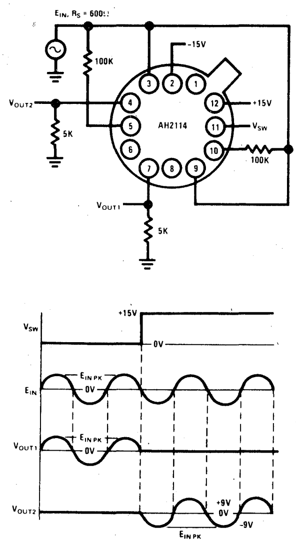


FIGURE 2.

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

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:

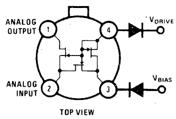
- Low ON Resistance 30Ω
- High Analog Signal Frequency 100 MHz
- High Toggle Rate 4 MHz
- Low Leakage Current 250 pA
- Large Analog Signal Swing ±15V
- Break Before Make Action

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

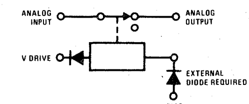
schematic and connection diagram

TO-72 Package



Order Number AM1000H or AM1001H or AM1002H See Package 9A

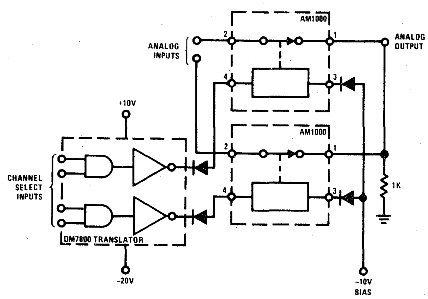
equivalent circuit



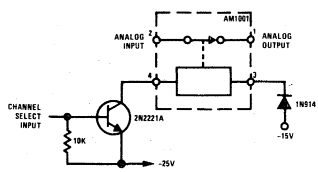
External diode required for drivers with pull-up circuit.

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

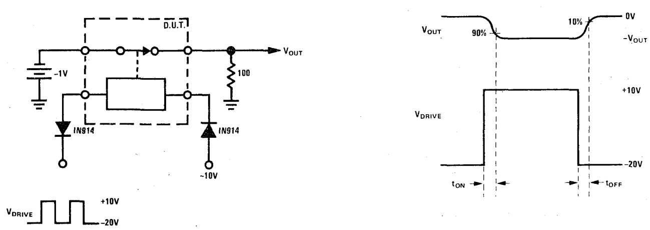
Note 1: The maximum voltage ratings may be applied between any pin or pins simultaneously. Power dissipation may be exceeded in some modes if the voltage pulse exceeds 10 ms. Normal operation will not cause excessive power dissipation even in a "D.C." switching application.

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



Analog Switches

AM2009/AM2009C, MM4504/MM5504 6-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.

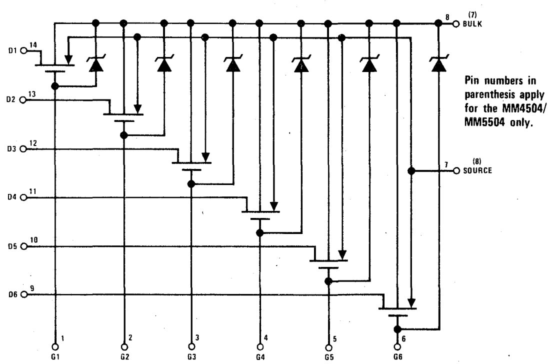
features

- 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.

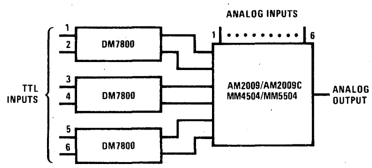
schematic diagram



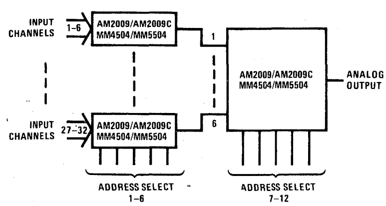
Order Number
AM2009F or AM2009CF
MM4504F or MM5504F
See Package 4

Order Number
AM2009D or AM2009CD
MM4504D or MM5504D
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
Voltage on Any Gate	−35V
Positive Voltage on Any Pin	+0.3V
Source or Drain Current	50 mA
Gate Current (forward direction of zener clamp)	0.1 mA
Total Power Dissipation (at T_A = 25°C)	900 mW
Power Dissipation — each gate circuit	150 mW
Operating Temperature Range AM2009	−55°C to +125°C
AM2009C	−25°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	LIMITS			UNITS
		MIN	TYP	MAX	
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

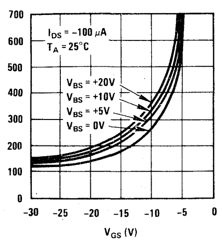
Note 1: Ratings apply over the specified temperature range and V_{BULK} = 0, unless otherwise specified.

Note 2: All other pins grounded.

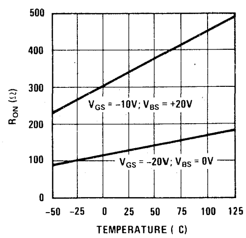
Note 3: Capacitance measured on dual-in-line package between pin under measurement to all other pins. Capacitances are guaranteed by design.

typical performance characteristics

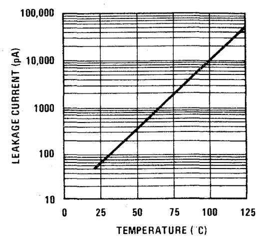
"ON" Resistance vs Gate-to-Source Voltage



"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.

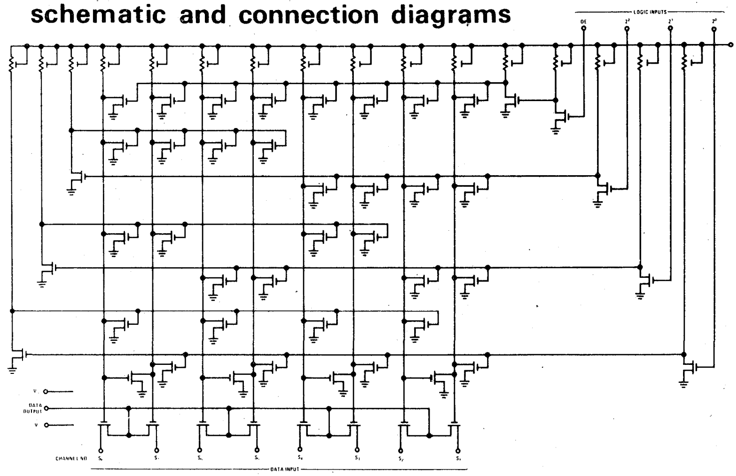
Important design features include:

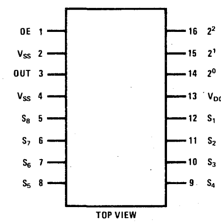
- TTL/DTL compatible input logic levels
- Operation from standard +5V and −15V supplies
- Wide analog voltage range — ±5V
- One-of-eight decoder on chip
- Output enable control
- Low ON resistance — 150Ω
- Input gate protection
- Low leakage currents — 0.5 nA

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.

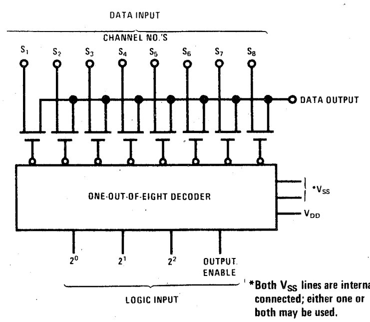
schematic and connection diagrams





Order Number
AM3705D or AM3705CD
See Package 2
AM3705F or AM3705CF
See Package 5

block diagram (MIL-STD-806B)



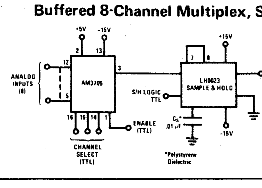
*Both V_{SS} lines are internally connected; either one or both may be used.

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 MIN	TYP	MAX	UNITS
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

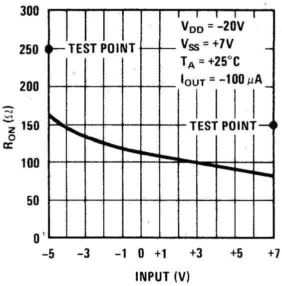
Note 1: All voltages referenced to V_{SS}.

Note 2: Ratings applies for ambient temperatures to +25°C, derate linearly at 3 mW/°C for ambient temperatures above +25°C.

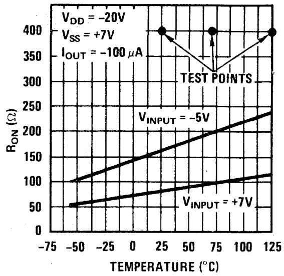
Note 3: Specifications apply for $T_A = 25°C$, $-24V \le V_{DD} \le -20V$, and $+5.0V \le V_{SS} \le +7.0V$; unless otherwise specified (all voltages are referenced to ground).

typical performance characteristics

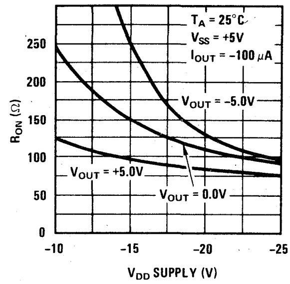
ON Resistance vs Analog Input Voltage



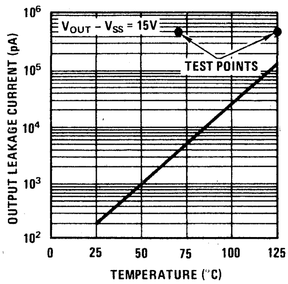
ON Resistance vs Ambient Temperature



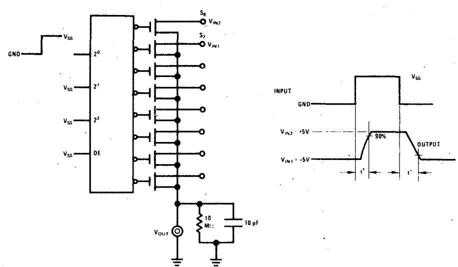
ON Resistance vs V_{DD} Supply Voltage



Output Leakage Current vs Ambient Temperature

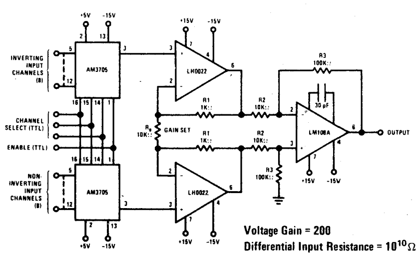


switching time test circuit



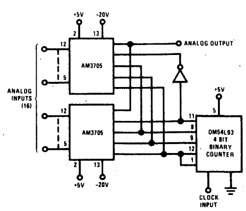
typical applications (con't.)

Differential Input MUX

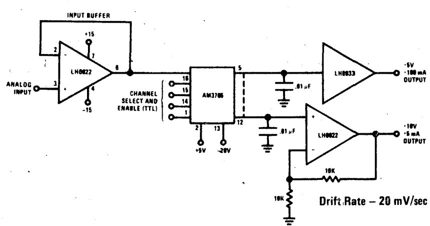


Voltage Gain = 200
Differential Input Resistance = 10^{10} Ω
CMRR = 100 dB
Input Current = 0.5 nA

16-Channel Commutator

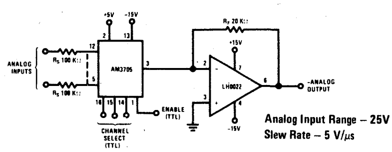


8-Channel Demultiplexer with Sample and Hold



Drift Rate – 20 mV/sec

Wide Input Range Analog Switch



Analog Input Range – 25V
Slew Rate – 5 V/μs

6

Analog Switches

AM9709, AM97C09, AH5009 series monolithic analog current switches

general description

A versatile family of monolithic JFET analog switches designed to economically fulfill a wide variety of multiplexing and analog switching applications.

Even numbered switches may be driven directly from standard 5V logic, whereas the odd numbered switches are intended for applications utilizing 10V or 15V logic. The monolithic construction guarantees tight resistance match and track.

The AM97C09 series is specifically intended to be driven from CMOS providing the best performance at lowest cost.

applications

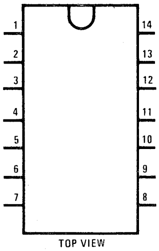
- AD/DA converters
- Micropower converters
- Industrial controllers
- Position controllers
- Data acquisition
- Active filters
- Signal multiplexers/demultiplexers
- Multiple channel AGC
- Quad compressors/expanders
- Choppers/demodulators
- Programmable gain amplifiers
- High impedance voltage buffer
- Sample and hold

features

- Interfaces with standard TTL and CMOS
- On-resistance match — 2 ohms
- Low "ON" resistance — 100 ohms
- Very low leakage — 50 pA
- Large analog signal range — ±10V peak
- High switching speed — 150 ns
- Excellent isolation between channels — 80 dB at 1 kHz

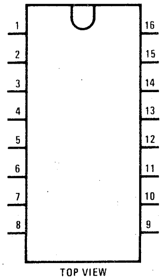
connection diagrams

Dual-In-Line Package



Order Number AM9709CN, AM9710CN, AM97C09CN, AM97C10CN, AH5009CN, AH5010CN, AH5013CN or AH5014CN
See Package 22

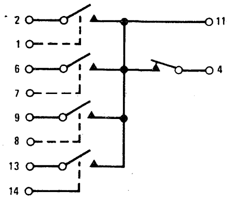
Dual-In-Line Package



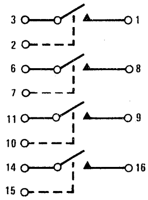
Order Number AM9711CN, AM9712CN, AM97C09CN, AM97C10CN, AH5011CN, AH5012CN, AH5015CN or AH5016CN
See Package 23

functional and schematic diagrams (Additional type on other pages)

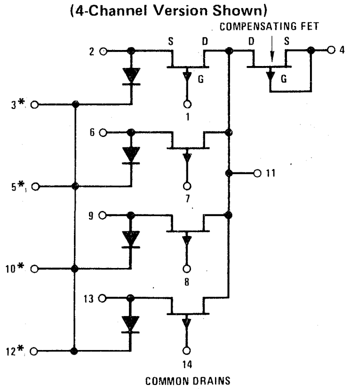
MUX Switches (4-Channel Version Shown)



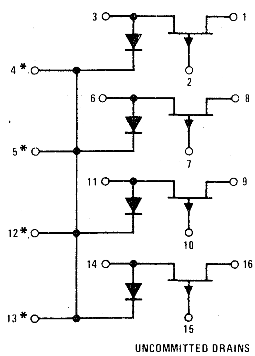
SPST Switches (Quad Version Shown)



MUX Switches (4-Channel Version Shown)



SPST Switches (Quad Version Shown)



*Note: All diode cathodes are internally connected to the substrate.

absolute maximum ratings

Input Voltage	
AM9709–12CN, AH5009–24CN	30V
AM97C09–12CN	25V
Positive Analog Signal Voltage	30V
Negative Analog Signal Voltage	–15V
Diode Current	10 mA
Drain Current	30 mA
Power Dissipation	500 mW
Operating Temperature Range	–25°C to +85°C
Storage Temperature Range	–65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics

AM9709, AM97C09, AH5009 (Notes 1 and 2)

PARAMETER		CONDITIONS	5V TTL AM9710CN AM9712CN		5V TTL AH5010–16 (EVEN SERIES)		5V–10V CMOS AM97C10CN AM9712CN		UNITS
			TYP	MAX	TYP	MAX	TYP	MAX	
I_{GSX}	Input Current "OFF"	V_{GD} = 11V, V_{SD} = 0.7V	0.01	2	0.01	0.2			nA
		T_A = 85°C		100		10			nA
I_{GSX}	Input Current "OFF"	V_{GD} = 15V, V_{SD} = 0.7V					0.01	2	nA
		T_A = 85°C						100	nA
$I_{D(OFF)}$	Leakage Current "OFF"	V_{SD} = 0.7V, V_{GS} = 3.8V	0.01	0.2	0.01	0.2			nA
		T_A = 85°C		10		10			nA
$I_{D(OFF)}$	Leakage Current "OFF"	V_{SD} = 0.7V, V_{GS} = 4.3V					0.01	2	nA
		T_A = 85°C						100	nA
$I_{G(ON)}$	Leakage Current "ON"	V_{GD} = 0V, I_S = 1 mA	0.08	1	0.08	1	0.08	1	nA
		T_A = 85°C		200		200		200	nA
$I_{G(ON)}$	Leakage Current "ON"	V_{GD} = 0V, I_S = 2 mA	0.13	5		1000	0.13	5	nA
		T_A = 85°C		10		10		10	μA
$I_{G(ON)}$	Leakage Current "ON"	V_{GD} = 0V, I_S = –2 mA	0.1	10		100	0.10	10	nA
		T_A = 85°C		20		100		20	μA
$r_{DS(ON)}$	Drain-Source Resistance	V_{GS} = 0.35V, I_S = 2 mA	90	150	90	150			Ω
		T_A = +85°C		240		240			Ω
$r_{DS(ON)}$	Drain-Source Resistance	V_{GS} = 0V, I_S = 2 mA					90	150	Ω
		T_A = 85°C						240	Ω
V_{DIODE}	Forward Diode Drop	I_D = 0.5 mA		0.8				0.8	V
$r_{DS(ON)}$	Match	V_{GS} = 0, I_D = 1 mA	4	20		50	4	20	Ω
T_{ON}	Turn "ON" Time	See ac Test Circuit	150	500	150	500	150	500	ns
T_{OFF}	Turn "OFF" Time	See ac Test Circuit	300	500	300	500	300	500	ns
CT	Cross Talk	See ac Test Circuit	120		120		120		dB

Note 1: Test conditions 25°C unless otherwise noted.
Note 2: "OFF" and "ON" notation refers to the conduction state of the FET switch.

6

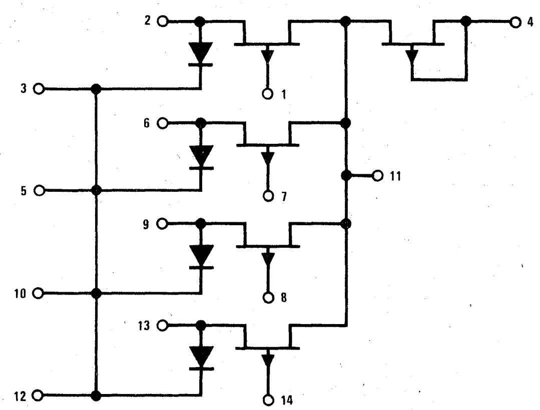
electrical characteristics (con't)

	PARAMETER	CONDITIONS	15V TTL		15V TTL		10–15V CMOS		UNITS
			AM9709CN AM9711CN		AH5009–15 (ODD SERIES)		AM97C09CN AM97C11CN		
			TYP	MAX	TYP	MAX	TYP	MAX	
I_{GSX}	Input Current "OFF"	V_{GD} = 11V, V_{SD} = 0.7V	0.01	2	0.01	0.2			nA
		T_A = 85°C		100		10			nA
I_{GSX}	Input Current "OFF"	V_{GD} = 15V, V_{SD} = 0.7V					0.01	2	nA
		T_A = 85°C						100	nA
$I_{D(OFF)}$	Leakage Current "OFF"	V_{SD} = 0.7V, V_{GS} = 9.3V					0.01	2	nA
		T_A = 85°C						100	nA
$I_{D(OFF)}$	Leakage Current "OFF"	V_{SD} = 0.7V, V_{GS} = 10.3V	0.01	2	0.01	0.2			nA
		T_A = 85°C		10		10			nA
$I_{G(ON)}$	Leakage Current "ON"	V_{GD} = 0V, I_S = 1 mA	0.04	0.5	0.04	0.5	0.04	0.5	nA
		T_A = 85°C		100		100		100	nA
$I_{G(ON)}$	Leakage Current "ON"	V_{GD} = 0V, I_S = 2 mA	0.07	2		2	0.07	2	nA
		T_A = 85°C		1		2		1	μA
$I_{G(ON)}$	Leakage Current "ON"	V_{GD} = 0V, I_S = −2 mA	0.05	5		100	0.05	5	nA
		T_A = 85°C		2		20		2	μA
$r_{DS(ON)}$	Drain-Source Resistance	V_{GS} = 0V, I_S = 2 mA					60	100	Ω
		T_A = 85°C						160	Ω
$r_{DS(ON)}$	Drain-Source Resistance	V_{GS} = 1.5V, I_S = 2 mA	60	100	60	100			Ω
		T_A = 85°C		160		160			Ω
V_{DIODE}	Forward Diode Drop	I_D = 0.5 mA		0.8				0.8	V
$r_{DS(ON)}$	Match	V_{GS} = 0, I_D = 1 mA	2	10		50	2	10	Ω
T_{ON}	Turn "ON" Time	See ac Test Circuit	150	500	150	500	150	500	ns
T_{OFF}	Turn "OFF" Time	See ac Test Circuit	300	500	300	500	300	500	ns
CT	Cross Talk	See ac Test Circuit	120		120		120		dB

schematic diagrams and pin connections

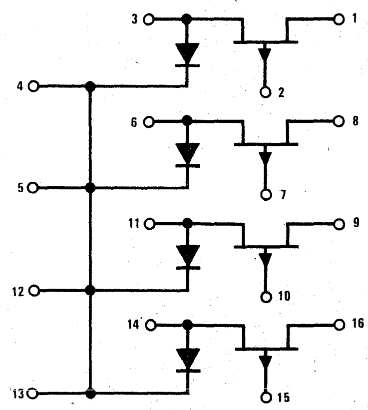
Four Channel

AM97C09CN ($R_{DS(ON)} \leq 100\Omega$, 10–15V CMOS)
AM97C10CN ($R_{DS(ON)} \leq 150\Omega$, 5–10V CMOS)
AM9709CN, AH5009CN ($R_{DS(ON)} \leq 100\Omega$, 15V TTL)
AM9710CN, AH5010CN ($R_{DS(ON)} \leq 150\Omega$, 5V TTL)



14-Pin DIP

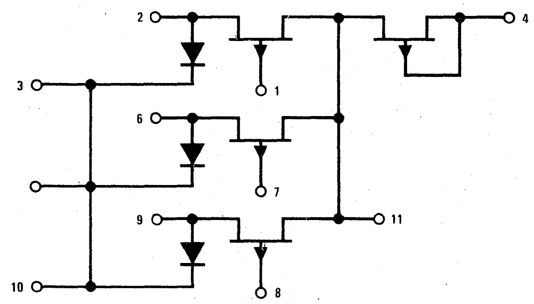
AM97C11CN ($R_{DS(ON)} \leq 100\Omega$, 10–15V CMOS)
AM97C12CN ($R_{DS(ON)} \leq 150\Omega$, 5–10V CMOS)
AM9711CN, AH5011CN ($R_{DS(ON)} \leq 100\Omega$, 15V TTL)
AM9712CN, AH5012CN ($R_{DS(ON)} \leq 150\Omega$, 5V TTL)



16-Pin DIP

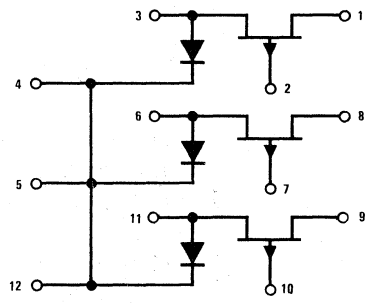
Three-Channel

AH5013CN ($R_{DS(ON)} \leq 100\Omega$, 15V TTL)
AH5014CN ($R_{DS(ON)} \leq 150\Omega$, 5V TTL)



14-Pin DIP

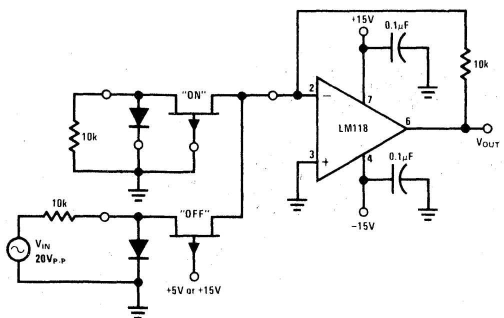
AH5015CN ($R_{DS(ON)} \leq 100\Omega$, 15V TTL)
AH5016CN ($R_{DS(ON)} \leq 150\Omega$, 5V TTL)



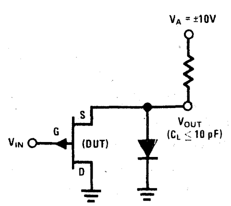
16-Pin DIP

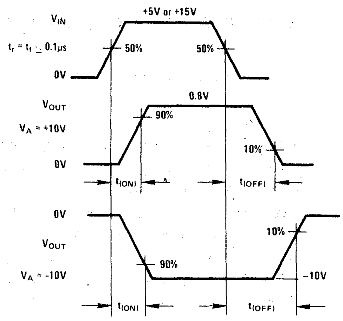
test circuits and switching time waveforms

Cross Talk Test Circuit



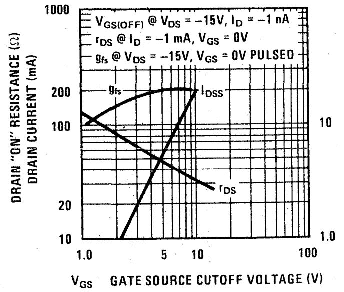
ac Test Circuit



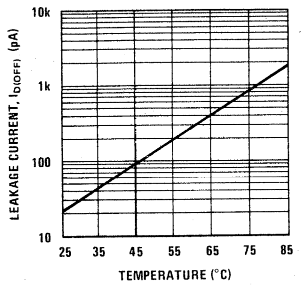


typical performance characteristics

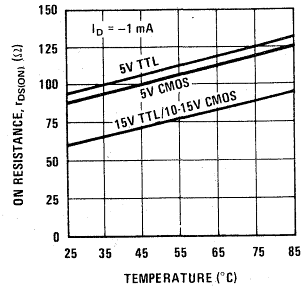
Parameter Interaction



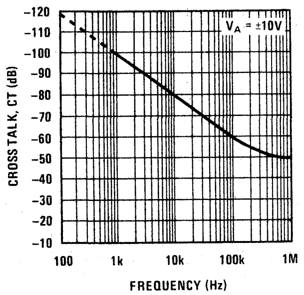
Leakage Current, $I_{D(OFF)}$ vs Temperature



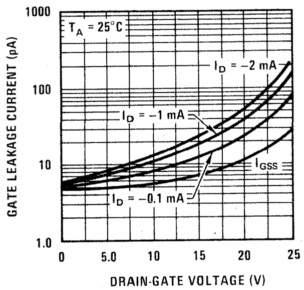
On Resistance, $r_{DS(ON)}$ vs Temperature



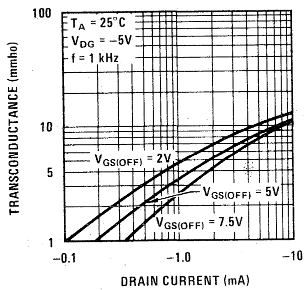
Cross Talk, CT vs Frequency



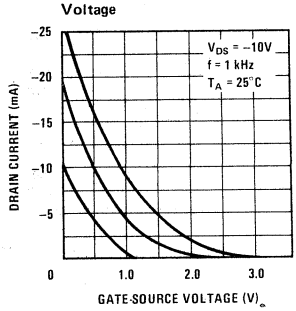
Leakage Current vs Drain-Gate Voltage



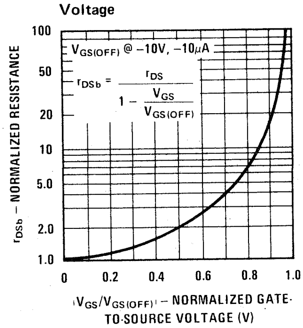
Transconductance vs Drain Current



Drain Current vs Bias Voltage



Normalized Drain Resistance vs Bias Voltage



applications information

Theory of Operation

The AM/AH 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 millivolts eliminates the need for a special gate driver, allowing the switches to be driven directly by standard TTL (AM9710), 5V–10V CMOS (AM97C10), open collector 15V TTL (AM9709), and 10–15V CMOS (AM97C09).

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 AM9709 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.*

applications information (con't)

The closed-loop gain of *Figure 1* is:

$$A_{VCL} = \frac{R2 + r_{DS(ON)Q2}}{R1 + r_{DS(ON)Q1}}$$

For R1 = R2, gain accuracy is determined by the $r_{DS(ON)}$ match between Q1 and Q2. Typical match between Q1 and Q2 is 4 ohms resulting in a gain accuracy of 0.05% (for R1 = R2 = 10 kΩ).

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 Q1 is clamped to about 0.7V by the diode (V_{GS} = 14.3V) ensuring that ac signals imposed on the 10V will not gate the FET "ON."

Selection of Gain Setting Resistors

Since the AM/AH 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 source to gate junction and the signal shunting diode resulting in leakage through these junctions. As shown in *Figure 2,* $I_{G(ON)}$ represents a finite error in the current reaching the summing junction of the op amp.

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:

$$R1_{(MIN)} \geq \frac{V_{A(MAX)}\,A_D}{I_{G(ON)}} \qquad (2a)$$

or:

$$\geq \frac{V_{A(MAX)}}{I_{DSS}/10} \qquad (2b)$$

whichever is worse.

Where: $V_{A(MAX)}$ = Peak amplitude of the analog input signal

A_D = Desired accuracy

$I_{G(ON)}$ = 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:

$$R1_{(MIN)} \geq \frac{10V}{\frac{20\ mA}{10}} = 5\ k\Omega$$

For R1 = 5k, I_S ≅ 10V/5k or 2 mA. The electrical characteristics guarantee an $I_{G(ON)} \leq 1\mu A$ at 85°C for the AM9710. Per the criterion of equation (2a):

$$R1_{(MIN)} \geq \frac{(10V)(10^{-3})}{1 \times 10^{-6}} \geq 10\ k\Omega$$

Since equation (2a) predicts a higher value, the 10k resistor should be used.

The "OFF" condition of the FET also affects gain accuracy. As shown in *Figure 3,* the leakage across Q2, $I_{D(OFF)}$ represents a finite error in the current arriving at the summing junction of the op amp.

Accordingly:

$$R1_{(MAX)} \leq \frac{V_{A(MIN)}\,A_D}{(N)\,I_{D(OFF)}}$$

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 $I_{D(OFF)}$ ≤ 10 nA at 85°C for the AM9709, $R1_{(MAX)}$ is:

$$R1_{(MAX)} \leq \frac{(1V)(10^{-3})}{(10)(10 \times 10^{-9})} = 10k$$

Selection of R2, of course, depends on the gain desired and for unity gain R1 = R2.

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.

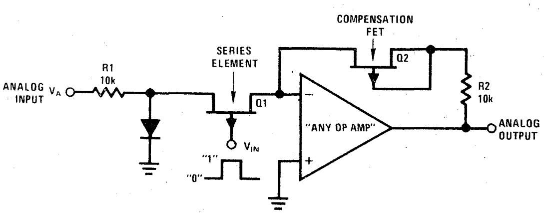


FIGURE 1. Use of Compensation FET

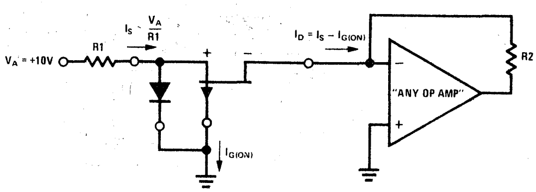


FIGURE 2. On Leakage Current, $I_{G(ON)}$

applications information (con't)

TTL Compatibility

Two input logic drive versions of AM/AH 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 AM9710, 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.

CMOS Compatibility

The cost effective AM97C09 series of switches is optimized for CMOS drive without resistor pull-up. The AM97C10's and AM97C12's are specified for 5V–10V operation while the AM97C09's and AM97C11's are specified for 10V–15V operation.

Definition of Terms

The terms referred to in the electrical characteristics tables are as defined in *Figure 6.*

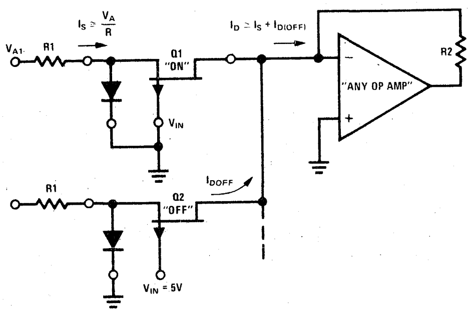


FIGURE 3.

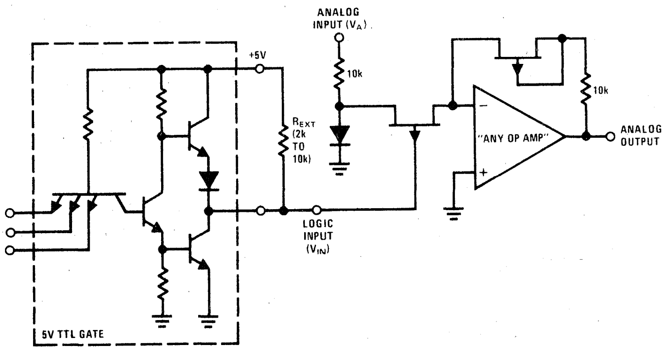


FIGURE 4. Interfacing with +5V TTL

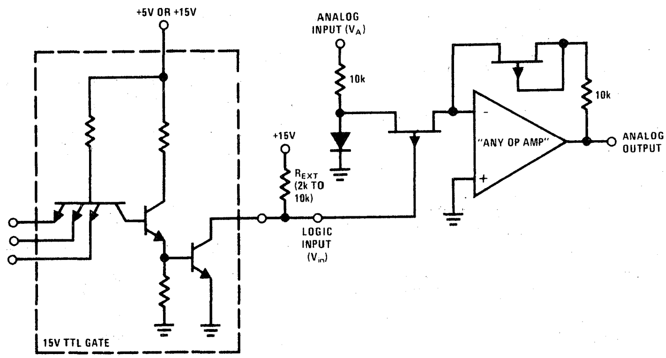


FIGURE 5. Interfacing with +15V Open Collector TTL

applications information (con't)

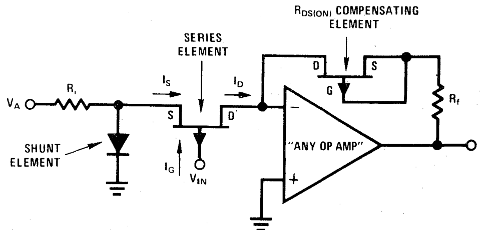
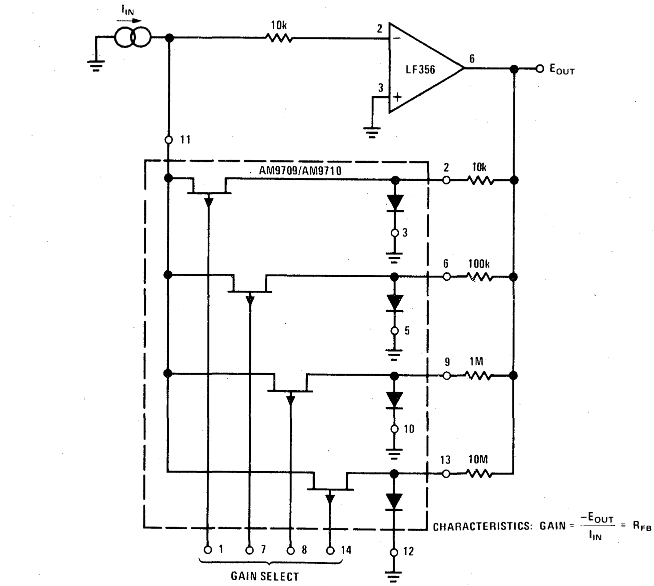


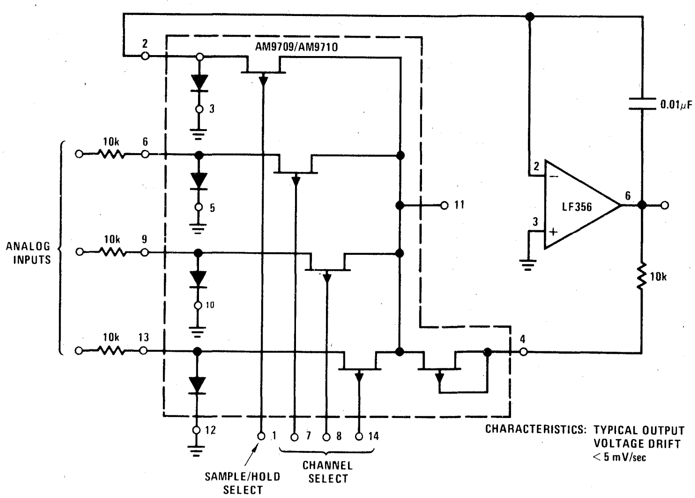
FIGURE 6. Definition of Terms

typical applications

Gain Programmable Amplifier



3-Channel Multiplexer with Sample and Hold



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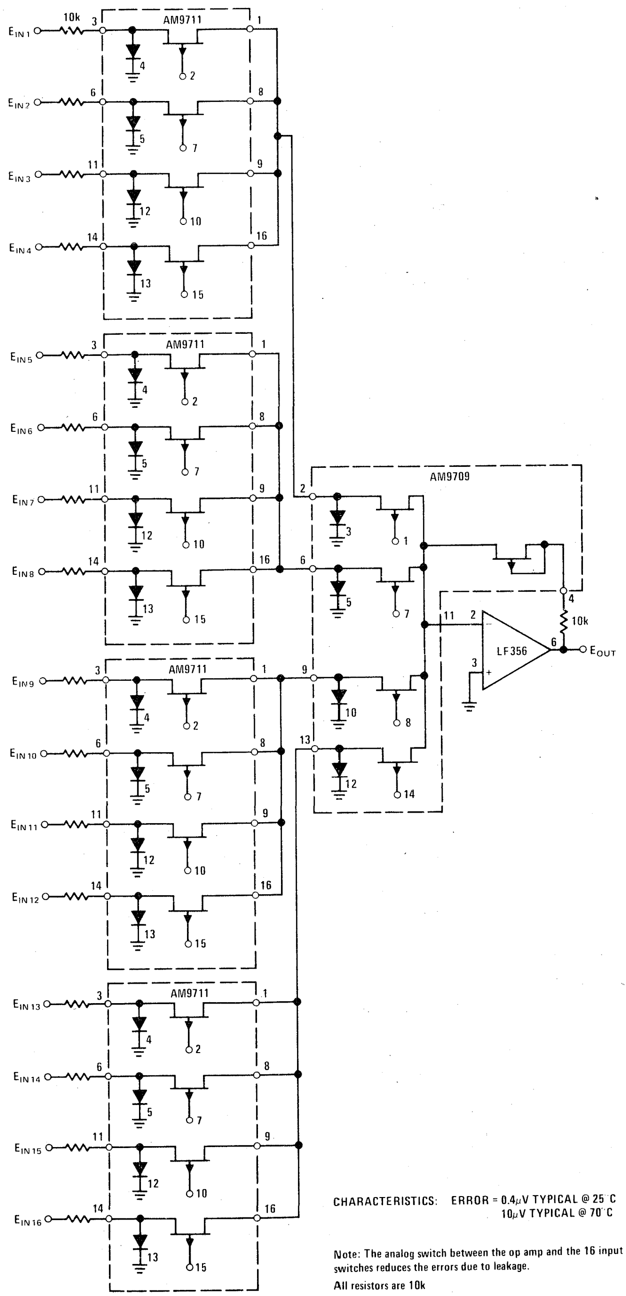
typical applications (con't)

16-Channel Multiplexer

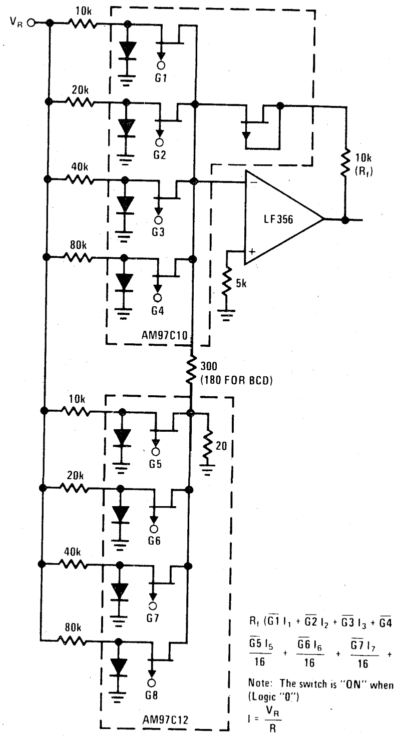


CHARACTERISTICS: ERROR = 0.4μV TYPICAL @ 25°C
10μV TYPICAL @ 70°C

Note: The analog switch between the op amp and the 16 input switches reduces the errors due to leakage.
All resistors are 10k

typical applications (con't)

8-Bit Binary (BCD) Multiplying D/A Converter



$$R_f\left(\overline{G1}\,I_1 + \overline{G2}\,I_2 + \overline{G3}\,I_3 + \overline{G4}\,I_4 + \frac{\overline{G5}\,I_5}{16} + \frac{\overline{G6}\,I_6}{16} + \frac{\overline{G7}\,I_7}{16} + \frac{\overline{G8}\,I_8}{16}\right.$$

Note: The switch is "ON" when G is at 0V (Logic "0")

$$I = \frac{V_R}{R}$$

Analog Switches

CD4007M/CD4007C dual complementary pair plus inverter

general description

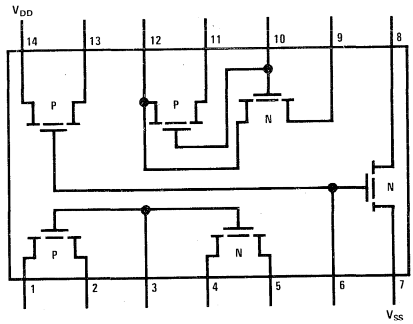
The CD4007M/CD4007C consists of three complementary pairs of N-channel and P-channel enhancement mode MOS transistors suitable for series/shunt applications. All inputs are protected from static discharge by diode clamps to V_{DD} and V_{SS}.

For proper operation the voltages at all pins must be constrained to be between V_{SS} − 0.3V and V_{DD} + 0.3V at all times.

features

- Wide supply voltage range — 3.0V to 15V
- High noise immunity — 0.45 V_{CC} typ

connection diagram



TOP VIEW

Note: All P-channel substrates are connected to V_{DD}, and all N-channel substrates are connected to V_{SS}.

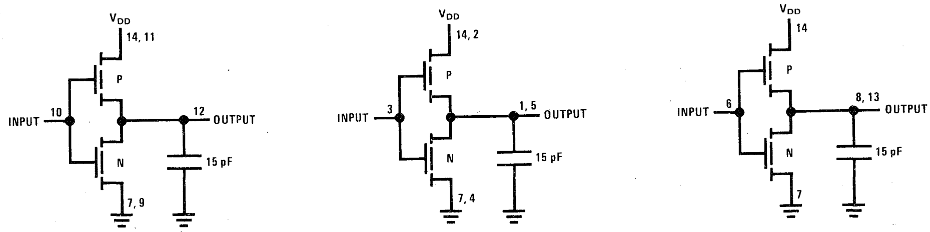
Order Number CD4007MD
See Package 1

Order Number CD4007MF
See Package 4

Order Number CD4007CJ
or CD4007MJ
See Package 16

Order Number CD4007CN
See Package 22

ac test circuits



absolute maximum ratings (Note 1)

Voltage at Any Pin	V_{SS} − 0.3V to V_{DD} + 0.3V
Operating Temperature Range	
CD4007M	−55°C to +125°C
CD4007C	−40°C to +85°C
Storage Temperature Range	−65°C to +150°C
Package Dissipation	500 mW
Operating V_{DD} Range	V_{SS} + 3.0V to V_{SS} + 15V
Lead Temperature (Soldering, 10 seconds)	300°C

dc electrical characteristics CD4007M

PARAMETER	CONDITIONS	LIMITS −55°C MIN	TYP	MAX	25°C MIN	TYP	MAX	125°C MIN	TYP	MAX	UNITS
Quiescent Device Current (I_L)	V_{DD} = 5V			0.05		0.001	0.05			3	µA
	V_{DD} = 10V			0.1		0.001	0.1			6	µA
Quiescent Device Dissipation/Package (P_D)	V_{DD} = 5V			0.25		0.005	0.25			15	µW
	V_{DD} = 10V			1		0.01	1			60	µW
Output Voltage Low Level (V_{OL})	V_{DD} = 5V			0.01		0	0.01			0.05	V
	V_{DD} = 10V			0.01		0	0.01			0.05	V
Output Voltage High Level (V_{OH})	V_{DD} = 5V	4.99			4.99	5		4.95			V
	V_{DD} = 10V	9.99			9.99	10		9.95			V
Noise Immunity (V_{NL}) (All Inputs)	V_{DD} = 5V, V_O = 3.6V	1.5			1.5	2.25		1.4			V
	V_{DD} = 10V, V_O = 7.2V	3			3	4.5		2.9			V
Noise Immunity (V_{NH}) (All Inputs)	V_{DD} = 5V, V_O = 0.95V	1.4			1.5	2.25		1.5			V
	V_{DD} = 10V, V_O = 2.9V	2.9			3	4.5		3			V
Output Drive Current N-Channel (I_DN)	V_{DD} = 5V, V_O = 0.4V, V_I = V_{DD}	0.75			0.6	1		0.4			mA
	V_{DD} = 10V, V_O = 0.5V, V_I = V_{DD}	1.6			1.3	2.5		0.95			mA
Output Drive Current P-Channel (I_DP)	V_{DD} = 5V, V_O = 2.5V, V_I = V_{SS}	−1.75			−1.4	−4		−1			mA
	V_{DD} = 10V, V_O = 9.5V, V_I = V_{SS}	−1.35			−1.1	−2.5		−0.75			mA
Input Current (I_I)						10					pA

dc electrical characteristics CD4007C

PARAMETER	CONDITIONS	LIMITS −40°C MIN	TYP	MAX	25°C MIN	TYP	MAX	85°C MIN	TYP	MAX	UNITS
Quiescent Device Current (I_L)	V_{DD} = 5V			0.5		0.005	0.5			15	µA
	V_{DD} = 10V			1		0.005	1			30	µA
Quiescent Device Dissipation/Package (P_D)	V_{DD} = 5V			2.5		0.025	2.5			75	µW
	V_{DD} = 10V			10		0.05	10			300	µW
Output Voltage Low Level (V_{OL})	V_{DD} = 5V			0.01		0	0.01			0.05	V
	V_{DD} = 10V			0.01		0	0.01			0.05	V
Output Voltage High Level (V_{OH})	V_{DD} = 5V	4.99			4.99	5		4.95			V
	V_{DD} = 10V	9.99			9.99	10		9.95			V
Noise Immunity (V_{NL}) (All Inputs)	V_{DD} = 5V, V_O = 3.6V	1.5			1.5	2.25		1.4			V
	V_{DD} = 10V, V_O = 7.2V	3			3	4.5		2.9			V
Noise Immunity (V_{NH}) (All Inputs)	V_{DD} = 5V, V_O = 0.95V	1.4			1.5	2.25		1.5			V
	V_{DD} = 10V, V_O = 2.9V	2.9			3	4.5		3			V
Output Drive Current N-Channel (I_DN)	V_{DD} = 5V, V_O = 0.4V, V_I = V_{DD}	0.35			0.3	1		0.24			mA
	V_{DD} = 10V, V_O = 0.5V, V_I = V_{DD}	1.2			1	2.5		0.8			mA
Output Drive Current P-Channel (I_DP)	V_{DD} = 5V, V_O = 2.5V, V_I = V_{SS}	−1.3			−1.1	−4		−0.9			mA
	V_{DD} = 10V, V_O = 9.5V, V_I = V_{SS}	−0.65			−0.55	−2.5		−0.45			mA
Input Current (I_I)						10					pA

Note 1: This device should not be connected to circuits with the power on because high transient voltages may cause permanent damage.

ac electrical characteristics CD4007M

$T_A = 25°C$ and $C_L = 15$ pF and input rise and fall times = 20 ns. Typical temperature coefficient for all values of $V_{DD} = 0.3\%/°C$.

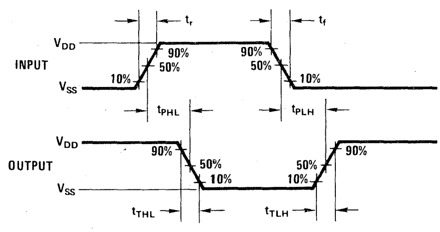
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Propagation Delay Time ($t_{PLH} = t_{PHL}$)	$V_{DD} = 5V$		35	60	ns
	$V_{DD} = 10V$		20	40	ns
Transition Time ($t_{TLH} = t_{THL}$)	$V_{DD} = 5V$		50	75	ns
	$V_{DD} = 10V$		30	40	ns
Input Capacitance (C_I)	Any Input		5		pF

ac electrical characteristics CD4007C

$T_A = 25°C$ and $C_L = 15$ pF and input rise and fall times = 20 ns. Typical temperature coefficient for all values of $V_{DD} = 0.3\%/°C$.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Propagation Delay Time ($t_{PLH} = t_{PHL}$)	$V_{DD} = 5V$		35	75	ns
	$V_{DD} = 10V$		20	50	ns
Transition Time ($t_{TLH} = t_{THL}$)	$V_{DD} = 5V$		50	100	ns
	$V_{DD} = 10V$		30	50	ns
Input Capacitance (C_I)	Any Input		5		pF

switching time waveforms



$t_r = t_f = 20$ ns

Analog Switches

CD4016M/CD4016C quad bilateral switch

general description

The CD4016M/CD4016C is a quad bilateral switch which utilizes P-channel and N-channel complementary MOS (CMOS) circuits to provide an extremely high "OFF" resistance and low "ON" resistance switch. The switch will pass signals in either direction and is extremely useful in digital switching.

- Extremely low leakage — $V_{is} = 5\ V_{p\text{-}p}$, $V_{DD} - V_{SS} = 10V$, $R_L = 10\ k\Omega$
- Transmits frequencies up to 10 MHz

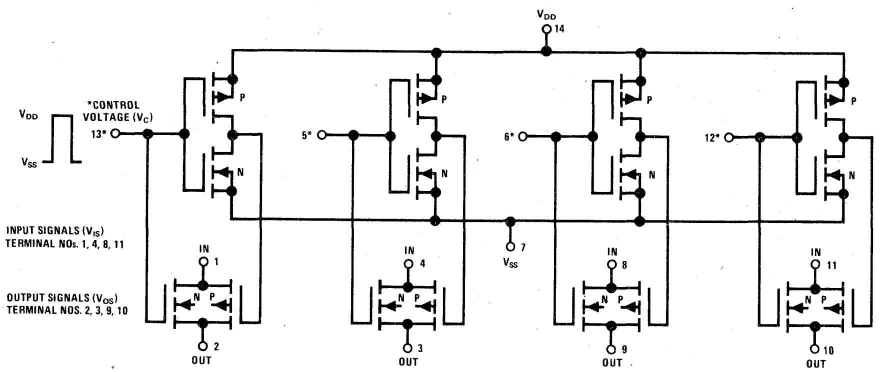
features

- Wide supply voltage range — 3V to 15V
- High noise immunity — 0.45 V_{CC} typ.
- Wide range of digital and analog levels — ±7.5 V_{PEAK}
- Low "ON" resistance — 300Ω typ. $V_{DD} - V_{SS} = 15V$
- Matched switch characteristics — $\Delta R_{ON} = 40\Omega$ typ.
- High "ON/OFF" output voltage ratio — 65 dB typ. @ $f_{is} = 10$ kHz, $R_L = 10k$
- High degree of linearity — .5% distortion typ. @ $f_{is} = 1$ kHz

applications

- Analog signal switching/multiplexing
  - Signal gating
  - Squelch control
  - Chopper
  - Modulator
  - Demodulator
  - Commutating switch
- Digital signal switching/multiplexing
- CMOS logic implementation
- Analog to digital/digital to analog conversion
- Digital control of frequency, impedance, phase, and analog-signal gain

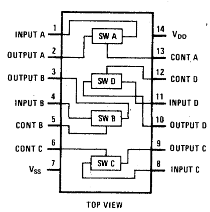
schematic and connection diagrams



Note 1: All switch P-channel substrates are internally connected to terminal No. 14.
Note 2: All switch N-channel substrates are internally connected to terminal No. 7.

Signal-level range: $V_{SS} < V_{is} > V_{DD}$

Normal operation: Control-line biasing, switch ON V_C "1" = V_{DD}, switch OFF V_C "0" = V_{SS}



TOP VIEW

Order Number CD4016MD
See Package 1
Order Number CD4016MF
See Package 4
Order Number CD4016CJ or CD4016MJ
See Package 16
Order Number CD4016CN
See Package 22

absolute maximum ratings

Voltage at Any Pin (Note 1)		V_{SS} −0.3V to V_{SS} +15.5V
Operating Temperature Range	CD4016M	−55°C to +125°C
	CD4016C	−40°C to +85°C
Storage Temperature Range		−65°C to +150°C
Package Dissipation		500 mW
Lead Temperature (Soldering, 10 sec)		300°C
Operating V_{DD} Range		V_{SS} +3V to V_{SS} +15V

electrical characteristics CD4016M

CHARACTERISTIC	SYMBOL	TEST CONDITIONS	LIMITS −55°C MIN	−55°C TYP	−55°C MAX	25°C MIN	25°C TYP	25°C MAX	125°C MIN	125°C TYP	125°C MAX	UNITS
Quiescent Dissipation per Package		TERMINALS / VOLTS APPLIED										
All Switches "OFF"	P_T	V_{DD} 14 +10 V_{SS} 7 GND V_C 5, 6, 12, 13 GND V_{is} 1, 4, 8, 11 ≤ +10 V_{os} 2, 3, 9, 10 ≤ +10			5		0.1	5			300	µW
All Switches "ON"	P_T	TERMINALS / VOLTS APPLIED V_{DD} 14 +10 V_{SS} 7 GND V_C 5, 6, 12, 13 +10 $V_{is} = V_{OS}$ 1-4, 8-11 ≤ +10			5		0.1	5			300	µW
Threshold Voltage N-Channel	$V_{TH}N$	I_{DS} = 10 µA V_{DD} = 5V, 10V, or 15V		1.7			1.5			1.3		V
P-Channel	$V_{TH}P$	I_{DS} = −10 µA V_{DD} = 5V, 10V, or 15V		−1.7			−1.5			−1.3		V
SIGNAL INPUTS (V_{is}) AND OUTPUTS (V_{os})		$V_C = V_{DD}$ / V_{SS} / V_{is}										
"ON" Resistance	R_{ON}	R_L = 10kΩ; +7.5V, −7.5V, +7.5V		120	360		200	400		300	600	Ω
		+7.5V, −7.5V, −7.5V		120	360		200	400		300	600	Ω
		+7.5V, −7.5V, ±0.25V		130	775		280	850		470	1230	Ω
		+5V, −5V, +5V		130	600		250	660		400	960	Ω
		+5V, −5V, −5V		130	600		250	660		400	960	Ω
		+5V, −5V, ±0.25V		325	1870		580	2000		900	2600	Ω
		+15V, 0V, +15V		120	360		200	400		300	600	Ω
		+15V, 0V, +0.25V		120	360		200	400		300	600	Ω
		+15V, 0V, 9.3V		150	775		300	850		490	1230	Ω
		+10V, 0V, +10V		130	600		250	660		400	960	Ω
		+10V, 0V, +0.25V		130	600		250	660		400	960	Ω
		+10V, 0V, 5.6V		300	1870		560	2000		880	2600	Ω
Δ "ON" Resistance Between Any 2 of 4 Switches	ΔR_{ON}	+7.5V, −7.5V, ±7.5V					10					Ω
		+5V, −5V, ±5V					15					Ω
Sine Wave Response (Distortion)		R_L = 10 kΩ, f_{is} = 1 kHz; +5V, −5V, 5V(p-p) (Note 3)					0.4					%
Input or Output Leakage—Switch "OFF" (Effective "OFF" Resistance)		V_{DD} / $V_C = V_{SS}$ / V_{is}: +7.5V, −7.5V, +7.5V					±100					pA
		+7.5V, −7.5V, −7.5V					±100					pA
		+5V, −5V, +5V					(Note 2)	125				nA
		+5V, −5V, −5V					(Note 2)	125				nA
Frequency Response—Switch "ON" (Sine Wave Input)		$V_C = V_{DD}$ = +5V, V_{SS} = −5V R_L = 1 kΩ, V_{is} = 5V(p-p) $20 \log_{10} \frac{V_{os}}{V_{is}} = -3$ dB					40					MHz
Feedthrough Switch "OFF"		V_{DD} = +5V, $V_C = V_{SS}$ = −5V $20 \log_{10} \frac{V_{os}}{V_{is}} = -50$ dB					1.25					MHz
Crosstalk Between any 2 of the 4 switches (Frequency at −50 dB)		R_L = 1 kΩ, $V_{is}(A)$ = 5V(p-p) $V_C(A) = V_{DD}$ = +5V $V_C(B) = V_{SS}$ = −5V $20 \log_{10} \frac{V_{os}(B)}{V_{is}(A)} = -50$ dB					0.9					MHz
Capacitance Input	C_{IS}	V_{DD} = +5V, $V_C = V_{SS}$ = −5V					4					pF
Output	C_{OS}						4					pF
Feedthrough	C_{IOS}						0.2					pF
Propagation Delay Signal Input to Signal Output	t_{pd}	$V_C = V_{DD}$ = +10V, V_{SS} = GND, C_L = 15 pF V_{is} = 10V (square wave) $t_r = t_f$ = 20 ns (input signal)					10					ns
CONTROL (V_C)												
Switch Threshold Voltage	$V_{TH}C$	$V_{is} \le V_{DD}$; $V_{DD} - V_{SS}$ = 15V, 10V, 5V; I_{IS} = 10 µA	0.7		2.9	0.5	1.5	2.7	0.2		2.4	V
Input Current	I_C	$V_{DD} - V_{SS}$ = 10V $V_C \le V_{DD} - V_{SS}$					±10					pA
Average Input Capacitance	C_C						5					pF
Crosstalk — Control Input to Signal Output		$V_{DD} - V_{SS}$ = 10V, R_L = 10 kΩ V_C = 10V (square wave)					50					mV
Turn "ON" Propagation Delay	$t_{pd}C$	$t_{rc} = t_{fc}$ = 20 ns, $V_{is} <$ 10V, C_L = 15 pF					20					ns
Maximum Allowable Control Input Repetition Rate		V_{DD} = 10V, V_{SS} = GND, R_L = 1 kΩ C_L = 15 pF V_C = 10V (square wave) $t_r = t_f$ = 20 ns					10					MHz

Note 1: The device should not be connected to circuits with the power on.
Note 2: ±10 X 10^{-3}.
Note 3: Symmetrical about 0V.

electrical characteristics CD4016C

CHARACTERISTIC	SYMBOL	TEST CONDITIONS	-40°C MIN	-40°C TYP	-40°C MAX	25°C MIN	25°C TYP	25°C MAX	85°C MIN	85°C TYP	85°C MAX	UNITS
Quiescent Dissipation per Package												
All Switches "OFF"	P_T	TERMINALS / VOLTS APPLIED: V_{DD} 14 +10; V_{SS} 7 GND; V_C 5, 6, 12, 13 GND; V_{is} 1, 4, 8, 11 ≤ +10; V_{os} 2, 3, 9, 10 ≤ +10			5		0.1	5			80	µW
All Switches "ON"	P_T	TERMINALS / VOLTS APPLIED: V_{DD} 14 +10; V_{SS} 7 GND; V_C 5, 6, 12, 13 +10; $V_{is} = V_{OS}$ 1-4, 8-11 ≤ +10			5		0.1	5			80	µW
Threshold Voltage N-Channel	$V_{TH}N$	I_{DS} = 10 µA, V_{DD} = 5V, 10V, or 15V		1.7			1.5			1.3		V
P-Channel	$V_{TH}P$	I_{DS} = 10 µA, V_{DD} = 5V, 10V, or 15V		-1.7			-1.5			-1.3		V
SIGNAL INPUTS (V_{is}) AND OUTPUTS (V_{os})												
"ON" Resistance	R_{ON}	R_L = 10kΩ; $V_C = V_{DD}$ +7.5V, V_{SS} -7.5V, V_{is} +7.5V		130	370		200	400		260	520	Ω
		$V_C = V_{DD}$ +7.5V, V_{SS} -7.5V, V_{is} -7.5V		130	370		200	400		260	520	Ω
		$V_C = V_{DD}$ +7.5V, V_{SS} -7.5V, V_{is} ±0.25V		160	790		280	850		400	1080	Ω
		$V_C = V_{DD}$ +5V, V_{SS} -5V, V_{is} +5V		150	610		250	660		340	840	Ω
		$V_C = V_{DD}$ +5V, V_{SS} -5V, V_{is} -5V		150	610		250	660		340	840	Ω
		$V_C = V_{DD}$ +5V, V_{SS} -5V, V_{is} ±0.25V		370	1900		580	2000		770	2380	Ω
		$V_C = V_{DD}$ +15V, V_{SS} 0V, V_{is} +15V		130	370		200	400		260	520	Ω
		$V_C = V_{DD}$ +15V, V_{SS} 0V, V_{is} +0.25V		130	370		200	400		260	520	Ω
		$V_C = V_{DD}$ +15V, V_{SS} 0V, V_{is} 9.3V		180	790		300	850		400	1080	Ω
		$V_C = V_{DD}$ +10V, V_{SS} 0V, V_{is} +10V		150	610		250	660		340	840	Ω
		$V_C = V_{DD}$ +10V, V_{SS} 0V, V_{is} +0.25V		150	610		250	660		340	2380	Ω
		$V_C = V_{DD}$ +10V, V_{SS} 0V, V_{is} 5.6V		350	1900		560	2000		750	2380	Ω
Δ "ON" Resistance Between Any 2 of 4 Switches	ΔR_{ON}	+7.5V, -7.5V, ±7.5V					10					Ω
		+5V, -5V, ±5V					15					Ω
Sine Wave Response (Distortion)		R_L = 10 kΩ, f_{is} = 1 kHz; +5V, -5V, 5V(p-p) (Note 3)					0.4					%
Input or Output Leakage—Switch "OFF" (Effective "OFF" Resistance)		V_{DD} +7.5V, $V_C = V_{SS}$ -7.5V, V_{is} +7.5V					±100					pA
		V_{DD} +7.5V, $V_C = V_{SS}$ -7.5V, V_{is} -7.5V					±100					pA
		V_{DD} +5V, $V_C = V_{SS}$ -5V, V_{is} +5V					(Note 2)	125				nA
		V_{DD} +5V, $V_C = V_{SS}$ -5V, V_{is} -5V					(Note 2)	125				nA
Frequency Response— Switch "ON" (Sine Wave Input)		R_L = 1 kΩ, V_{is} = 5V(p-p); $V_C = V_{DD}$ = +5V, V_{SS} = -5V; $20 \log_{10} \frac{V_{os}}{V_{is}} = -3$ dB					40					MHz
Feedthrough Switch "OFF"		R_L = 1 kΩ, V_{is} = 5V(p-p); V_{DD} = +5V, $V_C = V_{SS}$ = -5V; $20 \log_{10} \frac{V_{os}}{V_{is}} = -50$ dB					1.25					MHz
Crosstalk Between any 2 of the 4 switches (Frequency at -50 dB)		R_L = 1 kΩ, $V_{is}(A)$ = 5V(p-p); $V_C(A) = V_{DD}$ = +5V, $V_C(B) = V_{SS}$ = -5V; $20 \log_{10} \frac{V_{os}(B)}{V_{is}(A)} = -50$ dB					0.9					MHz
Capacitance Input	C_{IS}	V_{DD} = +5V, $V_C = V_{SS}$ = -5V					4					pF
Output	C_{OS}						4					pF
Feedthrough	C_{IOS}						0.2					pF
Propagation Delay Signal Input to Signal Output	t_{pd}	$V_C = V_{DD}$ = +10V, V_{SS} = GND, C_L = 15 pF; V_{is} = 10V (square wave); $t_r = t_f$ = 20 ns (input signal)					10					ns
CONTROL (V_C)												
Switch Threshold Voltage	$V_{TH}C$	$V_{is} < V_{DD}$; $V_{DD} - V_{SS}$ = 15V, 10V, 5V; I_{IS} = 10 µA				0.5	1.5	2.7				V
Input Current	I_C	$V_{DD} - V_{SS}$ = 10V; $V_C < V_{DD} - V_{SS}$					±10					pA
Average Input Capacitance	C_C						5					pF
Crosstalk – Control Input to Signal Output		$V_{DD} - V_{SS}$ = 10V, V_C = 10V (square wave); R_L = 10 kΩ					50					mV
Turn "ON" Propagation Delay	$t_{pd}C$	t_{rc} = t_{fc} = 20 ns; $V_{is} < 10V$, C_L = 15 pF					20					ns
Maximum Allowable Control Input Repetition Rate		V_{DD} = 10V, V_{SS} = GND, R_L = 1 kΩ; C_L = 15 pF; V_C = 10V (square wave); $t_r = t_f$ = 20 ns					10					MHz

Note 1: The device should not be connected to circuits with the power on.

Note 2: $\pm 10 \times 10^{-3}$.

Note 3: Symmetrical about 0V.

typical ON resistance characteristics

CHARACTERISTIC*	SUPPLY CONDITIONS		LOAD CONDITIONS					
			R_L = 1 kΩ		R_L = 10 kΩ		R_L = 100 kΩ	
	V_{DD} (V)	V_{SS} (V)	VALUE (Ω)	V_{is} (V)	VALUE (Ω)	V_{is} (V)	VALUE (Ω)	V_{is} (V)
R_{ON}	+15	0	200	+15	200	+15	180	+15
			200	0	200	0	200	0
R_{ON} (max.)	+15	0	300	+11	300	+9.3	320	+9.2
R_{ON}	+10	0	290	+10	250	+10	240	+10
			290	0	250	0	300	0
R_{ON} (max.)	+10	0	500	+7.4	560	+5.6	610	+5.5
R_{ON}	+5	0	860	+5	470	+5	450	+5
			600	0	580	0	800	0
R_{ON} (max.)	+5	0	1.7k	+4.2	7k	+2.9	33k	+2.7
R_{ON}	+7.5	−7.5	200	+7.5	200	+7.5	180	+7.5
			200	−7.5	200	−7.5	180	−7.5
R_{ON} (max.)	+7.5	−7.5	290	±0.25	280	±25	400	±0.25
R_{ON}	+5	−5	260	+5	250	+5	240	+5
			310	−5	250	−5	240	−5
R_{ON} (max.)	+5	−5	600	±0.25	580	±0.25	760	±0.25
R_{ON}	+2.5	−2.5	590	+2.5	450	+2.5	490	+2.5
			720	−2.5	520	−2.5	520	−2.5
R_{ON} (max.)	+2.5	−2.5	232k	±0.25	300k	±0.25	870k	±0.25

*Variation from a perfect switch: R_{ON} = 0Ω.

Analog Switches

CD4051M/CD4051C single 8-channel analog multiplexer/demultiplexer
CD4052M/CD4052C dual 4-channel analog multiplexer/demultiplexer
CD4053M/CD4053C triple 2-channel analog multiplexer/demultiplexer

general description

These analog multiplexers/demultiplexers are digitally controlled analog switches having low "ON" impedance and very low "OFF" leakage currents. Control of analog signals up to 15 Vp-p can be achieved by digital signal amplitudes of 3–15V. For example, if V_{DD} = 5V, V_{SS} = 0V and V_{EE} = –5V, analog signals from –5V–+5V can be controlled by digital inputs of 0–5V. The multiplexer circuits dissipate, extremely low quiescent power over the full $V_{DD} - V_{SS}$ and $V_{DD} - V_{EE}$ supply-voltage ranges, independent of the logic state of the control signals. When a logical "1" is present at the inhibit input terminal all channels are "OFF."

CD4051M/CD4051C is a single 8-channel multiplexer having three binary control inputs, A, B and C, and an inhibit input. The three binary signals select 1 of 8 channels to be turned "ON" and connect the input to the output.

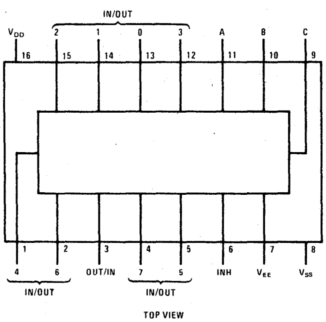
CD4052M/CD4052C is a differential 4-channel multiplexer having two binary control inputs, A and B, and an inhibit input. The two binary input signals select 1 of 4 pairs of channels to be turned on and connect the differential analog inputs to the differential outputs.

CD4053M/CD4053C is a triple 2-channel multiplexer having three separate digital control inputs, A, B and C and an inhibit input. Each control input selects one of a pair of channels which are connected in a single-pole double-throw configuration.

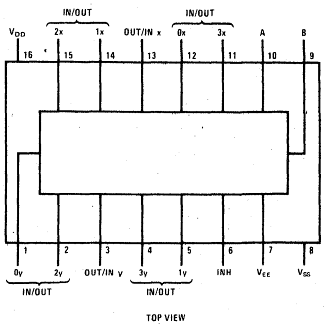
features

- Wide range of digital and analog signal levels: digital 3–15V, analog to 15 Vp-p
- Low "ON" resistance: 80Ω (typ) over entire 15 Vp-p signal-input range for $V_{DD} - V_{EE}$ = 15V
- High "OFF" resistance: input leakage ±10 pA (typ) at $V_{DD} - V_{EE}$ = 10V
- Logic level conversion for digital addressing signals of 3–15V ($V_{DD} - V_{SS}$ = 3–15V) to switch analog signals to 15 Vp-p ($V_{DD} - V_{EE}$ = 15V)
- Matched switch characteristics: ΔR_{ON} = 5Ω (typ) for $V_{DD} - V_{EE}$ = 15V
- Very low quiescent power dissipation under all digital-control input and supply conditions: 1µW typ at $V_{DD} - V_{SS} = V_{DD} - V_{EE}$ = 10V
- Binary address decoding on chip

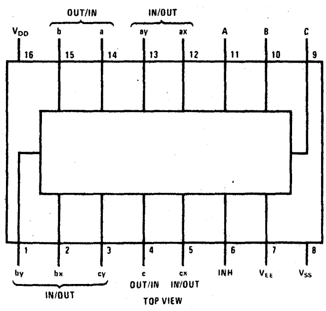
connection diagrams (Dual-In-Line and Flat Packages)



Order Number CD4051MD
See Package 2
Order Number CD4051MF
See Package 5
Order Number CD4051CJ or CD4051MJ
See Package 17
Order Number CD4051CN
See Package 23



Order Number CD4052MD
See Package 2
Order Number CD4052MF
See Package 5
Order Number CD4052CJ or CD4052MJ
See Package 17
Order Number CD4052CN
See Package 23



Order Number CD4053MD
See Package 2
Order Number CD4053MF
See Package 5
Order Number CD4053CJ or CD4053MJ
See Package 17
Order Number CD4053CN
See Package 23

absolute maximum ratings

Voltage at Any Control Input	V_{SS} − 0.3V to V_{DD} + 0.3V
Voltage at Any Switch Input or Output	V_{EE} − 0.3V to V_{DD} + 0.3V
Operating Temperature Range	
CD40XXM	−55°C to +125°C
CD40XXC	−40°C to +85°C
Storage Temperature Range	−65°C to +150°C
Package Dissipation	500 mW
Operating V_{DD} Range	V_{EE} + 3V to V_{EE} + 15V
	V_{SS} + 3V to V_{SS} + 15V

electrical characteristics CD4051M, CD4052M, CD4053M

PARAMETER	CONDITIONS	−55°C			25°C			125°C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
P_D Quiescent Dissipation Per Package	V_{DD} = 10V, V_{EE} = V_{SS} = 0V			100		1	100			6000	μW
R_{ON} "ON" Resistance (Peak for $V_{SS} \leq V_{IS} \leq V_{DD}$)	R_L = 10 kΩ, V_{SS} = 0, (Any Channel Selected); V_{DD} = 7.5V, V_{EE} = −7.5V, or V_{DD} = 15V, V_{EE} = 0V		60	220		80	280		145	320	Ω
	V_{DD} = 5V, V_{EE} = −5V, or V_{DD} = 10V, V_{EE} = 0V		85	400		120	400		190	550	Ω
	V_{DD} = 2.5V, V_{EE} = −2.5V, or V_{DD} = 5V, V_{EE} = 0V		210	3000		270	2500		360	5500	Ω
ΔR_{ON} Δ"ON" Resistance Between Any Two Channels	R_L = 10 kΩ, V_{SS} = 0, (Any Channel Selected); V_{DD} = 7.5V, V_{EE} = −7.5V, or V_{DD} = 15V, V_{EE} = 0V					5					Ω
	V_{DD} = 5V, V_{EE} = −5V, or V_{DD} = 10V, V_{EE} = 0V					10					Ω
Sine Wave Response (Distortion)	R_L = 10 kΩ, V_{SS} = 0, f_{IS} = 1 kHz; V_{DD} = 7.5V, V_{EE} = −7.5V					0.1					%
	V_{DD} = 5V, V_{EE} = −5V					0.2					%
	V_{DD} = 2.5V, V_{EE} = −2.5V					1					%
"OFF" Channel Leakage Current Any Channel "OFF"	V_{SS} = 0V, V_{DD} = 7.5V, V_{EE} = −7.5V, OUT/IN = ±7.5V, IN/OUT = 0V			±50		±0.01	±50			±500	nA
All Channels "OFF" (Common OUT/IN)	Inhibit = 5V, V_{SS} = 0V, V_{DD} = 7.5V, V_{EE} = −7.5V, OUT/IN = 0V, IN/OUT = ±7.5V; CD4051M			±400		±0.08	±400			±4000	nA
	CD4052M			±200		±0.04	±200			±2000	nA
	CD4053M			±100		±0.02	±100			±1000	nA
Frequency Response Channel "ON" (Sine Wave Input)	R_L = 1 kΩ, V_{IS} = 5V (p-p), V_{SS} = 0V, V_{DD} = 5V, V_{EE} = −5V, 20 Log_{10} V_{OS}/V_{IS} = −3 dB					40					MHz
Feedthrough Channel "OFF"	R_L = 1 kΩ, V_{IS} = 5V (p-p), V_{SS} = 0V, V_{DD} = 5V, V_{EE} = −5V, 20 Log_{10} V_{OS}/V_{IS} = −40 dB					1					MHz
Crosstalk Between Any Two Channels (Frequency at 40 dB)	R_L = 1 kΩ, $V_{IS}(A)$ = 5V (p-p), V_{SS} = 0V, V_{DD} = 5V, V_{EE} = −5V, 20 Log_{10} $V_{OS}(B)/V_{IS}(A)$ = −40 dB (Note 1)					1					MHz
Capacitance											
C_{IS} Input (IN/OUT)	V_{DD} = V_{EE} = V_{SS} = 0V					10					pF
C_{OS} Output (Common OUT/IN)	CD4051M					60					pF
	CD4052M					30					pF
	CD4053M					20					pF
C_{IOS} Feedthrough						0.2					pF
t_{PLH}, t_{PHL} Propagation Delay Signal Input to Signal Output	V_{DD} = 10V, V_{SS} = V_{EE} = Inhibit = 0V, C_L = 15 pF, V_{IS} = 10V (Square Wave), t_r, t_f = 20 ns (Input Signal)					10					ns

electrical characteristics (con't) CD4051M, CD4052M, CD4053M

PARAMETER		CONDITIONS		−55°C MIN	−55°C TYP	−55°C MAX	25°C MIN	25°C TYP	25°C MAX	125°C MIN	125°C TYP	125°C MAX	UNITS
CONTROL INPUTS A, B, C AND INHIBIT													
	Noise Immunity (Any Control Input)												
V_{NL}		$V_{IS} = V_{DD}$ through 1 kΩ,	$V_{DD} - V_{SS} = 10V$	3.0			3.0	4.5		2.9			V
		$V_{EE} = V_{SS}$	$V_{DD} - V_{SS} = 5V$	1.5			1.5	2.25		1.4			V
V_{NH}		$I_{IS} = 10 \mu A$	$V_{DD} - V_{SS} = 10V$	2.9			3.0	4.5		3.0			V
		$R_L = 1 k\Omega$ to V_{EE}	$V_{DD} - V_{SS} = 5V$	1.4			1.5	2.25		1.5			V
C_I	Average Input Capacitance							5					pF
t_{PHL}, t_{PLH}	Turn "ON" Propagation Delay Control Input-to-Signal Output	$C_L = 15 pF$, $R_L = 10 k\Omega$,	$V_{DD} = 10V$, $V_{EE} = 0V$					150	300				ns
		$V_{IS} \leq V_{DD}$, $t_r, t_f = 20 ns$,	$V_{DD} = 5V$, $V_{EE} = 0V$					400	800				ns
		V_{SS} = Inhibit = 0V, (Note 2)	$V_{DD} = 5V$, $V_{EE} = -5V$					200	400				ns
	Inhibit Input-to-Signal Output	$C_L = 15 pF$, $R_L = 10 k\Omega$,	$V_{DD} = 10V$, $V_{EE} = 0V$					200	400				ns
		$V_{IS} = V_{DD}$, $t_r, t_f = 20 ns$	$V_{DD} = 5V$, $V_{EE} = 0V$					550	1100				ns
	Inhibit Recovery Time	$V_{DD} = 10V$						200	400				ns

electrical characteristics CD4051C, CD4052C, CD4053C

PARAMETER		CONDITIONS			−40°C MIN	−40°C TYP	−40°C MAX	25°C MIN	25°C TYP	25°C MAX	85°C MIN	85°C TYP	85°C MAX	UNITS
P_D	Quiescent Dissipation Per Package	$V_{DD} = 10V$, $V_{EE} = V_{SS} = 0V$					1000		1	1000			6000	µW
R_{ON}	"ON" Resistance (Peak for $V_{SS} \leq V_{IS} \leq V_{DD}$)	$R_L = 10 k\Omega$, $V_{SS} = 0$, (Any Channel Selected)	$V_{DD} = 7.5V$, $V_{EE} = -7.5V$, or $V_{DD} = 15V$, $V_{EE} = 0V$			80	250		80	280		130	300	Ω
			$V_{DD} = 5V$, $V_{EE} = -5V$, or $V_{DD} = 10V$, $V_{EE} = 0V$			100	450		120	400		170	520	Ω
			$V_{DD} = 2.5V$, $V_{EE} = -2.5V$, or $V_{DD} = 5V$, $V_{EE} = 0V$			230	3500		270	2500		330	5200	Ω
ΔR_{ON}	Δ"ON" Resistance Between Any Two Channels	$R_L = 10 k\Omega$, $V_{SS} = 0$, (Any Channel Selected)	$V_{DD} = 7.5V$, $V_{EE} = -7.5V$, or $V_{DD} = 15V$, $V_{EE} = 0V$						5					Ω
			$V_{DD} = 5V$, $V_{EE} = -5V$, or $V_{DD} = 10V$, $V_{EE} = 0V$						10					Ω
	Sine Wave Response (Distortion)	$R_L = 10 k\Omega$, $V_{SS} = 0$, $f_{IS} = 1 kHz$	$V_{DD} = 7.5V$, $V_{EE} = -7.5V$						0.1					%
			$V_{DD} = 5V$, $V_{EE} = -5V$						0.2					%
			$V_{DD} = 2.5V$, $V_{EE} = -2.5V$						1					%
	"OFF" Channel Leakage Current Any Channel "OFF"	$V_{SS} = 0V$; OUT/IN = ±7.5V, IN/OUT = 0V	$V_{DD} = 7.5V$, $V_{EE} = -7.5V$				±50		±0.01	±50			±200	nA
	All Channels "OFF" (Common OUT/IN)	Inhibit = 5V,	$V_{DD} = 7.5V$,	CD4051C			±1600		±0.08	±400			±1600	nA
		$V_{SS} = 0V$	$V_{EE} = -7.5V$	CD4052C			±800		±0.04	±200			±800	nA
		OUT/IN = 0V, IN/OUT = ±7.5V		CD4053C			±400		±0.02	±100			±400	nA
	Frequency Response Channel "ON" (Sine Wave Input)	$R_L = 1 k\Omega$, $V_{IS} = 5V$ (p-p), $V_{SS} = 0V$	$V_{DD} = 5V$, $V_{EE} = -5V$, 20 $Log_{10} V_{OS}/V_{IS} = -3 dB$						40					MHz

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electrical characteristics (con't) CD4051C, CD4052C, CD4053C

	PARAMETER	CONDITIONS		−40°C MIN	−40°C TYP	−40°C MAX	25°C MIN	25°C TYP	25°C MAX	85°C MIN	85°C TYP	85°C MAX	UNITS
	Feedthrough Channel "OFF"	R_L = 1 kΩ, V_{IS} = 5V (p-p), V_{SS} = 0V	V_{DD} = 5V, V_{EE} = −5V, 20 Log_{10} V_{OS}/V_{IS} = −40 dB					1					MHz
	Crosstalk Between Any Two Channels (Frequency at 40 dB)	R_L = 1 kΩ, $V_{IS}(A)$ = 5V (p-p), V_{SS} = 0V	V_{DD} = 5V, V_{EE} = −5V, 20 Log_{10} $V_{OS}(B)/V_{IS}(A)$ = −40 dB (Note 1)					1					MHz
	Capacitance												
C_{IS}	Input (IN/OUT)	$V_{DD} = V_{EE} = V_{SS}$ = 0V						10					pF
C_{OS}	Output (Common OUT/IN)	$V_{DD} = V_{EE} = V_{SS}$ = 0V	CD4051C					60					pF
			CD4052C					30					pF
			CD4053C					20					pF
C_{IOS}	Feedthrough	$V_{DD} = V_{EE} = V_{SS}$ = 0V						0.2					pF
t_{PLH}, t_{PHL}	Propagation Delay Signal Input to Signal Output	V_{DD} = 10V, $V_{SS} = V_{EE}$ = Inhibit = 0V, C_L = 15 pF, V_{IS} = 10V (Square Wave), t_r, t_f = 20 ns (Input Signal)						10					ns
CONTROL INPUTS A, B, C AND INHIBIT													
	Noise Immunity (Any Control Input)												
V_{NL}		$V_{IS} = V_{DD}$ through 1 kΩ, $V_{EE} = V_{SS}$	$V_{DD} - V_{SS}$ = 10V	3.0			3.0	4.5		2.9			V
			$V_{DD} - V_{SS}$ = 5V	1.5			1.5	2.25		1.4			V
V_{NH}		I_{IS} = 10µA, R_L = 1kΩ to V_{EE}	$V_{DD} - V_{SS}$ = 10V	2.9			3.0	4.5		3.0			V
			$V_{DD} - V_{SS}$ = 5V	1.4			1.5	2.25		1.5			V
C_I	Average Input Capacitance							5					pF
t_{PHL}, t_{PLH}	Turn "ON" Propagation Delay Control Input-to-Signal Output	C_L = 15 pF, R_L = 10 kΩ, $V_{IS} \leq V_{DD}$, t_r, t_f = 20 ns, V_{SS} = Inhibit = 0V, (Note 2)	V_{DD} = 10V, V_{EE} = 0V					150	300				ns
			V_{DD} = 5V, V_{EE} = 0V					400	800				ns
			V_{DD} = 5V, V_{EE} = −5V					200	400				ns
	Inhibit Input-to-Signal Output	C_L = 15 pF, R_L = 10 kΩ, $V_{IS} = V_{DD}$, t_r, t_f = 20 ns	V_{DD} = 10V, V_{EE} = 0V					200	400				ns
			V_{DD} = 5V, V_{EE} = 0V					550	1100				ns
	Inhibit Recovery Time	V_{DD} = 10V						200	400				ns

Note 1: A,B are two arbitrary channels with A turned "ON" and B "OFF."

Note 2: Channel Overlap = Turn "ON" delay, where channel overlap is defined as the duration after control signal change during which two channels may be "ON" together.

Note 3: V_{IS} = input signal voltage, V_{OS} = output signal voltage, f_{IS} = input signal frequency.

special considerations

In certain applications the external load-resistor current may include both V_{DD} and signal-line components. To avoid drawing V_{DD} current when switch current flows into "In/Out" pin, the voltage drop across the bidirectional switch must not exceed 0.6V at $T_A \leq 25°C$, or 0.4V at $T_A > 25°C$ (calculated from R_{ON} values shown). No V_{DD} current will flow through R_L if the switch current flows into "Out/In" pin.

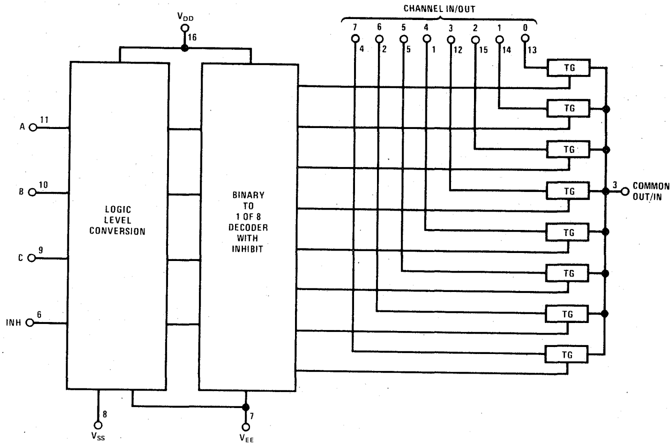
truth table

INPUT STATES				"ON" CHANNELS		
INHIBIT	C	B	A	CD4051A	CD4052A	CD4053A
0	0	0	0	0	0X, 0Y	cx, bx, ax
0	0	0	1	1	1X, 1Y	cx, bx, ay
0	0	1	0	2	2X, 2Y	cx, by, ax
0	0	1	1	3	3X, 3Y	cx, by, ay
0	1	0	0	4		cy, bx, ax
0	1	0	1	5		cy, bx, ay
0	1	1	0	6		cy, by, ax
0	1	1	1	7		cy, by, ay
1	*	*	*	NONE	NONE	NONE

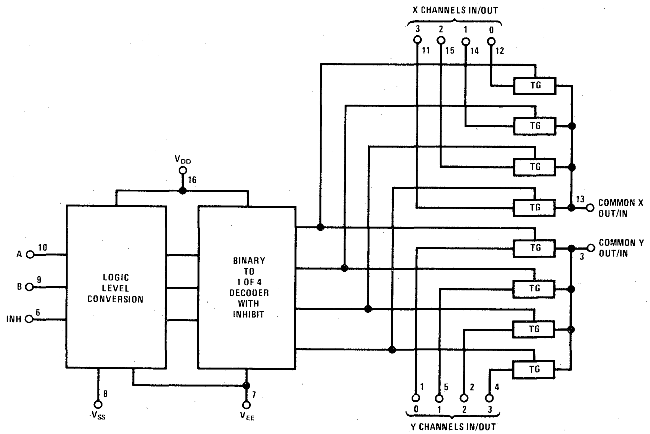
*Don't Care condition

schematic diagrams

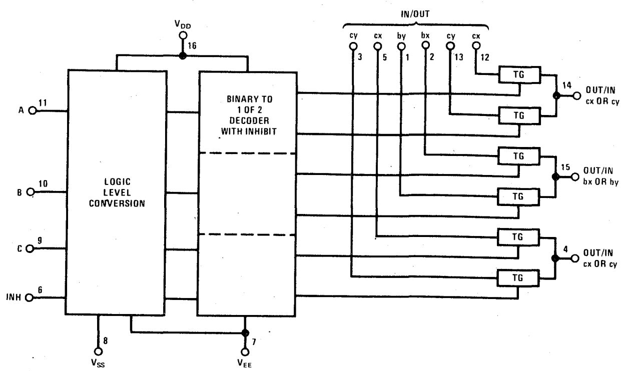
CD4051M/CD4051C



CD4052M/CD4052C

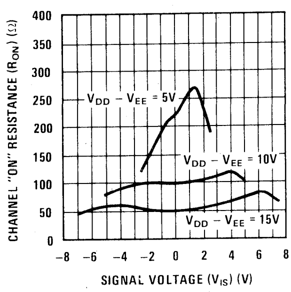


CD4053M/CD4053C

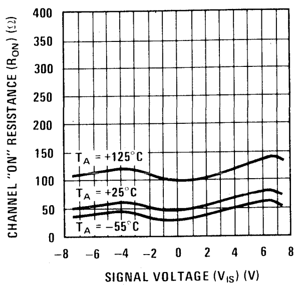


typical performance characteristics

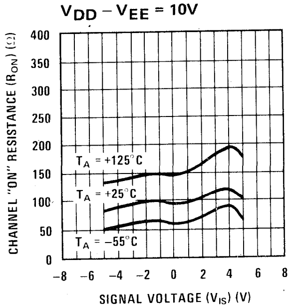
"ON" Resistance vs Signal Voltage for $T_A = 25°C$



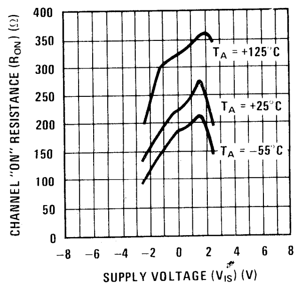
"ON" Resistance as a Function of Temperature for $V_{DD} - V_{EE} = 15V$



"ON" Resistance as a Function of Temperature for $V_{DD} - V_{EE} = 10V$



"ON" Resistance as a Function of Temperature for $V_{DD} - V_{EE} = 5V$



Analog Switches

CD4066M/CD4066C quad bilateral switch

general description

The CD4066M/CD4066C is a quad bilateral switch intended for the transmission or multiplexing of analog or digital signals. It is pin-for-pin compatible with CD4016M/CD4016C, but has a much lower ON resistance, and ON resistance is relatively constant over the input-signal range.

features

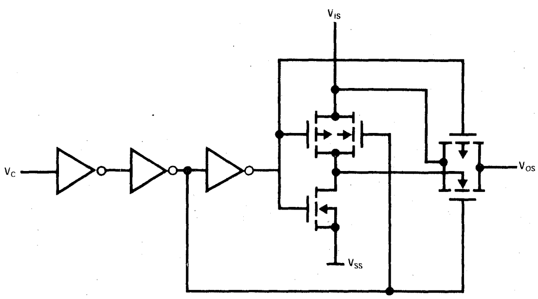
- Wide supply voltage range — 3V to 15V
- High noise immunity — 0.45 V_{DD} typ
- Wide range of digital and analog switching — ±7.5V_{PEAK}
- ON resistance for 15V operation — 80Ω typ
- Matched ON resistance over 15V signal input — 5Ω
- ON resistance flat over peak-to-peak signal range
- High ON/OFF output voltage ratio — 65 dB typ @ f_{is} = 10 kHz, R_L = 10 kΩ
- High degree of linearity — <0.5% distortion typ @ f_{is} = 1 kHz, V_{is} = 5V(p-p), $V_{DD} - V_{SS}$ = 10V, R_L = 10 kΩ
- Extremely low OFF switch leakage — 10 pA typ @ $V_{DD} - V_{SS}$ = 10V, T_A = 25°C
- Extremely high control input impedance — 10^{12}Ω typ
- Low crosstalk between switches — −50 dB typ @ f_{is} = 0.9 MHz, R_L = 1 kΩ
- Frequency response, switch ON — 40 MHz typ

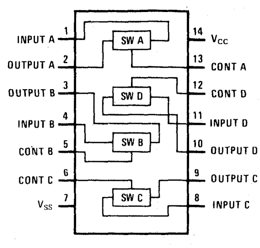
applications

- Analog signal switching/multiplexing
  - Signal gating
  - Squelch control
  - Chopper
  - Modulator/Demodulator
  - Commutating switch
- Digital signal switching/multiplexing
- CMOS logic implementation
- Analog to digital/digital to analog conversion
- Digital control of frequency, impedance, phase, and analog-signal gain

schematic and connection diagrams

1 of 4 Bilateral Switches





Order Number CD4066MD
See Package 1

Order Number CD4066MF
See Package 4

Order Number CD4066CJ or CD4066MJ
See Package 16

Order Number CD4066CN
See Package 22

absolute maximum ratings

Voltage at Any Pin (Note 1)	V_{SS} −0.3V to V_{SS} +15.5V
Operating Temperature Range	
CD4066M	−55°C to +125°C
CD4066C	−40°C to +85°C
Storage Temperature Range	−65°C to +150°C
Package Dissipation	500 mW
Operating V_{DD} Range	V_{SS} +3V to V_{SS} +15V
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (CD4066C)

CHARACTERISTIC	SYMBOL	TEST CONDITIONS	LIMITS −40°C MIN	−40°C TYP	−40°C MAX	25°C MIN	25°C TYP	25°C MAX	85°C MIN	85°C TYP	85°C MAX	UNITS
Quiescent Dissipation per Package All Switches OFF	P_T	TERMINALS / VOLTS APPLIED V_{DD} 14 +10 V_{SS} 7 GND V_C 5, 6, 12, 13 GND V_{is} 1, 4, 8, 11 ≤+10 V_{os} 2, 3, 9, 10 ≤+10			50		0.1	50			300	μW
All Switches ON		TERMINALS / VOLTS APPLIED V_{DD} 14 +10 V_{SS} 7 GND V_C 5, 6, 12, 13 +10 V_{is} = V_{OS} 1–4, 8–11 ≤+10 (Thru 100Ω)			50		0.1	50			300	μW
SIGNAL INPUTS (V_{is}) AND OUTPUTS (V_{os})												
ON Resistance	R_{ON}	R_L = 10 kΩ; V_C=V_{DD} / V_{SS} / V_{is}: +7.5V −7.5V −7.5 to +7.5V +15V 0V 0V to 15V		80	250		80	280		130	300	Ω
		+5V −5V −5V to +5V +10V 0V 0V to 10V		100	450		120	500		170	520	Ω
		+2.5V −2.5V −2.5 to +2.5V +5V 0V 0V to 5V		190	3500		270	5000		330	5200	Ω
ΔON Resistance Between Any 2 of 4 Switches	ΔR_{ON}	R_L = 10 kΩ +7.5V −7.5V −7.5 tc +7.5V +15V 0V 0V to 15V					5					Ω
		+5V −5V −5V to +5V +10V 0V 0V to 10V					10					Ω
Sine Wave Response (Distortion)		R_L = 10 kΩ, f_{is} = 1 kHz +5V −5V 5V(p-p) (Note 3)					0.4					%
Input or Output Leakage–Switch OFF (Effective OFF Resistance)		V_C=V_{SS} / V_{DD} / V_{is}: −7.5V +7.5V +7.5V −7.5V +7.5V −7.5V (Note 2)			±100		±0.1	±100			±200	nA
		−5V +5V +5V −5V +5V −5V (Note 2)			±100		±0.05	±100			±200	nA
Frequency Response–Switch ON (Sine Wave Input)		V_C = V_{DD} = +5V, V_{SS} = −5V R_L = 1 kΩ, V_{is} = 5V(p-p) $20 \log_{10} \frac{V_{os}}{V_{is}} = -3$ dB					40					MHz
Feedthrough Switch OFF		V_{DD} = +5V, V_C = V_{SS} = −5V $20 \log_{10} \frac{V_{os}}{V_{is}} = -50$ dB					1.25					MHz
Crosstalk Between Any 2 of the 4 Switches (Frequency at −50 dB)		R_L = 1 kΩ, $V_{is}(A)$ = 5V(p-p) $V_C(A)$ = V_{DD} = +5V $V_C(B)$ = V_{SS} = −5V $20 \log_{10} \frac{V_{os}(B)}{V_{is}(A)} = -50$ dB					0.9					MHz
Capacitance												
Input	C_{IS}	V_{DD} = +5V, V_C = V_{SS} = −5V					8					pF
Output	C_{OS}	V_{DD} = +5V, V_C = V_{SS} = −5V					8					pF
Feedthrough	C_{IOS}	V_{DD} = +5V, V_C = V_{SS} = −5V					0.5					pF
Propagation Delay Signal Input to Signal Output	t_{pd}	V_C = V_{DD} = +10V, V_{SS} = GND, C_L = 15 pF V_{is} = 10V (square wave) t_r = t_f = 20 ns (input signal)					10					ns

electrical characteristics (CD4066C Continued)

CHARACTERISTIC	SYMBOL	TEST CONDITIONS	LIMITS -40°C MIN	-40°C TYP	-40°C MAX	25°C MIN	25°C TYP	25°C MAX	85°C MIN	85°C TYP	85°C MAX	UNITS
CONTROL (V_C)												
Noise Immunity	V_{NL}	$V_{is} \leq V_{DD}$ $V_{DD} - V_{SS} = 10V$ $I_{is} = 10\mu A$	2			2	4.5		2			V
Input Current	I_C	$V_{DD} - V_{SS} = 10V$ $V_C \leq V_{DD} - V_{SS}$					±10					pA
Average Input Capacitance	C_C						5					pF
Crosstalk–Control Input to Signal Output		$R_L = 10\ k\Omega$ $V_{DD} - V_{SS} = 10V$ $V_C = 10V$ (square wave)					50					mV
Turn ON Propagation Delay	$t_{pd}C$	$t_{rc} = t_{fc} = 20\ ns$ $V_{is} < 10V$, $C_L = 15\ pF$					35					ns
Maximum Allowable Control Input Repetition Rate		$R_L = 1\ k\Omega$, $V_{DD} = 10V$, $V_{SS} = GND$ $C_L = 15\ pF$ $V_C = 10V$ (square wave) $t_r = t_f = 20\ ns$					10					MHz

Note 1: The device should not be connected to circuits with the power on.

Note 2: Limit determined by minimum feasible leakage measurement for automatic testing.

Note 3: Symmetrical about 0V.

electrical characteristics (CD4066M)

CHARACTERISTIC	SYMBOL	TEST CONDITIONS	LIMITS -55°C MIN	-55°C TYP	-55°C MAX	25°C MIN	25°C TYP	25°C MAX	125°C MIN	125°C TYP	125°C MAX	UNITS
Quiescent Dissipation per Package All Switches OFF	P_T	TERMINALS / VOLTS APPLIED V_{DD} 14 +10 V_{SS} 7 GND V_C 5, 6, 12, 13 GND V_{is} 1, 4, 8, 11 ≤+10 V_{os} 2, 3, 9, 10 ≤+10			5		0.1	5			300	μW
All Switches ON	P_T	TERMINALS / VOLTS APPLIED V_{DD} 14 +10 V_{SS} 7 GND V_C 5, 6, 12, 13 +10 $V_{is} = V_{os}$ 1, 4, 8, 11 ≤+10 (Thru 100Ω)			5		0.1	5			300	μW
SIGNAL INPUTS (V_{is}) AND OUTPUTS (V_{os})												
ON Resistance	R_{ON}	$R_L = 10\ k\Omega$; $V_C = V_{DD}$, V_S, V_{is}: +7.5V −7.5V −7.5V to +7.5V +15V 0V 0V to 15V		60	220		80	280		145	320	Ω
		+5V −5V −5V to +5V +10V 0V 0V to 10V		85	400		120	500		190	550	Ω
		+2.5V −2.5V −2.5V to +2.5V +5V 0V 0V to 5V		160	3000		270	5000		360	5500	Ω
ΔON Resistance Between Any 2 of 4 Switches	ΔR_{ON}	$R_L = 10\ k\Omega$ +7.5V −7.5V −7.5V to +7.5V +15V 0V 0V to 15V					5					Ω
		+5V −5V −5V to +5V +10V 0V 0V to 10V					10					Ω
Sine Wave Response (Distortion)		$R_L = 10\ k\Omega$ +5V −5V 5V(p-p) $f_{is} = 1\ kHz$ (Note 3)					0.4					%
Input or Output Leakage–Switch OFF (Effective OFF Resistance)		$V_C = V_{SS}$, V_{DD}, V_{is}: −7.5V +7.5V +7.5V −7.5V +7.5V −7.5V (Note 2)			±100		±0.1	±100			±500	nA
		−5V +5V +5V −5V +5V −5V (Note 2)			±100		±0.01	±100			±500	nA
Frequency Response–Switch ON (Sine Wave Input)		$R_L = 1\ k\Omega$, $V_{is} = 5V$ (p-p) $V_C = V_{DD} = +5V$, $V_{SS} = -5V$ $20 \log_{10} \frac{V_{os}}{V_{is}} = -3\ dB$					40					MHz
Feedthrough Switch OFF		$V_{DD} = +5V$, $V_C = V_{SS} = -5V$ $20 \log_{10} \frac{V_{os}}{V_{is}} = -50\ dB$					1.25					MHz

electrical characteristics (CD4066M Continued)

CHARACTERISTIC	SYMBOL	TEST CONDITIONS	LIMITS −55°C MIN	−55°C TYP	−55°C MAX	25°C MIN	25°C TYP	25°C MAX	125°C MIN	125°C TYP	125°C MAX	UNITS
Crosstalk Between Any 2 of the 4 Switches (Frequency at −50 dB)		$R_L = 1\,k\Omega$, $V_C(A) = V_{DD} = +5V$, $V_C(B) = V_{SS} = -5V$, $V_{is}(A) = 5V(p\text{-}p)$, $20\,Log_{10}\frac{V_{os}(B)}{V_{is}(A)} = -50\,dB$					0.9					MHz
Capacitance												
Input	C_{IS}	$V_{DD} = +5V$, $V_C = V_{SS} = -5V$					8					pF
Output	C_{OS}	$V_{DD} = +5V$, $V_C = V_{SS} = -5V$					8					pF
Feedthrough	C_{IOS}	$V_{DD} = +5V$, $V_C = V_{SS} = -5V$					0.5					pF
Propagation Delay Signal Input to Signal Output	t_{pd}	$V_C = V_{DD} = +10V$, $V_{SS} = GND$, $C_L = 15\,pF$, $V_{is} = 10V$ (square wave), $t_r = t_f = 20\,ns$ (input signal)					10					ns
CONTROL (V_C)												
Noise Immunity	V_{NL}	$V_{is} \leq V_{DD}$, $V_{DD} - V_{SS} = 10V$, $I_{is} = 10\mu A$	2			2	4.5		2			V
Input Current	I_C	$V_{DD} - V_{SS} = 10V$, $V_C \leq V_{DD} - V_{SS}$					±10					pA
Average Input Capacitance	C_C						5					pF
Crosstalk—Control Input to Signal Output		$R_L = 10\,k\Omega$, $V_{DD} - V_{SS} = 10V$, $V_C = 10V$ (square wave)					50					mV
Turn ON Propagation Delay	$t_{pd}C$	$t_{rc} = t_{fc} = 20\,ns$, $V_{is} \leq 10V$, $C_L = 15\,pF$					35					ns
Maximum Allowable Control Input Repetition Rate		$V_{DD} = 10V$, $V_{SS} = GND$, $R_L = 1\,k\Omega$, $C_L = 15\,pF$, $V_C = 10V$ (square wave), $t_r = t_f = 20\,ns$					10					MHz

Note 1: The device should not be connected to circuits with the power on.
Note 2: Limit determined by minimum feasible leakage measurement for automatic testing.
Note 3: Symmetrical about 0V.

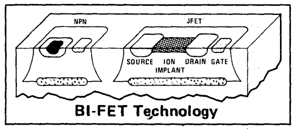
special considerations

In applications where separate power sources are used to drive V_{DD} and the signal input, the V_{DD} current capability should exceed V_{DD}/R_L (R_L = effective external load of the 4 CD4066M/CD4066C bilateral switches). This provision avoids any permanent current flow or clamp action on the V_{DD} supply when power is applied or removed from CD4066M/CD4066C.

In certain applications, the external load-resistor current may include both V_{DD} and signal-line components. To avoid drawing V_{DD} current when switch current flows into terminals 1, 4, 8 or 11, the voltage drop across the bidirectional switch must not exceed 0.8V at $T_A \leq 25°C$, or 0.6V at $T_A > 25°C$ (calculated from R_{ON} values shown).

No V_{DD} current will flow through R_L if the switch current flows into terminals 2, 3, 9 or 10.

Analog Switches



quad SPST JFET analog switches

LF11331/LF12331/LF13331	4 normally open switches with disable
LF11332/LF12332/LF13332	4 normally closed switches with disable
LF11333/LF12333/LF13333	2 normally closed switches and 2 normally open switches with disable
LF11201/LF12201/LF13201	4 normally closed switches
LF11202/LF12202/LF13202	4 normally open switches

general description

These devices are a monolithic combination of bipolar and JFET technology producing the industry's first one chip quad JFET switch. A unique circuit technique is employed to maintain a constant resistance over the analog voltage range of ±10V. The input is designed to operate from minimum TTL levels, and switch operation also ensures a break-before-make action.

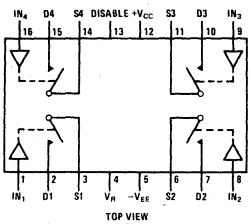
features

- Analog signals are not loaded
- Constant "ON" resistance for signals up to ±10V and 100 kHz
- Pin compatible with CMOS switches with the advantage of blow out free handling
- Small signal analog signals to 50 MHz
- Break-before-make action $t_{OFF} < t_{ON}$
- High open switch isolation at 1.0 MHz −50 dB
- Low leakage in "OFF" state <1.0 nA
- TTL, DTL, RTL compatibility
- Single disable pin opens all switches in package on LF11331, LF11332, LF11333
- LF11201 is pin compatible with DG201

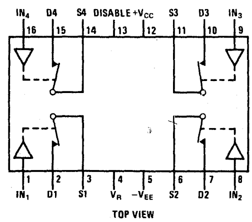
These devices operate from ±15V supplies and swing a ±10V analog signal. The JFET switches are designed for applications where a dc to medium frequency analog signal needs to be controlled.

connection diagrams (Dual-In-Line Packages) (All Switches Shown are For Logical "0")

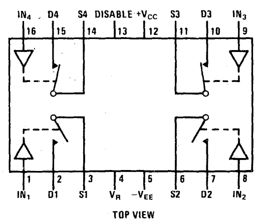
LF11331/LF12331/LF13331



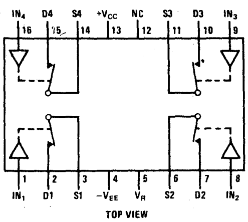
LF11332/LF12332/LF13332



LF11333/LF12333/LF13333



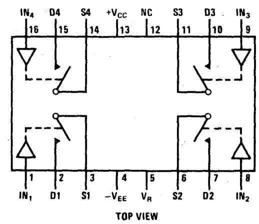
LF11201/LF12201/LF13201



Order Number LF11201D, LF12201D, LF13201D, LF11202D, LF12202D, LF13202D, LF11331D, LF12331D, LF13331D, LF11332D, LF12332D, LF13332D, LF11333D, LF12333D or LF13333D
See Package 2

Order Number LF12201N, LF13201N, LF12202N, LF13202N, LF12331N, LF13331N, LF12332N, LF13332N, LF12333N or LF13333N
See Package 23

LF11202/LF12202/LF13202



test circuit and schematic diagram

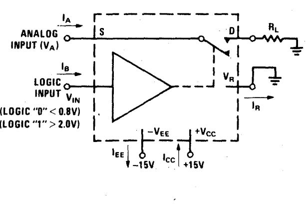


FIGURE 1. Typical Circuit for One Switch

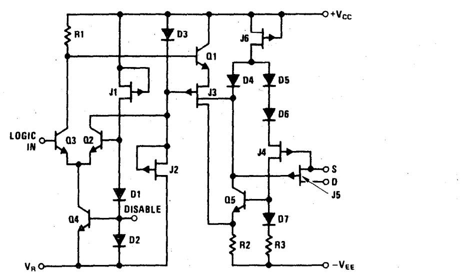


FIGURE 2. Schematic Diagram (Normally Open)

6

absolute maximum ratings

Positive Supply – Negative Supply (V_{CC}–V_{EE})	36V
Reference Voltage	$V_{EE} \leq V_R \leq V_{CC}$
Logic Input Voltage	V_R –4.0V $\leq V_{IN} \leq V_R$ +6.0V
Analog Voltage	$V_{EE} \leq V_A \leq V_{CC}$ +6V; $V_A \leq V_{EE}$ +36V
Analog Current	$\lvert I_A \rvert$ < 20 mA
Power Dissipation (Note 1)	
Molded DIP (N Suffix)	500 mW
Cavity DIP (D Suffix)	900 mW
Operating Temperature Range	
LF11201, 2 and LF11331, 2, 3	–55°C to +125°C
LF12201, 2 and LF12331, 2, 3	–25°C to +85°C
LF13201, 2 and LF13331, 2, 3	0°C to +70°C
Storage Temperature	–65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Notes 2, 7)

SYMBOL	PARAMETER	CONDITIONS		LF11331/2/3 LF11201/2			LF12331/2/3 LF12201/2 LF13331/2/3 LF13201/2			UNITS
				MIN	TYP	MAX	MIN	TYP	MAX	
R_{ON}	"ON" Resistance	V_A = 0, I_D = 1 mA	T_A = 25°C		150	200		150	250	Ω
					200	300		200	350	Ω
R_{ON} Match	"ON" Resistance Matching		T_A = 25°C		5	20		10	50	Ω
V_A	Analog Range			±10	±11		±10	±11		V
$I_{S(ON)}$ +	Leakage Current in "ON" Condition	Switch "ON," V_S = V_D = ±10V	T_A = 25°C		0.3	5		0.3	10	nA
$I_{D(ON)}$					3	100		3	30	nA
$I_{S(OFF)}$	Source Current in "OFF" Condition	Switch "OFF," V_S = +10V, V_D = –10V	T_A = 25°C		0.4	5		0.4	10	nA
					3	100		3	30	nA
$I_{D(OFF)}$	Drain Current in "OFF" Condition	Switch "OFF," V_S = +10V, V_D = –10V	T_A = 25°C		0.1	5		0.1	10	nA
					3	100		3	30	nA
V_{INH}	Logical "1" Input Voltage			2.0			2.0			V
V_{INL}	Logical "0" Input Voltage					0.8			0.8	V
I_{INH}	Logical "1" Input Current	V_{IN} = 5V	T_A = 25°C		3.6	10		3.6	40	μA
						25			100	μA
I_{INL}	Logical "0" Input Current	V_{IN} = 0.8	T_A = 25°C			0.1			0.1	μA
						1			1	μA
t_{ON}	Delay Time "ON"	V_S = ±10V, *(Figure 3)*	T_A = 25°C		500			500		ns
t_{OFF}	Delay Time "OFF"	V_S = ±10V, *(Figure 3)*	T_A = 25°C		90			90		ns
$t_{ON} - t_{OFF}$	Break-Before-Make	V_S = ±10V, *(Figure 3)*	T_A = 25°C		80			30		ns
$C_{S(OFF)}$	Source Capacitance	Switch "OFF," V_S = ±10V	T_A = 25°C		4.0			4.0		pF
$C_{D(OFF)}$	Drain Capacitance	Switch "OFF," V_D = ±10V	T_A = 25°C		3.0			3.0		pF
$C_{S(ON)}$ + $C_{D(ON)}$	Active Source and Drain Capacitance	Switch "ON," V_S = V_D = 0V	T_A = 25°C		5.0			5.0		pF
$I_{SO(OFF)}$	"OFF" Isolation	*(Figure 4)*, (Note 3)	T_A = 25°C		–50			–50		dB
CT	Crosstalk	*(Figure 4)*, (Note 3)	T_A = 25°C		–65			–65		dB
SR	Analog Slew Rate	(Note 4)	T_A = 25°C		50			50		V/μs
I_{DIS}	Disable Current	*(Figure 5)*, (Note 5)	T_A = 25°C		0.4	1.0		0.6	1.5	mA
					0.6	1.5		0.9	2.3	mA
I_{EE}	Negative Supply Current	All Switches "OFF," V_S = ±10V	T_A = 25°C		3.0	5.0		4.3	7.0	mA
					4.2	7.5		6.0	10.5	mA
I_R	Reference Supply Current	All Switches "OFF," V_S = ±10V	T_A = 25°C		2.0	4.0		2.7	5.0	mA
					2.8	6.0		3.8	7.5	mA
I_{CC}	Positive Supply Current	All Switches "OFF," V_S = ±10V	T_A = 25°C		4.5	6.0		7.0	9.0	mA
					6.3	9.0		9.8	13.5	mA

Note 1: For operating at high temperature the molded DIP products must be derated based on a +100°C maximum junction temperature and a thermal resistance of +150°C/W, devices in the cavity DIP are based on a +150°C maximum junction temperature and are derated at +100°C/W.

Note 2: Unless otherwise specified, V_{CC} = +15V, V_{EE} = –15V, V_R = 0V, and limits apply for –55°C $\leq T_A \leq$ +125°C for the LF11331,2,3 and the LF11201,2, –25°C $\leq T_A \leq$ +85°C for the LF12331,2,3 and the LF12201,2, and 0°C $\leq T_A \leq$ +70°C for the LF13331,2,3 and the LF13201, 2.

Note 3: These parameters are limited by the pin to pin capacitance of the package.

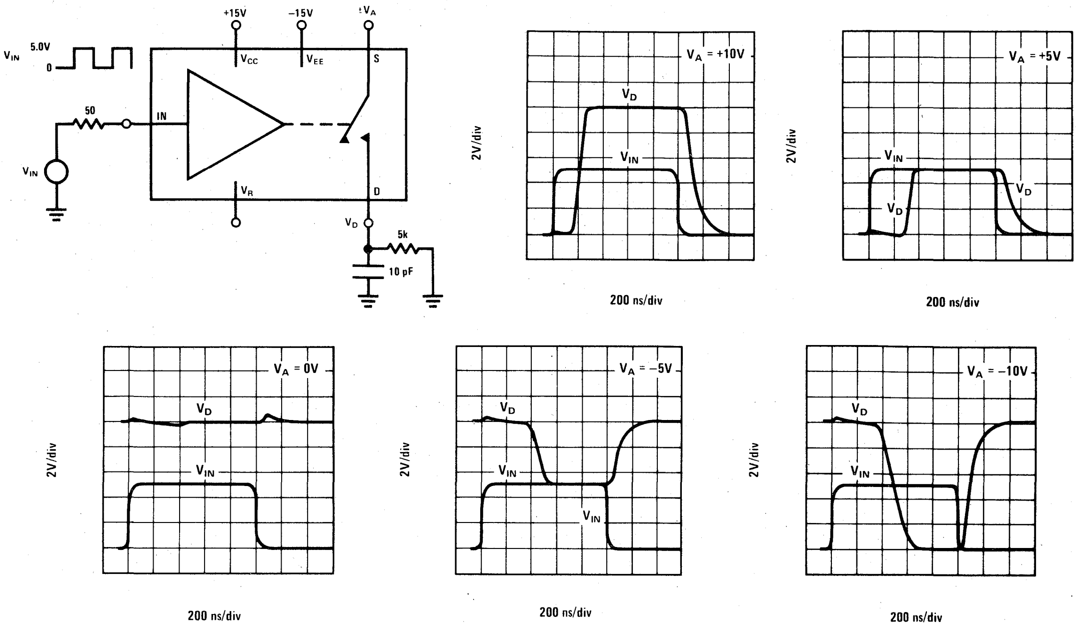
Note 4: This is the analog signal slew rate above which the signal is distorted as a result of finite internal slew rates.

Note 5: All switches in the device are turned "OFF" by saturating a transistor at the disable node as shown in *Figure 5*. The delay times will be approximately equal to the t_{ON} or t_{OFF} plus the delay introduced by the external transistor.

Note 6: This graph indicates the analog current at which 1% of the analog current is lost when the drain is positive with respect to the source.

test circuit and typical performance curves

Delay Time, Rise Time, Settling Time, and Switching Transients



additional test circuits

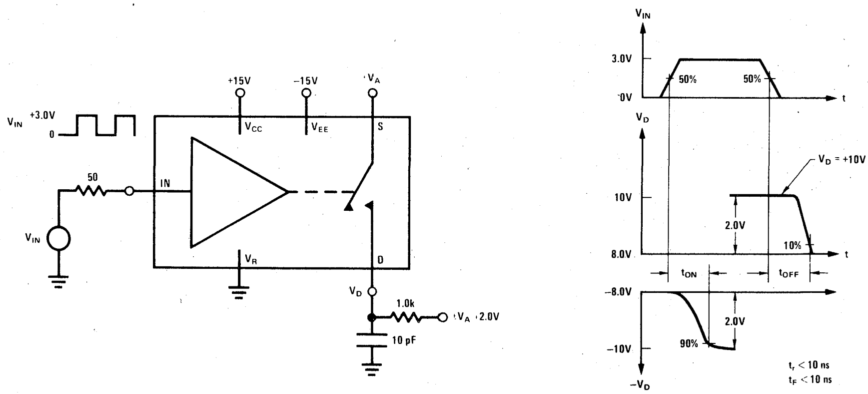
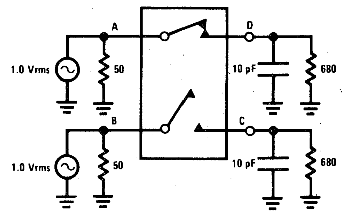


FIGURE 3. t_{ON}, t_{OFF} Test Circuit and Waveforms for a Normally Open Switch

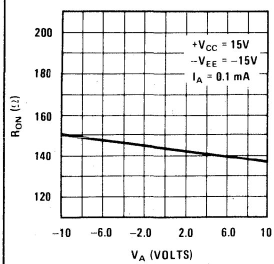


OFF ISOLATION = $20 \log \frac{V_C}{V_B}$ CROSSTALK = $20 \log \frac{V_C}{V_A}$

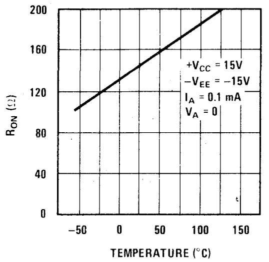
FIGURE 4. "OFF" Isolation, Crosstalk, Small Signal Response

typical performance characteristics

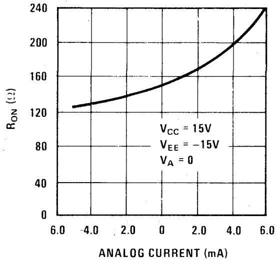
"ON" Resistance



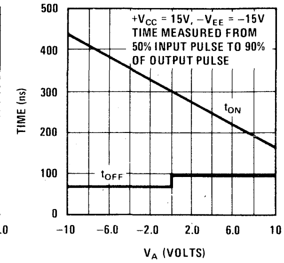
"ON" Resistance



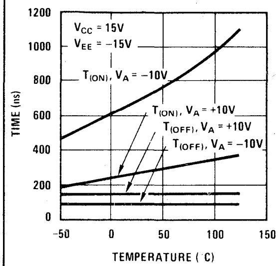
"ON" Resistance



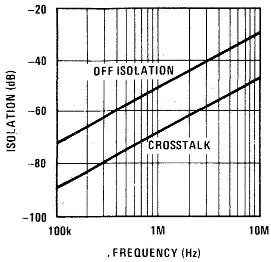
Break-Before-Make Action



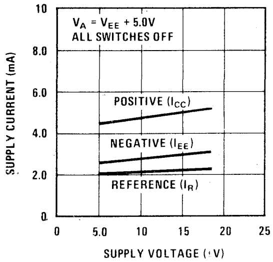
Switching Times



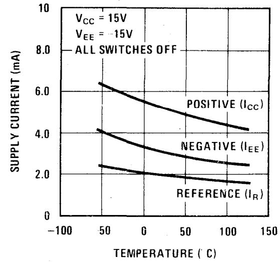
Crosstalk and "OFF" Isolation vs Frequency Using Test Circuit of *Figure 5*



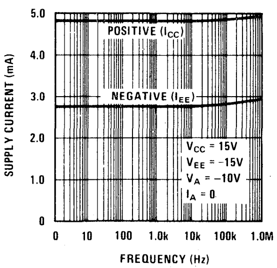
Supply Current



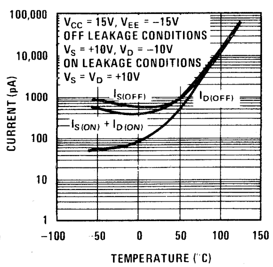
Supply Current



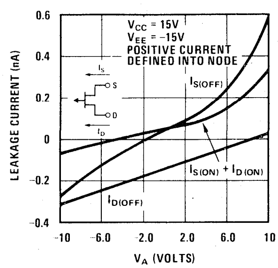
Supply Current



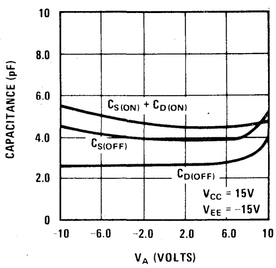
Switch Leakage Currents



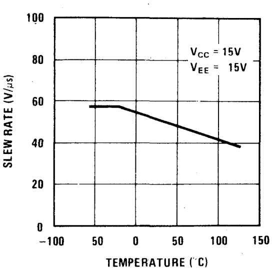
Switch Leakage Current



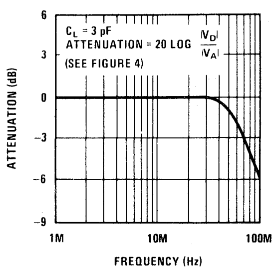
Switch Capacitances



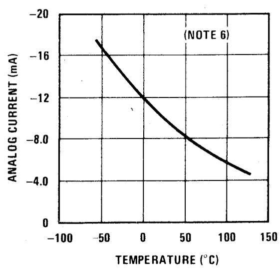
Slew Rate of Analog Voltage Above Which Signal Loading Occurs



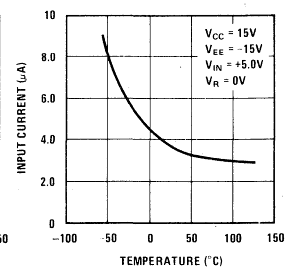
Small Signal Response



Maximum Accurate Analog Current vs Temperature



Logical "1" Input Bias Current



application hints

GENERAL INFORMATION

These devices are monolithic quad JFET analog switches with "ON" resistances which are essentially independent of analog voltage or analog current. The leakage currents are typically less than 1 nA at 25°C in both the "OFF" and "ON" switch states and introduce negligible errors in most applications. Each switch is controlled by minimum TTL logic levels at its input and is designed to turn "OFF" faster than it will turn "ON." This prevents two analog sources from being transiently connected together during switching. The switches were designed for applications which require break-before-make action, no analog current loss, medium speed switching times and moderate analog currents.

Because these analog switches are JFET rather than CMOS, they do not require special handling.

LOGIC INPUTS

The logic input (IN), of each switch, is referenced to two forward diode drops (1.4V at 25°C) from the reference supply (V_R) which makes it compatible with DTL, RTL, and TTL logic families. For normal operation, the logic "0" voltage can range from 0.8V to −4.0V with respect to V_R and the logic "1" voltage can range from 2.0V to 6.0V with respect to V_R, provided V_{IN} is not greater than (V_{CC} − 2.5V). If the input voltage is greater than (V_{CC} − 2.5V), the input current will increase. If the input voltage exceeds 6.0V or −4.0V with respect to V_R, a resistor in series with the input should be used to limit the input current to less than 100μA.

ANALOG VOLTAGE AND CURRENT

Analog Voltage

Each switch has a constant "ON" resistance (R_{ON}) for analog voltages from (V_{EE} + 5V) to (V_{CC} − 5V). For analog voltages greater than (V_{CC} − 5V), the switch will remain ON independent of the logic input voltage. For analog voltages less than (V_{EE} + 5V), the ON resistance of the switch will increase. Although the switch will not operate normally when the analog voltage is out of the previously mentioned range, the source voltage can go to either (V_{EE} + 36V) or (V_{CC} + 6V), whichever is more positive, and can go as negative as V_{EE} without destruction. The drain (D) voltage can also go to either (V_{EE} + 36V) or (V_{CC} + 6V), whichever is more positive, and can go as negative as (V_{CC} − 36V) without destruction.

Analog Current

With the source (S) positive with respect to the drain (D), the R_{ON} is constant for low analog currents, but will increase at higher currents (>5 mA) when the FET enters the saturation region. However, if the drain is positive with respect to the source and a small analog current loss at high analog currents (Note 6) is tolerable, a low R_{ON} can be maintained for analog currents greater than 5 mA at 25°C.

LEAKAGE CURRENTS

The drain and source leakage currents, in both the ON and the OFF states of each switch, are typically less than 1 nA at 25°C and less than 100 nA at 125°C. As shown in the typical curves, these leakage currents are dependent on power supply voltages, analog voltage, analog current and the source to drain voltage.

DELAY TIMES

The delay time OFF (t_{OFF}) is essentially independent of both the analog voltage and temperature. The delay time ON (t_{ON}) will decrease as either ($V_{CC} - V_A$) decreases or the temperature decreases.

POWER SUPPLIES

The voltage between the positive supply (V_{CC}) and either the negative supply (V_{EE}) or the reference supply (V_R) can be as much as 36V. To accommodate variations in input logic reference voltages, V_R can range from V_{EE} to (V_{CC} − 4.5V). Care should be taken to ensure that the power supply leads for the device never become reversed in polarity or that the device is never inadvertantly installed backwards in a test socket. If one of these conditions occurs, the supplies would zener an interal diode to an unlimited current; and result in a destroyed device.

SWITCHING TRANSIENTS

When a switch is turned OFF or ON, transients will appear at the load due to the internal transient voltage at the gate of the switch JFET being coupled to the drain and source by the junction capacitances of the JFET. The magnitude of these transients is dependent on the load. A lower value R_L produces a lower transient voltage. A negative transient occurs during the delay time ON, while a positive transient occurs during the delay time OFF. These transients are relatively small when compared to faster switch families.

DISABLE NODE

This node can be used, as shown in *Figure 5,* to turn all the switches in the unit off independent of logic inputs. Normally, the node floats freely at an internal diode drop (≈ 0.7V) above V_R. When the external transistor in *Figure 5* is saturated, the node is pulled very close to V_R and the unit is disabled. Typically, the current from the node will be less than 1 mA. This feature is not available on the LF11201 or LF11202 series.

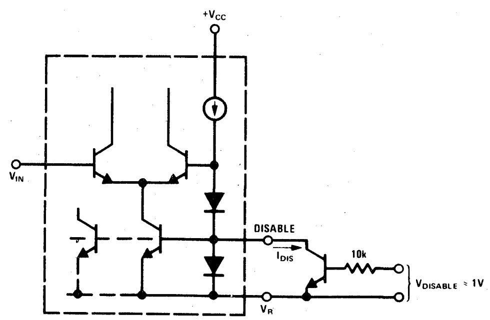
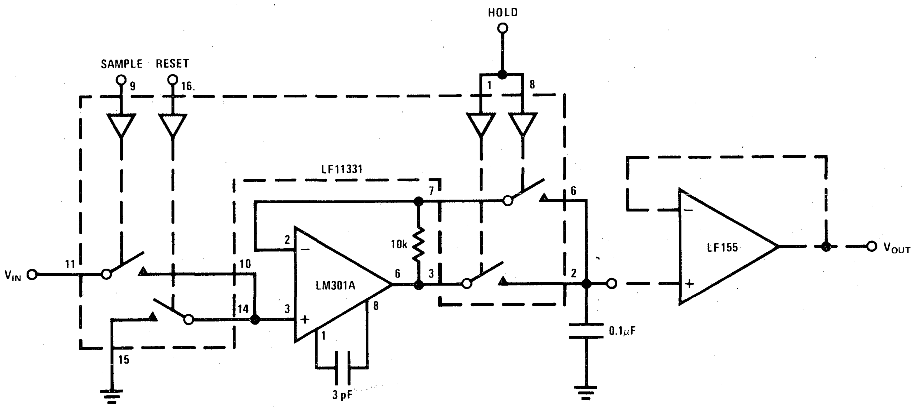


FIGURE 5. Disable Function

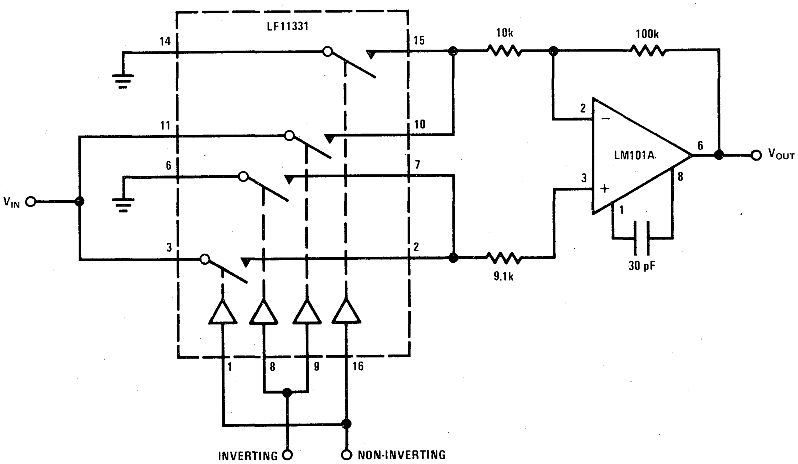
6

typical applications

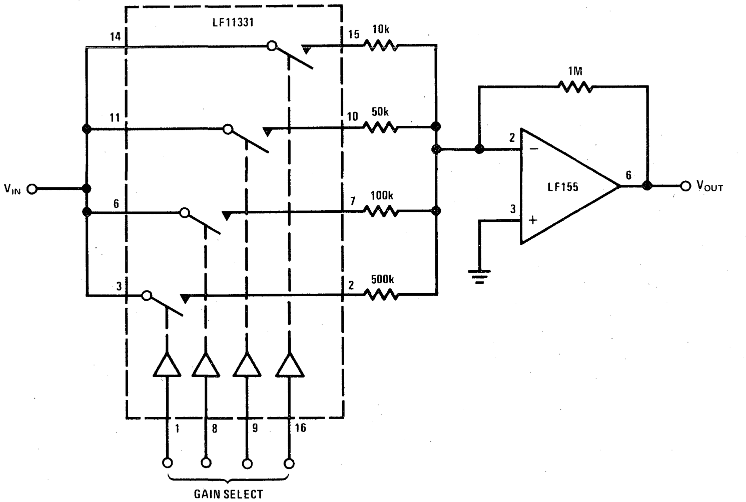
Sample and Hold with Reset



Programmable Inverting Non-Inverting Operational Amplifier

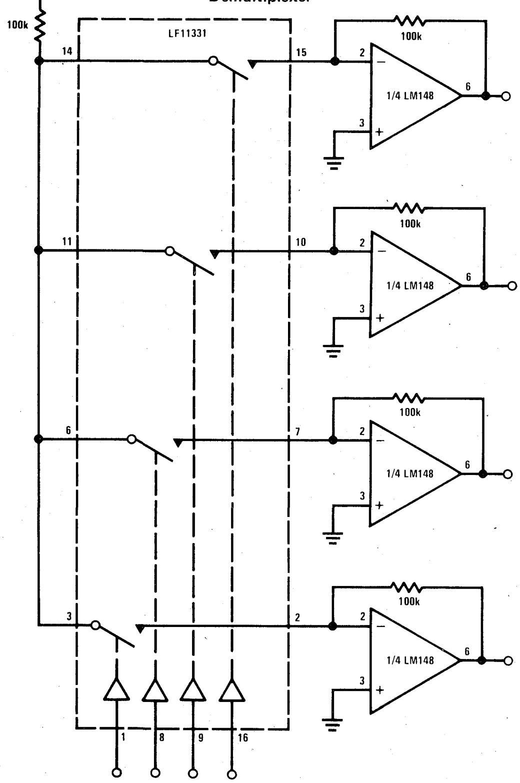


Programmable Gain Operational Amplifier

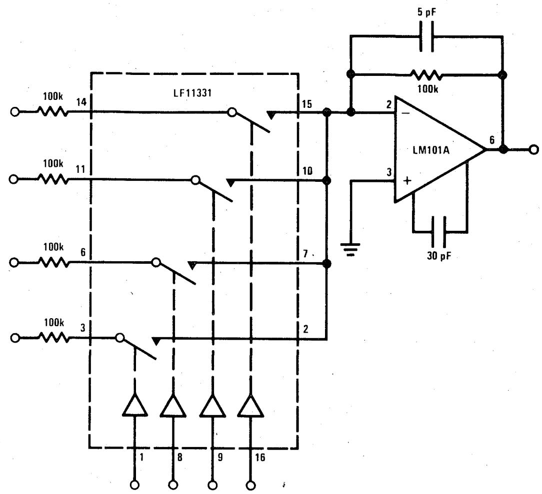


typical applications (con't)

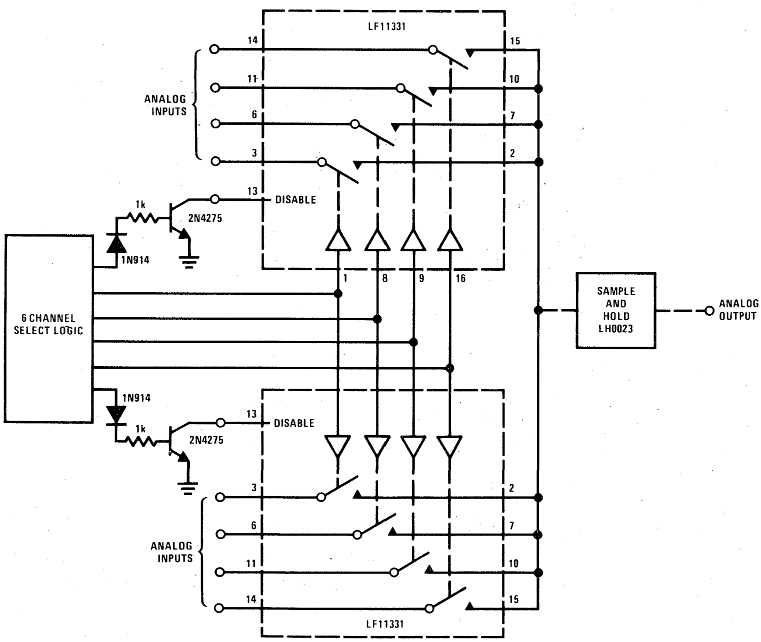
Demultiplexer



Multiplexer/Mixer

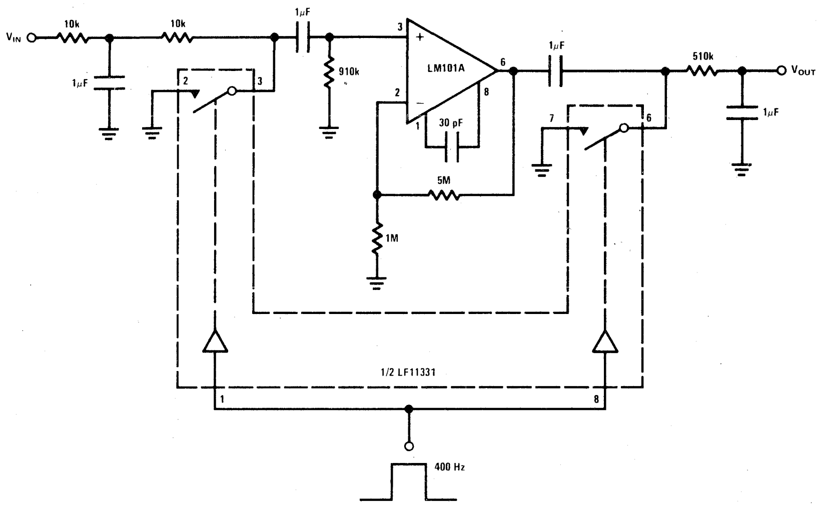


8-Channel Analog Commutator with 6-Channel Select Logic

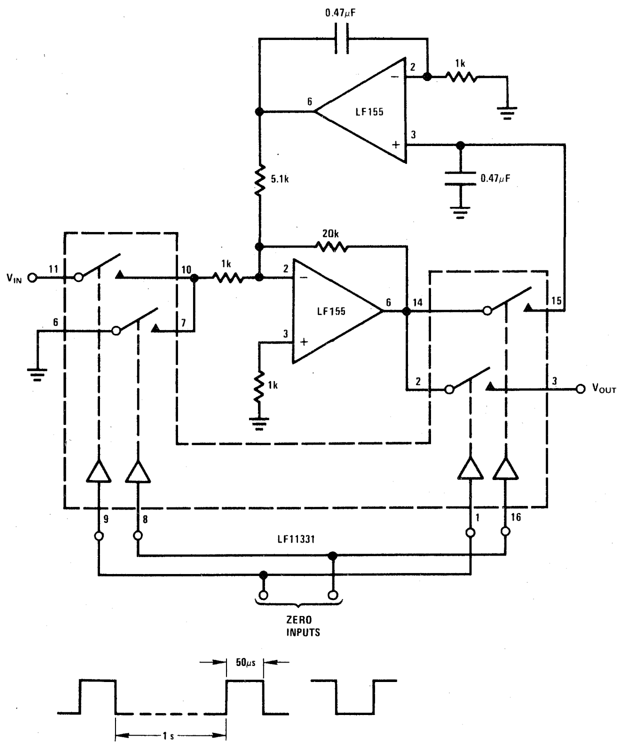


typical applications (con't)

Chopper Channel Amplifier

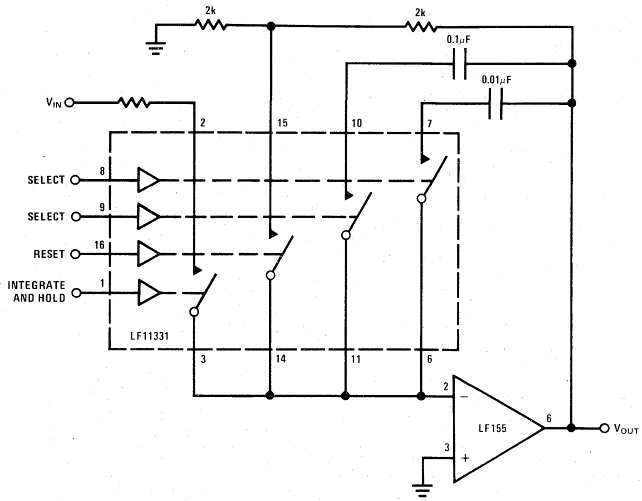


Self-Zeroing Operational Amplifier

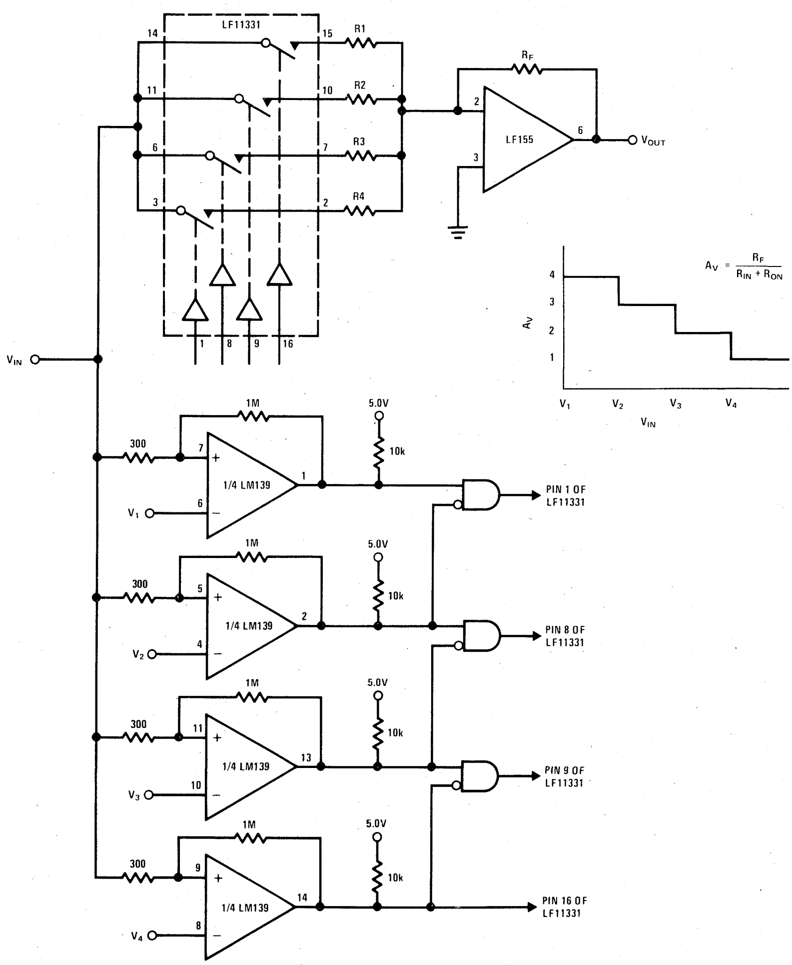


typical applications (con't)

Programmable Integrator with Reset and Hold



Staircase Transfer Function Operational Amplifier



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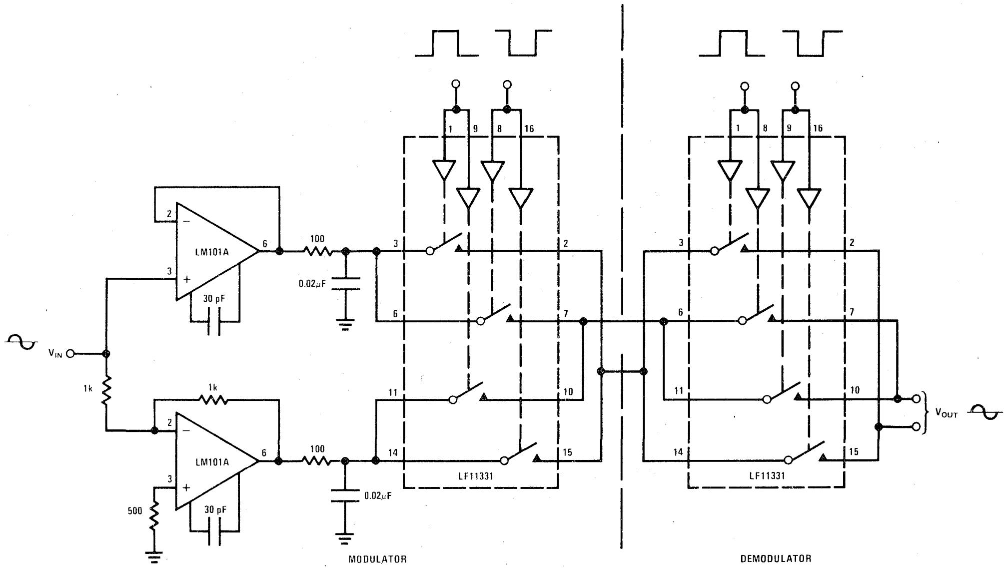
typical applications (con't)

DSB Modulator-Demodulator



Analog Switches

Future Product

LF11508/LF12508/LF13508 8-channel analog multiplexer

general description

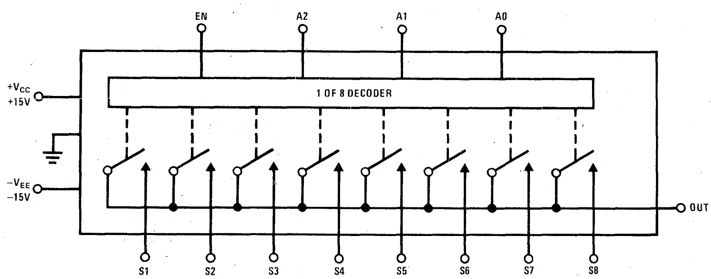
The LF11508/LF12508/LF13508 is an 8-channel analog multiplexer which connects the output to one of the 8 analog inputs depending on the state of a 3-bit binary address. An enable control allows disconnecting the output, thereby providing a package select function.

This device is fabricated with National's Bi-FET technology which provides ion-implanted JFETs for the analog switch on the same chip as the bipolar decode and switch drive circuitry. This technology makes possible low constant "ON" resistance with analog input voltage variations. This device does not suffer from latch-up problems or static charge blow-out problems associated with similar CMOS parts. The digital inputs are designed to operate from both TTL and CMOS levels while always providing a definite break-before-make action.

features

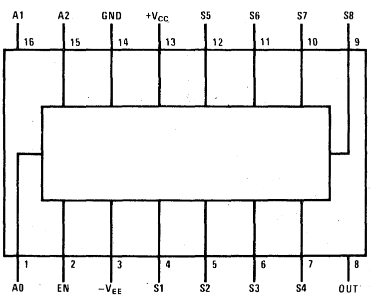
- JFET switches rather than CMOS
- No static discharge blow-out problem
- No SCR latch-up problems
- Analog signal range +12V, −15V
- Constant "ON" resistance for analog signals between −10V and +10V
- "ON" resistance 350Ω typ
- Digital inputs compatible with TTL and CMOS
- Output enable control
- Break-before-make action: t_{OFF} = 0.2μs; t_{ON} = 1μs typ

functional diagram



connection diagram

Dual-In-Line Package



TOP VIEW

Order Number LF11508D, LF12508D or LF13508D
See Package 2

truth table

EN	A2	A1	A0	SWITCH ON
H	L	L	L	1
H	L	L	H	2
H	L	H	L	3
H	L	H	H	4
H	H	L	L	5
H	H	L	H	6
H	H	H	L	7
H	H	H	H	8
L	X	X	X	NONE

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

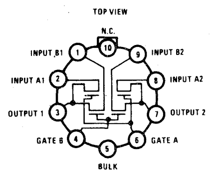
These devices are useful in many airborne and ground support systems requiring multiplexing, analog transmission, and numerous signal routing applications. The use of low threshold transistors (V_{TH} = 2 volts) permits operations with large analog input swings (± 10 volts) at low gate voltages (−20 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.

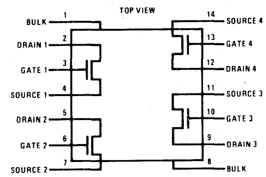
The MM450, MM451, MM452 and MM455 are specified for operation over the −55°C to +125°C military temperature range. The MM550, MM551, MM552 and MM555 are specified for operation over the −25°C to +70°C temperature range.

schematic and connection diagrams



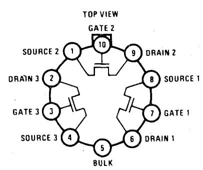
Note: Pin 5 connected to case and device bulk.
MM450, MM550

Order Number MM450H or MM550H
See Package 12



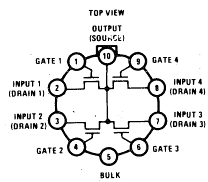
Note 1: Pins 1 and 8 connected to case and device bulk. Drain and Source may be interchanged.
MM452F, MM552F.
Note 2: MM452D and MM552D (dual-in-line packages) have same pin connections as MM452F and MM552F shown above.

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

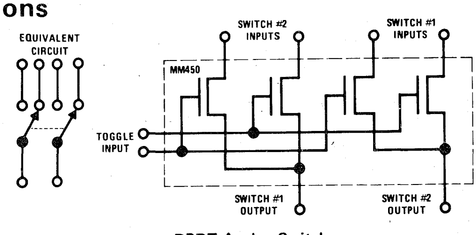
Order Number MM455H or MM555H
See Package 12



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.

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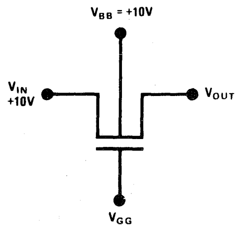
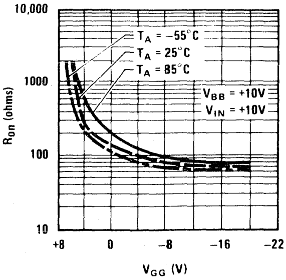
typical dynamic input characteristics (T_A = 25°C Unless Otherwise Noted)

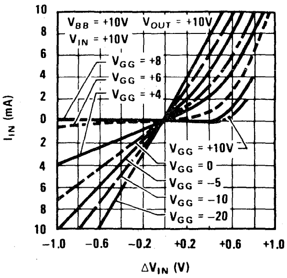
CONDITION 1: ANALOG INPUT VOLTAGE AT +10 VOLTS



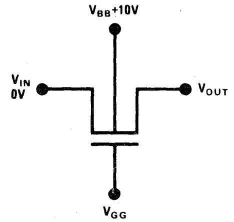
Ron vs VGG



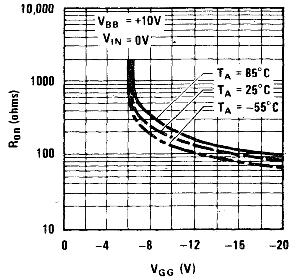
Dynamic Ron



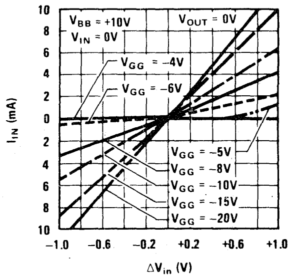
CONDITION 2: ANALOG INPUT VOLTAGE AT 0 VOLTS



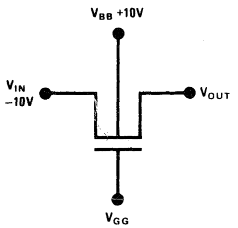
Ron vs VGG



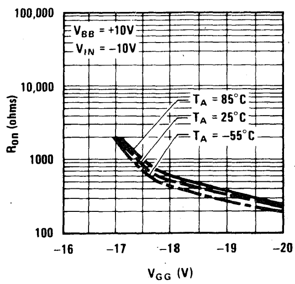
Dynamic Ron



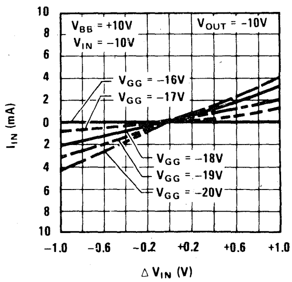
CONDITION 3: ANALOG INPUT VOLTAGE AT −10 VOLTS



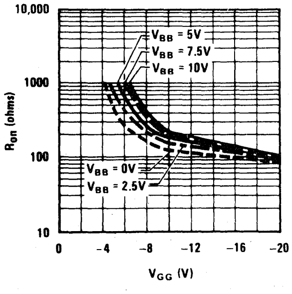
Ron vs VGG



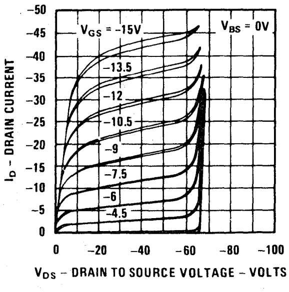
Dynamic Ron



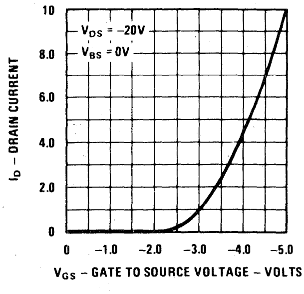
Ron vs VGG



Typical Drain Characteristics

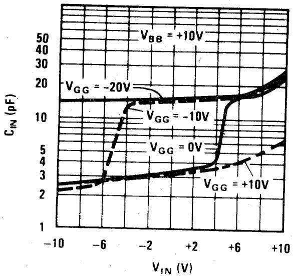


Drain Current vs Gate To Source Voltage

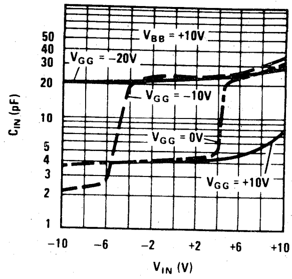


typical input capacitance characteristics

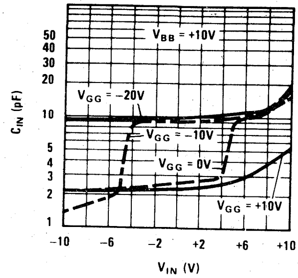
MM450, MM550
C_{IN} vs V_{IN}



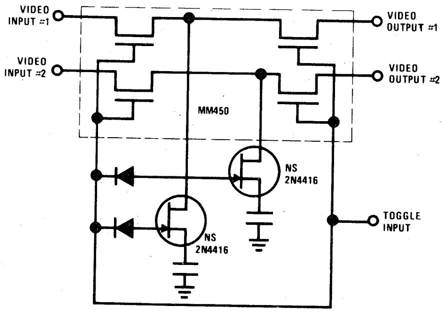
MM451, MM551
C_{IN} vs V_{IN}



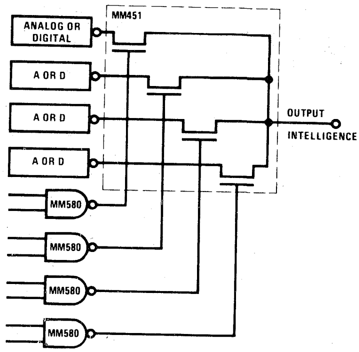
MM452, MM552, MM455, MM555
C_{IN} vs V_{IN}



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.

6

Analog Switches

MM454/MM554 4-channel commutator

general description

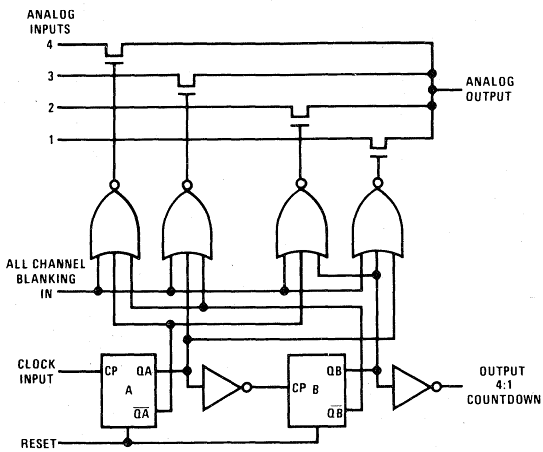
The MM454/MM554 is a 4-channel analog commutator capable of switching four analog input channels sequentially onto an output line. The device is constructed on a single silicon chip using MOS P Channel enhancement transistors; it contains all the digital circuitry necessary to sequentially turn ON the four analog switch transistors permitting multiplexing of the analog input data. The device features:

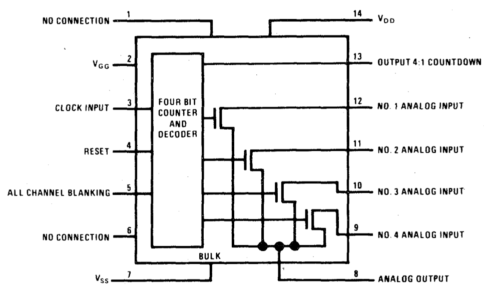
- High Analog Voltage Handling ±10V
- High Commutating Rate 500 kHz
- Low Leakage Current (T_A = 25°C) 200 pA; (T_A = 85°C) 50 nA
- All Channel Blanking input provided
- Reset capability provided
- Low ON Resistance 200Ω

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.

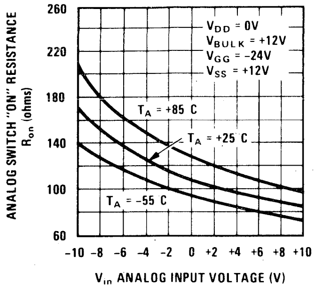
Note 2: These specifications apply over the indicated operating temperature range for V_{GG} = −24V, V_{DD} = 0V, V_{SS} = +12V, V_{RESET} = +12V, V_{BLANK} = +12V. ON resistance measured at 1 mA, OFF resistance and leakage measured with all analog inputs and output common. Capacitance measured at 1 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.

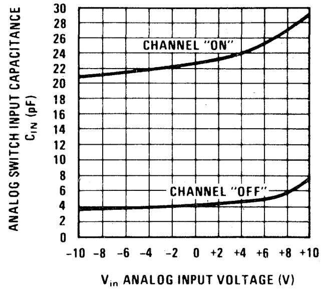
Note 4: Logic input voltage must not be more positive than V_{SS}.

typical performance characteristics

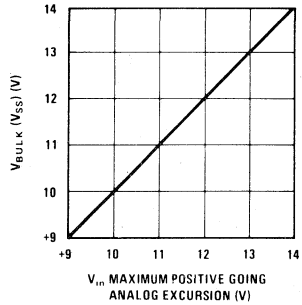
RON vs Analog Voltage



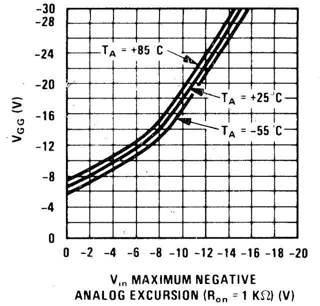
CIN vs VIN



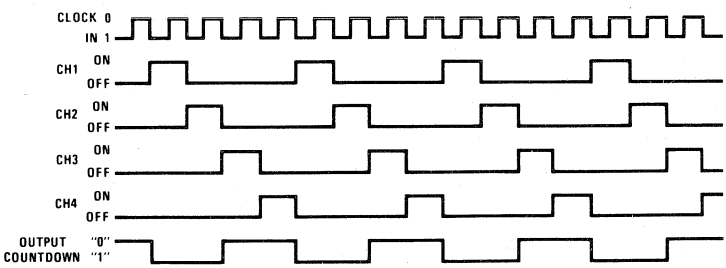
Plus VIN (max) vs VBULK



Minus VIN (max) vs VGG

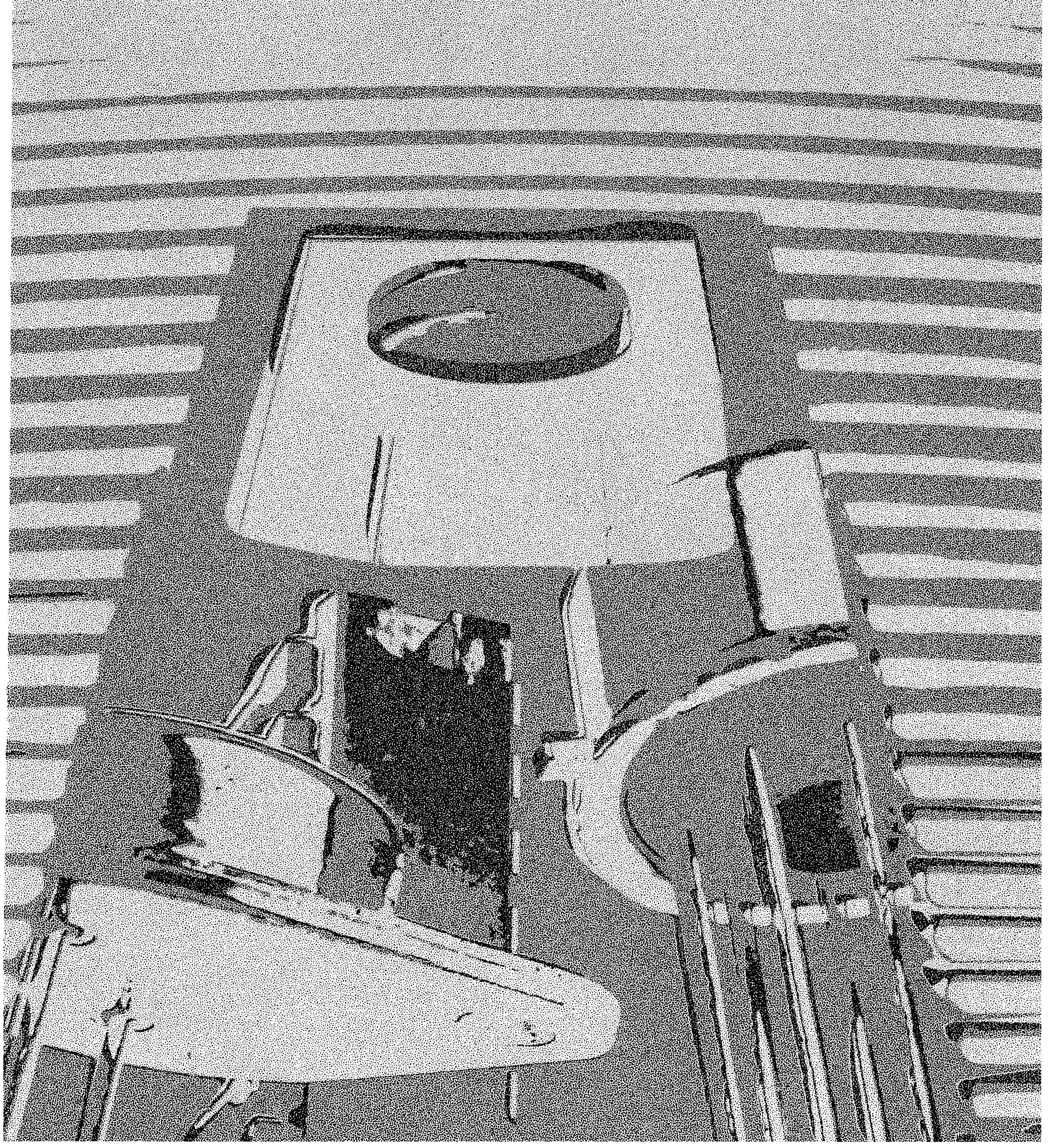


timing diagram



NOTE: "0" LEVEL = +12V
"1" LEVEL = 0V (GND)

National Semiconductor
SAMPLE AND HOLD
Section 7



Sample and Hold

Section Contents

*Product added to this Data Book since last printing.

7

Definition of Terms

Acquisition Time: The time required to acquire a new analog input voltage with an output step of 10V. Note that acquisition time is not just the time required for the output to settle, but also includes the time required for all internal nodes to settle so that the output assumes the proper value when switched to the hold mode.

Aperture Time: The delay required between "Hold" command and an input analog transition, so that the transition does not affect the held output.

Dynamic Sampling Error: The error introduced into the held output due to a changing analog input at the time the hold command is given. Error is expressed in mV with a given hold capacitor value and input slew rate. Note that this error term occurs even for long sample times.

Gain Error: The ratio of output voltage swing to input voltage swing in the sample mode expressed as a percent difference.

Hold Settling Time: The time required for the output to settle within 1 mV of final value after the "hold" logic command.

Hold Step: The voltage step at the output of the sample and hold when switching from sample mode to hold mode with a steady (dc) analog input voltage. Logic swing is 5V.

Sample and Hold

LF198/LF298/LF398 monolithic sample and hold circuits

general description

The LF198/LF298/LF398 are monolithic sample and hold circuits which utilize BI-FET technology to obtain ultra-high dc accuracy with fast acquisition of signal and low droop rate. Operating as a unity gain follower, dc gain accuracy is 0.002% typical and acquisition time is as low as 6μs to 0.01%. A bipolar input stage is used to achieve low offset voltage and wide bandwidth. Input offset adjust is accomplished with a single pin and does not degrade input offset drift. The wide bandwidth allows the LF198 to be included inside the feedback loop of 1 MHz op amps without having stability problems. Input impedance of $10^{10}\Omega$ allows high source impedances to be used without degrading accuracy.

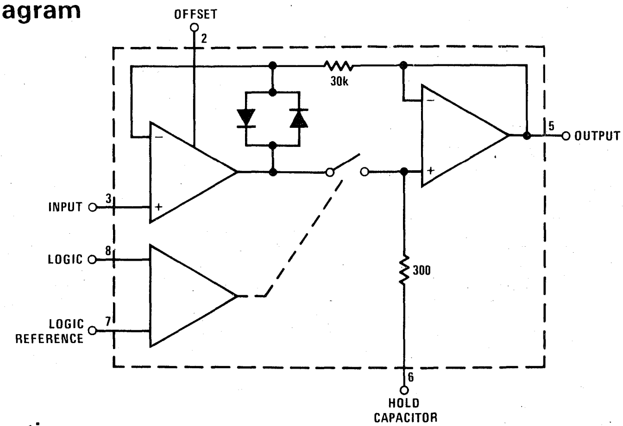
P-channel junction FET's are combined with bipolar devices in the output amplifier to give droop rates as low as 5 mV/min with a 1μF hold capacitor. The JFET's have much lower noise than MOS devices used in previous designs and do not exhibit high temperature instabilities. The overall design guarantees no feedthrough from input to output in the hold mode even for input signals equal to the supply voltages.

features

- Operates from ±5V to ±18V supplies
- Less than 10μs acquisition time
- TTL, PMOS, CMOS compatible logic input
- 0.5 mV typical hold step at C_h = 0.01μF
- Low input offset
- 0.002% gain accuracy
- Low output noise in hold mode
- Input characteristics do not change during hold mode
- High supply rejection ratio in sample or hold
- Wide bandwidth

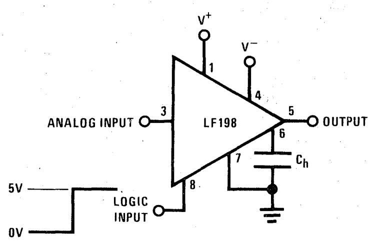
Logic inputs on the LF198 are fully differential with low input current, allowing direct connection to TTL, PMOS, and CMOS. Differential threshold is 1.4V. The LF198 will operate from ±5V to ±18V supplies. It is available in an 8-lead TO-5 package.

functional diagram

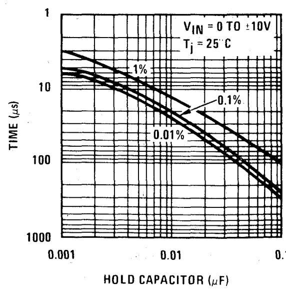


typical applications

Typical Connection



Acquisition Time



absolute maximum ratings

Supply Voltage	±18V
Power Dissipation (Package Limitation) (Note 1)	500 mW
Operating Ambient Temperature Range	
LF198	−55°C to +125°C
LF298	−25°C to +85°C
LF398	0°C to +70°C
Storage Temperature Range	−65°C to +150°C
Input Voltage	Equal to Supply Voltage
Logic To Logic Reference Differential Voltage (Note 2)	+7V, −30V
Output Short Circuit Duration	Indefinite
Hold Capacitor Short Circuit Duration	10 sec
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 3)

PARAMETER	CONDITIONS	LF198/LF298			LF398			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Input Offset Voltage, (Note 6)	$T_j = 25°C$		1	3		2	7	mV
	Full Temperature Range			5			10	mV
Input Bias Current, (Note 6)	$T_j = 25°C$		5	25		10	50	nA
	Full Temperature Range			75			100	nA
Input Impedance	$T_j = 25°C$		10^{10}			10^{10}		Ω
Gain Error	$T_j = 25°C$, $R_L = 10k$		0.002	0.005		0.004	0.01	%
	Full Temperature Range			0.02			0.02	%
Feedthrough Attenuation Ratio at 1 kHz	$T_j = 25°C$, $C_h = 0.01\mu F$	86	96		80	90		dB
Output Impedance	$T_j = 25°C$, "HOLD" mode		0.5	2		0.5	4	Ω
	Full Temperature Range			4			6	Ω
"HOLD" Step, (Note 4)	$T_j = 25°C$, $C_h = 0.01\mu F$, $V_{OUT} = 0$		0.5	2.0		1.0	2.5	mV
Supply Current, (Note 6)	$T_j \geq 25°C$		4.5	5.5		4.5	6.5	mA
Logic and Logic Reference Input Current	$T_j = 25°C$		2	10		2	10	μA
Leakage Current into Hold Capacitor (Note 6)	$T_j = 25°C$, (Note 5) Hold Mode		30	100		30	200	pA
Acquisition Time to 0.1%	$\Delta V_{OUT} = 10V$, $C_h = 1000\ pF$		4			4		μs
	$C_h = 0.01\mu F$		20			20		μs
Hold Capacitor Charging Current	$V_{IN} - V_{OUT} = 2V$		5			5		mA
Supply Voltage Rejection Ratio	$V_{OUT} = 0$	80	110		80	110		dB
Differential Logic Threshold	$T_j = 25°C$	0.8	1.4	2.4	0.8	1.4	2.4	V

Note 1: The maximum junction temperature of the LF198 is 150°C, for the LF298, 115°C, and for the LF398, 100°C. When operating at elevated ambient temperature, the TO-5 package must be derated based on a thermal resistance (Θ_{jA}) of 150°C/W.

Note 2: Although the differential voltage may not exceed the limits given, the common-mode voltage on the logic pins may be equal to the supply voltages without causing damage to the circuit. For proper logic operation, however, one of the logic pins must always be at least 2V below the positive supply and 3V above the negative supply.

Note 3: Unless otherwise specified, the following conditions apply. Unit is in "sample" mode, $V_S = \pm 15V$, $T_j = 25°C$, $-11.5V \leq V_{IN} \leq +11.5V$, $C_h = 0.01\mu F$, and $R_L = 10\ k\Omega$. Logic reference voltage = 0V and logic voltage = 2.5V.

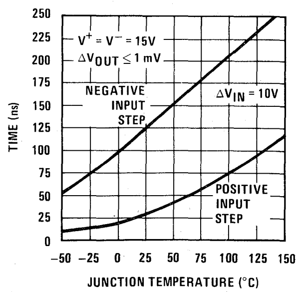
Note 4: Hold step is sensitive to stray capacitive coupling between input logic signals and the hold capacitor. 1 pF, for instance, will create an additional 0.5 mV step with a 5V logic swing and a 0.01μF hold capacitor. Magnitude of the hold step is inversely proportional to hold capacitor value.

Note 5: Leakage current is measured at a *junction* temperature of 25°C. The effects of junction temperature rise due to power dissipation or elevated ambient can be calculated by doubling the 25°C value for each 11°C increase in chip temperature. Leakage is guaranteed over full input signal range.

Note 6: These parameters guaranteed over a supply voltage range of ±5 to ±18V.

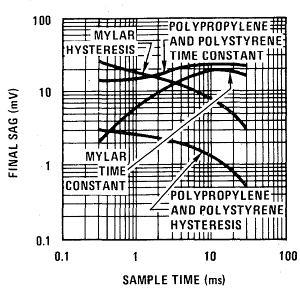
typical performance characteristics

Aperture Time*

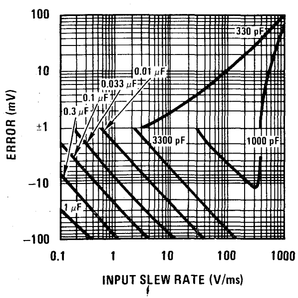


*See definition

Capacitor Hysteresis

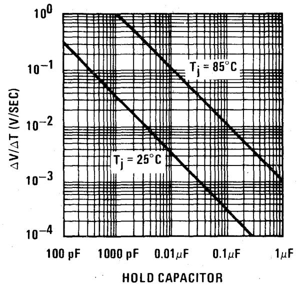


Dynamic Sampling Error

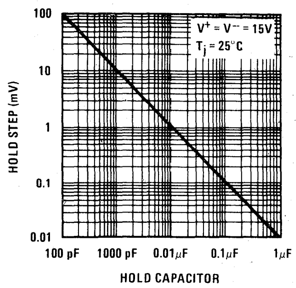


typical performance characteristics (con't)

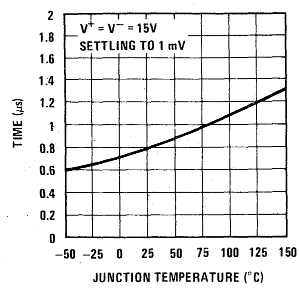
Output Droop Rate



Hold Step

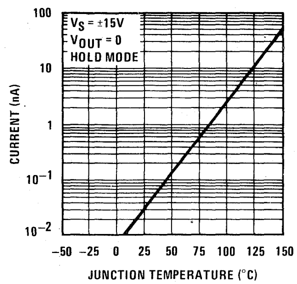


"Hold" Settling Time*

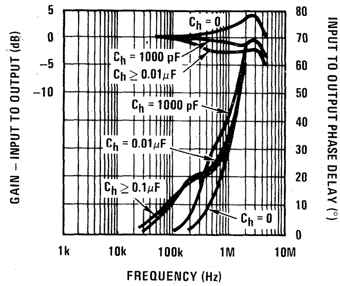


*See definition

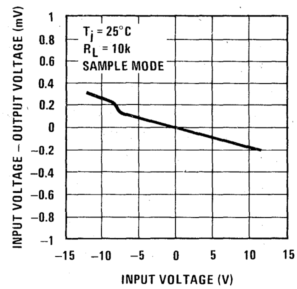
Leakage Current into Hold Capacitor



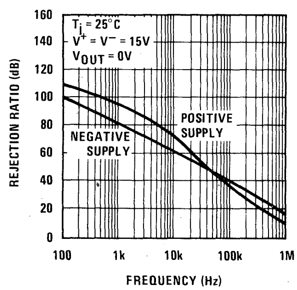
Phase and Gain (Input to Output, Small Signal)



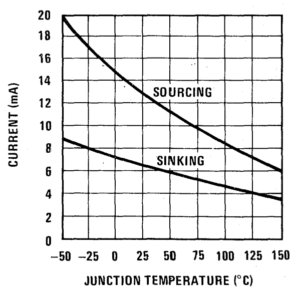
Gain Error



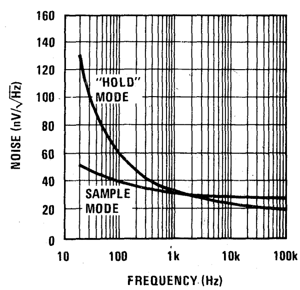
Power Supply Rejection



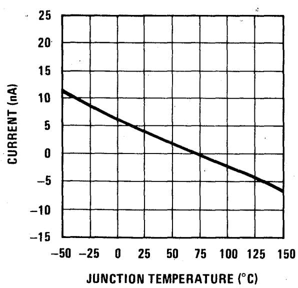
Output Short Circuit Current



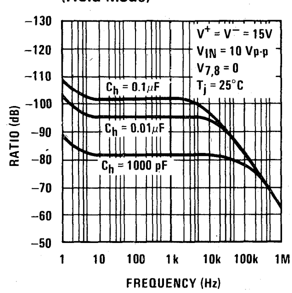
Output Noise



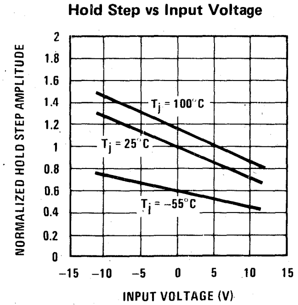
Input Bias Current



Feedthrough Rejection Ratio (Hold Mode)



Hold Step vs Input Voltage



application hints

Hold Capacitor

Hold step, acquisition time, and droop rate are the major trade-offs in the selection of a hold capacitor value. Size and cost may also become important for larger values. Use of the curves included with this data sheet should be helpful in selecting a reasonable value of capacitance. Keep in mind that for fast repetition rates or tracking fast signals, the capacitor drive currents may cause a significant temperature rise in the LF198.

A significant source of error in an accurate sample and hold circuit is dielectric absorption in the hold capacitor. A mylar cap, for instance, may "sag back" up to 0.2% after a quick change in voltage. A long "soak" time is required before the circuit can be put back into the hold mode with this type of capacitor. Dielectrics with very low hysteresis are polystyrene, polypropylene, and Teflon. Other types such as mica and polycarbonate are not nearly as good. Ceramic is unusable with > 1% hysteresis. The advantage of polypropylene over polystyrene is that it extends the maximum ambient temperature from 85°C to 100°C. For more exact data, see the curve labeled dielectric absorption error vs sample time. The hysteresis numbers on the curve are final values, taken after full relaxation. The hysteresis error can be significantly reduced if the output of the LF198 is digitized quickly after the hold mode is initiated. The hysteresis relaxation time constant in polypropylene, for instance, is 10–50 ms. If A-to-D conversion can be made within 1 ms, hysteresis error will be reduced by a factor of ten.

DC and AC Zeroing

DC zeroing is accomplished by connecting the offset adjust pin to the wiper of a 1 kΩ potentiometer which has one end tied to V^+ and the other end tied through a resistor to ground. The resistor should be selected to give ≈0.6 mA through the 1k potentiometer.

AC zeroing (hold step zeroing) can be obtained by adding an inverter with the adjustment pot tied input to output. A 10 pF capacitor from the wiper to the hold capacitor will give ±4 mV hold step adjustment with a 0.01μF hold capacitor and 5V logic supply. For larger logic swings, a smaller capacitor (< 10 pF) may be used.

Logic Rise Time

For proper operation, logic signals into the LF198 must have a minimum dV/dt of 0.2 V/μs. Slower signals will cause excessive hold step. If a R/C network is used in front of the logic input for signal delay, calculate the slope of the waveform at the threshold point to ensure that it is at least 0.2 V/μs.

Sampling Dynamic Signals

Sample error due to moving input signals probably causes more confusion among sample-and-hold users than any other parameter. The primary reason for this is that many users make the assumption that the sample and hold amplifier is truly locked on to the input signal while in the sample mode. In actuality, there are finite phase delays through the circuit creating an input-output differential for fast moving signals. In addition, although the output may have settled, the hold capacitor has an additional lag due to the 300Ω series resistor on the chip. This means that at the moment the "hold" command arrives, the hold capacitor voltage may be somewhat different than the actual analog input. The effect of these delays is opposite to the effect created by delays in the logic which switches the circuit from sample to hold. For example, consider an analog input of 20 Vp-p at 10 kHz. Maximum dV/dt is 0.6 V/μs. With no analog phase delay and 100 ns logic delay, one could expect up to (0.1μs)(0.6V/μs) = 60 mV error if the "hold" signal arrived near maximum dV/dt of the input. A positive-going input would give a ±60 mV error. Now assume a 1 MHz (3 dB) bandwidth for the overall analog loop. This generates a phase delay of 160 ns. If the hold capacitor sees this exact delay, then error due to analog delay will be (0.16μs)(0.6 V/μs) = –96 mV. Total output error is +60 mV (digital) –96 mV (analog) for a total of –36 mV. To add to the confusion, analog delay is proportional to hold capacitor value while digital delay remains constant. A family of curves (dynamic sampling error) is included to help estimate errors.

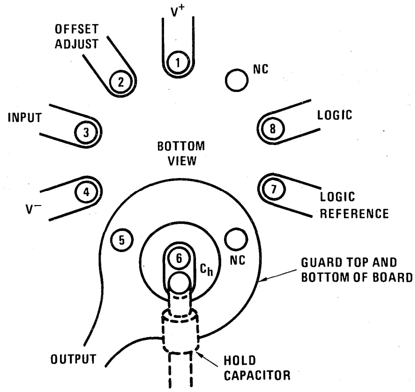
A curve labeled Aperture Time has been included for sampling conditions where the input is steady during the sampling period, but may experience a sudden change nearly coincident with the "hold" command. This curve is based on a 1 mV error fed into the output.

A second curve, Hold Settling Time indicates the time required for the output to settle to 1 mV after the "hold" command.

Digital Feedthrough

Fast rise time logic signals can cause hold errors by feeding externally into the analog input at the same time the amplifier is put into the hold mode. To minimize this problem, board layout should keep logic lines as far as possible from the analog input. Grounded guarding traces may also be used around the input line, especially if it is driven from a high impedance source. Reducing high amplitude logic signals to 2.5V will also help.

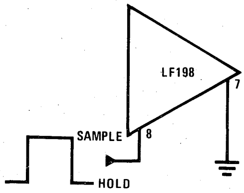
Guarding Technique



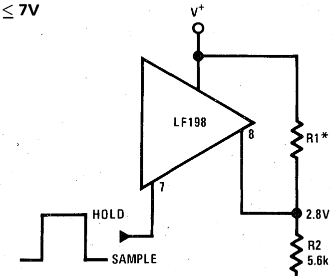
Use 10-pin layout. Guard around C_h is tied to output.

logic input configurations

TTL & CMOS
$3V \le V_L$ (Hi State) $\le 7V$

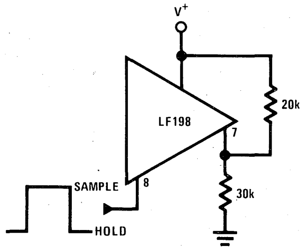


Threshold = 1.4V

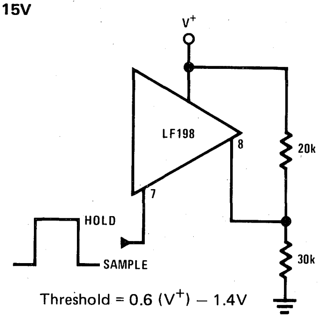


Threshold = 1.4V
*Select for 2.8V at pin 8

CMOS
$7V \le V_L$ (Hi State) $\le 15V$

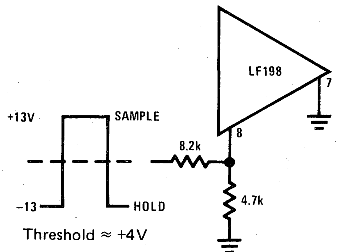


Threshold = 0.6 (V^+) + 1.4V

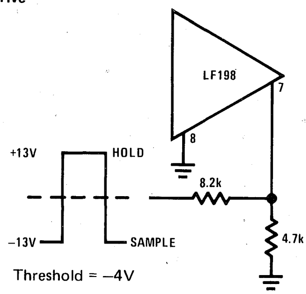


Threshold = 0.6 (V^+) − 1.4V

Op Amp Drive



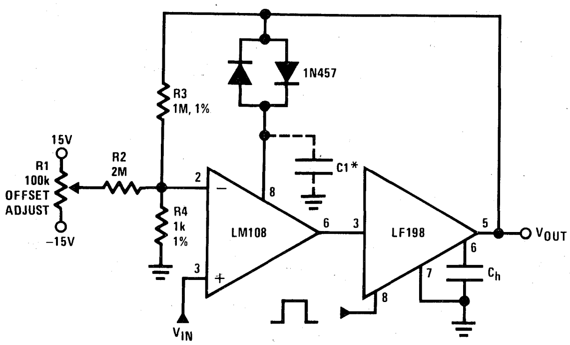
Threshold ≈ +4V



Threshold = −4V

typical applications (con't)

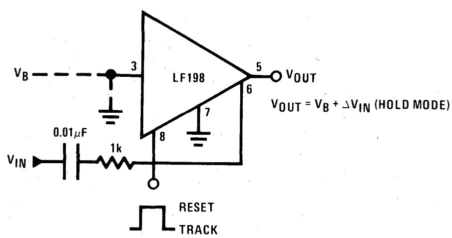
X1000 Sample & Hold



*For lower gains, the LM108 must be frequency compensated

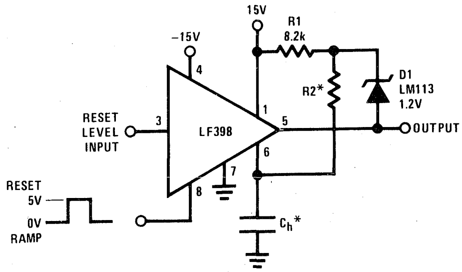
Use $\approx \frac{100}{A_V}$ pF from comp 2 to ground

Sample and Difference Circuit
(Output Follows Input in Hold Mode)



typical applications (con't)

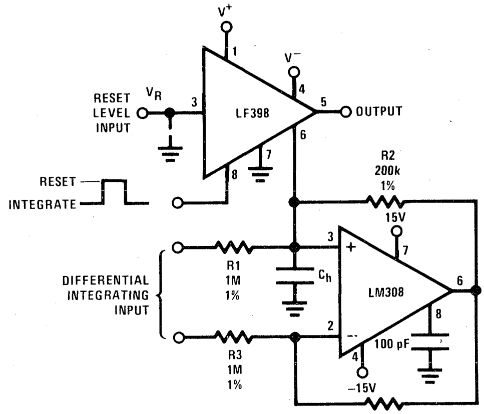
Ramp Generator with Variable Reset Level



*Select for ramp rate
R ≥ 10k

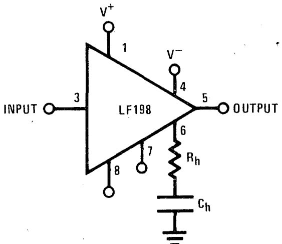
$$\frac{\Delta V}{\Delta T} = \frac{1.2V}{(R2)(C_h)}$$

Integrater with Programmable Reset Level



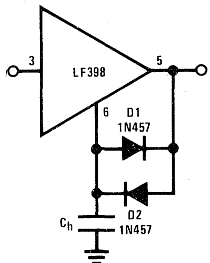
$$V_{OUT}\text{ (Hold Mode)} = \left[\frac{1}{(R1)(C_h)}\int_0^t V_{IN} dt\right] + \left[V_R\right]$$

Output Holds at Average of Sampled Input

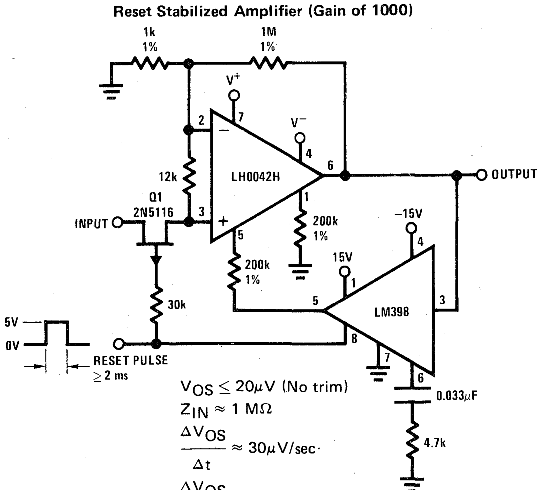


$$\text{Select } (R_h)(C_h) >> \frac{1}{2\pi f_{IN}\text{ (Min)}}$$

Increased Slew Current



Reset Stabilized Amplifier (Gain of 1000)



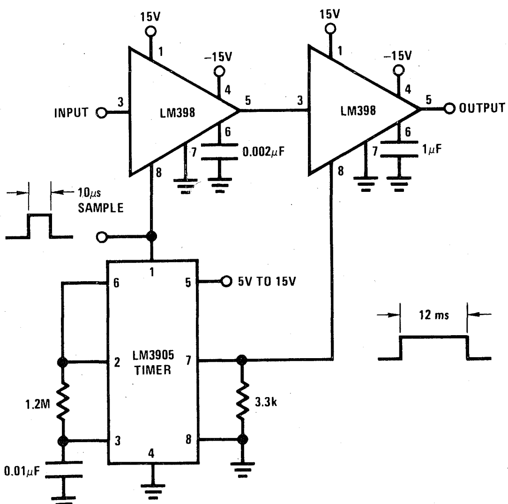
$V_{OS} \leq 20\mu V$ (No trim)

$Z_{IN} \approx 1\ M\Omega$

$\frac{\Delta V_{OS}}{\Delta t} \approx 30\mu V/sec$

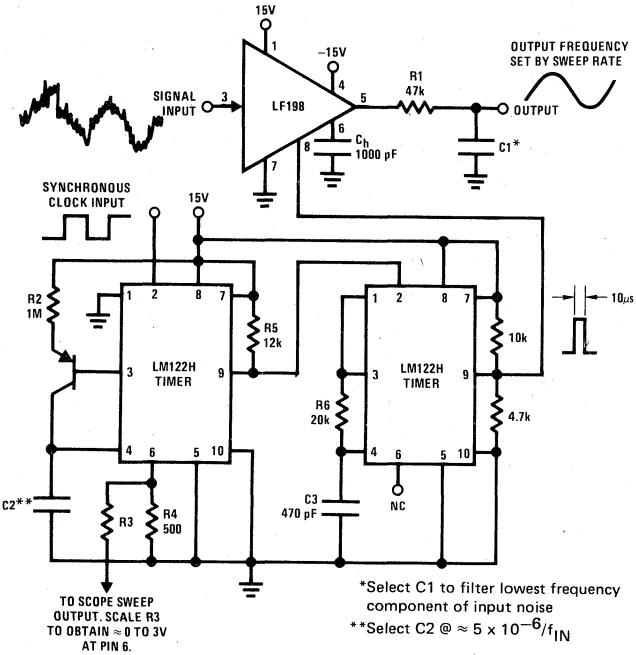
$\frac{\Delta V_{OS}}{\Delta T} \approx 0.1\mu V/°C$

Fast Acquisition, Low Droop Sample & Hold



typical applications (con't)

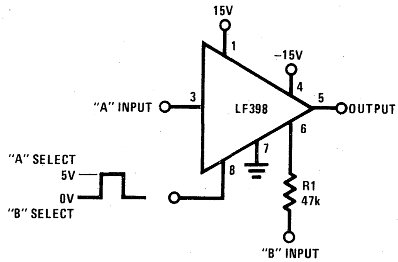
Synchronous Correlator for Recovering Signals Below Noise Level



*Select C1 to filter lowest frequency component of input noise

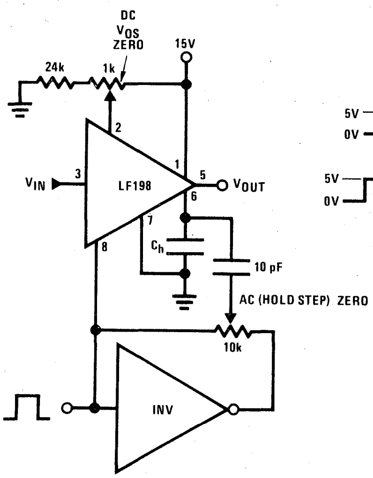
**Select C2 @ ≈ $5 \times 10^{-6}/f_{IN}$

2-Channel Switch

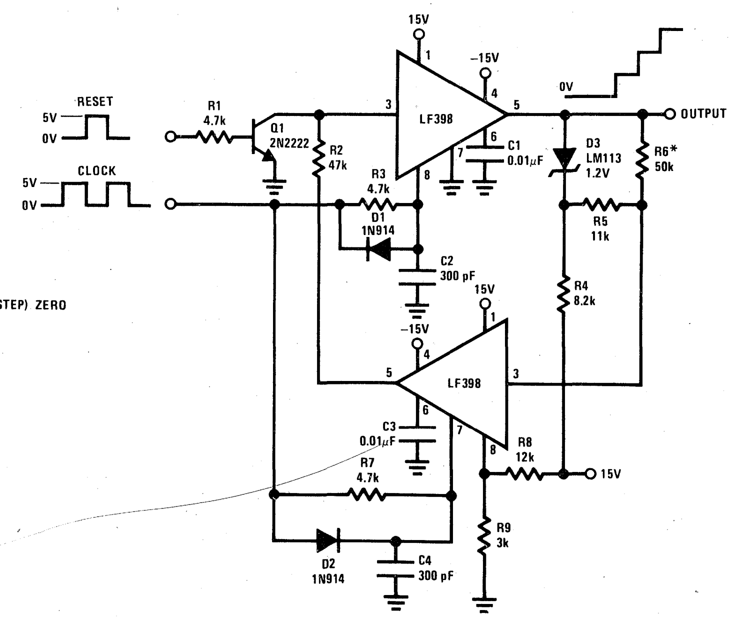


	A	B
Gain	1 ±0.02%	1 ±0.2%
Z_{IN}	$10^{10}\Omega$	47 kΩ
BW	≃1 MHz	≈400 kHz
Crosstalk @ 1 kHz	−90 dB	−90 dB
Offset	≤ 6 mV	≤ 75 mV

DC & AC Zeroing



Staircase Generator

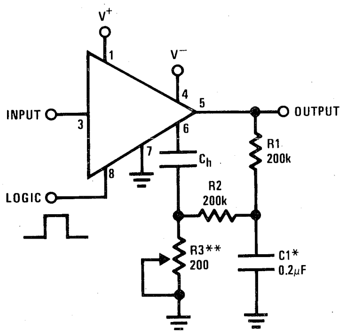


*Select for step height
50k → ≃ 1V Step

7

typical applications (con't)

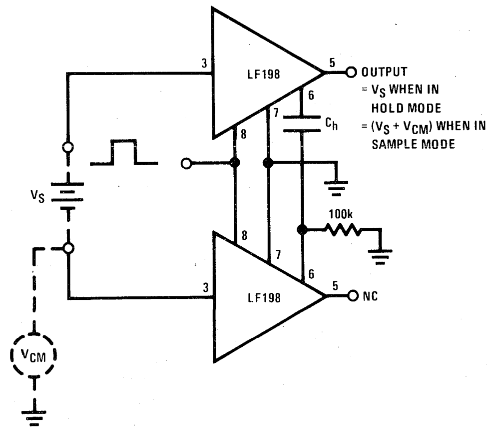
Capacitor Hysteresis Compensation



*Select for time constant C1 = $\frac{\tau}{100k}$

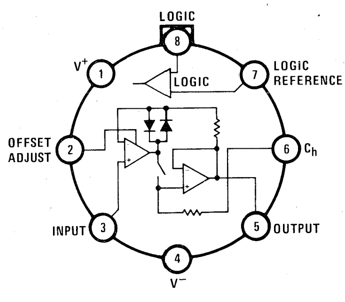
**Adjust for amplitude

Differential Hold



connection diagram

Metal Can Package



TOP VIEW

Order Number LF198H, LF298H or LF398H
See Package 11

Sample and Hold

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

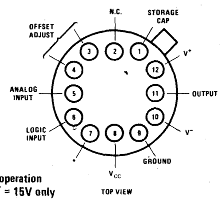
features

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

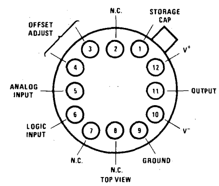
LH0023/LH0023C

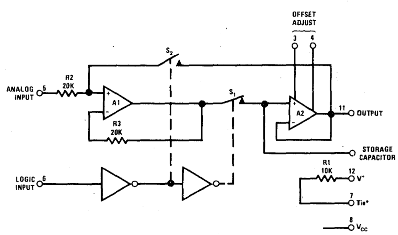


*Tie for operation with V+ = 15V only

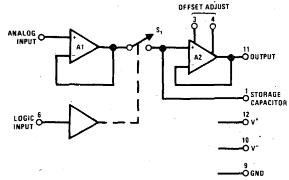
Order Number LH0023G or LH0023CG or LH0043G or LH0043CG
See Package 6

LH0043/LH0043C





*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						UNITS
		LH0023			LH0023C			
		MIN	TYP	MAX	MIN	TYP	MAX	
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)

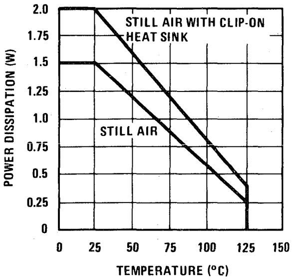
PARAMETER	CONDITIONS	LIMITS						UNITS
		LH0043			LH0043C			
		MIN	TYP	MAX	MIN	TYP	MAX	
Hold (Logic "1") Input Voltage		2.0			2.0			V
Hold (Logic "1") Input Current	$V_6 = 2.4V$			5.0			5.0	μA
Sample (Logic "0") Input Voltage				0.8			0.8	V
Sample (Logic "0") Input Current	$V_6 = 0.4V$			1.5			1.5	mA
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/μs
Output Offset Voltage (without null)	$R_S \le 10k$, $V_5 = 0V$, $V_6 = 0V$			±40			±40	mV
Analog Voltage Output Range	$R_L \ge 1k$, $T_A = 25°C$	±10	±11		±10	±11		V
	$R_L \ge 2k$	±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 $T_C = 25°C$.

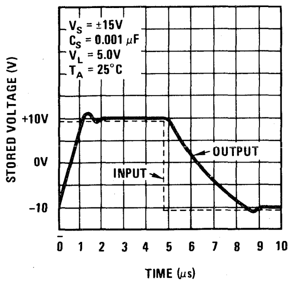
7

typical performance characteristics

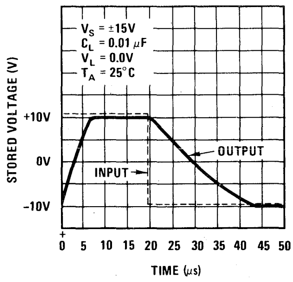
Power Dissipation



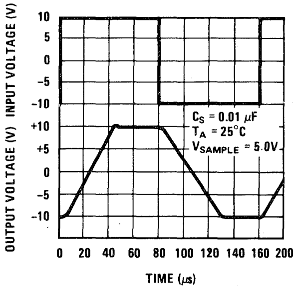
Sample Acquisition Time—LH0043



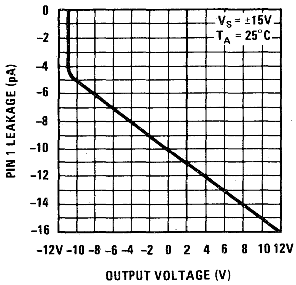
Sample Acquisition Time—LH0043



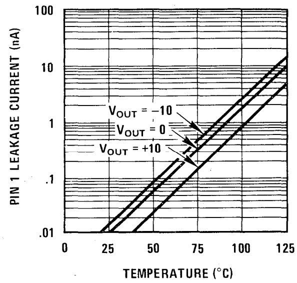
Sample Acquisition Time—LH0023



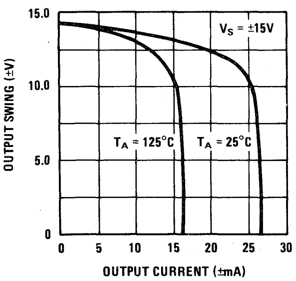
Pin 1 Leakage Current vs Output Voltage



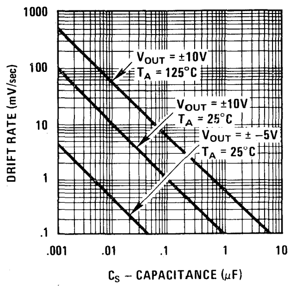
Pin 1 Leakage Current vs Temperature



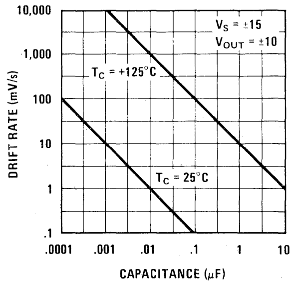
Output Current Limiting



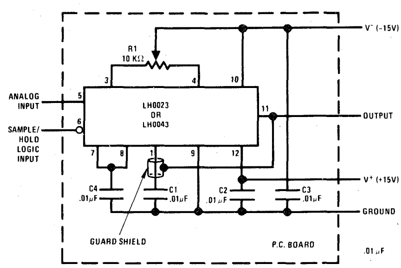
Drift Rate vs Capacitance



Drift vs Capacitance (LH0043)



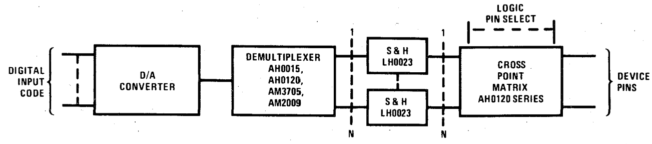
typical applications



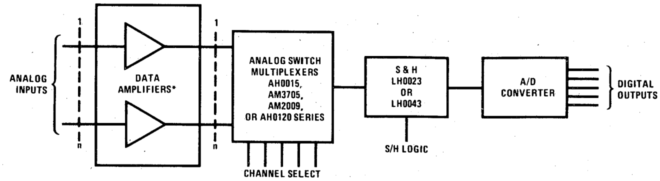
Note 1: C1 is polystyrene.
Note 2: C2, C3, C4 are cermic disc.
Note 3: Jumper 7–8 and C4 not required for LH0043.
Note 4: R1 optional if zero trim is required.

How to Build a Sample and Hold Module

typical applications (con't)

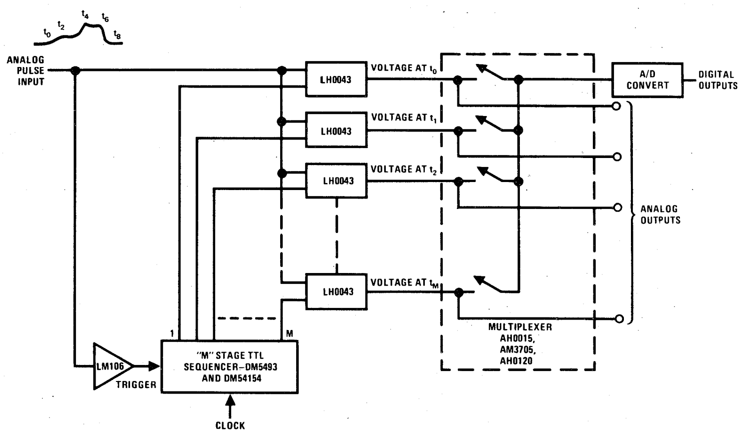


Forcing Function Setup for Automatic Test Gear

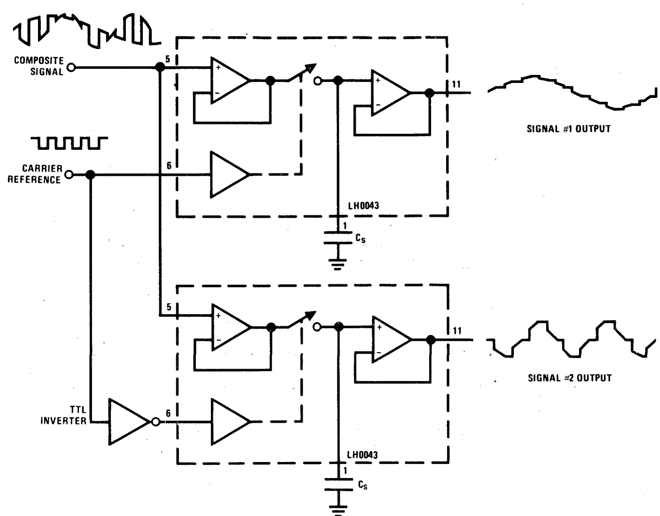


*See op amp selection guide for details. Most popular types include LH0052, LH175, LM108, LM112 and LM116.

Data Acquisition System



Single Pulse Sampler

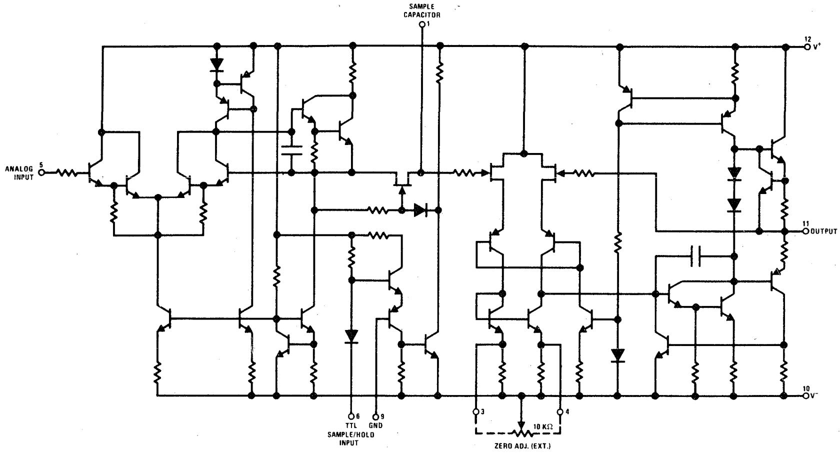


Two Channel Double Sideband Demodulator

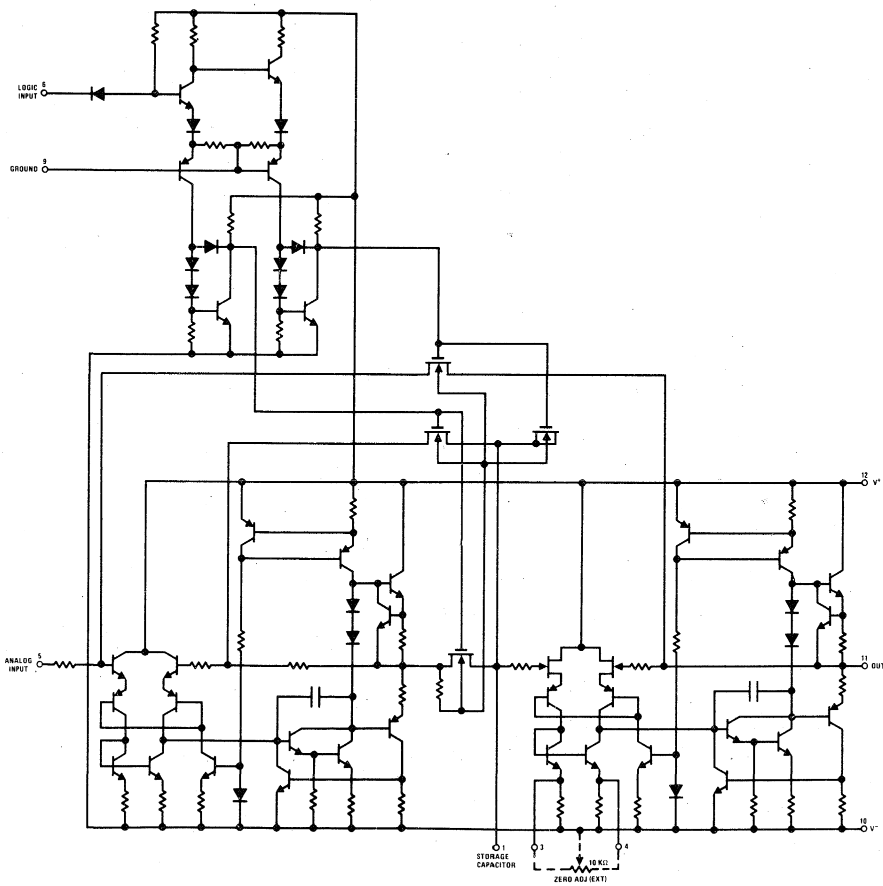
7

schematic diagrams

LH0043/LH0043C



LH0023/LH0023C



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

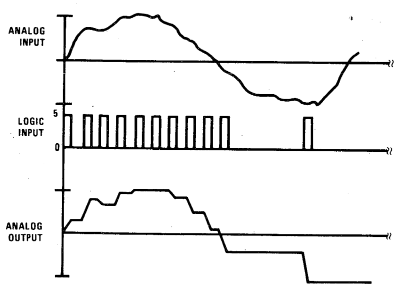
The LH0023/LH0023C is comprised of input buffer amplifier, A1, analog switches, S1 and S2, a

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^-.

Sample and Hold

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.

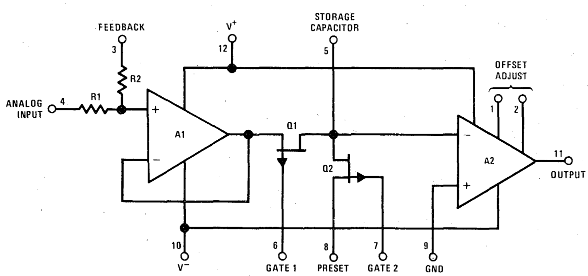
The device is ideally suited for a variety of high speed data acquisition applications including analog buffer memories for A to D conversion and synchronous demodulation.

An auxiliary switch within the device extends its usefulness in applications such as preset integrators.

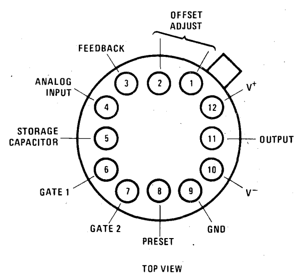
features

- 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

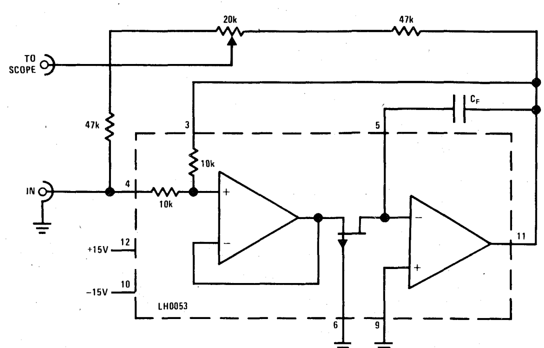


Metal Can Package



Order Number LH0053G or LH0053CG See Package 6

ac test circuit



Acquisition Time Test Circuit

7

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)

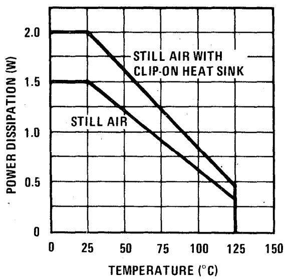
PARAMETER	CONDITIONS	LIMITS						UNITS
		LH0053			LH0053C			
		MIN	TYP	MAX	MIN	TYP	MAX	
Sample (Gate "0") Input Voltage				0.5			0.5	V
Sample (Gate "0") Input Current	V_6 = 0.5V, T_A = 25°C			−5.0			−5.0	μA
	V_6 = 0.5			−100			−100	μA
Hold (Gate "1") Input Voltage		4.5			4.5			V
Hold (Gate "1") Input Current	V_6 = 4.5V, T_A = 25°C			1.0			1.0	nA
	V_6 = 4.5V			1.0			1.0	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		5.0	7.0		5.0	10	mV
	V_4 = 0V, V_6 = 0.5V			10			15	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,		6.0	30		10	50	pA
	V_4 = ±10V			30			3.0	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.

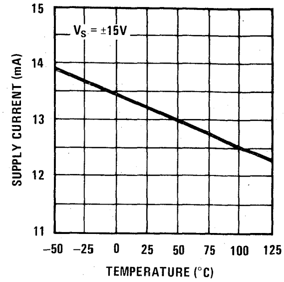
Note 2: Sample accuracy may be nulled by inserting a potentiometer in the feedback loop. This compensates for source impedance and feedback resistor tolerances.

typical performance characteristics

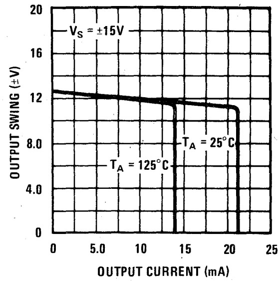
Power Dissipation



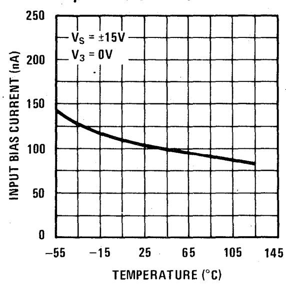
Supply Current vs Temperature



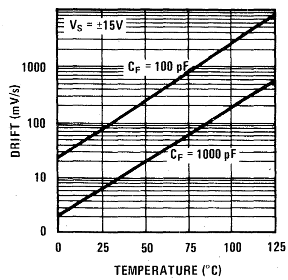
Output Current Limiting



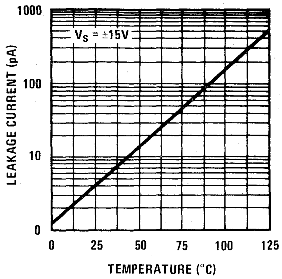
Input Bias Current



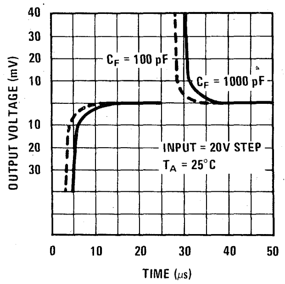
Drift



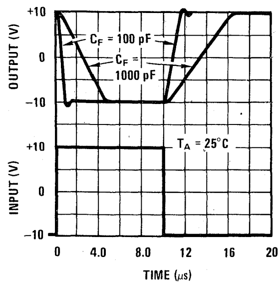
Leakage Current at Pin 5



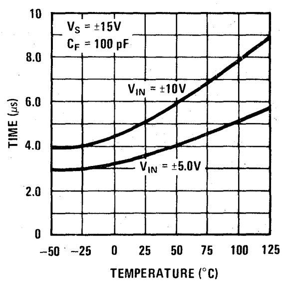
Sample Acquisition Time



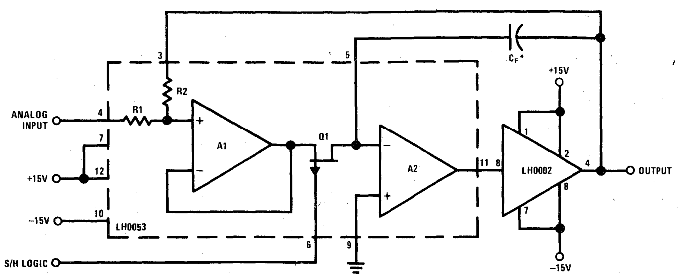
Output Slew Rate



Acquisition Time vs Temperature



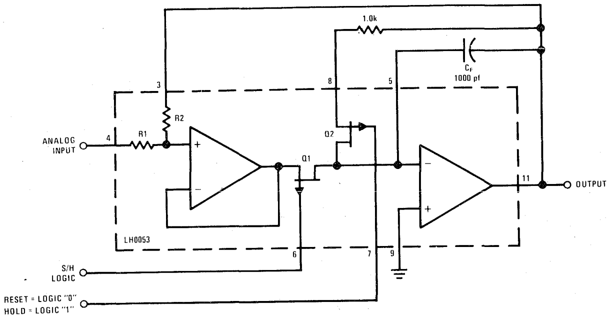
typical applications



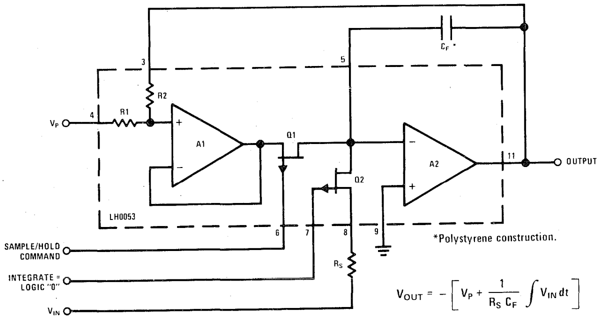
*Polystyrene construction.

Increasing Output Drive Capability

typical applications (con't)



Sample and Hold with Reset



$$V_{OUT} = -\left[V_P + \frac{1}{R_S C_F}\int V_{IN}\,dt\right]$$

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 = 10Ω, 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 (≅ 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 ≅ 5.0 mA

t_{S2} = The setting time of output amplifier ≅ 1.0μs

applications information (con't)

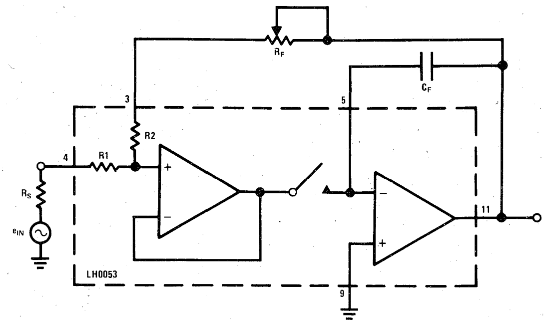


FIGURE 1. Non-Zero Source Impedance Compensation

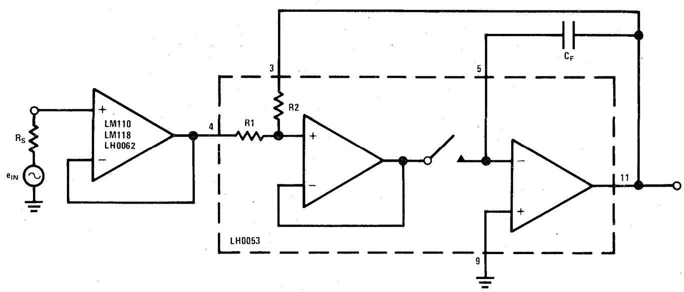


FIGURE 2. Non-Zero Source Impedance Buffering

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.

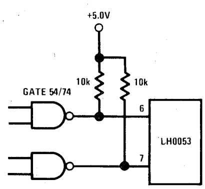


FIGURE 3. TTL Logic Compatibility

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.

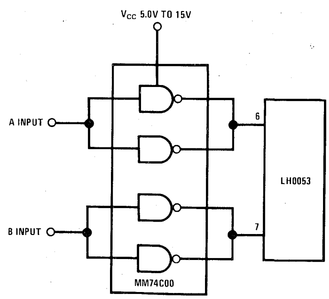


FIGURE 4. CMOS Logic Compatibility

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 $0.1\mu F$ disc capacitors in order to prevent oscillation. Should this procedure prove inadequate, the disc capacitors should be parallel with $4.7\mu F$ 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.

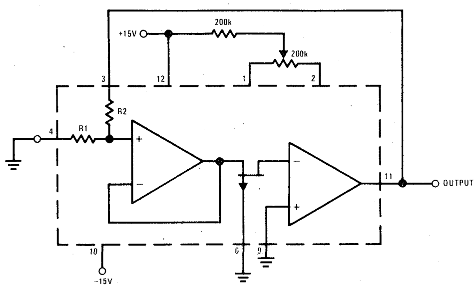
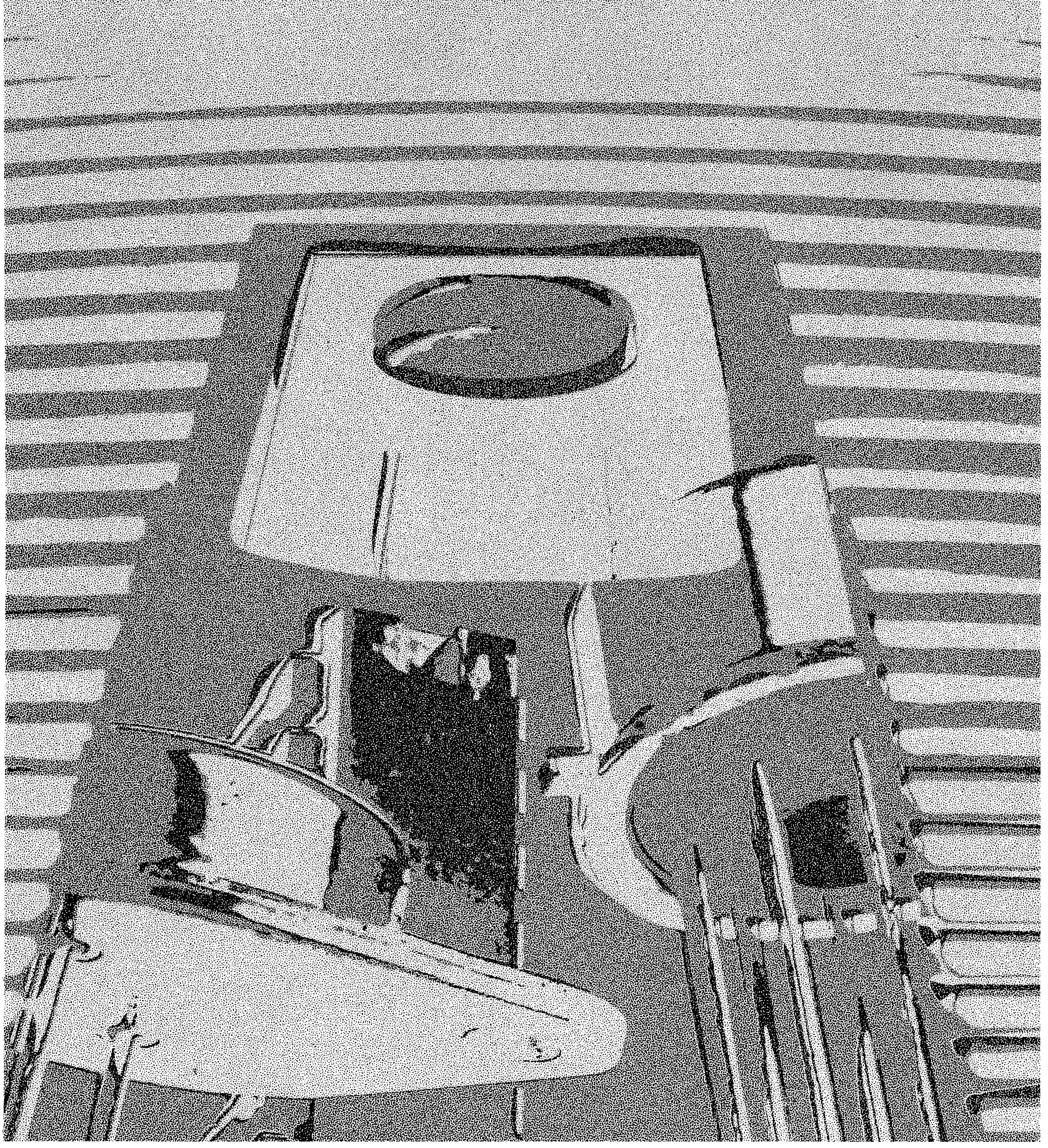


FIGURE 5. Offset Null Circuit

National Semiconductor
A to D, D to A
Section 8



A to D, D to A

Section Contents

*Product added to this Data Book since last printing.

8

Definition of Terms

Full-Scale Error: Full-scale error is a measure of the output error between an ideal D/A and the actual device output. Ideally, for the DA1200 full-scale is V_{REF} − 1 LSB. For V_{REF} = 10.240V and unipolar operation, $V_{FULLSCALE}$ = 10.240V − 2.5 mV = 10.2375V. Departures from this value include internal gain, scaling, and reference errors. Full-scale error is adjustable as discussed in the **Applications** section.

Linearity Error: Linearity error is the maximum deviation from a straight line passing through the end-points of the D/A transfer characteristic. It is measured after calibrating for zero and full-scale. The linearity error of the DA1200 series is guaranteed to be less than ±½ LSB or 0.0122% of F.S. for the DA1200/DA1200C and ±0.0488% of F.S. for the DA1201/DA1201C. Linearity error is a design parameter intrinsic to the device and cannot be externally adjusted.

Monotonicity: Monotonicity is a characteristic of the D/A which requires a non-negative output step for an increasing input digital code. Monotonicity, therefore, demands no back steps or sign changes of the D/A transfer characteristic slope.

Offset Voltage: Offset voltage is an output voltage other than zero volts for unipolar operation (and other than minus full-scale for bipolar operation) with all bits turned "OFF." In the DA1200 series this error resides primarily in the output amplifier, A3. Offset voltage is adjustable to zero as discussed in the applications section.

Power Supply Sensitivity: Power supply sensitivity is a measure of the effect of power supply changes on the D/A full-scale output.

Resolution: Resolution is defined as the reciprocal of the number of discrete steps in the D/A output (as designed). It is directly related to the number of switches or bits within the D/A. For example, the DA1200 has 2^{12} or 4096 steps. Resolution may therefore be expressed variously as 12 bits, as 1 part in 2^{12}, as 1 part in 4096, or as a percentage (1/4096 x 100 = 0.0244%). The DA1202 has 1000 steps and 3 BCD digits. Resolution may be expressed as 0.1% or 3 BCD digits.

Settling Time: Two settling time parameters are specified for the DA1200 series. Full-scale settling time requires a zero to full-scale or full-scale to zero output change. One LSB settling time requires one LSB output change. In both instances, settling time is the time required from a code transition until the D/A output reaches within ±½ LSB of final output value.

A to D, D to A
Future Product

AD1200 low cost 12-bit A/D converter building block

general description

The AD1200 is a 12-bit binary analog building block designed for use with a successive approximation register to build a fast A/D converter. It includes 12 precision current sources and switches, precision laser-trimmed thin film ladder network, precision reference, and high speed FET comparator. The AD1200 is specifically tailored to match the DM2502/DM2503/DM2504 or MM54C905/MM74C905.

The AD1200 comes in a 24-pin plastic DIP and 24-pin metal DIP. The AD1200A and AD1200C have 0.01% ±1/2 LSB accuracy; the AD1200B and AD1200D have 0.05% ±1/2 LSB accuracy.

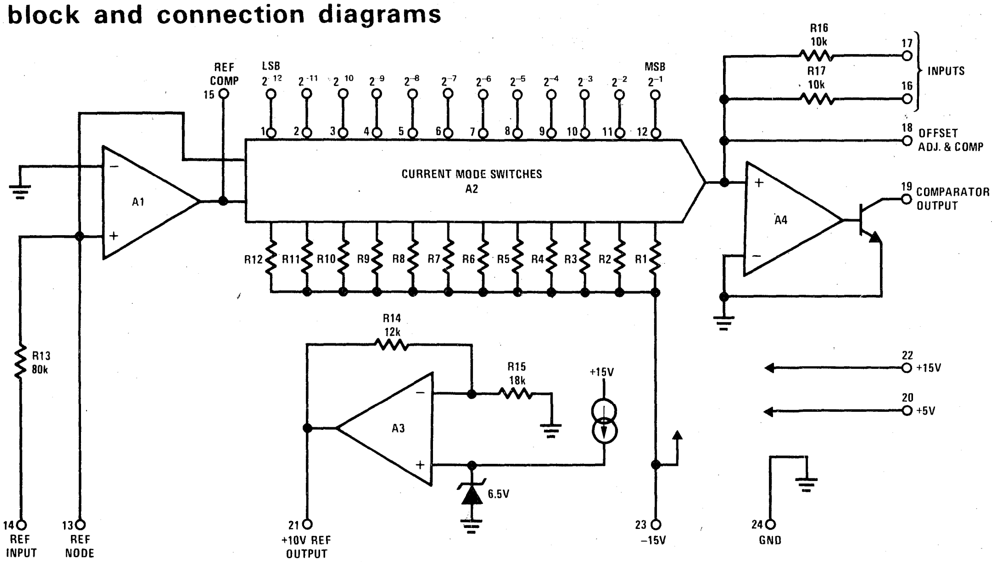
features

- Low cost
- Internal reference and FET comparator
- TTL, DTL, CMOS logic levels
- Standard power supplies ±15V, +5V

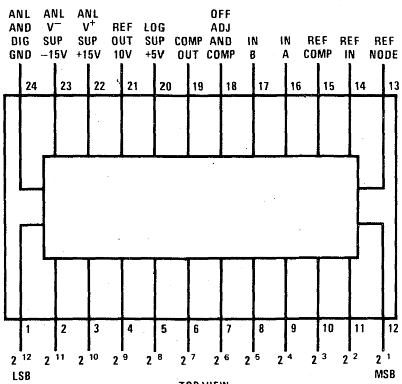
key specifications

- Resolution 12 bits
- Accuracy 0.01% ±1/2 LSB
- Conversion speed 15μs

block and connection diagrams



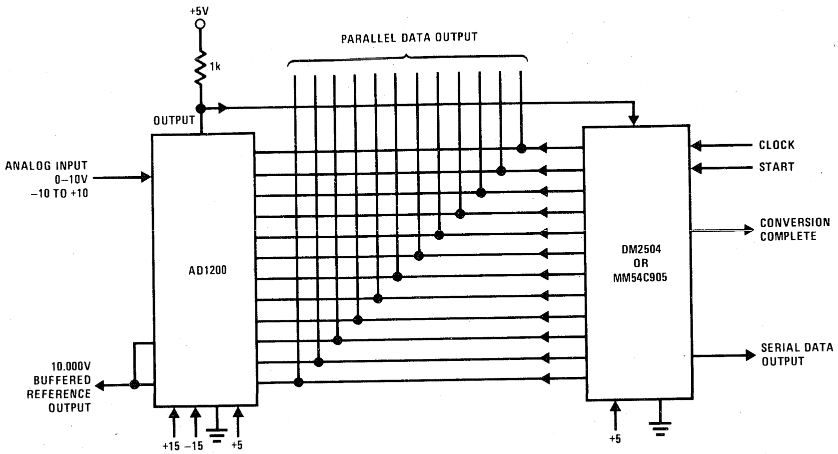
Dual-In-Line Package



TOP VIEW

Order Number AD1200N
See Package 29A

typical application



12-Bit Successive Approximation A to D

AD1210 12-bit CMOS A/D converter general description

The AD1210 is a low power 12-bit successive approximation analog-to-digital converter. Included within the device are the successive approximation logic, analog switches, precision laser trimmed thin film R-2R ladder network and FET input comparator. The AD1210 will operate over a wide supply range, convert bipolar or unipolar signals, and operate in start-stop or continuous conversion modes. The binary outputs are directly compatible with CMOS logic levels. The only active external component required is the reference.

The AD1210 is available in 24-pin plastic DIP or 24-pin metal DIP.

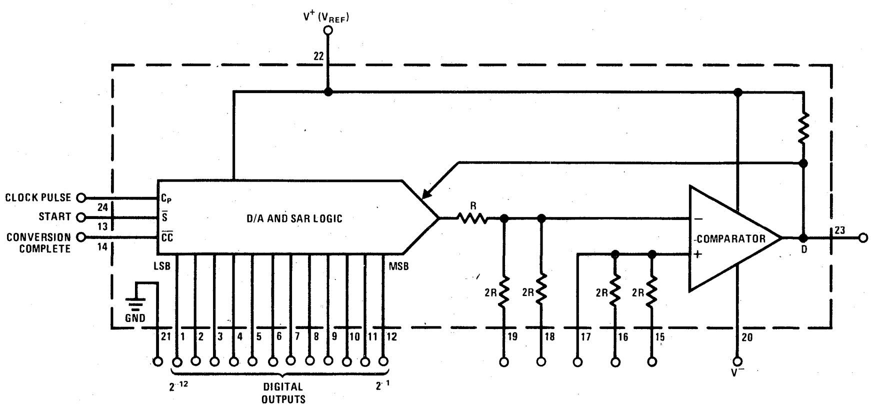
features

- Wide supply range 3V to 15V
- Single reference voltage
- CMOS compatible
- Low power consumption
- Single supply operation for single polarity voltages
- Internal comparator
- Provision for truncation
- Start/stop or continuous conversion
- High analog input impedance

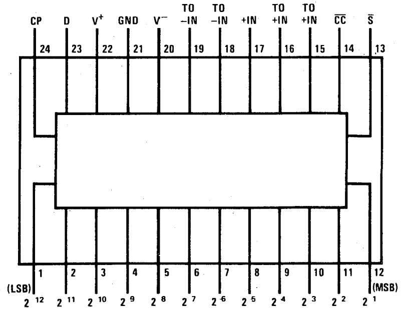
key specifications

- Resolution 12 bits
- Linearity ±1/2 LSB
- Clock rate up to 500 kHz
- Conversion rate 20 kHz
- Power consumption 75 mW @ +15V

block and connection diagrams



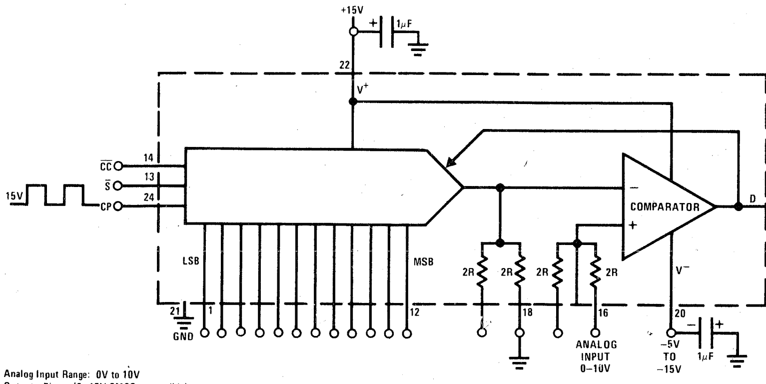
Dual-In-Line Package



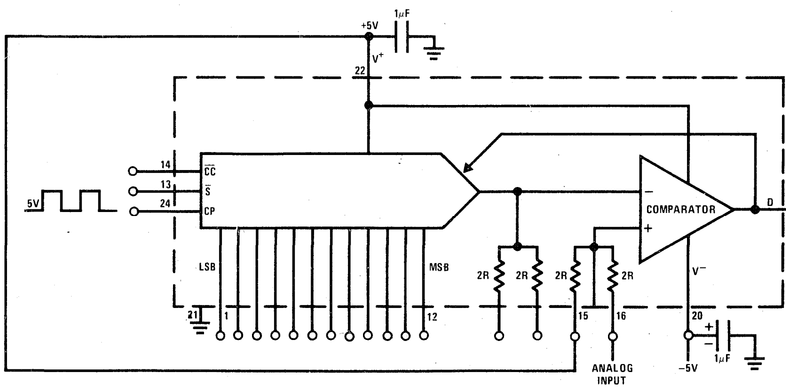
TOP VIEW

Order Number AD1210D
See Package 2A
Order Number AD1210N
See Package 29A

typical applications



Analog Input Range: 0V to 10V
Output: Binary (0–15V CMOS compatible)



Analog Input Range: −5V to +5V
Output: Offset Binary (0–5V CMOS compatible)

DA1200/DA1201 12-bit (binary) digital-to-analog converters
DA1202/DA1203 3-digit (BCD) digital-to-analog converters

general description

The DA1200 series of D/A converters is a family of precision low-cost converter building blocks intended to fulfill a wide range of industrial and military D/A applications. These devices are complete functional blocks requiring only application of power for operation. The design combines a precision 12-bit weighted current source (12 current switches and 12-bit thin-film resistor network), a rapid-settling operational amplifier, and 10.24V (for binary series) or 10.00V (for BCD series) buffered reference.

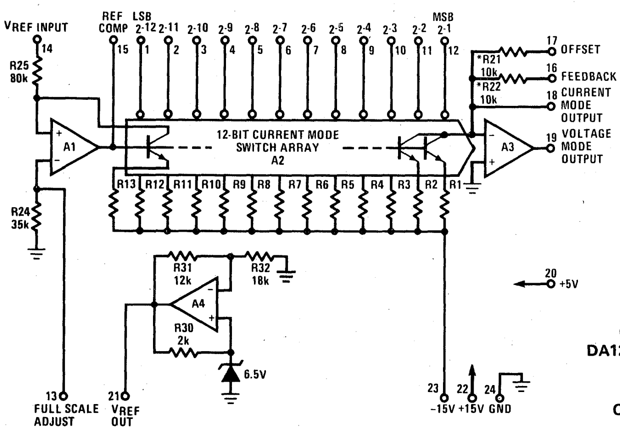
Input coding options include complementary binary and complementary BCD formats. In all instances, a logic "low" (≤ 0.8V) turns a given bit ON, and a logic "high" (≥ 2.0V) turns the bit OFF. Output format may be programmed for bipolar (±10V) or unipolar (0 to 10V) operation using internally supplied thin-film resistor pin strap options. Current mode operation is also available from 0 to 2mA (for binary) or 0 to 1.25mA (for BCD).

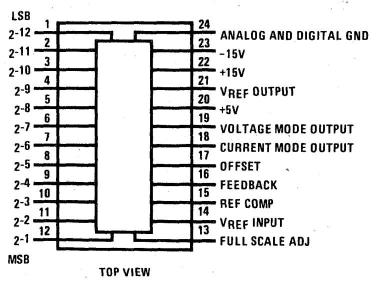
The entire series is available in hermetically sealed 24-lead DIP for military or stringent industrial applications, and in a 24-lead cavity plastic DIP.

features

- Circuit completely self-contained
- Both current and voltage-mode outputs
- Standard power supplies: ±15V and +5V
- Internal reference: 10.24V for binary
  10.00V for BCD
- 0 to 2mA, ±10V or 0 to 10V output by strapping internal resistors; other scales by external resistors
- ±1/2 LSB (binary) or ±1/10 LSD (BCD) linearity
- Fast settling time: 1.5μs in current mode
  2.5μs in voltage mode
- TTL and CMOS compatible complementary binary or BCD input logic format
- 12 bits, expandable to 14 or 16 bits
- Standard dual-width DIP package

block and connection diagrams





Order Number DA1200D, DA1200CD, DA1201D, DA1201CD, DA1202D, DA1202CD, DA1203D or DA1203CD
See Package 42

Order Number DA1200CN, DA1201CN, DA1202CN or DA1203CN
See Package 43

*R21 ≡ R22 ≡ 16k for DA1202/1203 (BCD)

absolute maximum ratings

Supply Voltage (V^+ & V^-)		±18V
Logic Supply Voltage (V_{CC})		±10V
Logic Input Voltage		−0.7V to +18V
Reference Input Voltage		−0V, +18V
Power Dissipation		(see graphs)
Short Circuit Duration (pins 18, 19 & 21)		Continuous
Operating Temperature Range		
DA1200, DA1201, DA1202, DA1203		−55°C to +125°C
DA1200C, DA1201C, DA1202C, DA1203C		−25°C to +85°C
Storage Temperature Range	(D Package)	−65°C to +150°C
	(N Package)	−25°C to +100°C
Lead Temperature (soldering, 10 sec.)		300°C

dc electrical characteristics DA1200/1201 binary D/A (Notes 1, 2)

PARAMETER	CONDITIONS	DA1200/1200C			DA1201/1201C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Resolution		12			10			Bits
Linearity Error (Note 3)	T_A = 25°C			±0.0122			±0.0488	% FS
				±0.0244			±0.0976	% FS
Offset Voltage	T_A = 25°C		1	5		1	5	mV
				10			10	mV
Voltage Mode Full-Scale Error (Note 3)	V_{REF} = 10.240V		0.01	0.1		0.02	0.2	% FS
Voltage Mode Full-Scale Error	Pin 21 connected to Pin 14, T_A = 25°C		0.1	0.6		0.1	0.7	% FS
Monotonicity (Notes 3, 4)		Guaranteed over the temperature range						
Voltage Mode Power Supply Sensitivity	ΔV^+ = ±2V, T_A = 25°C, V_{REF} = 10.240V		0.002	0.02		0.002	0.02	% FS/V
	ΔV^- = ±2V		0.002	0.02		0.002	0.02	% FS/V
	ΔV_{CC} = ±1V		0.002	0.02		0.002	0.02	% FS/V
Output Voltage Range	R_L = 2k	±10.5	±12		±10.5	±12		V
Voltage Mode Output Short Circuit Current Limit	T_A = 25°C		20	50		20	50	mA
Current Mode Voltage Compliance	(Note 6)	±2.5			±2.5			V
Current Mode Output Impedance			15			15		kΩ
Reference Voltage	0mA ≤ I_{REF} ≤ 2mA, T_A = 25°C	10.190	10.240	10.290	10.190	10.240	10.290	V
Logic "1" Input Voltage (Bit OFF)		2.0			2.0			V
Logic "0" Input Voltage (Bit ON)				0.8			0.8	V
Logic "1" Input Current (Bit OFF)	V_{IN} = 2.5V		1	10		1	10	µA
Logic "0" Input Current (Bit ON)	V_{IN} = 0V		−10	−100		−10	−100	µA
Power Supply Current I^+	V^+ = 15.0V, T_A = 25°C		10	15		10	15	mA
I^-	V^- = −15.0V		25	30		25	30	mA
I_{CC}	V_{CC} = 5.0V		20	25		20	25	mA

dc electrical characteristics DA1202/1203 3-digit BCD D/A (Notes 1, 2)

PARAMETER	CONDITIONS	DA1202/1202C			DA1203/1203C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Resolution		3			3			Digits
Linearity Error (Note 5)	$T_A = 25°C$			0.01 0.02			0.05 0.1	% FS % FS
Offset Voltage	$T_A = 25°C$		1	5 10		1	5 10	mV mV
Voltage Mode Full-Scale Error (Note 5)	$V_{REF} = 10.000V$		0.01	0.1		0.02	0.2	% FS
Voltage Mode Full-Scale Error	Pin 21 connected to Pin 14, $T_A = 25°C$		0.5	0.6			0.7	% FS
Monotonicity (Notes 4, 5)		Guaranteed over the temperature range						
Voltage Mode Power Supply Sensitivity	$\Delta V^+ = \pm 2V$ $\Delta V^- = \pm 2V$ $\Delta V_{CC} = \pm 1V$ $T_A = 25°C$, $V_{REF} = 10.000V$		0.002 0.002 0.002	0.02 0.02 0.02		0.002 0.002 0.002	0.02 0.02 0.02	% FS/V % FS/V % FS/V
Voltage Mode Output Voltage Range	$R_L = 2k$	±10.5	±12		±10.5	±12		V
Voltage Mode Output Short Circuit Limit	$T_A = 25°C$		20	50		20	50	mA
Current Mode Compliance	(Note 6)	±2.5			±2.5			V
Current Mode Output Impedance			10			10		kΩ
Reference Voltage	$0 \leqslant I_{REF} \leqslant 2mA$, $T_A = 25°C$	9.950	10.000	10.050	9.950	10.000	10.050	V
Logic "1" Input Voltage (Bit OFF)		2.0			2.0			V
Logic "0" Input Voltage (Bit ON)				0.8			0.8	V
Logic "1" Input Current (Bit OFF)	$V_{IN} = 2.5V$		1	10		1	10	μA
Logic "0" Input Current (Bit ON)	$V_{IN} = 0V$		−10	−100		−10	−100	μA
Power Supply Current I^+	$V^+ = 15.0V$, $T_A = 25°C$		10	15		10	15	mA
Power Supply Current I^-	$V^- = -15.0V$, $T_A = 25°C$		25	30		25	30	mA
Power Supply Current I_{CC}	$V_{CC} = 5.0V$, $T_A = 25°C$		20	25		20	25	mA

ac characteristics DA1200/1201/1202/1203

PARAMETER	CONDITIONS ($T_A = 25°C$)	MIN	TYP	MAX	UNITS
Voltage Mode ±1 LSB Settling Time (Note 6)	DA1200/1202, $V_\epsilon \leqslant 1.25mV$		1.5	3.0	μs
	DA1201/1203, $V_\epsilon \leqslant 5.0mV$		1	3.0	μs
Voltage Mode Full-Scale Change Settling Time (Note 6)	DA1200/1202, $V_\epsilon \leqslant 1.25mV$		2.5	5.0	μs
	DA1201/1203, $V_\epsilon \leqslant 5.0mV$		2.0	5.0	μs
Current Mode Full-Scale Settling Time	$R_L = 1k\Omega$, $C_L \leqslant 20pF$ $0 \leqslant \Delta I_{OUT} \leqslant 2mA$		1.5		μs
Voltage Mode Slew Rate	$-10V \leqslant \Delta V_{OUT} \leqslant +10V$		15		V/μs

Note 1: Unless otherwise noted, these specifications apply for $V^+ = 15.0V$, $V^- = -15.0V$, and $V_{CC} = 5.0V$ over the temperature range −55°C to +125°C for the DA1200/1201/1202/1203 and −25°C to +85°C for the DA1200C/1201C/1202C/1203C.

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

Note 3: Unless otherwise noted, this specification applies for $V_{REF} = 10.24V$, and over the temperature range −25°C to +85°C. Testing conditions include adjustment of offset to 0V and full-scale to 10.2375V.

Note 4: The DA1200, DA1202 and DA1203 are tested for monotonicity by stimulating all bits; the DA1201 is tested for monotonicity by stimulating only the 10 MSBs and holding the 2 LSBs at 2.0V (i.e., 2 LSBs are OFF).

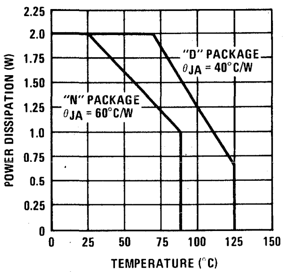
Note 5: Unless otherwise noted, this specification applies for $V_{REF} = 10.000V$, and over the temperature range −25°C to +85°C. Testing conditions include adjustment of offset to 0V and full-scale to 9.990V.

Note 6: Not tested — guaranteed by design.

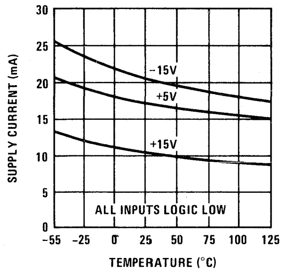
Note 7: ($\Delta V_{OUT} = 10V$)

typical performance

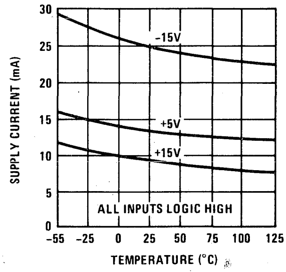
Maximum Power Dissipation

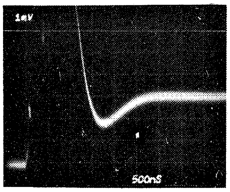


Supply Current vs Temperature

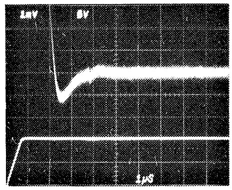


Supply Current vs Temperature

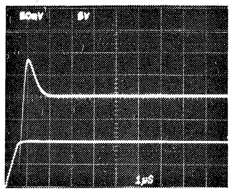




1 LSB Trans
1011 . . . 1 → 1100 . . . 0
V_O = 0, 10V
C_F = 30pF
T_A = 25°C



10V Full Scale Settling Time



10V Full Scale Pulse Response

applications information

1. Introduction

The DA1200 series D/A converters are designed to minimize adjustments and user-supplied external components. For example, included in the package are a buffered reference, offset nulled output amplifier, and application resistors as well as the basic 12-bit current mode D/A.

However, the DA1200 series is a sophisticated building block. **Its principles of operation and the following applications information should be read before applying power to the device.**

The user is referred to National Semiconductor Application Notes AN-156 and AN-157 for additional information.

2. Power Supply Selection & Decoupling

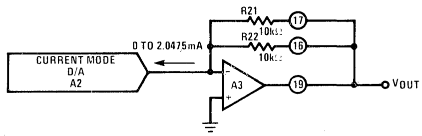
Selection of power supplies is important in applications requiring 0.01% accuracy. The ±15V supplies should be well regulated (±15V ± 0.1%) with less than 0.5mVrms of output noise and hum.

To realize the full speed capability of the device, all three power supply leads should be bypassed with 1µF tantalum electrolytic capacitors in shunt with 0.01µF ceramic disc capacitors no farther than ½ inch from the device package.

3. Unipolar and Bipolar Operation

The DA1200 series D/A's may be configured for either unipolar or bipolar operation using resistors provided with the device. Figures 1A and 1B illustrate the proper connection for binary and BCD unipolar operation.

Bipolar operation is accomplished by offsetting the output amplifier A3 as shown in figures 2A and 2B.



$$^*V_{OUT} = (I_{ZERO} \text{ to } I_{FULLSCALE})\left(\frac{R21 \cdot R22}{R21 + R22}\right)$$

$$= (0\text{mA to } 2.0475\text{mA})(5\text{k}\Omega)$$

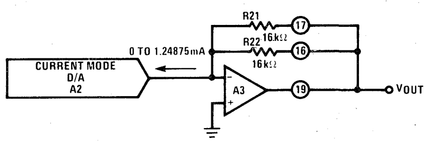
$$= 0\text{V to } +10.2375\text{V}$$

*Values shown are for V_{REF} = 10.240V.

$$1 \text{ LSB Voltage Step} = \frac{10.240\text{V}}{4096} = 2.5\text{mV}.$$

$$1 \text{ LSB Current Step} = \frac{2.5\text{mV}}{5.0\text{k}\Omega} = 0.5\mu\text{A}$$

FIGURE 1A. DA1200/DA1201 Unipolar Operation



$$^*V_{OUT} = (I_{ZERO} \text{ to } I_{FULLSCALE})\left(\frac{R21 \cdot R22}{R21 + R22}\right)$$

$$= (0 \text{ to } 1.24875\text{mA})(8\text{k}\Omega)$$

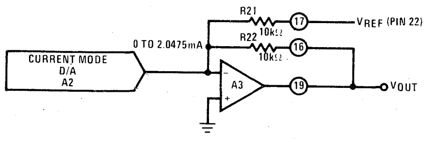
$$= 0\text{V to } 9.990\text{V}$$

*Values shown are for V_{REF} = 10.000V.

$$1 \text{ LSD Voltage Step} = \frac{10.000}{1000} = 10\text{mV}$$

$$1 \text{ LSD Current Step} = \frac{10\text{mV}}{8\text{k}\Omega} = 1.25\mu\text{A}$$

FIGURE 1B. DA1202/DA1203 Unipolar Operation



$^{*}V_{OUT} = (0 \text{ to } 2.0475\text{mA})R22 - \frac{V_{REF}}{R22} R21$

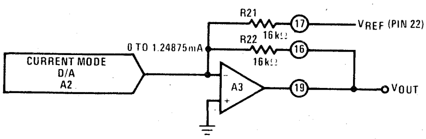
$= (0 \text{ to } 2.0475\text{mA})R22 - V_{REF},\ R21 \equiv R22$

$= -10.240 \text{ to } +10.235\text{V}$

*Values shown are for $V_{REF} = 10.240\text{V}$

1 LSB = 5mV.

FIGURE 2A. DA1200/DA1201 Bipolar Operation



$^{*}V_{OUT} = (0\text{mA to } 1.24875\text{mA})(R22) - \frac{R22}{R21} V_{REF}$

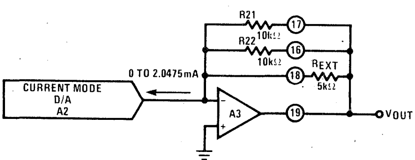
$= -10.000\text{V to } +9.80\text{V}$

*Values shown are for $V_{REF} = 10.000\text{V}$.

1 LSD Voltage Step = 20mV.

FIGURE 2B. DA1202/DA1203 Bipolar Operation

External resistors may be used to achieve alternate zero and full-scale voltages. It is advantageous to utilize R21 and R22 even in these applications since they are closely matched in TCR and temperature to the internal array. Figure 3 illustrates the recommended circuit for zero to 5V operation. R_{EXT} should be of metal film or wire-wound construction with a TCR of less than 10ppm/°C.



$R_{TOTAL} = (R21) \parallel (R22) \parallel (R_{EXT}) = \frac{V_{FULLSCALE}}{2\text{mA}} = 2.5\text{k}\Omega.$

FIGURE 3. DA1200 0 to 5.120V Operation

4. Offset and Full-Scale Adjust

If higher precision is required in the zero and full-scale, external adjustments may be made. The circuit of figure 4 illustrates the recommended circuit to adjust offset and full-scale of the DA1200 series. The circuit will work equally well for unipolar or bipolar operation.

In bipolar operation, the offset is adjusted at minus full-scale; in the unipolar case at zero scale.

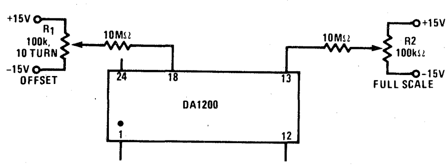


FIGURE 4. Offset & Full-Scale Adjust

For the values shown in figure 4, R1 will allow a ±7mV offset adjustment for the unipolar case and ±15mV for the bipolar case. R2 will allow a ±50mV adjustment of full scale.

5. Current Mode Operation

Access to the summing junction of A3 affords current mode operation either with a resistive load or to drive a fast-settling external operational amplifier. The loop around A3 should not be closed in current mode operation. There is a ±2.5V maximum compliance voltage at A2's output (pin 18) which restricts the maximum size of the load resistor; i.e., $R_L \times I_{FULLSCALE} \leqslant 2.5\text{V}$.

Note: $I_{FULLSCALE} \approx 2\text{mA}$ for DA1200/DA1201 and $\approx 1.25\text{mA}$ for DA1202/DA1203.

6. Settling Time & Glitch Minimization

The settling time of the DA1200 series and the glitch which occurs between major input code changes may be improved by placing a 10 to 30pF capacitor between pins 18 (current-mode output) and 19 (voltage mode output). The capacitor is used to cancel output capacitance of the current mode D/A and stray capacitance at pin 18.

7. Current Output Boosting

The DA1200 series may be operated as a "power D/A" by including a current buffer such as the LH0002 or LH0063 in the loop with A3 as shown in figure 5.

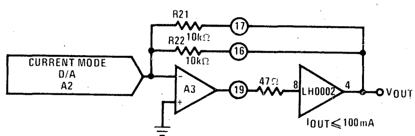


FIGURE 5. Current Boosted Output

8. Logic Input Coding

The sense of the logic inputs to the DA1200 series is complementary; i.e., a given bit is turned ON by an active "low" input. Table I summarizes input status for the unipolar and bipolar complementary binary and BCD codes.

Other input codes may also be used. For example, the twos complement code, which is used extensively in computer and microprocessor applications, may be converted to the DA1200 complementary bipolar format by inverting all bits except the MSB. The inversion may be accomplished in the microprocessor by software control, or by hardware using standard hex-inverters.

9. Reference Voltage

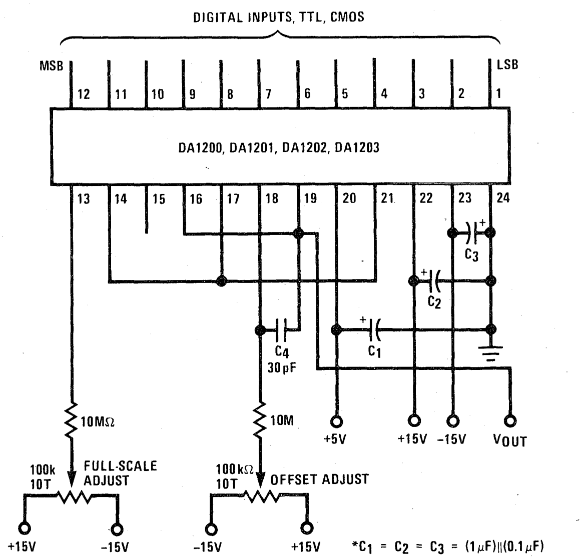
External reference voltages may be used with the DA1200 series. Voltages other than 10.240 or 10.000V in the range of +5.0V to 11V will work satisfactorily for voltage mode operation. Full-scale voltage is always $V_{REF} - 1$ LSB where 1 LSB = $V_{REF}/4096$ (binary) or $V_{REF}/1000$ (BCD). Full-scale current (for binary) may be predicted by:

$$I_{FULLSCALE} = (V_{REF})(0.19995117)\text{mA}$$

CODE TYPE	(Note 7) INPUT CODE MSB LSB	OUTPUT STATE	OUTPUT VOLTAGE (Note 8)	OUTPUT CURRENT
Unipolar Complementary Binary	0000 0000 0000	Full-Scale	+10.2375V	2.0475mA
	1111 1111 1110	1 LSB ON	+2.500mV	0.500μA
	1111 1111 1111	Zero Scale	Zero	Zero
Bipolar Complementary Binary	0000 0000 0000	Full-Scale	+10.235V	+1.0235mA
	0111 1111 1111	Half Full-Scale	–0.000V	0.000mA
	1111 1111 1110	1 LSB ON	–10.235V	–1.0235mA
	1111 1111 1111	Zero Scale	–10.240V	–1.0240mA
Unipolar Complementary BCD	0110 0110 0110	Full-Scale	+9.990V	1.24875mA
	1111 1111 1110	1 LSB ON	10.000mV	1.250μA
	1111 1111 1111	Zero Scale	Zero	Zero
Bipolar Complementary BCD	0110 0110 0110	Full-Scale	9.980V	+0.62375mA
	1010 1111 1111	Half Full-Scale	0.000V	Zero
	1111 1111 1110	1 LSB ON	–9.980V	–0.62375mA
	1111 1111 1111	Zero Scale	–10.00V	–0.625mA

Note 7: Logic input sense is such that an active low ($V_{IN} \leq 0.8V$) turns a given bit ON and is represented as a logic "0" in the table.
Note 8: V_{REF} = 10.240V for the DA1200/1201 and 10.000V for the DA1202/1203.

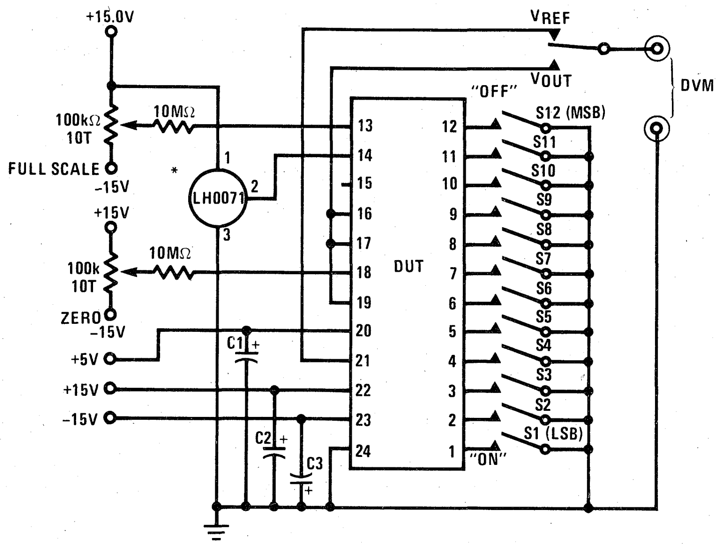
typical application



20 Volt Full-Scale Complementary D/A

dc test circuit

*LH0070 for DA1202/1203



C1 = C2 = C3 = 4.7μF (solid tantalum) in parallel with a 0.01μF ceramic disc

A to D, D to A

DM2502, DM2503, DM2504 successive approximation registers

general description

The DM2502, DM2503 and DM2504 are 8-bit and 12-bit TTL registers designed for use in successive approximation A/D converters. These devices contain all the logic and control circuits necessary in combination with a D/A converter to perform successive approximation analog-to-digital conversions.

The DM2502 has 8 bits with serial capability and is not expandable.

The DM2503 has 8 bits and is expandable without serial capability.

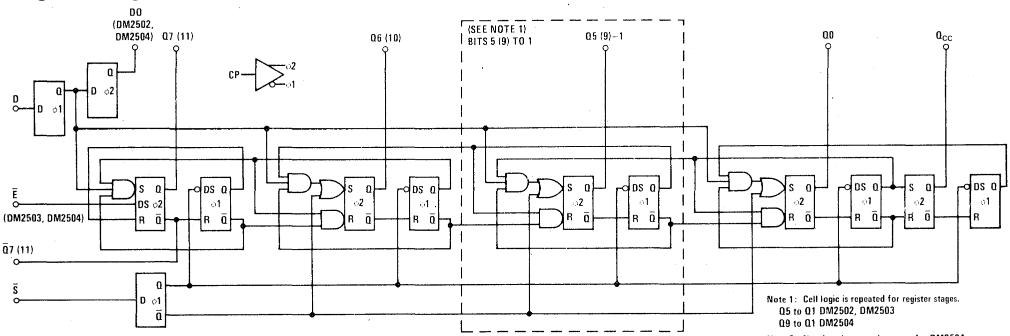
The DM2504 has 12 bits with serial capability and expandability.

All three devices are available in ceramic DIP, ceramic flatpak, and molded Epoxy-B DIPs. The DM2502, DM2503 and DM2504 operate over −55°C to +125°C; the DM2502C, DM2503C and DM2504C operate over 0°C to +70°C.

features

- Complete logic for successive approximation A/D converters
- 8-bit and 12-bit registers
- Capable of short cycle or expanded operation
- Continuous or start-stop operation
- Compatible with D/A converters using any logic code
- Active low or active high logic outputs
- Use as general purpose serial-to-parallel converter or ring counter

logic diagram

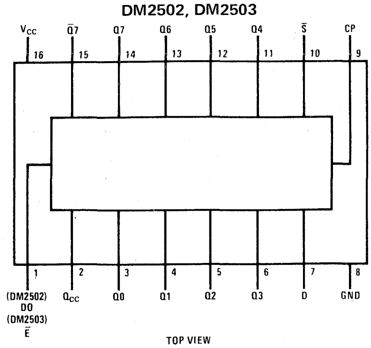


Note 1: Cell logic is repeated for register stages. Q5 to Q1 DM2502, DM2503 Q9 to Q1 DM2504

Note 2: Numbers in parentheses are for DM2504.

connection diagrams (Dual-In-Line and Flat Packages)

DM2502, DM2503

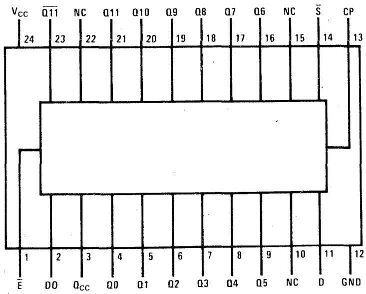


Order Number DM2502J, DM2502CJ, DM2503J or DM2503CJ
See Package 17

Order Number DM2502CN or DM2503CN
See Package 23

Order Number DM2502W, DM2502CW, DM2503W, or DM2503CW
See Package 41

DM2504



Order Number DM2504F or DM2504CF
See Package 5A

Order Number DM2504J or DM2504CJ
See Package 17A

Order Number DM2504CN
See Package 29A

absolute maximum ratings (Note 1)

Supply Voltage	7V
Input Voltage	5.5V
Output Voltage	5.5V
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

operating conditions

	MIN	MAX	UNITS
Supply Voltage, V_{CC}			
DM2502C, DM2503C, DM2504C	4.75	5.25	V
DM2502, DM2503, DM2504	4.5	5.5	V
Temperature, T_A			
DM2502C, DM2503C, DM2504C	0	+70	°C
DM2502, DM2503, DM2504	−55	+125	°C

electrical characteristics (Notes 2 and 3) V_{CC} = 5.0V, T_A = 25°C, C_L = 15 pF, unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Logical "1" Input Voltage (V_{IH})	V_{CC} = Min	2.0			V
Logical "1" Input Current (I_{IH})	V_{CC} = Max				
CP Input	V_{IH} = 2.4V		6	40	μA
D, $\overline{E}$, $\overline{S}$ Inputs	V_{IH} = 2.4V		6	80	μA
All Inputs	V_{IH} = 5.5V			1.0	mA
Logical "0" Input Voltage (V_{IL})	V_{CC} = Min			0.8	V
Logical "0" Input Current (I_{IL})	V_{CC} = Max				
CP, $\overline{S}$ Inputs	V_{IL} = 0.4V		−1.0	−1.6	mA
D, $\overline{E}$ Inputs	V_{IL} = 0.4V		−1.0	−3.2	mA
Logical "1" Output Voltage (V_{OH})	V_{CC} = Min, I_{OH} = −0.48 mA	2.4	3.6		V
Output Short Circuit Current (Note 4) (I_{OS})	V_{CC} = Max; V_{OUT} = 0.0V; Output High; CP, D, $\overline{S}$, High; $\overline{E}$ Low	−10	−20	−45	mA
Logical "0" Output Voltage (V_{OL})	V_{CC} = Min, I_{OL} = 9.6 mA		0.2	0.4	V
Supply Current (I_{CC})	V_{CC} = Max, All Outputs Low				
DM2502C			65	95	mA
DM2502			65	85	mA
DM2503C			60	90	mA
DM2503			60	80	mA
DM2504C			90	124	mA
DM2504			90	110	mA
Propagation Delay to a Logical "0" From CP to Any Output (t_{pd0})		10	18	28	ns
Propagation Delay to a Logical "0" From $\overline{E}$ to Q7 (Q11) Output (t_{pd0})	CP High, $\overline{S}$ Low DM2503, DM2503C, DM2504, DM2504C Only		16	24	ns
Propagation Delay to a Logical "1" From CP to Any Output (t_{pd1})		10	26	38	ns
Propagation Delay to a Logical "1" From $\overline{E}$ to Q7 (Q11) Output (t_{pd1})	CP High, $\overline{S}$ Low DM2503, DM2503C, DM2504, DM2504C Only		13	19	ns
Set-Up Time Data Input ($t_{s(D)}$)		−10	4	8	ns
Set-Up Time Start Input ($t_{s(\overline{S})}$)		0	9	16	ns
Minimum Low CP Width (t_{PWL})			30	42	ns
Minimum High CP Width (t_{PWH})			17	24	ns
Maximum Clock Frequency (f_{MAX})		15	21		MHz

Note 1: "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. Except for "Operating Temperature Range" they are not meant to imply that the devices should be operated at these limits. The table of "Electrical Characteristics" provides conditions for actual device operation.

Note 2: Unless otherwise specified min/max limits apply across the −55°C to +125°C temperature range for the DM2502, DM2503 and DM2504, and across the 0°C to +70°C range for the DM2502C, DM2503C and DM2504C. All typicals are given for V_{CC} = 5.0V and T_A = 25°C.

Note 3: All currents into device pins shown as positive, out of device pins as negative, all voltages referenced to ground unless otherwise noted. All values shown as max or min on absolute value basis.

Note 4: Only one output at a time should be shorted.

application information

OPERATION

The registers consist of a set of master latches that act as the control elements in the device and change state on the input clock high-to-low transition and a set of slave latches that hold the register data and change on the input clock low-to-high transition. Externally the device acts as a special purpose serial-to-parallel converter that accepts data at the D input of the register and sends the data to the appropriate slave latch to appear at the register output and the DO output on the DM2502 and DM2504 when the clock goes from low-to-high. There are no restrictions on the data input; it can change state at any time except during a short interval centered about the clock low-to-high transition. At the same time that data enters the register bit the next less significant bit register is set to a low ready for the next iteration.

The register is reset by holding the $\overline{S}$ (Start) signal low during the clock low-to-high transition. The register synchronously resets to the state Q7 (11) low, and all the remaining register outputs high. The Q_{CC} (Conversion Complete) signal is also set high at this time. The $\overline{S}$ signal should not be brought back high until after the clock low-to-high transition in order to guarantee correct resetting. After the clock has gone high resetting the register, the $\overline{S}$ signal must be removed. On the next clock low-to-high transition the data on the D input is set into the Q7 (11) register bit and the Q6 (10) register bit is set to a low ready for the next clock cycle. On the next clock low-to-high transition data enters the Q6 (10) register bit and Q5 (9) is set to a low. This operation is repeated for each register bit in turn until the register has been filled. When the data goes into Q0, the Q_{CC} signal goes low, and the register is inhibited from further change until reset by a Start signal.

The DM2502, DM2503 and DM2504 have a specially tailored two-phase clock generator to provide non-overlapping two-phase clock pulses (i.e., the clock waveforms intersect below the thresholds of the gates they drive). Thus, even at very slow dV/dt rates at the clock input (such as from relatively weak comparator outputs), improper logic operation will not result.

LOGIC CODES

All three registers can be operated with various logic codes. Two's complement code is used by offsetting the comparator 1/2 full range + 1/2 LSB and using the complement of the MSB ($\overline{Q7}$ or $\overline{Q11}$) with a binary D/A converter. Offset binary is used in the same manner but with the MSB (Q7 or Q11). BCD D/A converters can be used with the addition of illegal code suppression logic.

ACTIVE HIGH OR ACTIVE LOW LOGIC

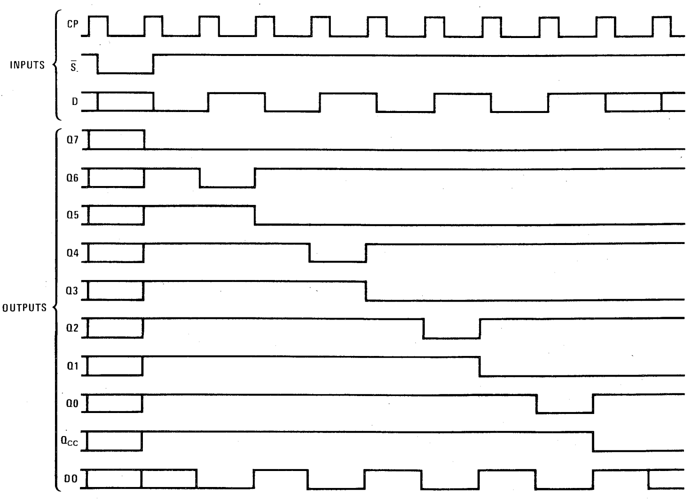
The register can be used with either D/A converters that require a low voltage level to turn on, or D/A converters that require a high voltage level to turn the switch on. If D/A converters are used which turn on with a low logic level, the resulting digital output from the register is active low. That is, a logic "1" is represented as a low voltage level. If D/A converters are used that turn on with a high logic level then the digital output is active high; a logic "1" is represented as a high voltage level.

EXPANDED OPERATION

An active low enable input, $\overline{E}$, on the DM2503 and DM2504 allows registers to be connected together to form a longer register by connecting the clock, D, and $\overline{S}$ inputs in parallel and connecting the Q_{CC} output of one register to the $\overline{E}$ input of the next less significant register. When the start signal resets the register, the $\overline{E}$ signal goes high, forcing the Q7 (11) bit high and inhibiting the register from accepting data until the previous register is full and its Q_{CC} goes low. If only one register is used the $\overline{E}$ input should be held at a low logic level.

timing diagram

DM2502, DM2503



application information (con't)

SHORT CYCLE

If all bits are not required, the register may be truncated and conversion time saved by using a register output going low rather than the Q_{CC} signal to indicate the end of conversion. If the register is truncated and operated in the continuous conversion mode, a lock-up condition may occur on power turn-on. This condition can be avoided by making the start input the OR function of Q_{CC} and the appropriate register output.

COMPARATOR BIAS

To minimize the digital error below ±1/2 LSB, the comparator must be biased. If a D/A converter is used which requires a low voltage level to turn on, the comparator should be biased +1/2 LSB. If the D/A converter requires a high logic level to turn on, the comparator must be biased −1/2 LSB.

definition of terms

CP: The clock input of the register.

D: The serial data input of the register.

DO: The serial data out. (The D input delayed one bit).

$\overline{E}$: The register enable. This input is used to expand the length of the register and when high forces the Q7 (11) register output high and inhibits conversion. When not used for expansion the enable is held at a low logic level (ground).

Q_i i = 7 (11) to 0: The outputs of the register.

Q_{CC}: The conversion complete output. This output remains high during a conversion and goes low when a conversion is complete.

Q7 (11): The true output of the MSB of the register.

$\overline{Q}$7 (11): The complement output of the MSB of the register.

$\overline{S}$: The start input. If the start input is held low for at least a clock period the register will be reset to Q7 (11) low and all the remaining outputs high. A start pulse that is low for a shorter period of time can be used if it meets the set-up time requirements of the $\overline{S}$ input.

truth table

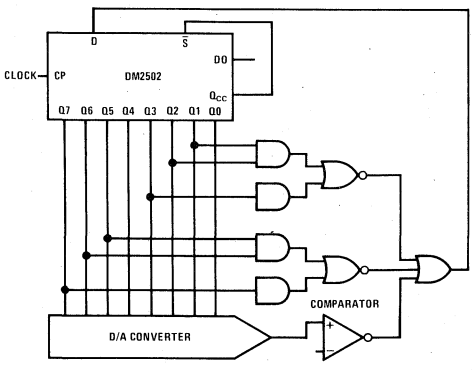
DM2502, DM2503

TIME	INPUTS			OUTPUTS[1]									
t_n	D	$\overline{S}$	$\overline{E}$[2]	DO[3]	Q7	Q6	Q5	Q4	Q3	Q2	Q1	Q0	Q_{CC}
0	X	L	L	X	X	X	X	X	X	X	X	X	X
1	D7	H	L	X	L	H	H	H	H	H	H	H	H
2	D6	H	L	D7	D7	L	H	H	H	H	H	H	H
3	D5	H	L	D6	D7	D6	L	H	H	H	H	H	H
4	D4	H	L	D5	D7	D6	D5	L	H	H	H	H	H
5	D3	H	L	D4	D7	D6	D5	D4	L	H	H	H	H
6	D2	H	L	D3	D7	D6	D5	D4	D3	L	H	H	H
7	D1	H	L	D2	D7	D6	D5	D4	D3	D2	L	H	H
8	D0	H	L	D1	D7	D6	D5	D4	D3	D2	D1	L	H
9	X	H	L	D0	D7	D6	D5	D4	D3	D2	D1	D0	L
10	X	X	L	X	D7	D6	D5	D4	D3	D2	D1	D0	L
	X	X	H	X	H	NC	NC	NC	NC	NC	NC	NC	NC

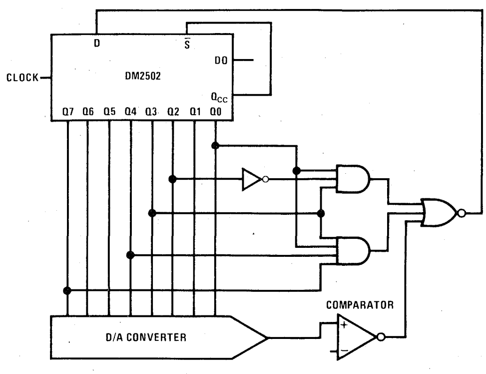
Note 1: Truth table for DM2504 is extended to include 12 outputs.
Note 2: Truth table for DM2502 does not include $\overline{E}$ column or last line in truth table shown.
Note 3: Truth table for DM2503 does not include D0 column.

H = High Voltage Level
L = Low Voltage Level
X = Don't Care
NC = No Change

typical applications



Active High

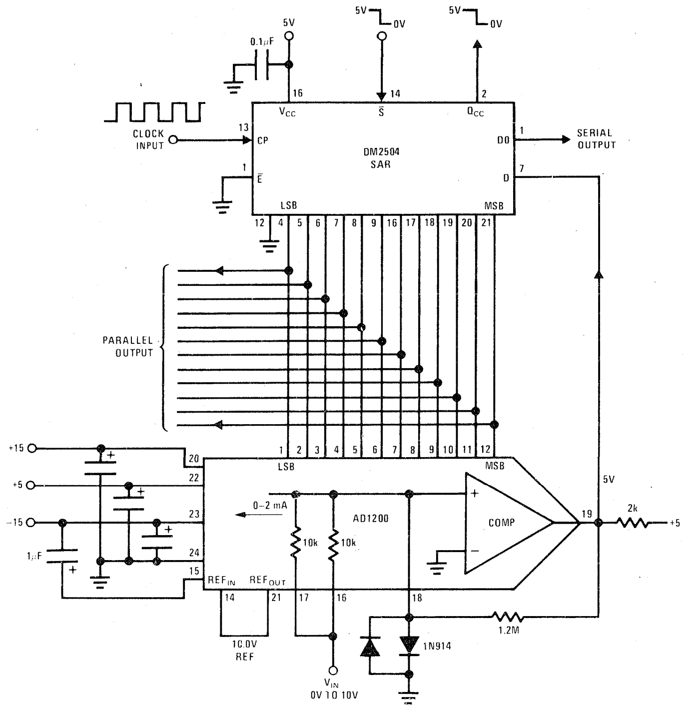


Active Low

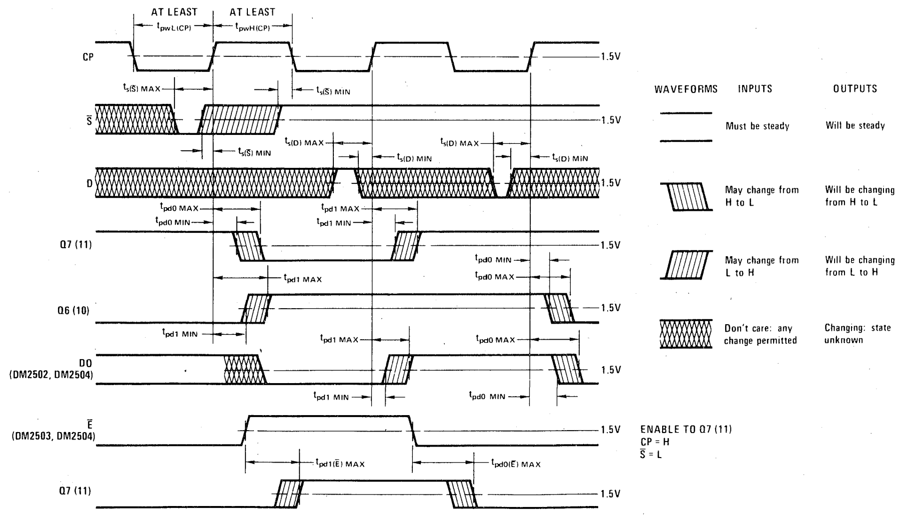
BCD Illegal Code Suppression

typical applications (con't)

High Speed 12-Bit A/D Converter



switching time waveforms



A to D, D to A
Future Products

LF11300 dual slope A/D analog building block
MM5330 BCD dual slope A/D digital building block
MM5863 12-bit binary dual slope A/D digital building block

general description

LF113C0

The LF11300 is the analog front end for a dual slope A/D converter. It is designed for use with either the MM5330 BCD digital building block or the MM5863 12-bit binary digital building block. The LF11300 provides a high impedance FET input, handles ±10V analog inputs with polarity indications and has automatic offset correction.

MM5330

The MM5330 provides multiplexed 4-1/2 digit BCD outputs, digit selects, polarity indicator, and overrange indication. It is used for 2-1/2, 3-1/2, or 4-1/2 digit panel meters. The LF11300 may be used as the analog front end or a discrete implementation may be used.

MM5863

The MM5863 provides a 12-bit parallel TRI-STATE® binary output or a 12-bit serial output. Overrange and polarity indication are also provided. A set of latches insures valid digital data at all times. Thus a practical low cost, accurate, 12-bit converter for use with microprocessors can be constructed, even though conversion speed is 20 ms.

features

LF11300

- Auto zero and auto polarity
- FET input — >100 MΩ impedance
- ±10V analog range
- Clock rate (f_C) — 1 kHz to 500 kHz
- Conversion rate — $10{,}000/f_C$
- Ratiometric inputs
- ±15V, +5V supplies
- 0.02% ±1 LSB accuracy
- No zero or full scale adjustments

MM5330

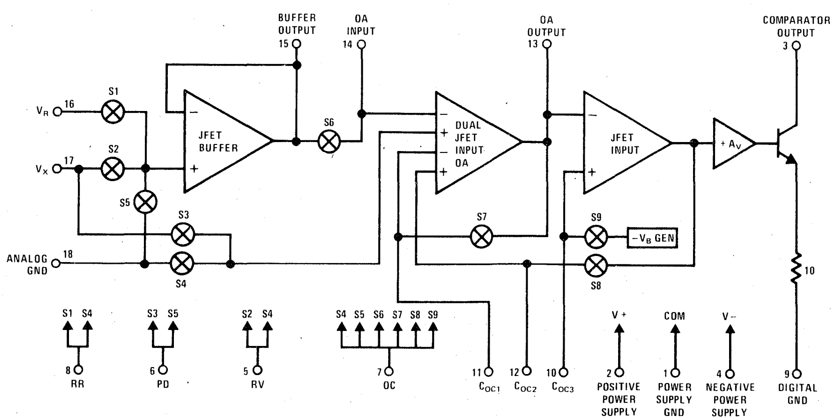
- 4-1/2 digit BCD output
- Overrange indicator
- Polarity indicator

MM5863

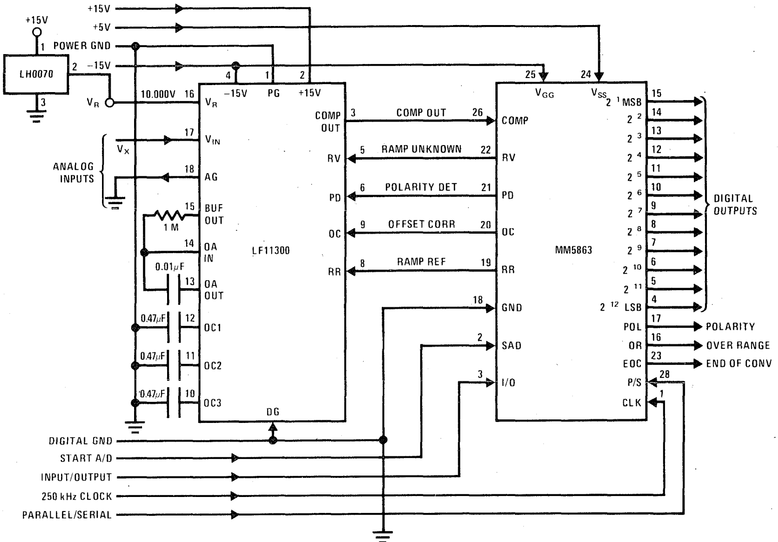
- 12-bit binary output
- Parallel or serial
- TRI-STATE® output
- Polarity indicator
- Overrange indicator

block diagram

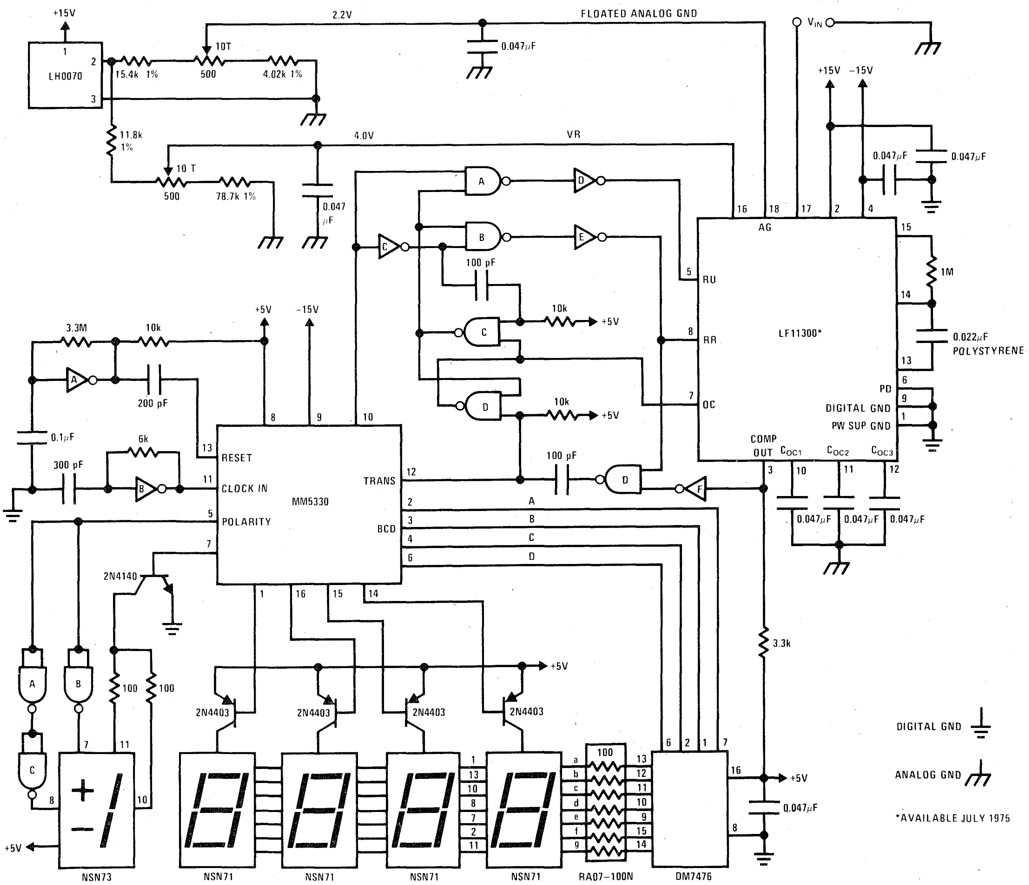
LF11300



typical applications

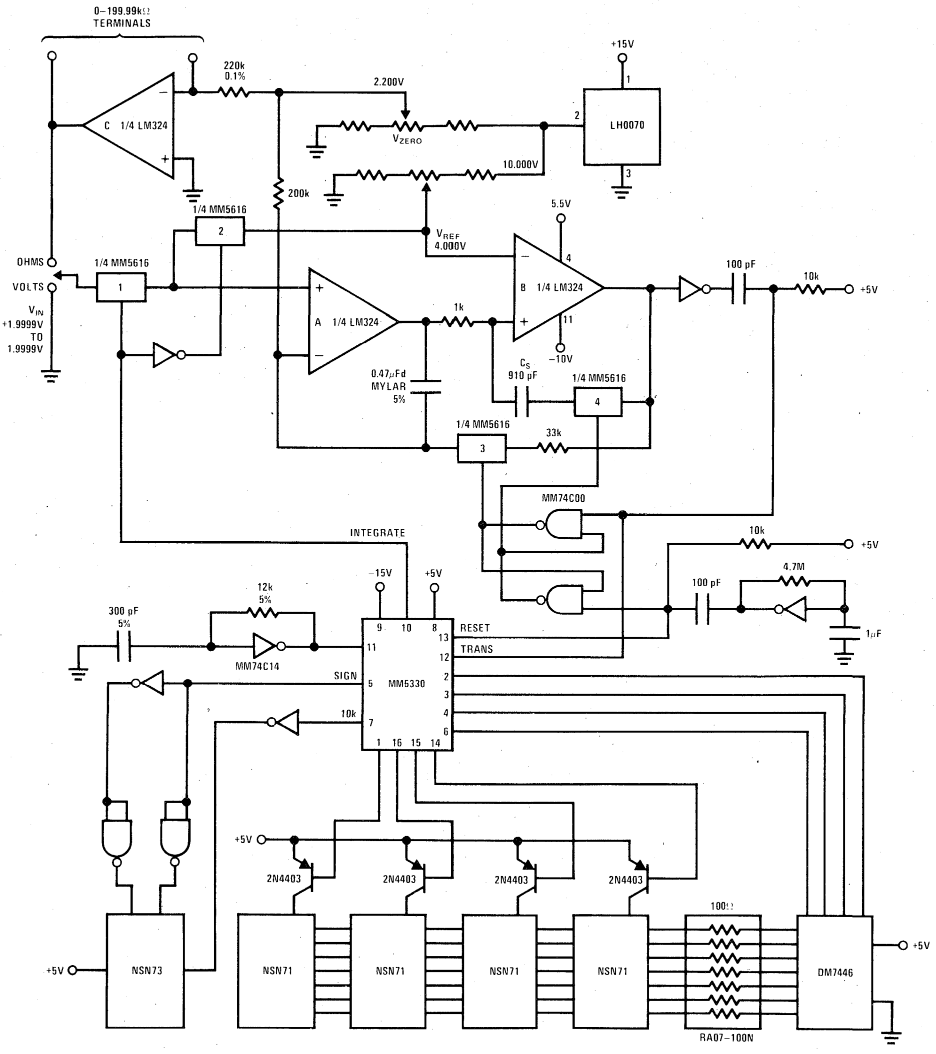


LF11300, MM5863 12-Bit Binary A/D Converter System



LF11300, MM5330 DPM Application

typical applications (con't)



MM5330 Discrete DPM Application

LM13340 quad current switch

general description

The LM13340 is a high speed 4-bit current switch intended for use in D/A and A/D converters having up to 12-bit linearity. The current magnitude of each of the four logic operated switches is weighted by an external voltage reference and a precision resistor. These switch currents are summed internally to produce a single output current proportional to the binary or BCD logic input code. Combining the reference transistor with external circuitry provides compensation for β and V_{BE} variations with temperature. An unusually low logic input sink current of 100μA or less results in both TTL and CMOS compatibility.

Logic levels of the LM13340, which are ground referenced, are independent of baseline voltage variations.

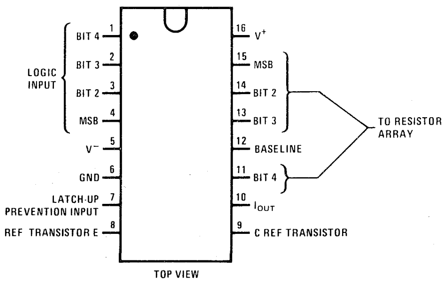
A diode incorporated in the LM13340 can be used to prevent system latch-up when driving the baseline with an op amp.

features

- 12-bit linearity
- 200 ns settling time
- 40 ns switching speed
- TTL and CMOS compatible
- Wide power supply range
- Low logic input current
- Logic levels are ground referenced and not dependent on ladder potentials
- Eliminates system latch-up
- Power dissipation unaffected by bit pattern
- Isothermal layout

connection diagram

Dual-In-Line Package



Order Number 13340-1D, LM13340-2D or LM13340-3D
See Package 2
Order Number LM13340-1N, LM13340-2N or LM13340-3N
See Package 23

truth table

LOGIC INPUT				NOMINAL OUTPUT CURRENT - mA
0	0	0	0	1.875
0	0	0	1	1.750
0	0	1	0	1.625
0	0	1	1	1.500
0	1	0	0	1.375
0	1	0	1	1.250
0	1	1	0	1.125
0	1	1	1	1.000
1	0	0	0	0.875
1	0	0	1	0.750
1	0	1	0	0.625
1	0	1	1	0.500
1	1	0	0	0.375
1	1	0	1	0.250
1	1	1	0	0.125
1	1	1	1	0.000

A to D, D to A

Future Product

MM4357/MM5357 8-bit A/D converter

general description

The MM4357/MM5357 is an 8-bit monolithic A/D converter using P-channel ion-implanted MOS technology. It contains a high input impedance comparator, 256 series resistors and analog switches, control logic and output latches. Conversion is performed using a successive approximation technique where the unknown analog voltage is compared to the resistor tie points using analog switches. When the appropriate tie point voltage matches the unknown voltage, conversion is complete and the digital outputs contain an 8-bit complementary binary word corresponding to the unknown. The binary output is TRI-STATE to permit bussing on common data lines.

The MM4357 is specified over −55°C to +125°C and the MM5357 is specified over 0°C to +70°C.

features

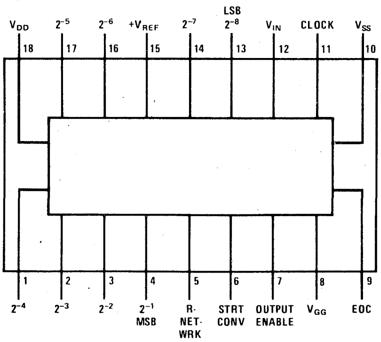
- Low cost
- ±5V, 10V input ranges
- No missing codes
- High input impedance
- Ratiometric conversion
- TRI-STATE outputs
- Fast
- Contains output latches
- TTL compatible

key specs

■ Resolution	8 bits
■ Linearity	±1/2 LSB
■ Conversion speed	40µs
■ Input impedance	>100 MΩ
■ Supply voltages	+5V, −12V, GND
■ Clock range	5.0 kHz to 2.0 MHz

connection diagram

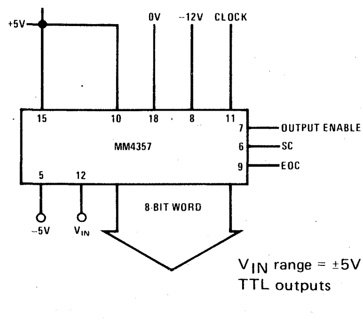
Dual-In-Line Package



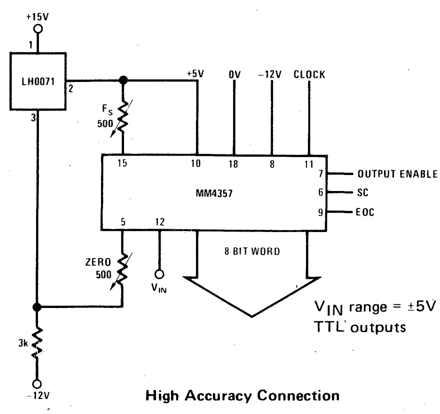
TOP VIEW

Order Number MM4357D or MM5357D
See Package 2D
Order Number MM5357N
See Package 29

typical applications



General Connection



High Accuracy Connection

absolute maximum ratings

Supply Voltage (V_{DD})	V_{SS} − 22V
Supply Voltage (V_{GG})	V_{SS} − 22V
Voltage at Any Input	V_{SS} + 0.3V to V_{SS} − 22V
Operating Temperature	
MM4357/MM4357B	−55°C to +125°C
MM5357/MM5357B	0°C to +70°C
Storage Temperature	150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 1)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Nonlinearity (Note 2)	T_A = 25°C, MM4357/MM5357		±1/4	±1/2	LSB
	MM4357/MM5357		±1/2	±1	LSB
	T_A = 25°C, MM4357B/MM5357B		±1/2	±1	LSB
	MM4357B/MM5357B		±1	±2	LSB
Differential Nonlinearity	MM4357/MM5357		±1/8	±1/4	LSB
	MM4357B/MM5357B		±1/4	±1/2	LSB
Quantization Error				±1/2	LSB
Zero Error (Not Adjusted)	T_A = 25°C				
	MM4357/MM5357		±1/2	±1	LSB
	MM4357B/MM5357B		±1	±2	LSB
Zero Error Temperature Coefficient			0.0005	0.001	%/°C
Full Scale Error	T_A = 25°C				
	MM4357/MM5357		±1/2	±1	LSB
	MM4357B/MM5357B		±1	±2	LSB
Full Scale Error Temperature Coefficient			0.0005	0.001	%/°C
Input Impedance		100			MΩ
Power Supply Rejection	15.5V ≤ (V_{SS} − V_{GG}) ≤ 18.5V		0.005	0.01	%/V
Logical "1" Input Voltage	All Inputs	V_{SS}−1.5	V_{SS}−2.5	V_{SS}+0.3	V
Logical "0" Input Voltage	All Inputs	V_{GG}		V_{SS}−4.2	V
Logical Input Leakage	All Inputs, T_A = 25°C, V_{IL} = V_{SS}−10V		0.01	0.5	µA
Logical "1" Output Voltage	All Outputs, I_{OH} = 100µA	2.4	4.5		V
Logical "0" Output Voltage	All Outputs, I_{OL} = 1.6 mA			0.4	V
Disabled Output Leakage	All Outputs, T_A = 25°C, V_{OL} = V_{SS}−10V			2	µA
Minimum Clock Frequency	0°C ≤ T_A ≤ +70°C		5	50	kHz
	−55°C ≤ T_A ≤ +125°C		10	100	kHz
Maximum Clock Frequency	0°C ≤ T_A ≤ +70°C	1000	2000		kHz
	−55° ≤ T_A ≤ +125°C	500	1000		kHz
Clock Pulse Width		500	150		ns
TRI-STATE Enable/Disable Time			500	1000	ns
Conversion Time	T_A = 25°C		20	40	µs
				80	µs
Power Supply Current	T_A = 25°C		10	15	mA
				23	mA
Guaranteed Supply Range	(Note 3)	13		21	V

Note 1: These specifications apply for V_{SS} = +5V, V_{GG} = −12V, and V_{DD} = 0V; over −55°C to +125°C for the MM4357/MM4357B and over 0°C to +70°C for the MM5357/MM5357B unless otherwise specified.

Note 2: This specification is measured with 500Ω potentiometers connected to pins 5 and 15, V_{REF} = 10.00V, and with zero error and full scale error corrected to zero at T_A = 25°C. Temperature specifications apply with no readjustment made in the zero and full scale pots.

Note 3: This specification defines the range over which functional operation is guaranteed.

Note 4: Zero error and full scale error for the MM4357/MM5357 are guaranteed to be adjustable to zero.

OPERATION

The MM4357 contains a network with 256–300Ω resistors in series. Analog switch taps are made at the junction of each resistor and at each end of the network. In operation, a reference (10.00V) is applied across this network of 256 resistors. An analog input (V_{IN}) is first compared to the center point of the ladder via the appropriate switch. If V_{IN} is larger than $V_{REF}/2$, the internal logic changes the switch points and now compares V_{IN} and 3/4 V_{REF}. This process, known as successive approximation, continues until the best match of V_{IN} and V_{REF}/N is made. N now defines a specific tap on the resistor network. When the conversion is complete, the logic loads a binary word corresponding to this tap into the output latch and an end of conversion (EOC) logic level appears. The output latches hold this valid data until a new conversion is completed and new data is loaded into the latches. The data transfer occurs in about 200 ns so that valid data is present virtually all the time.

REFERENCE

The reference applied across the 256 resistor network determines the analog input range. V_{REF} = 10.00V with the top of the reference connected to +5V gives a ±5V range. The reference can be level shifted between V_{SS} and V_{GG}. However, the V_{REF} pin (pin 15) must not exceed V_{SS} and the R network pin (pin 5) must not go below V_{GG} + 5V.

Other reference voltages may be used (such as 10.24V). If a 5V reference is used, the analog range will be 5V and accuracy will be reduced by a factor of 2. Thus, for maximum accuracy it is desireable to operate with at least a 10V reference.

POWER SUPPLIES

Standard supplies are V_{SS} = +5V, V_{GG} = −12V and V_{DD} = 0V. Device accuracy is dependent on stability of the reference voltage and has slight sensitivity to $V_{SS} - V_{GG}$, typically 0.005%/V. V_{DD} has no effect on accuracy.

The output logic levels swing from V_{SS} to V_{DD}. Thus, TTL levels are generated with the standard supplies or CMOS levels occur with V_{SS} = 10V, V_{GG} = −7V and V_{DD} = 0V.

Maximum supply voltage, $V_{SS} - V_{GG}$, is 22V without damage to the device. The maximum operating voltage at which accuracy specs are measured is $V_{SS} - V_{GG}$ = 18.5V. Functional operation is guaranteed over 13V to 21V.

CLOCK

The MM4357 requires a TTL level (referenced to V_{SS}) clock with guaranteed minimum pulse width of 500 ns. Duty cycle is not critical. Conversion time is (1/f) x 40.

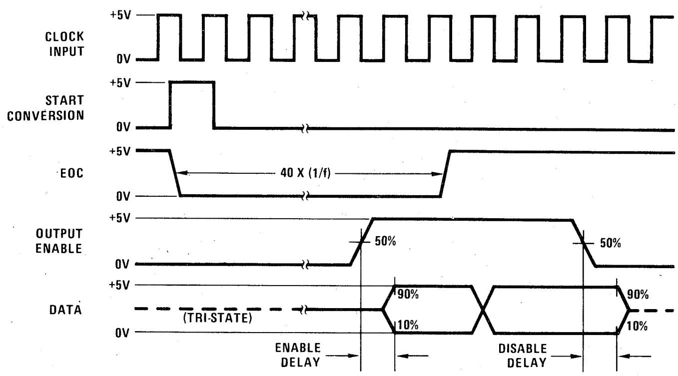
ZERO AND FULL SCALE ADJUSTMENT

In many applications, sufficient accuracy can be obtained by connecting pin 15 directly to the top of the reference. If maximum accuracy is desired, 500Ω pots should be used at both ends of the network and adjusted for zero and full scale.

The top and bottom resistors in the ladder are somewhat less than the nominal 300Ω used throughout the ladder. This permits zero and full scale adjust range with only one pot and no extra supplies. Common practice for zero adjust is to set the transition from 11111111 to 11111110 to occur at 1/2 LSB (20 mV for a 10.24V scale).

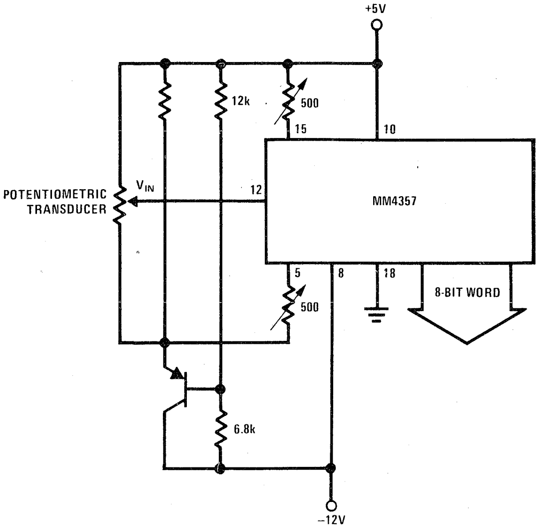
To set full scale, adjust the 500Ω pot on pin 15 until the 00000001 to 00000000 transition occurs 1 1/2 LSB from full scale (60 mV less than full scale for a 10.24V scale).

timing diagram

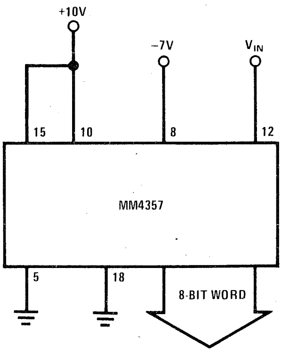


Data is complementary binary (full scale is all "0's" output).

typical applications (con't)

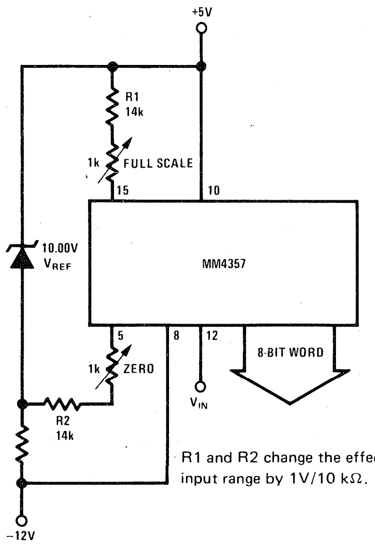


Ratiometric Input Signal with Tracking Reference



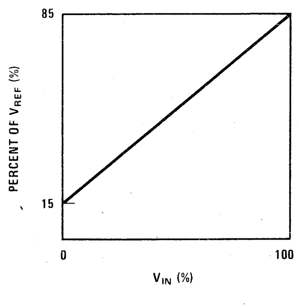
0V to 10V V_{IN} Range
0V to 10V Output Levels

Hi-Voltage CMOS Output Levels



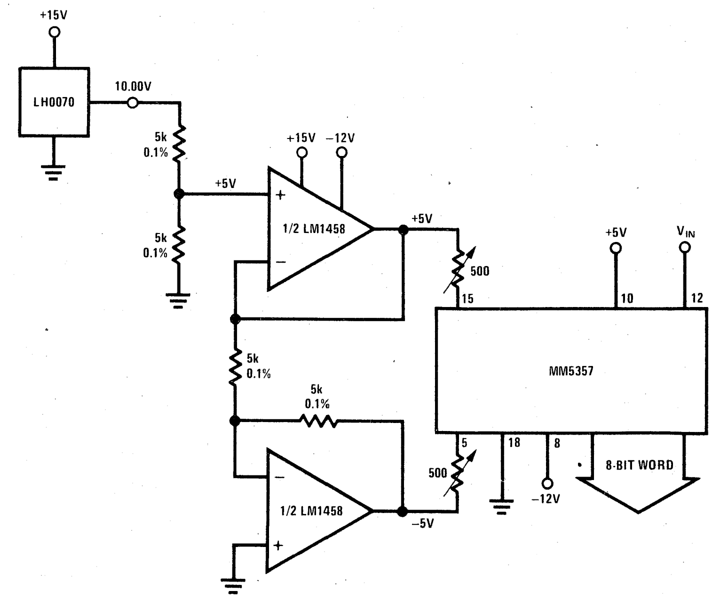
R1 and R2 change the effective input range by 1V/10 kΩ.

Level Shifted Input Signal Range



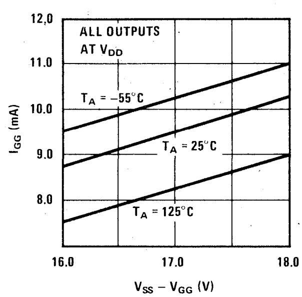
Level Shifted Zero and Full Scale for Transducers

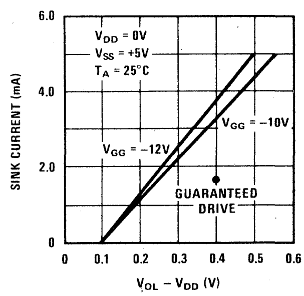
typical applications (con't)

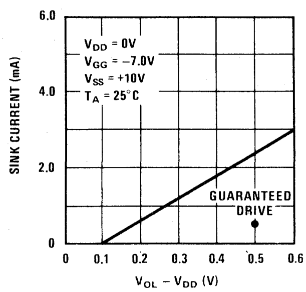


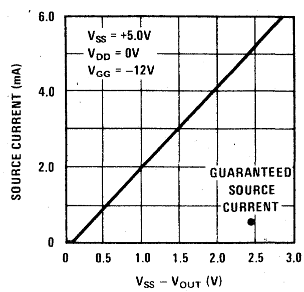
Ground Referenced Input Signal

typical performance characteristics









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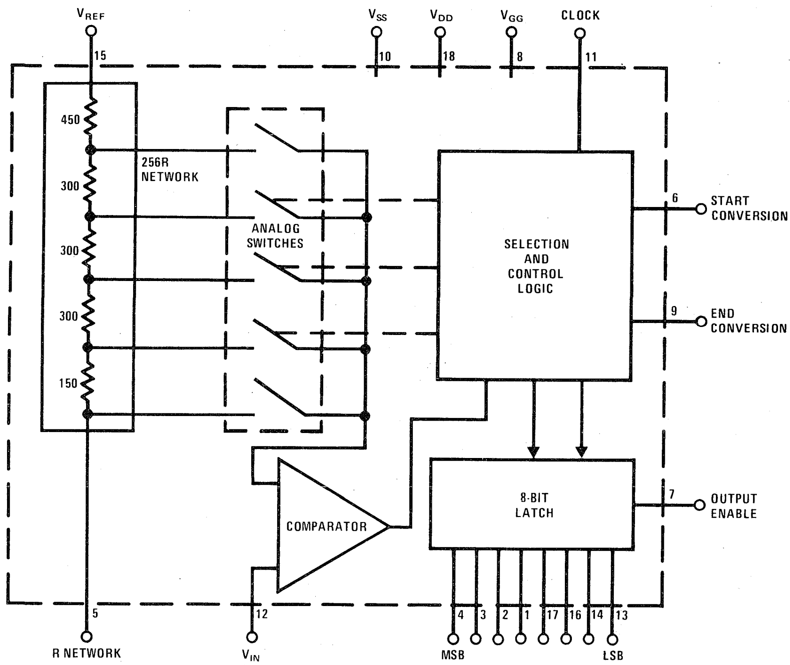
block diagram



MM54C905/MM74C905 12-bit successive approximation register

general description

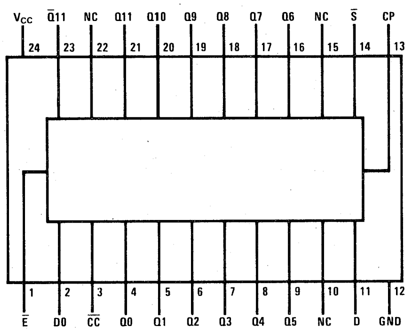
The MM54C905/MM74C905 CMOS 12-bit successive approximation register contains all the digit control and storage necessary for successive approximation analog-to-digital conversion. Because of the unique capability of CMOS to switch to each supply rail without any offset voltage, it can also be used in digital systems as the control and storage element in repetitive routines.

features

- Wide supply voltage range 3.0V to 15V
- Guaranteed noise margin 1.0V
- High noise immunity 0.45 V_{CC} typ
- Low power TTL compatibility fan out of 2 driving 74L
- Provision for register extension or truncation
- Operates in START/STOP or continuous conversion mode
- Drive ladder switches directly. For 10 bits or less with 50k/100k R/2R ladder network

connection diagram

Dual-In-Line Package



Order Number MM54C905D or MM74C905D
See Package 2A
Order Number MM74C905N
See Package 29A

truth table

TIME	INPUTS			OUTPUTS													
t_n	D	$\overline{S}$	$\overline{E}$	D0	Q11	Q10	Q9	Q8	Q7	Q6	Q5	Q4	Q3	Q2	Q1	Q0	$\overline{CC}$
0	X	L	L	X	X	X	X	X	X	X	X	X	X	X	X	X	X
1	D11	H	L	X	L	H	H	H	H	H	H	H	H	H	H	H	H
2	D10	H	L	D11	D11	L	H	H	H	H	H	H	H	H	H	H	H
3	D9	H	L	D10	D11	D10	L	H	H	H	H	H	H	H	H	H	H
4	D8	H	L	D9	D11	D10	D9	L	H	H	H	H	H	H	H	H	H
5	D7	H	L	D8	D11	D10	D9	D8	L	H	H	H	H	H	H	H	H
6	D6	H	L	D7	D11	D10	D9	D8	D7	L	H	H	H	H	H	H	H
7	D5	H	L	D6	D11	D10	D9	D8	D7	D6	L	H	H	H	H	H	H
8	D4	H	L	D5	D11	D10	D9	D8	D7	D6	D5	L	H	H	H	H	H
9	D3	H	L	D4	D11	D10	D9	D8	D7	D6	D5	D4	L	H	H	H	H
10	D2	H	L	D3	D11	D10	D9	D8	D7	D6	D5	D4	D3	L	H	H	H
11	D1	H	L	D2	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	L	H	H
12	D0	H	L	D1	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	L	H
13	X	H	L	D0	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0	L
14	X	X	L	X	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0	L
	X	X	H	X	H	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC	NC

H = High level
L = Low level
X = Don't care
NC = No change

absolute maximum ratings (Note 1)

Voltage at Any Pin	−0.3V to V_{CC} +0.3V
Operating Temperature Range	
MM54C905	−55°C to +125°C
MM74C905	−40°C to +85°C
Storage Temperature Range	−65°C to +150°C
Package Dissipation	500 mW
Operating V_{CC} Range	3.0V to 15V
Absolute Maximum V_{CC}	16V
Lead Temperature (Soldering, 10 seconds)	300°C

dc electrical characteristics

Min/max limits apply across temperature range, unless otherwise noted.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
CMOS TO CMOS					
Logical "1" Input Voltage ($V_{IN(1)}$)	V_{CC} = 5.0V V_{CC} = 10V	3.5 8.0			V V
Logical "0" Input Voltage ($V_{IN(0)}$)	V_{CC} = 5.0V V_{CC} = 10V			1.5 2.0	V V
Logical "1" Output Voltage ($V_{OUT(1)}$)	V_{CC} = 5.0V, I_O = −10μA V_{CC} = 10V, I_O = −10μA	4.5 9.0			V V
Logical "0" Output Voltage ($V_{OUT(0)}$)	V_{CC} = 5.0V, I_O = 10μA V_{CC} = 10V, I_O = 10μA			0.5 1.0	V V
Logical "1" Input Current ($I_{IN(1)}$)	V_{CC} = 15V, V_{IN} = 15V		0.005	1.0	μA
Logical "0" Input Current ($I_{IN(0)}$)	V_{CC} = 15V, V_{IN} = 0V	−1.0	−0.005		μA
Supply Current (I_{CC})	V_{CC} = 15V		0.05	300	μA
CMOS/LPTTL INTERFACE					
Logical "1" Input Voltage ($V_{IN(1)}$) MM54C905 MM74C905	 V_{CC} = 4.5V V_{CC} = 4.75V	 V_{CC}−1.5 V_{CC}−1.5			 V V
Logical "0" Input Voltage ($V_{IN(0)}$) MM54C905 MM74C905	 V_{CC} = 4.5V V_{CC} = 4.75V			 0.8 0.8	 V V
Logical "1" Output Voltage ($V_{OUT(1)}$) MM54C905 MM74C905	 V_{CC} = 4.5V, I_O = −360μA V_{CC} = 4.75V, I_O = −360μA	 2.4 2.4			 V V
Logical "0" Output Voltage ($V_{OUT(0)}$) MM54C905 MM74C905	 V_{CC} = 4.5V, I_O = 360μA V_{CC} = 4.75V, I_O = 360μA			 0.4 0.4	 V V
OUTPUT DRIVE (See 54C/74C Family Characteristics Data Sheet)					
Output Source Current (I_{SOURCE}) (P-Channel)	V_{CC} = 5.0V, V_{OUT} = 0V T_A = 25°C	−1.75	−3.3		mA
Output Source Current (I_{SOURCE}) (P-Channel)	V_{CC} = 10V, V_{OUT} = 0V T_A = 25°C	−8.0	−15		mA
Output Sink Current (I_{SINK}) (N-Channel)	V_{CC} = 5.0V, V_{OUT} = V_{CC} T_A = 25°C	1.75	3.6		mA
Output Sink Current (I_{SINK}) (N-Channel)	V_{CC} = 10V, V_{OUT} = V_{CC} T_A = 25°C	8.0	16		mA
Q11–Q0 Outputs R_{SOURCE}	V_{CC} = 10V ±5% V_{OUT} = V_{CC} − 0.3V T_A = 25°C	150		350	Ω
R_{SINK}	V_{CC} = 10V ±5% V_{OUT} = 0.3V T_A = 25°C	80		230	Ω

ac electrical characteristics $T_A = 25°C$, $C_L = 50$ pF, unless otherwise specified.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Propagation Delay Time From Clock Input To Outputs (Q0–Q11) ($t_{pd(Q)}$)	$V_{CC} = 5.0V$		200	350	ns
	$V_{CC} = 10V$		80	150	ns
Propagation Delay Time From Clock Input To D_O ($t_{pd(D_O)}$)	$V_{CC} = 5.0V$		180	325	ns
	$V_{CC} = 10V$		70	125	ns
Propagation Delay Time From Register Enable ($\overline{E}$) To Output (Q11) ($t_{pd(\overline{E})}$)	$V_{CC} = 5.0V$		190	350	ns
	$V_{CC} = 10V$		75	150	ns
Propagation Delay Time From Clock To $\overline{CC}$ ($t_{pd(\overline{CC})}$)	$V_{CC} = 5.0V$		190	350	ns
	$V_{CC} = 10V$		75	0.50	ns
Data Input Set-Up Time (t_{DS})	$V_{CC} = 5.0V$	80			ns
	$V_{CC} = 10V$	30			ns
Start Input Set-Up Time (t_{SS})	$V_{CC} = 5.0V$	80			ns
	$V_{CC} = 10V$	30			ns
Minimum Clock Pulse Width (t_{PWL}, t_{PWH})	$V_{CC} = 5.0V$	250	125		ns
	$V_{CC} = 10V$	100	50		ns
Maximum Clock Rise and Fall Time (t_r, t_f)	$V_{CC} = 5.0V$			15	μs
	$V_{CC} = 10V$			5	μs
Maximum Clock Frequency (f_{MAX})	$V_{CC} = 5.0V$	2	4		MHz
	$V_{CC} = 10V$	5	10		MHz
Clock Input Capacitance (C_{CLK})	Clock Input (Note 2)		10		pF
Input Capacitance (C_{IN})	Any Other Input (Note 2)		5		pF
Power Dissipation Capacitance (C_{PD})	(Note 3)		100		pF

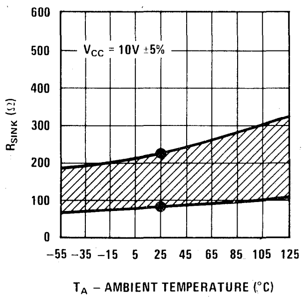
Note 1: "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. Except for "Operating Temperature Range" they are not meant to imply that the devices should be operated at these limits. The table of "Electrical Characteristics" provides conditions for actual device operation.

Note 2: Capacitance is guaranteed by periodic testing.

Note 3: C_{PD} determines the no load ac power consumption of any CMOS device. For complete explanation see 54C/74C Family Characteristics application note, AN-90.

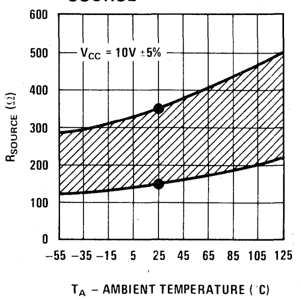
typical performance characteristics

R_{SINK} vs Temperature



● These points are guaranteed by automatic testing.

R_{SOURCE} vs Temperature



● These points are guaranteed by automatic testing.

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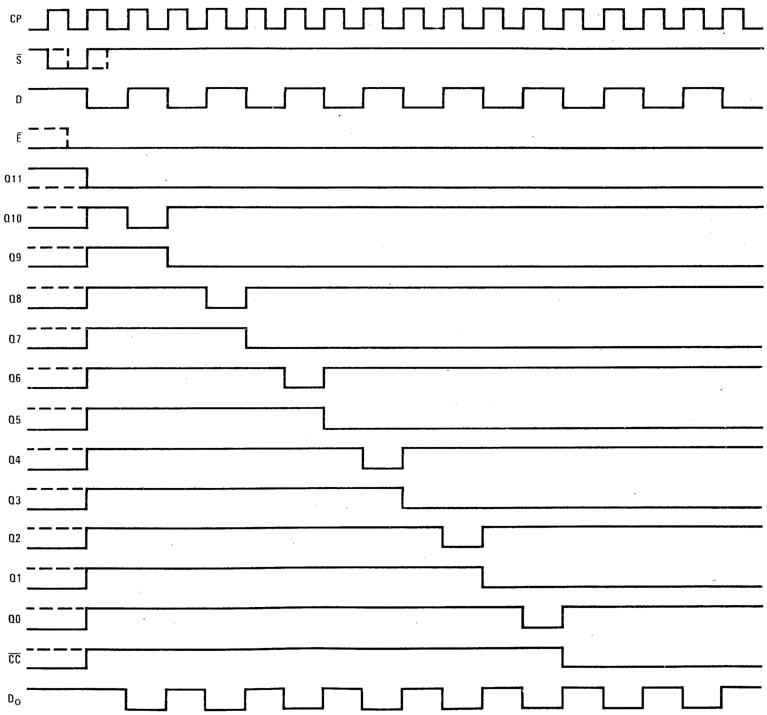
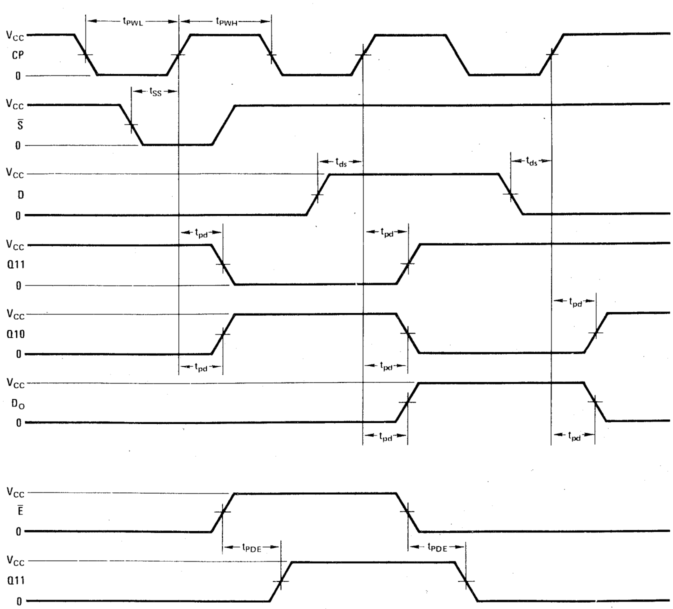
timing diagram



switching time waveforms



USER NOTES FOR A/D CONVERSION

The register can be used with either current switches that require a low voltage level to turn the switch ON or current switches that require a high voltage level to turn the switch ON. If current switches are used which turn ON with a low logic level, the resulting digit output from the register is active low. That is, a logic "1" is represented as a low voltage level. If current switches are used which turn ON with a high logic level, the resulting digit output is active high. A logic "1" is represented as a high voltage level.

For a maximum error of ±1/2 LSB, the comparator must be biased. If current switches that require a high voltage level to turn ON are used, the comparator should be biased +1/2 LSB and if the current switches require a low logic level to turn ON, then the comparator must be biased −1/2 LSB.

The register can be used to perform 2's complement conversion by offsetting the comparator one half full range +1/2 LSB and using the complement of the MSB Q11 as the sign bit.

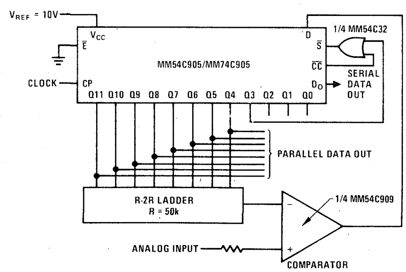
If the register is truncated and operated in the continuous conversion mode, a lock-up condition may occur on power-ON. This situation can be overcome by making the START input the "OR" function of $\overline{CC}$ and the appropriate register output.

The register, by suitable selection of register ladder network, can be used to perform either binary or BCD conversion.

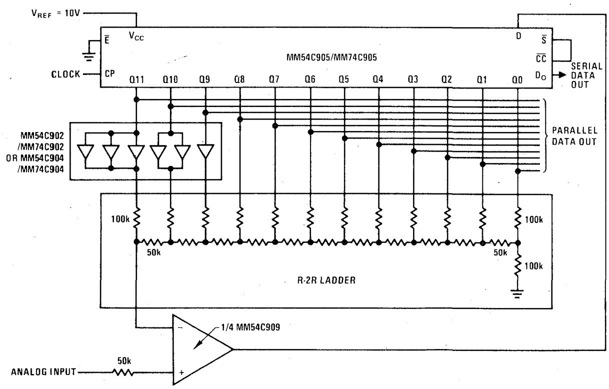
The register outputs can drive the 10 bits or less with 50k/100k R/2R ladder network directly for V_{CC} = 10V or higher. In order to drive the 12-bit 50k/100k ladder network and have the ±1/2 LSB resolution, the MM54C902/MM74C902 or MM54C904/MM74C904 is used as buffers, three buffers for MSB (Q11), two buffers for Q10, and one buffer for Q9.

typical applications

12-Bit Successive Approximation A-to-D Converter Operating in Continuous 8-Bit Truncated Mode



12-Bit Successive Approximation A-to-D Converter, Operating in Continuous Mode, Drives the 50k/100k Ladder Network Directly



definition of terms

CP: Register *clock* input.

$\overline{CC}$: *Conversion complete*—this output remains at $V_{OUT(1)}$ during a conversion and goes to $V_{OUT(0)}$ when conversion is complete.

D: Serial *data* input—connected to comparator output in A-to-D applications.

$\overline{E}$: *Register enable*—this input is used to expand the length of the register. When $\overline{E}$ is at $V_{IN(1)}$ Q11 is forced to $V_{OUT(1)}$ and inhibits conversion. When not used for expansion $\overline{E}$ must be connected to $V_{IN(0)}$ (GND).

Q11: True register MSB output.

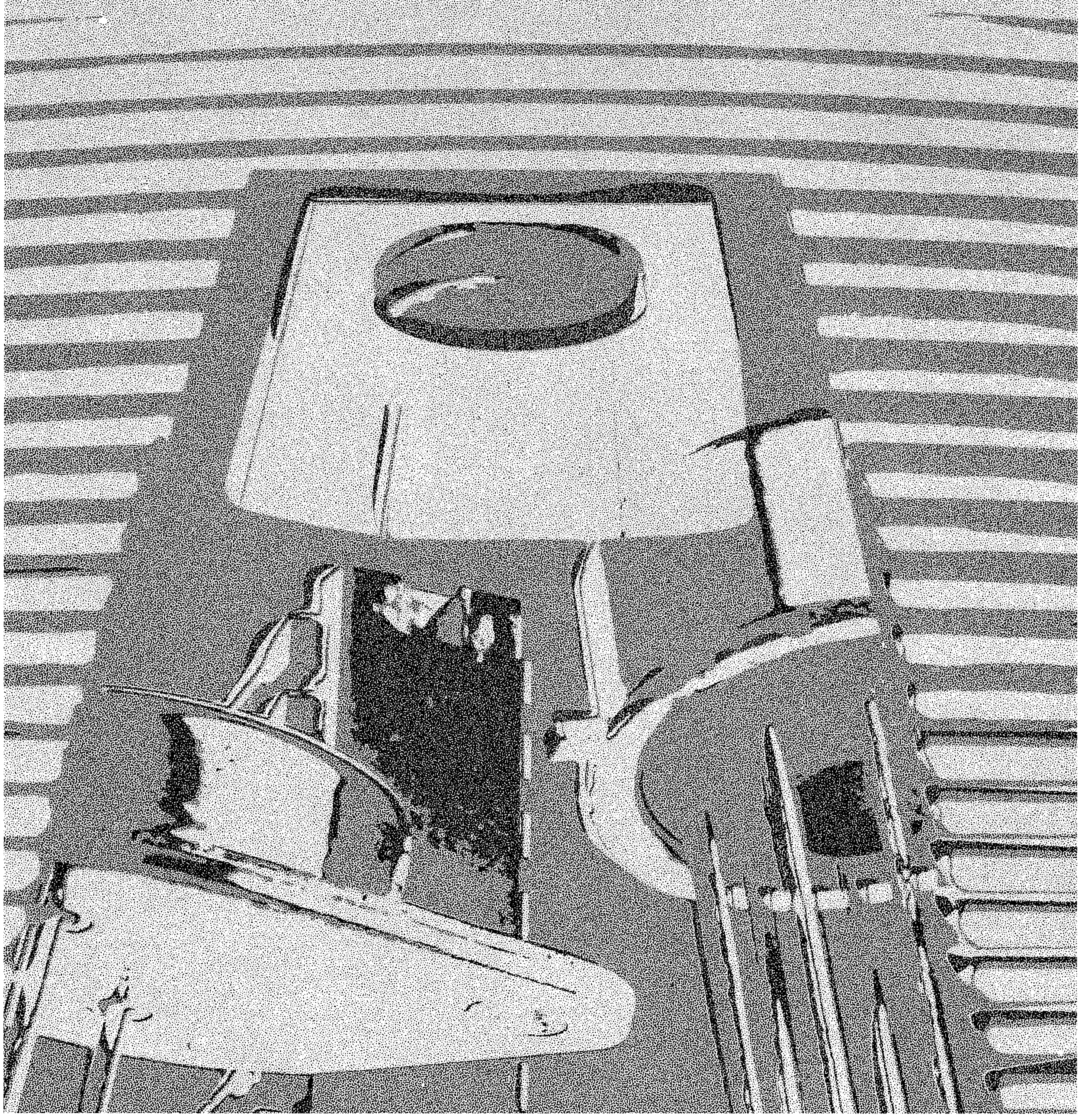
$\overline{Q}$11: Complement of register MSB output.

Qi (i = 0 to 11): Register outputs.

$\overline{S}$: *Start input*—holding start input at $V_{IN(0)}$ for at least one clock period will initiate a conversion by setting MSB (Q11) at $V_{OUT(0)}$ and all other output (Q10—Q0) at $V_{OUT(1)}$. If set-up time requirements are met, a conversion may be initiated by holding start input at $V_{IN(0)}$ for less than one clock period.

DO: *Serial data output*—D input delayed by one clock period.

National Semiconductor
INDUSTRIAL/AUTOMOTIVE/ FUNCTIONAL BLOCKS
Section 9



Industrial/Automotive/Functional Blocks

Section Contents

Expansion of the previously named "Functional Blocks" section of the Linear Data Book to include Industrial Control and Automotive circuits marks a major change, indicative of National Semiconductor's continuously growing line of linear integrated circuits. A dozen new devices appear within this section. A brief introduction outlining new products and pointing out data sheet revisions follows.

INDUSTRIAL CONTROL CIRCUITS

*Product added to this Data Book since last printing.

Revision of the LM555 Timer data sheet adds three more guaranteed maximum parameter limits to facilitate worst case designs. A complement to the popular LM555, where multiple timers are required, is the new LM556 dual timer. One 14-pin package contains two complete LM555 timers operating independently.

Two new integrated circuits, useful in a variety of industrial control applications, are the LM1815 Adaptive Sense Amplifier and the LM1830 Fluid Detector. The LM1815 finds use in position sensing done with notched wheels; as a zero crossing switch; and for tachometer operated motor speed control circuits. The LM1830 allows a monolithic approach to fluid detection systems; offering user selected determination of presence, absence, or level of any conductive liquid.

AC power line monitoring for fault currents is easily done with the new LM1850 Ground Fault Interrupter integrated circuit. The LM1850 includes a full-wave rectifier bridge as well as provisions for phase control of external SCR and TRIAC devices.

The LM3909 LED Flasher/Oscillator completes the new products found in this section. Specifically designed to flash LED's when operated from a single 1.5V battery, the LM3909 finds other applications in trigger circuits, sirens, sense alarms and sound effect circuits.

Industrial temperature control designs requiring sensor applications are directed to the LM3911 and LX5700 temperature transducer devices found in the "Functional Blocks" subsection.

Section Contents (con't)

AUTOMOTIVE CIRCUITS

*Product added to this Data Book since last printing.

1976 marks the first year that National's line of integrated circuits dedicated to automotive applications appears under a separate heading. This reflects the expanding products available and the increased role of IC's in automotive design. Each device meets the stringent temperature ranges required, with special attention given to operation from the transient plagued single supply.

Previously introduced automotive products include the quad op amps, comparators and current differencing amplifiers.

For automotive entertainment products, see the "Audio, Radio & TV Circuits" sections of this handbook.

New automotive products include dual versions of the popular quad comparator and op amp. Also new is the LM2907, LM2917 Tachometer/Speed Switch intended to interface directly with variable reluctance magnetic pickups for applications where the frequency input must be converted to a voltage linearly proportional to frequency.

Several applications are illustrated in the data sheet from speed switches to anti-skid devices.

The LM1815 adaptive sense amplifier is particularly designed for providing timing reference signals from slotted or pegged rotors. Applications include on-board spark timing controls, diagnostic equipment, factory test systems.

LM1830 was specifically designed for sensing low coolant levels in radiators. The device features ac excitation of the probe to avoid corrosion problems. The circuit is capable of driving LED's, loudspeakers and other loads.

Section Contents (con't)

FUNCTIONAL BLOCKS

*Product added to this Data Book since last printing.

Four new products add to the growing list of available circuits collectively known as "Functional Blocks." The first expands National's PLL devices to include the LM1391, LM1394 Phase-Lock Blocks. The LM1391, LM1394 features a stable VCO, pulse phase detector and variable duty-cycle output; and offers a cost-effective alternative where variable frequency, or phase-lock operation is required with a high voltage open collector output.

The popular LX5600 Temperature Transducer gave rise to the introduction of the low-cost LM3911 Temperature Controller device contained within this section. Featuring a temperature sensor, a stable voltage reference and an operational amplifier, the LM3911 makes cost effective, accurate temperature measurement systems possible.

Completing the list of new products is the LM1812 Ultrasonic Transceiver. This unique monolithic IC contains a complete 12W ultrasonic transmitter and receiver that drives power into a transducer, receives an echo and operates a display lamp.

Industrial/Automotive/Functional Blocks

Definition of Terms

Capacitor Saturation Voltage: The offset voltage remaining on the timing capacitor after capacitor discharge current has dropped to zero.

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.

Common-Mode Rejection Ratio: The ratio of the change in input offset voltage to the peak-to-peak input voltage range.

Comparator Input Current: The average current flowing from the R/C pin during the timing cycle.

C_t: Timing capacitor connected between the R/C terminal and the ground 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.

Input Bias Current: The average of the two input currents.

Input Offset Current: The difference in the current into the two input terminals when the supply (output) current is 4.0 mA.

Input Offset Voltage: The voltage which must be applied between the input terminals through equal resistances to obtain 4.0 mA of supply (output) current.

Input Resistance: The ratio of the change in input voltage to the change in input current at either input with the other input connected to 1.0 Vdc.

Input Voltage Range: The range of voltages on the input terminals for which the device operates within specifications.

Linearity: The deviation in output voltage from a straight line output over a specified temperature excursion.

Long Term Stability: The change of a particular parameter when operated at maximum temperature for 1000 hours.

Maximum Power Dissipation: The maximum total device dissipation for which the timer will operate within specifications.

Open Loop Output Resistance: The ratio of a specified supply (output) voltage change to the resulting change in supply (output) current at the specified current level.

Open Loop Transconductance: The ratio of the supply (output) current SPAN to the input voltage required to produce that SPAN.

Open Loop Supply Current: The supply current required with the signal amplifier A2 biased off (inverting input positive, non-inverting input negative) and no load on the V_{REF} terminal.

This represents a measure of the minimum low end signal current.

Output Leakage Current: The maximum current flowing into the collector of the output transistor when the transistor is in the "OFF" state.

Output Sink Current: The current available to flow into a load from a positive supply over a specified output voltage range.

Output Source Current: The current available to flow into a load from the output to V^-, over a specified output voltage range.

Output Voltage: The voltage referred to the V^+ terminal from the output terminal with the input and output connected. (This voltage is the temperature output of the LM3911 and so includes errors in the sensor section and op amp section.)

Power Supply Rejection Ratio: The ratio of the change in input offset voltage to the change in supply (output) voltage producing it.

Reference Voltage Line Regulation: The ratio of the change in V_{REF} to the peak-to-peak change in supply (output) voltage producing it.

Reference Voltage Load Regulation: The change in V_{REF} for a stipulated change in I_{REF}.

Reset Resistor: The equivalent resistor which may be used to calculate the discharge time of the timing capacitor, $t_{DISCHARGE} = (5)\ (C_t)\ (R_{RESET})$.

Reverse Breakdown Voltage: The voltage appearing between the V^+ and V^- terminals at a specified current.

R_t: Timing resistor connected between V_{REF} and the R/C terminal.

Temperature Stability: The percentage in output voltage for a thermal variation from room temperature to either temperature extreme.

Timing Ratio: The ratio of the firing voltage at the R/C pin to the reference voltage.

Trigger Current: The current flowing into or out of the trigger terminal at the specified trigger voltage.

Trigger Voltage: The voltage required at the trigger terminal to initiate a timing cycle, referenced to the ground pin.

Industrial/Automotive/Functional Blocks

LH0045/LH0045C 2-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.

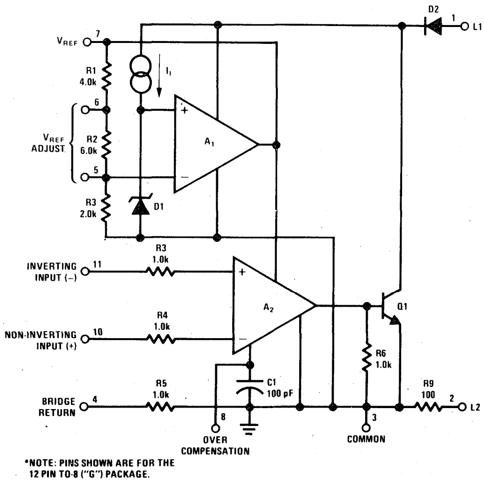
Designed for use with various sensors, the LH0045/LH0045C will interface with thermocouples, strain gauges, or thermistors. The use of the power supply leads as the signal output eliminates two or three extra wires in remote signal applications. Also, current output minimizes susceptibility to voltage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

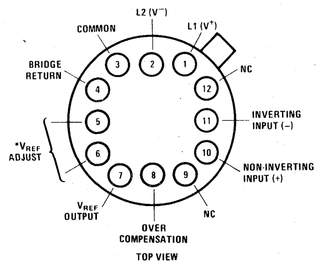
The LH0045/LH0045C is intended to fulfill a wide variety of process control, instrumentation, and data acquisition applications. The LH0045 is guaranteed over the temperature range of −55°C to +125°C; whereas the LH0045C is guaranteed from −25°C to +85°C.

equivalent schematic and connection diagrams



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

TO-8



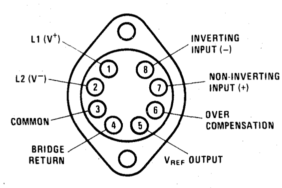
TOP VIEW

*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

9

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

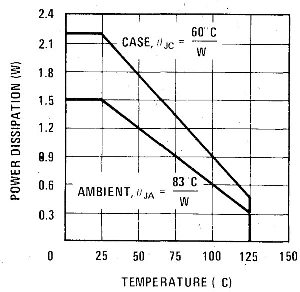
electrical characteristics (Note 1)

PARAMETER	CONDITIONS	LIMITS						UNITS
		LH0045			LH0045C			
		MIN	TYP	MAX	MIN	TYP	MAX	
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

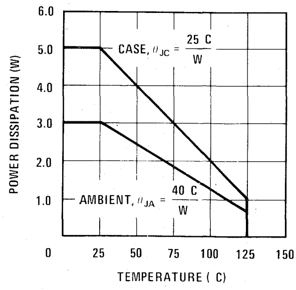
Note 1: Unless otherwise specified, these specifications apply for $+10V \leq V_S \leq +50V$, pin 5 shorted to pin 6 on the LH0045G, over the temperature range −55°C to +125°C for the LH0045 and −25°C to +85°C for the LH0045C.

typical performance characteristics

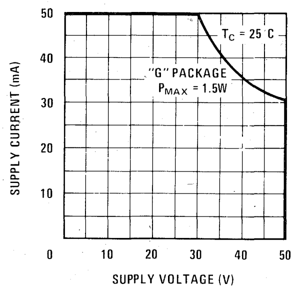
LH0045G Maximum Power Dissipation



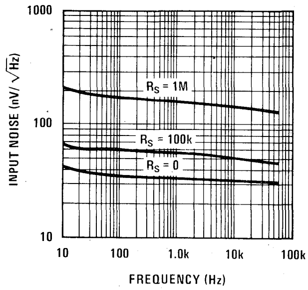
LH0045K Maximum Power Dissipation



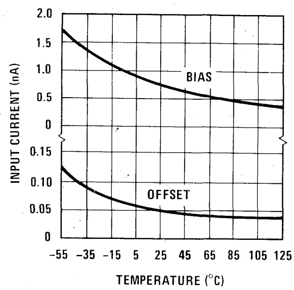
Safe Operating Area



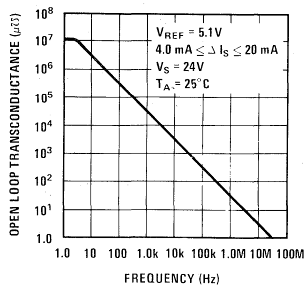
Input Noise Voltage



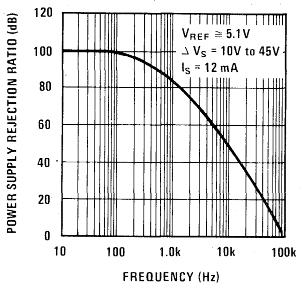
Input Currents



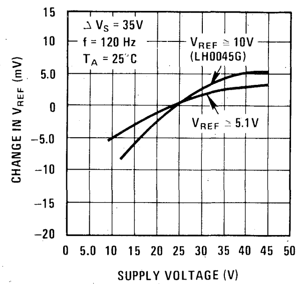
Open Loop Transconductance vs Frequency



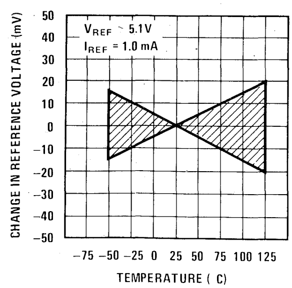
Power Supply Rejection Ratio vs Frequency



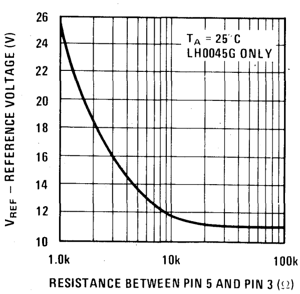
V_{REF} Line Regulation



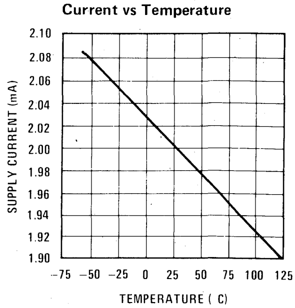
Variation of V_{REF} With Temperature Normalized to 25°C



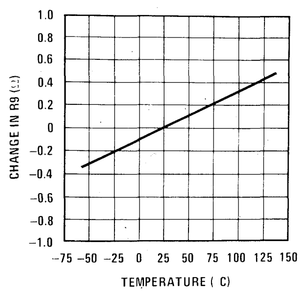
V_{REF} vs Resistance Between Pin 5 and Pin 3



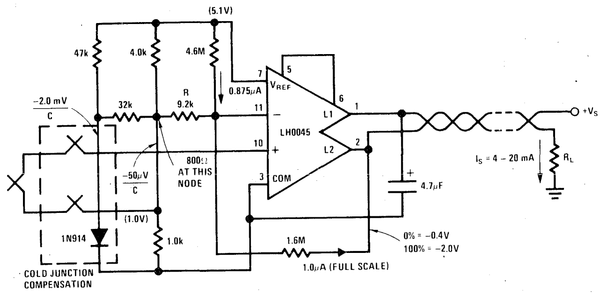
Open Loop Supply Current vs Temperature



Change in R9 With Temperature Normalized to 25°C

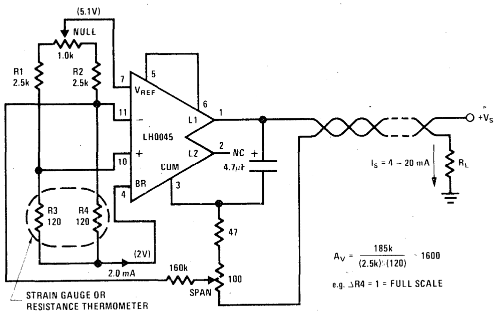


typical applications*



FOR 1μA FULL SCALE, R_{IN} = V_{IN}/1μA = 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

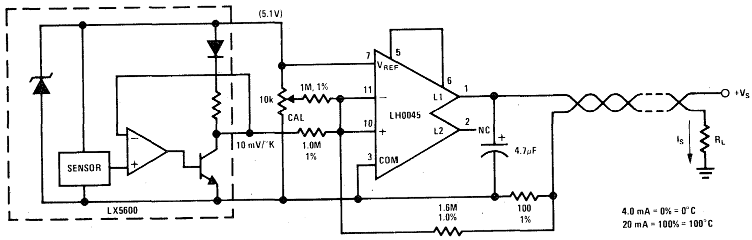
Thermocouple Input Transmitter



$A_V = \frac{185k}{(2.5k)/(120)} \approx 1600$

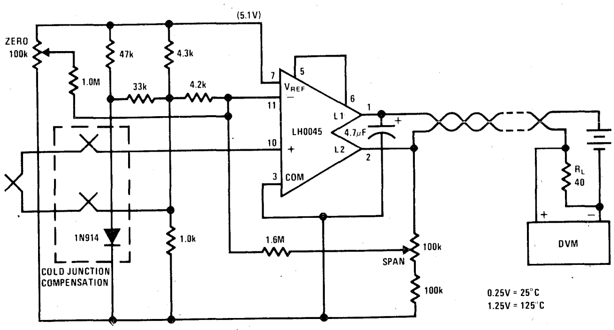
e.g. ΔR4 = 1 = FULL SCALE

Resistance Bridge Input Transmitter



4.0 mA = 0% = 0°C
20 mA = 100% = 100°C

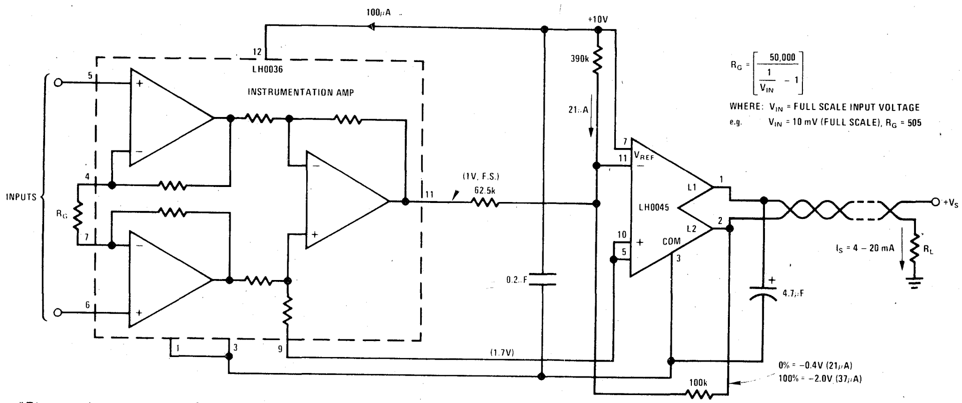
Electronic Temperature Sensor



0.25V = 25°C
1.25V = 125°C

*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.

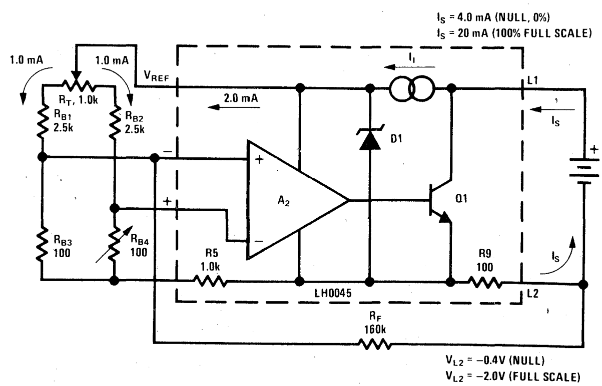


FIGURE 1. LH0045 Simplified Schematic

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.

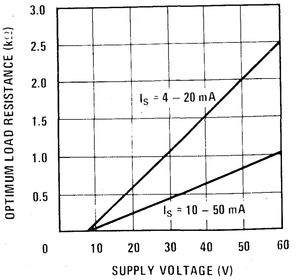


FIGURE 2. Optimum Load Resistance vs Supply Voltage

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.

applications information (con't)

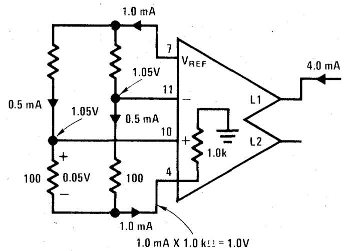


FIGURE 3. Use of Bridge Return

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:

$R = 400\ M\Omega$

$C1$ = 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 $\leq 1.0\Omega$

General Characteristics

a. $0°C \leq T_A \leq +75°C$

b. Overall Accuracy $\leq 0.5\%$

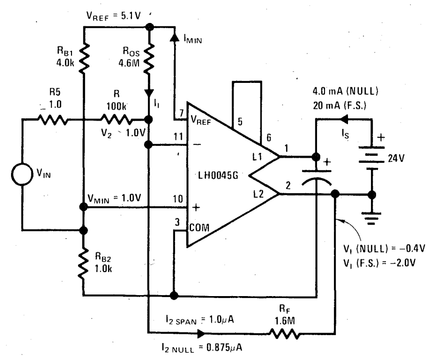


FIGURE 4. Design Example Circuit

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 ΔI_B) errors due to $\Delta I_B/\Delta T$ will be less than 0.1%. For SPAN = 16 mA.

$$V_{SPAN} = \Delta V_1 = -(16\ mA)(R9) = -1.6V$$

9

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

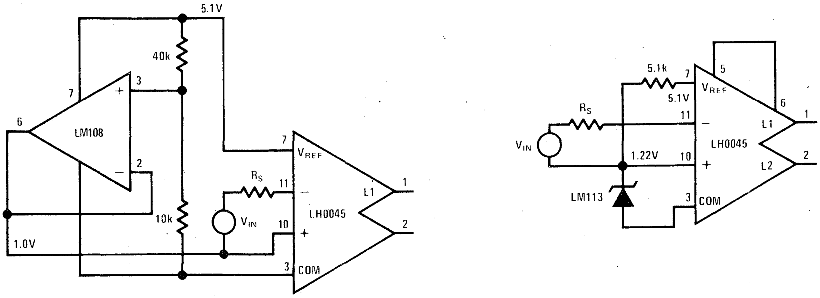


FIGURE 5. Alternate Biasing Techniques

applications information (con't)

$$\therefore R = \frac{(V_{IN})\,(R_F)}{(I_{SPAN})\,(R9)}$$

$$R = \frac{(100\text{ mV})\,(1.6\text{ M}\Omega)}{(16\text{ mA})\,(100\Omega)}$$

$$R = 100\text{ k}\Omega$$

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

$$R_{B2} \geq \frac{V_{MIN}}{I_{MIN}}$$

$$R_{B2} \geq \frac{1\text{ VOLT}}{I_{NULL} - I_{SOL}}$$

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.

$$\Delta V_{REF} = \left(\frac{60^\circ C}{W}\,(0.077W) + 75^\circ C\right)\left(\frac{0.2\text{ mV}}{^\circ C}\right) + \frac{0.5\text{ mV}}{V}\,(16V)$$

$$\Delta V_{REF} = 24\text{ mV}$$

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}

$K = \dfrac{R_{B2}}{R_{B1} + R_{B2}}$

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

$\dfrac{\Delta R9}{\Delta T}$ = 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.

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:

$$\frac{\Delta I_S}{I_{SPAN}} = \underbrace{0.12\%}_{\Delta V_{REF}} + \underbrace{0.26\%}_{\Delta V_{OS}} + \underbrace{0.08\%}_{\Delta R9} = 0.46\%$$

Industrial/Automotive/Functional Blocks

LM122/LM222/LM322, LM2905/LM3905 precision timers

general description

The LM122 series are precision timers that offer great versatility with high accuracy. They operate with 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 series 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 series 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.

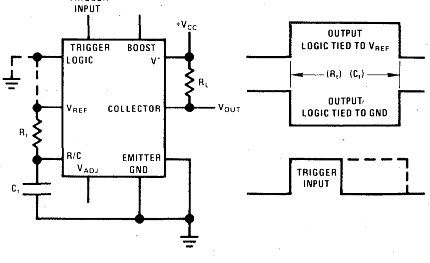
The comparator used in the LM122 utilizes high gain PNP input transistors to achieve 300 pA typical input bias current over a common mode range of 0V to 3V. A **boost** terminal allows the user to increase comparator operating current for timing periods less than 1 ms. This lets the timer operate over 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, and the LM322 is specified from 0°C to +70°C. The LM2905/LM3905 are identical to the LM122 series except that the **boost** and V_{REF} pin options are not available, limiting minimum timing period to 1 ms.

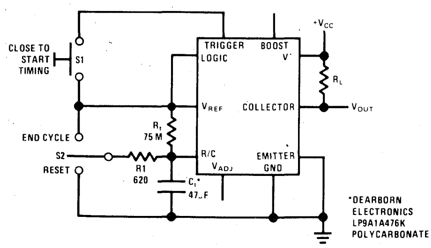
features

- Immune to changes in trigger voltage during timing interval
- Timing periods from microseconds to hours
- Internal logic reversal
- Immune to power supply ripple 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

typical applications



Basic Timer-Collector Output and Timing Chart



One Hour Timer with Reset and Manual Cycle End

9

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

Operating Temperature Range	
LM122	$-55°C \le T_A \le +125°C$
LM222	$-25°C \le T_A \le +85°C$
LM322	$0°C \le T_A \le +70°C$
LM2905	$-40°C \le T_A \le +85°C$
LM3905	$0°C \le T_A \le +70°C$

electrical characteristics (Note 2)

PARAMETER	CONDITIONS	LM122/LM222			LM322			LM2905/LM3905			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Timing Ratio	$T_A = 25°C$, $4.5V \le V^+ \le 40V$	0.626	0.632	0.638	0.620	0.632	0.644	0.620	0.632	0.644	
	Boost Tied to V^+, (Note 3)	0.620	0.632	0.644	0.620	0.632	0.644				
Comparator Input Current	$T_A = 25°C$, $4.5V \le V^+ \le 40V$		0.3	1.0		0.3	1.5		0.5	1.5	nA
	Boost Tied to V^+		30	100		30	100				nA
Trigger Voltage	$T_A = 25°C$, $4.5V \le V^+ \le 40V$	1.2	1.6	2	1.2	1.6	2	1.2	1.6	2	V
Trigger Current	$T_A = 25°C$, $V_{TRIG} = 2V$		25			25			25		µA
Supply Current	$T_A \ge 25°C$, $4.5V \le V^+ \le 40V$		2.5	4		2.5	4.5		2.5	4.5	mA
Timing Ratio	$4.5V \le V^+ \le 40V$	0.62		0.644	0.61		0.654	0.61		0.654	
	Boost Tied to V^+	0.62		0.644	0.61		0.654				
Comparator Input Current	$4.5V \le V^+ \le 40V$	−5		5	−2		2	−2.5		2.5	nA
	Boost Tied to V^+, (Note 4)			100			150				nA
Trigger Voltage	$4.5V \le V^+ \le 40V$	0.8		2.5	0.8		2.5	0.8		2.5	V
Trigger Current	$V_{TRIG} = 2.5V$			200			200			200	µA
Output Leakage Current	$V_{CE} = 40V$			1			5			5	µA
Capacitor Saturation Voltage	$R_t \ge 1\ M\Omega$		2.5			2.5			2.5		mV
	$R_t = 10\ k\Omega$		25			25			25		mV
Reset Resistance			150			150			150		Ω
Reference Voltage	$T_A = 25°C$	3	3.15	3.3	3	3.15	3.3	3	3.15	3.3	V
Reference Regulation	$0 \le I_{OUT} \le 3$ mA		20	50		20	50		20	50	mV
	$4.5V \le V^+ \le 40V$		6	25		6	25		6	25	mV
Collector Saturation Voltage	$I_L = 8$ mA		0.25	0.4		0.25	0.4		0.25	0.4	V
	$I_L = 50$ mA		0.7	1.4		0.7	1.4		0.7	1.4	V
Emitter Saturation Voltage	$T_A = 25°C$, $I_L = 3$ mA		1.8	2.2		1.8	2.2		1.8	2.2	V
	$T_A = 25°C$, $I_L = 50$ mA		2.1	3		2.1	3		2.1	3	V
Average Temperature Coefficient of Timing Ratio			0.003			0.003			0.003		%/°C
Minimum Trigger Width	$V_{TRIG} = 3V$		0.25			0.25			0.25		µs

Note 1: Continuous output shorts are not allowed. Short circuit duration at ambient temperatures up to 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.

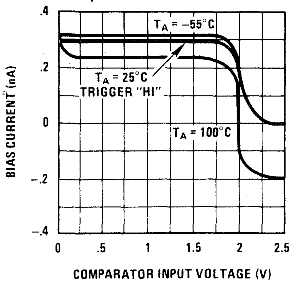
Note 2: These specifications apply for $T_{AMIN} \le T_A \le T_{AMAX}$ unless otherwise noted.

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.

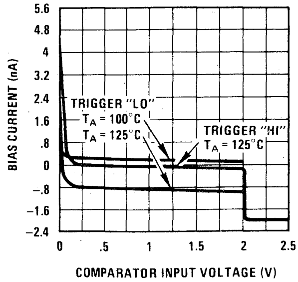
Note 4: Sign reversal may occur at high temperatures (> 100°C) where comparator input current is predominately leakage. See typical curves.

typical performance characteristics

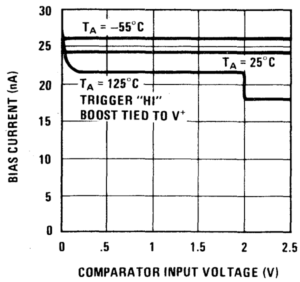
Comparator Bias Current



Comparator Bias Current

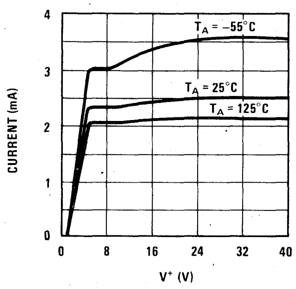


Comparator Bias Current (LM122/LM222/LM322)

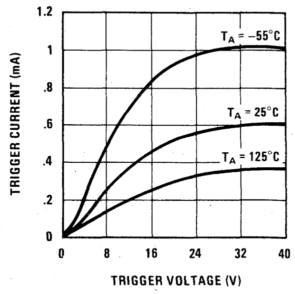


typical performance characteristics (con't)

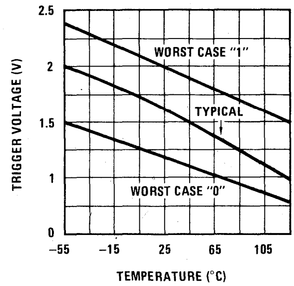
Supply Current



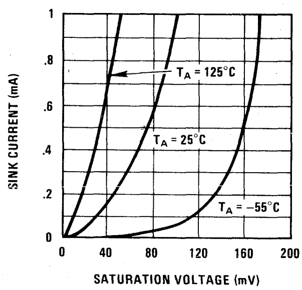
Trigger Input Characteristics



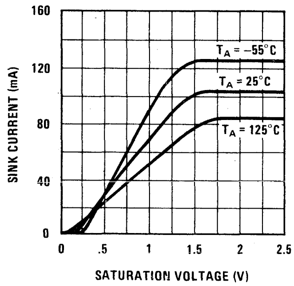
Trigger Threshold



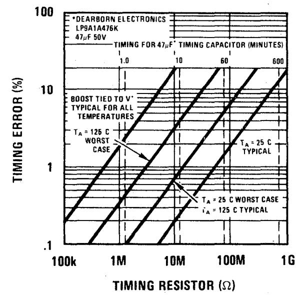
Output Transistor Saturation Characteristics at Low Currents



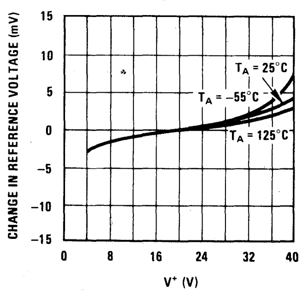
Collector Output Saturation Characteristics at High Current



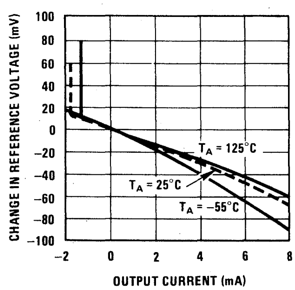
Timing Error Due to Comparator Bias Current



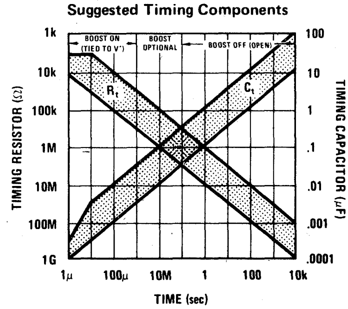
Reference Regulation



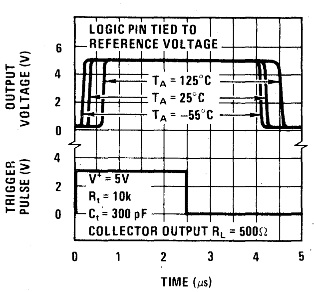
Reference Regulation



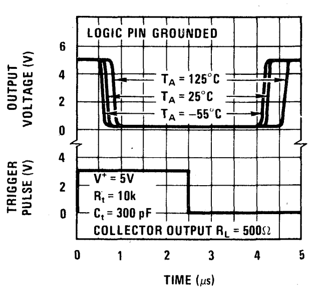
Suggested Timing Components



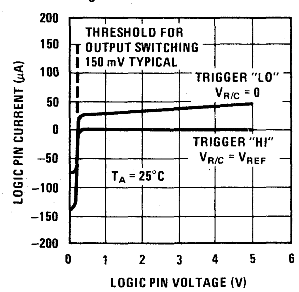
Short Output Pulse (LM122/LM222/LM322)



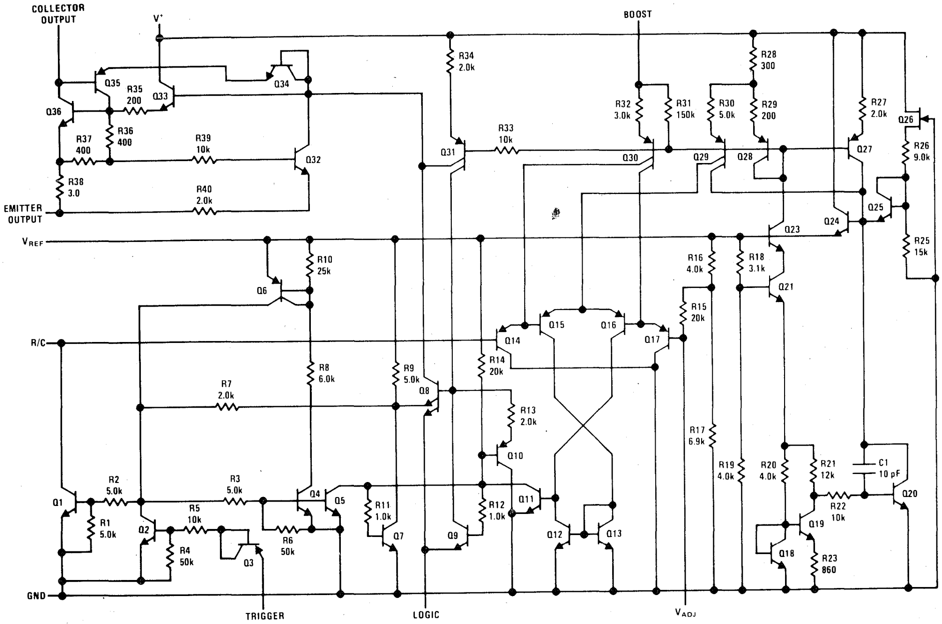
Short Output Pulse (LM122/LM222/LM322)



Logic Pin Characteristics

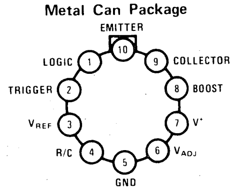


schematic diagram



connection diagrams

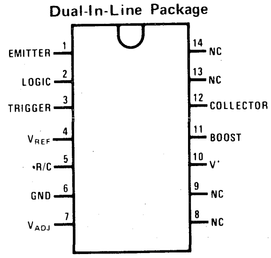
Metal Can Package



TOP VIEW

Order Number LM122H, LM22H or LM322H
See Package 14

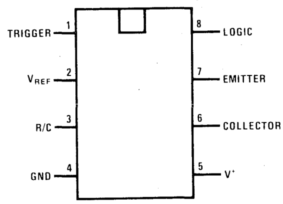
Dual-In-Line Package



TOP VIEW

Order Number LM322N
See Package 22

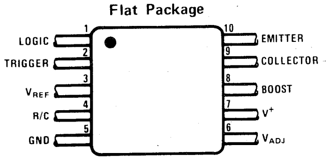
Dual-In-Line Package



TOP VIEW

Order Number LM2905N or LM3905N
See Package 20

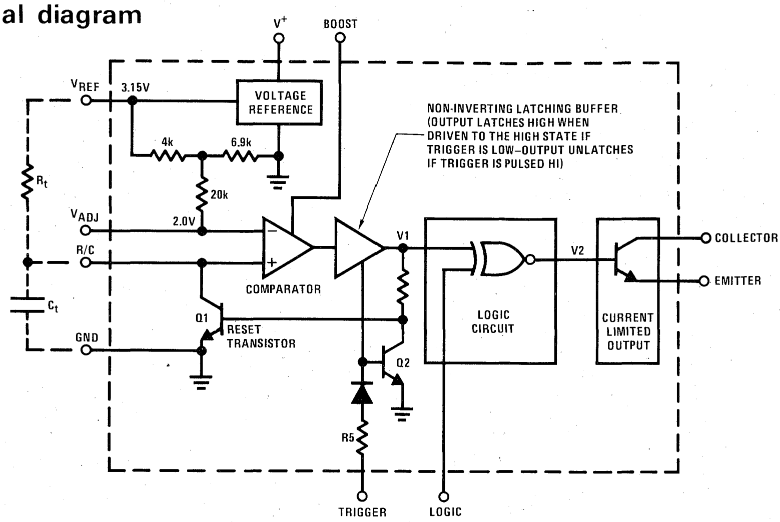
Flat Package



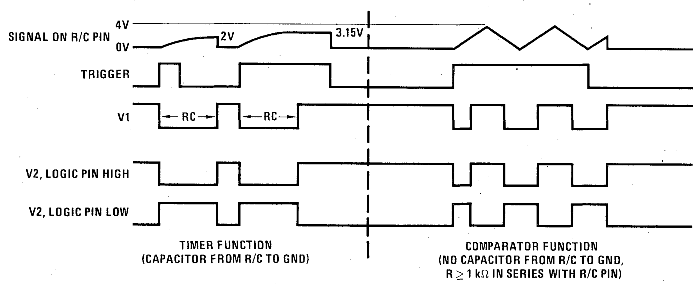
TOP VIEW

Order Number LM122F
See Package 3

functional diagram



timing diagram



pin function description

One of the main features of the LM122 is its great versatility. Since this device is unique, a description of the functions and limitations of each pin is in order. This will make it much easier to follow the discussion of the various applications presented in this note.

V^+ is the positive supply terminal of the LM122. When using a single supply, this terminal may be driven by any voltage between 4.5V and 40V. The effect of supply variations on timing period is less than 0.005%/V, so supplies with high ripple content may be used without causing pulse width changes. Supply bypassing on V^+ is not generally needed but may be necessary when driving highly reactive loads. Quiescent current drawn from the V^+ terminal is typically 2.5 mA, independent of the supply voltage. Of course, additional current will be drawn if the reference is externally loaded.

The $\mathbf{V_{REF}}$ pin is the output of a 3.15V series regulator referenced to the ground pin. Up to 5.0 mA can be drawn from this pin for driving external networks. In most applications the timing resistor is tied to $\mathbf{V_{REF}}$, but it need not be in situations where a more linear charging current is required. The regulated voltage is very useful in applications where the LM122 is not used as a timer; such as switching regulators, variable reference comparators, and temperature controllers. Typical temperature drift of the reference is less than 0.01%/°C.

The **trigger** terminal is used to start a timing cycle (see functional diagram). Initially, Q1 is saturated, C_t is discharged and the latching buffer output (V1) is latched high. A trigger pulse unlatches the buffer, V1 goes low and turns Q1 off. The timing capacitor C_t connected from R/C to GND will begin to charge. When the voltage at the R/C terminal reaches the 2.0V threshold of the comparator, the comparator toggles, latching the buffer output (V1) in the high state. This turns on Q1, discharges the capacitor C_t and the cycle is ready to begin again.

If the **trigger** is held high as the timing period ends, the comparator will toggle and V1 will go high exactly as before. However, V1 will not be latched and the capacitor will not discharge until the trigger again goes low. When the trigger goes low, V1 remains high but is now latched.

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pin function description (con't)

Trigger threshold is typically 1.6V at 25°C and has a temperature dependence of −5.0 mV/°C. Current drawn from the **trigger** source is typically 20μA at threshold, rising to 600μA at 30V, then leveling off due to FET action of the series resistor, R5. For negative input trigger voltages, the only current drawn is leakage in the nA region. The **trigger** can be driven from supplies as high as ±40V, even when device supply voltage is only 5V.

The **R/C** pin is tied to the non-inverting side of the comparator and to the collector of Q1. Timing ends when the voltage on this pin reaches 2.0V (1 RC time constant referenced to the 3.15V regulator). Q1 turns on only if the trigger voltage has dropped below threshold. In comparator or regulator applications of the timer, the trigger is held permanently high and the R/C pin acts just like the input to an ordinary comparator. The maximum voltages which can be applied to this pin are +5.5V and −0.7V. Current from the **R/C** pin is typically 300 pA when the voltage is negative with respect to the V_{ADJ} terminal. For higher voltages, the current drops to leakage levels. In the boosted mode, input current is typically 30 nA. Gain of the comparator is very high, 200,000 or more, depending on the state of the logic reverse pin and the connection of the output transistor.

The **ground** pin of the LM122 need not necessarily be tied to system ground. It can be connected to any positive or negative voltage as long as the supply is negative with respect to the V^+ terminal. Level shifting may be necessary for the input **trigger** if the **trigger** voltage is referred to system ground. This can be done by capacitive coupling or by actual resistive or active level shifting. One point must be kept in mind; the emitter output must not be held above the **ground** terminal with a low source impedance. This could occur, for instance, if the emitter were grounded when the **ground** pin of the LM122 was tied to a negative supply.

The terminal labeled V_{ADJ} is tied to one side of the comparator and to a voltage divider between V_{REF} and **ground**. The divider voltage is set at 63.2% of V_{REF} with respect to ground—exactly one RC time constant. The impedance of the divider is increased to about 30k with a series resistor to present a minimum load on external signals tied to V_{ADJ}. This resistor is a pinched type with a typical variation in nominal value of −50%, +100% and a TC of 0.7%/°C. For this reason, external signals (typically a pot between V_{REF} and **ground**) connected to V_{ADJ} should have a source resistance as low as possible. For small changes in V_{ADJ}, up to several kΩ is all right, but for large variations, 250Ω or less should be maintained. This can be accomplished with a 1k pot, since the maximum impedance from the wiper is 250Ω. If a voltage is forced on V_{ADJ} from a hard source, voltage should be limited to −0.5, and +5.0V, or current limited to ±1.0 mA. This includes capacitively coupled signals because even small values of capacitors contain enough energy to degrade the input stage if the capacitor is driven with a large, fast slewing signal. The V_{ADJ} pin may be used to abort the timing cycle. Grounding this pin during the timing period causes the timer to react just as if the capacitor voltage had reached its normal RC trigger point; the capacitor discharges and the output charges state. An exception to this occurs if the trigger pin is held high when the V_{ADJ} pin is grounded. In this case, the output changes state, but the capacitor does not discharge.

If the trigger drops while V_{ADJ} is being held low, discharge will occur immediately and the cycle will be over. If the trigger is still high when V_{ADJ} is released, the output may or may not change state, depending the voltage across the timing capacitor. For voltages below 2.0V across the timing capacitor, the output will change state immediately, then once more as the voltage rises past 2.0V. For voltages above 2.0V, no change will occur in the output. This pin is not available on the LM2905/LM3905.

In noisy environments or in comparator-type applications, a bypass capacitor on the V_{ADJ} terminal may be needed to eliminate spurious outputs because it is high impedance point. The size of the cap will depend on the frequency and energy content of the noise. A 0.1μF will generally suffice for spike suppression, but several μF may be used if the timer is subjected to high level 60 Hz EMI.

The **emitter** and the **collector** outputs of the timer can be treated just as if they were an ordinary transistor with 40V minimum collector-emitter breakdown voltage. Normally, the **emitter** is tied to the **ground** pin and the signal is taken from the **collector**, or the **collector** is tied to V^+ and the signal is taken from the **emitter**. Variations on these basic connections are possible. The **collector** can be tied to any positive voltage up to 40V when the signal is taken from the **emitter**. However, the **emitter** will not be pulled higher than the supply voltage on the V^+ pin. Connecting the **collector** to a voltage less than the V^+ voltage is allowed The **emitter** should not be connected to a low impedance load other than that to which the ground pin is tied. The transistor has built-in current limiting with a typical knee current of 120 mA. Temporary short circuits are allowed; even with **collector-emitter** voltages up to 40V. The power x time product, however, must not exceed 15 watt-seconds for power levels above the maximum rating of the package. A short to 30V, for instance, can not be held for more than 4 seconds. These levels are based on 40°C maximum initial chip temperature. When driving inductive loads, always use a clamp diode to protect the transistor from inductive kick-back.

A **boost** pin is provided on the LM122 to increase the speed of the internal comparator. The comparator is normally operated at low current levels for lowest possible input current.

pin function description (con't)

For timing periods less than 1 ms, where low input current is not needed, comparator operating current can be increased several orders of magnitude. Shorting the boost terminal to V^+ increases the emitter current of the vertical PNP drivers in the differential stage from 25 nA to 5µA. This pin is not available on the LM2905/LM3905.

With the timer in the unboosted state, timing periods are accurate down to about 1 ms. In the boosted mode, loss of accuracy due to comparator speed is only about 800 ns, so timing periods of several microseconds can be used. The 800 ns error is relatively insensitive to temperature, so temperature coefficient of pulse width is still good.

The **Logic** pin is used to reverse the signal appearing at the output transistor. An open or "high" condition on the **logic** pin programs the output transistor to be "off" during the timing period and "on" all other times. Grounding the **logic** pin reverses the sequence to make the transistor "on" during the timing period. Threshold for the **logic** pin is typically 150 mV with 150µA flowing out of the terminal. If an active drive to the **logic** pin is desired, a saturated transistor drive is recommended, either with a discrete transistor or the open collector output of integrated logic. A maximum V_{SAT} of 75 mV at 200µA is required. Minimum and maximum voltages that may appear on the **logic** pin are 0 and +5.0, respectively.

typical applications (con't)

Basic Timers

Figure 1 is a basic timer using the collector output. R_t and C_t set the time interval with R_L as the load. During the timing interval the output may be

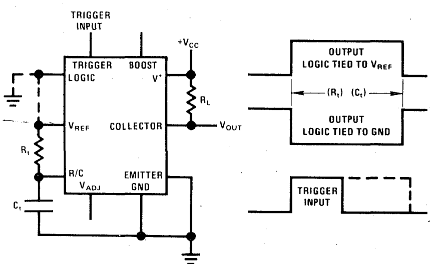


FIGURE 1. Basic Timer-Collector Output and Timing Chart

either high or low depending on the connection of the logic pin. Timing waveforms are shown in the sketch along side *Figure 1*. Note that the trigger pulse may be either shorter or longer than the output pulse width.

Figure 2 is again a basic timer, but with the output taken from the emitter of the output transistor. As with the collector output, either a high or low condition may be obtained during the timing period.

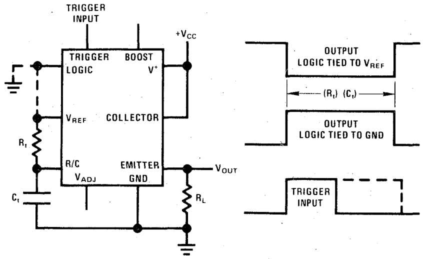


FIGURE 2. Basic Timer-Emitter Output and Timing Chart

Simulating a Thermal Delay Relay

Figure 3 is an application where the LM122 is used to simulate a thermal delay relay which

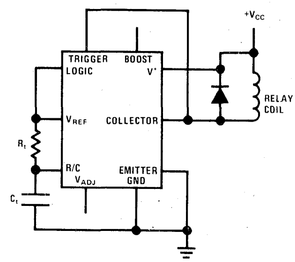


FIGURE 3. Time Out on Power Up (Relay Energized R_tC_t Seconds After V_{CC} is Applied)

prevents power from being applied to other circuitry until the supply has been on for some time. The relay remains de-energized for R_t C_t seconds after V_{CC} is applied, then closes and stays energized until V_{CC} is turned off. *Figure 4* is a similar circuit except that the relay is energized

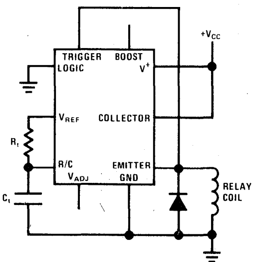


FIGURE 4. Time Out on Power Up (Relay Energized *Until* R_tC_t Seconds After V_{CC} is Applied)

as soon as V_{CC} is applied. R_t C_t seconds later, the relay is de-energized and stays off until the V_{CC} supply is recycled.

typical applications (con't)

+5V Supply Driving 28V Relay

Figure 5 shows the timer interfacing 5V logic to a high voltage relay. Although the V^+ terminal could be tied to the +28V supply, this may be

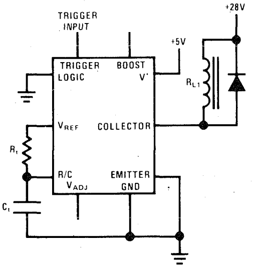


FIGURE 5. 5V Logic Supply Driving 28V Relay

an unnecessary waste of power in the IC or require extra wiring if the LM122 is on a logic card. In either case, the threshold for the trigger is 1.6V.

30V Supply Interfacing with 5V Logic

Figure 6 indicates the ability of the timer to interface to digital logic when operating off a high supply voltage. V_{OUT} swings between +5V and ground with a minimum fanout of 5 for medium speed TTL. If the logic is sensitive to rise/fall time of the trailing edge of the output pulse, the trigger pin should be low at that time.

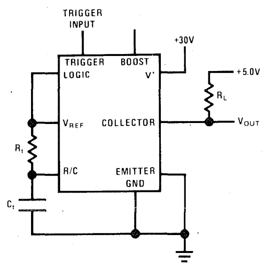


FIGURE 6. 30V Supply Interfacing with 5V Logic

Astable Operation

The LM122 can be made into a self-starting oscillator by feeding the output back to the trigger input through a capacitor as shown in *Figure 7*. Operating frequency is $1/(R_t + R_1)(C_t)$. The output is a narrow negative pulse whose width is approximately $2R_2\ C_f$. For optimum frequency stability, C_f should be as small as possible. The minimum value is determined by the time required to discharge C_t through the internal discharge transistor. A conservative value for C_f can be chosen from the graph included with *Figure 20*. For frequencies below 1 kHz, the frequency error introduced by C_f is a few tenths of one percent or less for $R_t \geq 500k$.

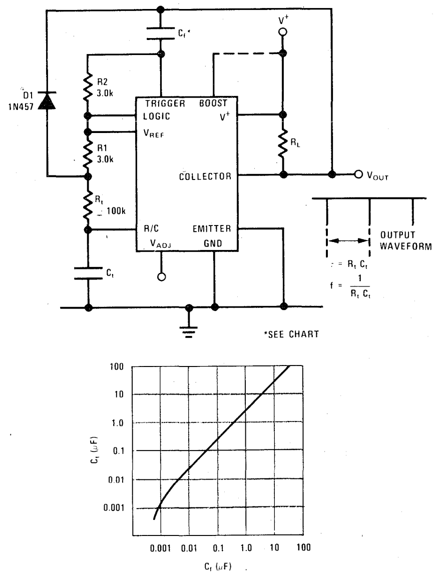


FIGURE 7. Oscillator

One Hour Timer with Reset and Manual Cycle End

Figure 8 shows the LM122 connected as a one hour timer with manual controls for start, reset, and cycle end. S1 starts timing, but has no effect after timing has started. S2 is a center off switch which can either end the cycle prematurely with the appropriate change in output state and discharging of C_t, or cause C_t to be reset to 0V without a change in output. In the latter case, a new timing period starts as soon as S2 is released.

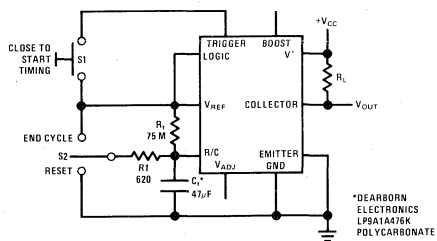


FIGURE 8. One Hour Timer with Reset and Manual Cycle End

The average charging current through R_t is about 30 nA, so some attention must be paid to parts layout to prevent stray leakage paths. The suggested timing capacitor has a typical self time constant of 300 hours and a guaranteed minimum of 25 hours at +25°C. Other capacitor types may be used if sufficient data is available on their leakage characteristics.

typical applications (con't)

Two Terminal Time Delay Switch

The LM122 can be used as a two terminal time delay switch if an "on" voltage drop of 2V to 3V can be tolerated. In *Figure 9*, the timer is used to drive a relay "on" $R_t \cdot C_t$ seconds after application of power. "off" current of the switch is 4 mA maximum, and "on" current can be as high as 50 mA.

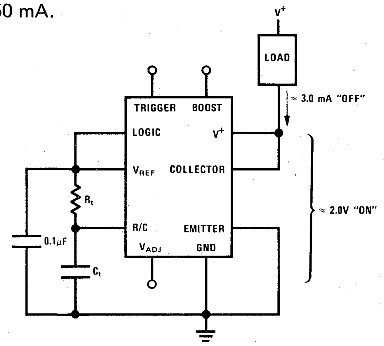


FIGURE 9. 2-Terminal Time Delay Switch

Zero Power Dissipation Between Timing Intervals

In some applications it is desirable to reduce supply current drain to zero between timing cycles. In *Figure 10* This is accomplished by using an external PNP as a latch to drive the V^+ pin of the timer.

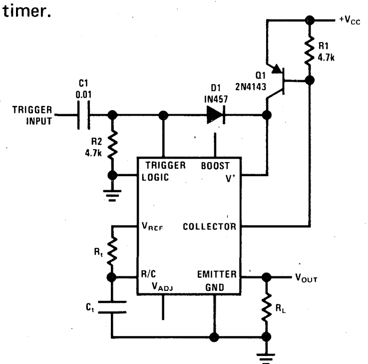


FIGURE 10. Zero Power Dissipation Between Timing Intervals

Between timing periods Q1 is off and no supply current is drawn. When a trigger pulse of 5V minimum amplitude is received, the LM122 output transistor and Q1 latch for the duration of the timing period. D1 prevents the step on the V^+ pin from coupling back into the trigger pin. If the trigger input is a short pulse, C1 and R2 may be eliminated. R_L must have a minimum value of $(V_{CC})/(2.5\text{ mA})$.

Frequency to Voltage Converter

An accurate frequency to voltage converter can be made with the LM122 by averaging output pulses with a simple one pole filter as shown in *Figure 11.* Pulse width is adjusted with R2 to provide initial calibration at 10 kHz. The collector of the output transistor is tied to V_{REF}, giving constant amplitude pulses equal to V_{REF} at the emitter output. R4 and C1 filter the pulses to give a dc output equal to, $(R_t)(C_t)(V_{REF})(f)$. Linearity is about 0.2% for a 0V to 1V output. If better linearity is desired R5 can be tied to the summing node of an op amp which has the filter in the feedback path. If a low output impedance is desired, a unity gain buffer such as the LM110 can be tied to the output. An analog meter can be driven directly by placing it in series with R5 to ground. A series RC network across the meter to provide damping will improve response at very low frequencies.

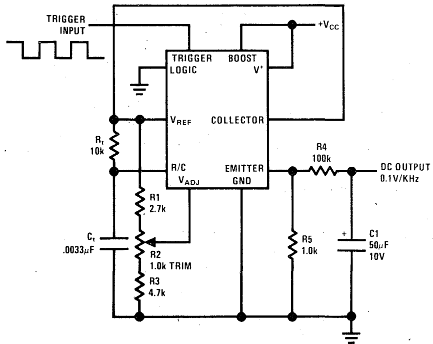


FIGURE 11. Frequency to Voltage Converter. (Tachometer) Output Independent of Supply Voltage

Pulse Width Detector

By driving the logic terminal of the LM122 simultaneous to the trigger input, a simple, accurate pulse width detector can be made *(Figure 12).*

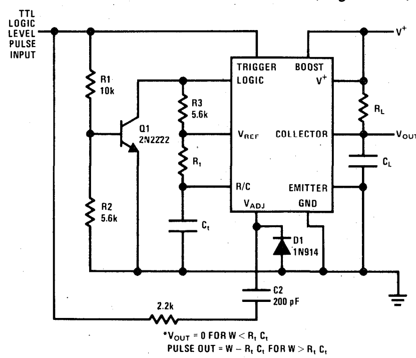


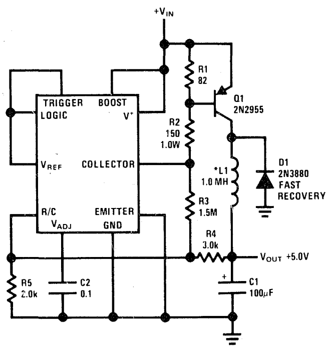
FIGURE 12. Pulse Width Detector

In this application the logic terminal is normally held high by R3. When a trigger pulse is received, Q1 is turned on, driving the logic terminal to ground. The result of triggering the timer and reversing the logic at the same time is that the output does not change from its initial low condition. The only time the output will change states is when the trigger input stays high longer than one time period set by R_t and C_t. The output pulse width is equal to the input trigger width minus R_t C_t. C2 insures no output pulse for short (< RC) trigger pulses by prematurely resetting the timing capacitor when the trigger pulse drops. C_L filters the narrow spikes which would occur at the output due to propagation delays during switching.

typical applications (con't)

5V Switching Regulator

Figure 13 is an application where the LM122 does not use its timing function. A switching regulator is made using the internal reference and comparator to drive a PNP transistor switch. Features of this circuit include a 5.5V minimum input voltage at 1A output current, low part count, and good efficiency (> 75%) for input voltages to 10V. Line and load regulation are less than 0.5% and output ripple at the switching frequency is only 30 mV. Q1 is an inexpensive plastic device which does not need a heatsink for ambient temperature up to 50°C. D1 should be a fast switching diode. Output voltage can be adjusted between 1V and 30V by choosing proper values for R2, R3, R4, and R5. For outputs less than 2V, a divider with 250Ω Thevinin resistance must be connected between V_{REF} and ground with its tap point tied to V_{ADJ}.



*NO. 22 WIRE WOUND ON MOLYBDENUM PERMALLOY CORE

FIGURE 13. 5V Switching Regulator with 1 Amp Output and 5.5V Minimum Input

application hints

Aborting a Timing Cycle

The LM122 does not have an input specifically allocated to a stop-timing function. If such a function is desired, it may be accomplished several ways:

- Ground V_{ADJ}
- Raise R/C more positive than V_{ADJ}
- Wire "OR" the output

Grounding V_{ADJ} will end the timing cycle just as if the timing capacitor had reached its normal discharge point. A new timing cycle can be started by the trigger terminal as soon as the ground is released. A switching transistor is best for driving V_{ADJ} to as near ground as possible. Worst case sink current is about 300µA.

A timing cycle may also be ended by a positive pulse to a resistor ($R \leq R_t/100$) in series with the timing capacitor. The pulse amplitude must be at least equal to V_{ADJ} (2.0V), but should not exceed 5.0V. When the timing capacitor discharges, a negative spike of up to 2.0V will occur across the resistor, so some caution must be used if the drive pulse is used for other circuitry.

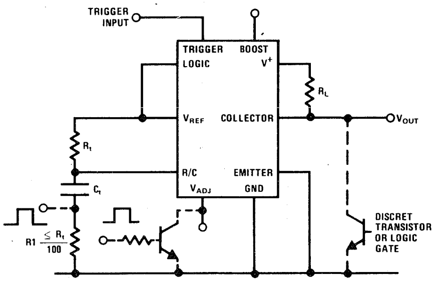


FIGURE 14. Cycle Interrupt

The output of the timer can be wire ORed with a discrete transistor or an open collector logic gate output. This allows overriding of the timer output, but does not cause the timer to be reset until its normal cycle time has elapsed.

Using the LM122 as a Comparator

A built-in reference and zero volt common mode limit make the LM122 very useful as a comparator. Threshold may be adjusted from zero to three volts by driving the V_{ADJ} terminal with a divider tied to V_{REF}. Stability of the reference voltage is typically ±1% over a temperature range of −55°C to +125°C. Offset voltage drift in the comparator is typically 25µV/°C in the boosted mode and 50µV/°C unboosted. A resistor can be inserted in series with the input to allow overdrives up to ±50V as shown in *Figure 15.* There is actually no limit on input voltage as long as current is limited to ±1 mA. The resistor shown contributes a worst case of 5 mV to initial offset. In the unboosted mode, the error drops to 0.25 mV maximum. The capability of operating off a single 5V supply with internal reference should make this comparator very useful.

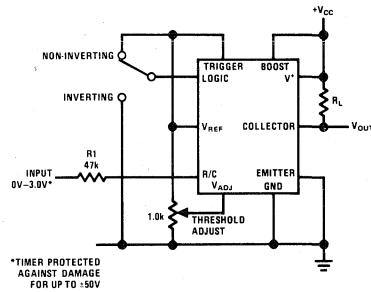


FIGURE 15. Comparator with 0V to 3V Threshold

application hints (con't)

Eliminating Timing Cycle Upon Initial Application of Power

The LM122 will normally start a timing cycle (with no trigger input) when V^+ is first turned on. If this characteristic is undesirable, it can be defeated by tying the timing capacitor to V_{REF} instead of ground as shown in *Figure 16.* This connection does not affect operation of the timer in any other way. If an electrolytic timing capacitor is used, be sure the negative end is tied to the R/C pin and the positive end to V_{REF}. A 1.0 kΩ resistor should be included in series with the timing capacitor to limit the surge current load on V_{REF} when the capacitor is discharged.

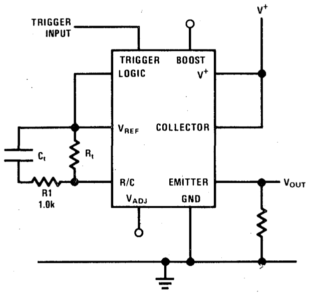
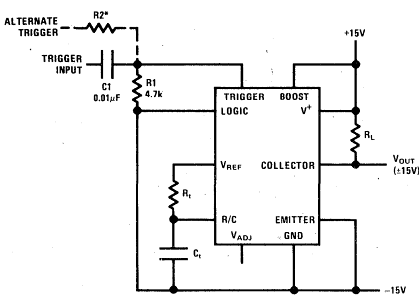


FIGURE 16. Eliminating Initial Timing Cycle

Using Dual Supplies

The LM122 can be operated off dual supplies as shown in *Figure 17.* The only limitation is that the emitter terminal cannot be tied to ground, it must either drive a load referred to V^- or be actually tied to V^- as shown. Although capacitive coupling is shown for the trigger input (to allow 5V triggering), a resistor can be substituted for C1. R2 must be chosen to give proper level shifting between the trigger signal and the trigger pin of the timer. Worst case "lo" on the trigger pin (with respect to V^-) is 0.8V, and worst case "high" is 2.5V. R2 may be calculated from the divider equation with R1 to give these levels.



*SELECT FOR PROPER LEVEL SHIFT
EMITTER TERMINAL OR EMITTER LOAD MUST BE TIED TO GND PIN OF TIMER.

FIGURE 17. Operating Off Dual Supplies

Linearizing the Charging Sweep

In some applications (such as a linear pulse width modulator) it may be desireable to have the timing capacitor charge from a constant current source. A simple way to accomplish this is shown in *Figure 18.*

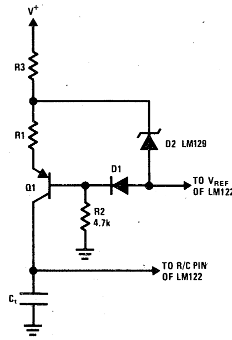


FIGURE 18. Temperature Compensated Linear Charging Sweep

Q1 converts the current through R1 to a current source independent of the voltage across C_t. R2, R3, D1, and D2 are added to make the current through R1 independent of supply variations and temperature changes. (D2 is a low TC type) D2 and R3 can be omitted if the V^+ supply is stable and D1 and R2 can be omitted also if temperature stability if not critical. With D1, D2, R2 and R3 omitted, the current through R1 will change about 0.015%/°C with a 15V supply and 0.1%/°C with a 5.0V supply.

Triggering with Negative Edge

Although the LM122 is triggered by a positive going trigger signal, a differentiator tied to a normally "high" trigger will result in negative edge triggering. In *Figure 19,* R1 serves the dual purpose of holding the trigger pin normally high and differentiating the input trigger pulse coupled through C1. The timing diagram included with Figure 21 shows that triggering actually occurs a short time after the negative going trigger, while positive going triggers have no effect. The delay time between a negative trigger signal and actual

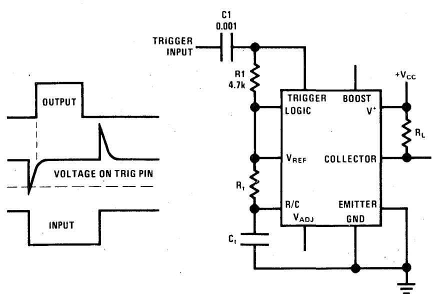


FIGURE 19. Timer Triggered by Negative Edge of Input Pulse

application hints (con't)

starts of timing is approximately (0.5 to 1.5) (R1 • C1) depending on the trigger amplitude, or about 2.5 to 7.5μs with the values shown. This time will have to be increased for C_t larger than 0.01μF because C_t is charged to V_{REF} whenever the trigger pin is kept high and must reset itself during the short time that the trigger pin voltage is low. A conservative value for C1 is:

$$C1 \geq \frac{C_t}{10}$$

Chain of Timers

The LM122 can be connected as a chain of timers quite easily with no interface required. In *Figure 20A and 20B*, two possible connections are shown. In both cases, the output of the timer is low during the timing period so that the positive going signal at the end of timing period can trigger the next timer. There is no limitation on the timing period of one timer with respect to any other timer before or after it, because the trigger input to any timer can be high or low when that timer ends its timing period.

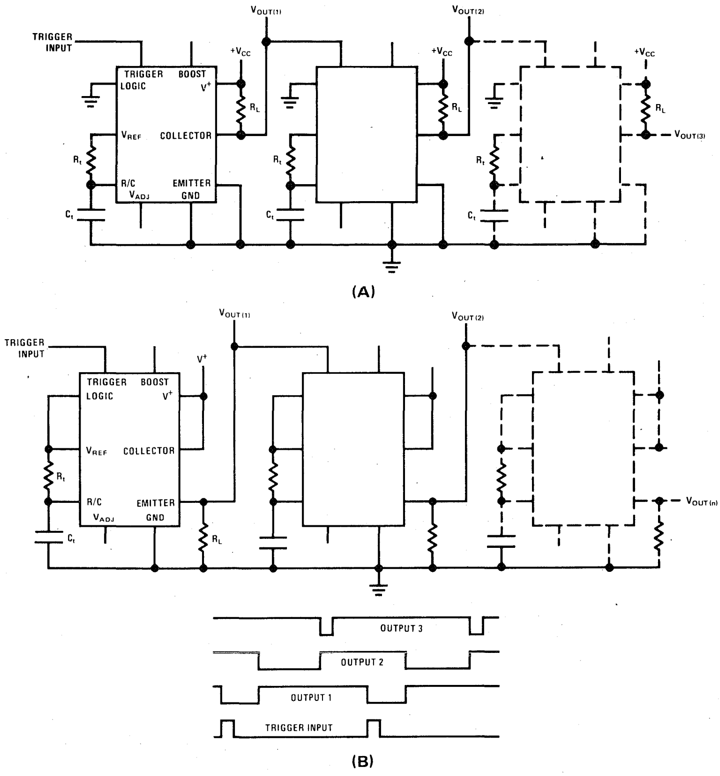


FIGURE 20. Chain of Timers

Industrial/Automotive/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.

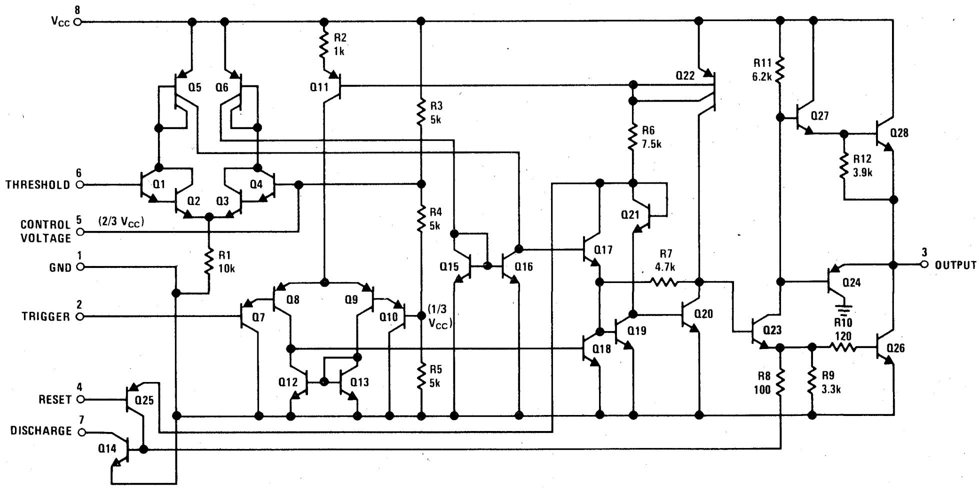
features

- 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

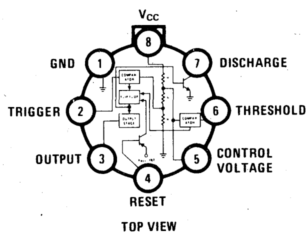
- Precision timing
- Pulse generation
- Sequential timing
- Time delay generation
- Pulse width modulation
- Pulse position modulation
- Linear ramp generator

schematic diagram



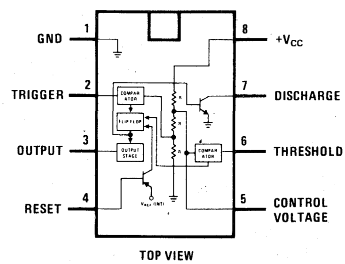
connection diagrams

Metal Can Package



Order Number LM555H or LM555CH
See Package 11

Dual-In-Line Package



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 = ∞		10	12		10	15	mA
	(Low State) (Note 2)							
Timing Error, Monostable								
Initial Accuracy			0.5	2		1		%
Drift with Temperature	R_A, R_B = 1k to 100 k,		30			50		ppm/°C
	C = 0.1μF, (Note 3)							
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	5		2.25	7	%
Drift with Temperature			90			150		ppm/°C
Accuracy over Temperature			2.5			3.0		%
Drift with Supply			0.15	0.2		0.30	0.5	%/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			0.01	0.5		0.5	0.9	μA
Reset Voltage		0.4	0.5	1	0.4	0.5	1	V
Reset Current			0.1	0.4		0.1	0.4	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	100		80	200	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.

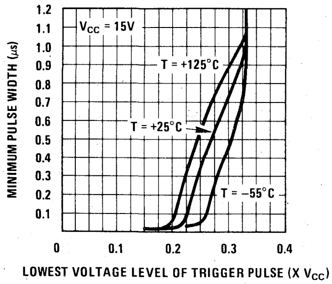
Note 3: Tested at V_{CC} = 5V and V_{CC} = 15V.

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.

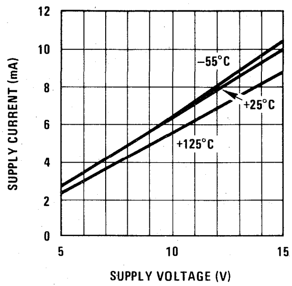
Note 5: No protection against excessive pin 7 current is necessary providing the package dissipation rating will not be exceeded.

typical performance characteristics

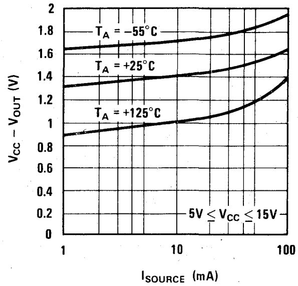
Minimum Pulse Width Required for Triggering



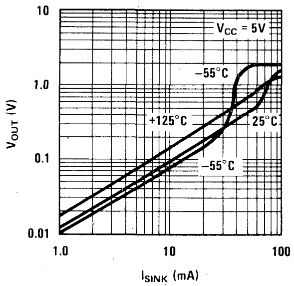
Supply Current vs Supply Voltage



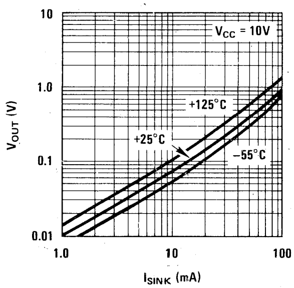
High Output Voltage vs Output Source Current



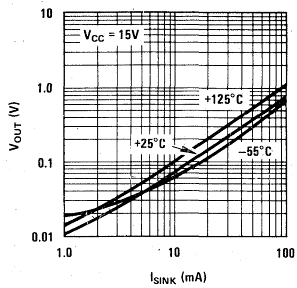
Low Output Voltage vs Output Sink Current



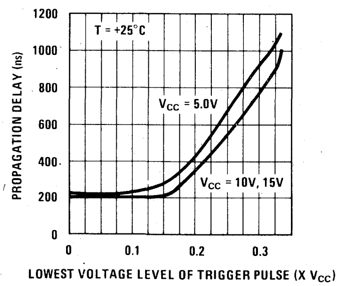
Low Output Voltage vs Output Sink Current



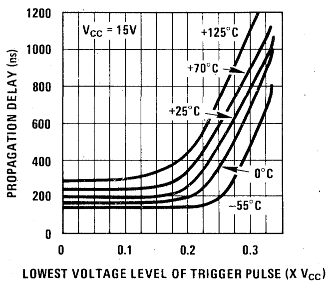
Low Output Voltage vs Output Sink Current



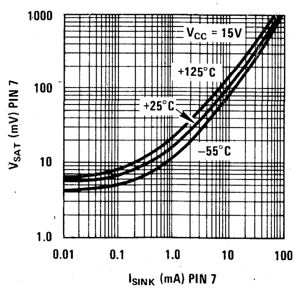
Output Propagation Delay vs Voltage Level of Trigger Pulse



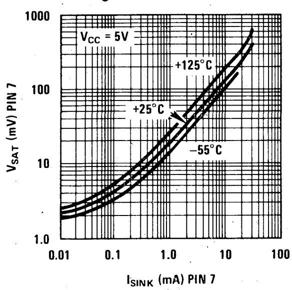
Output Propagation Delay vs Voltage Level of Trigger Pulse



Discharge Transistor (Pin 7) Voltage vs Sink Current



Discharge Transistor (Pin 7) Voltage vs Sink Current



9

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.

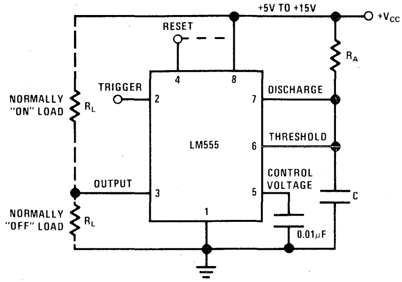


FIGURE 1. Monostable

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.

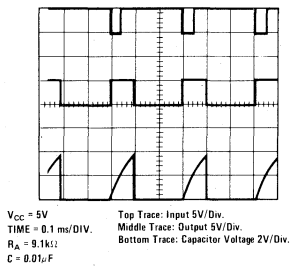


FIGURE 2. Monostable Waveforms

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

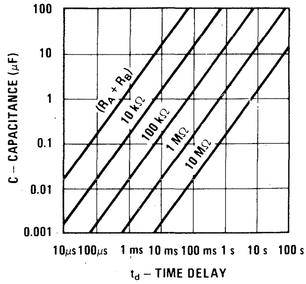


FIGURE 3. Time Delay

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.

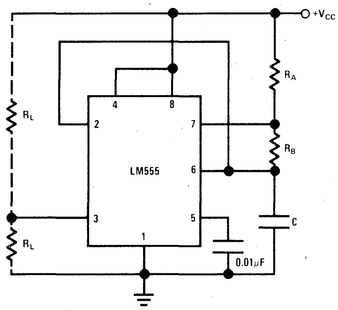


FIGURE 4. Astable

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.

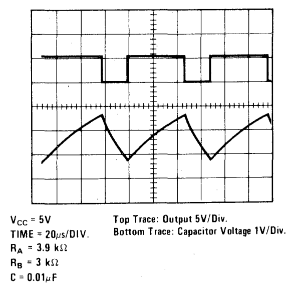


FIGURE 5. Astable Waveforms

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: $D = \dfrac{R_B}{R_A + 2R_B}$

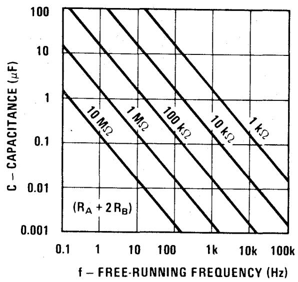


FIGURE 6. Free Running Frequency

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.

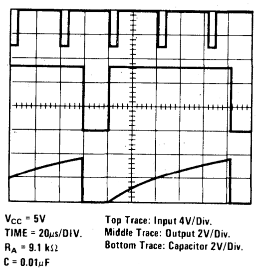


FIGURE 7. Frequency Divider

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.

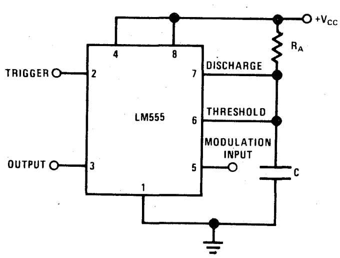


FIGURE 8. Pulse Width Modulator

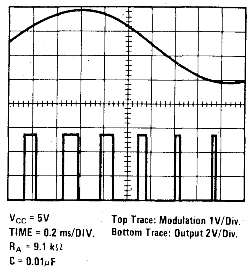


FIGURE 9. Pulse Width Modulator

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.

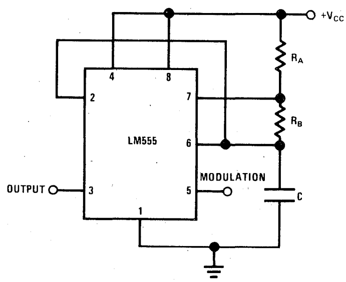


FIGURE 10. Pulse Position Modulator

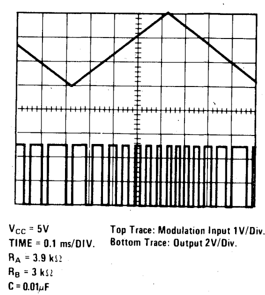


FIGURE 11. Pulse Position Modulator

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.

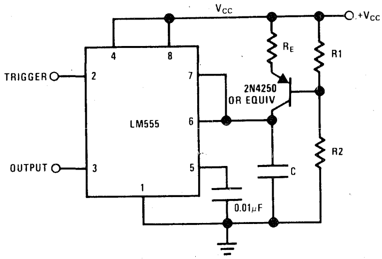


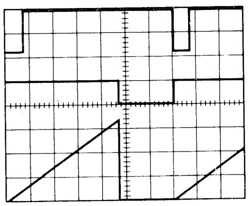
FIGURE 12.

Figure 13 shows waveforms generated by the linear ramp.

The time interval is given by:

$$T = \frac{2/3\, V_{CC}\, R_E\, (R_1 + R_2)\, C}{R_1\, V_{CC} - V_{BE}\, (R_1 + R_2)}$$

$V_{BE} \simeq 0.6V$



V_{CC} = 5V
TIME = 20μs/DIV.
R_1 = 47 kΩ
R_2 = 100 kΩ
R_E = 2.7 kΩ
C = 0.01μF

Top Trace: Input 3V/Div.
Middle Trace: Output 5V/Div.
Bottom Trace: Capacitor Voltage 1V/Div.

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 $f = \dfrac{1}{t_1 + t_2}$

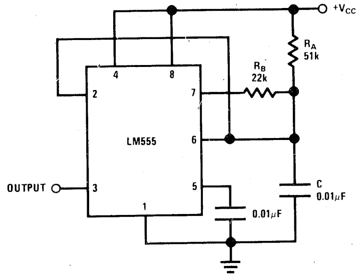


FIGURE 14. 50% Duty Cycle Oscillator

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.

Industrial/Automotive/Functional Blocks

LM556/LM556C dual timer

general description

The LM556 Dual timing circuit is a highly stable controller capable of producing accurate time delays or oscillation. The 556 is a dual 555. 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 200 mA.

- 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

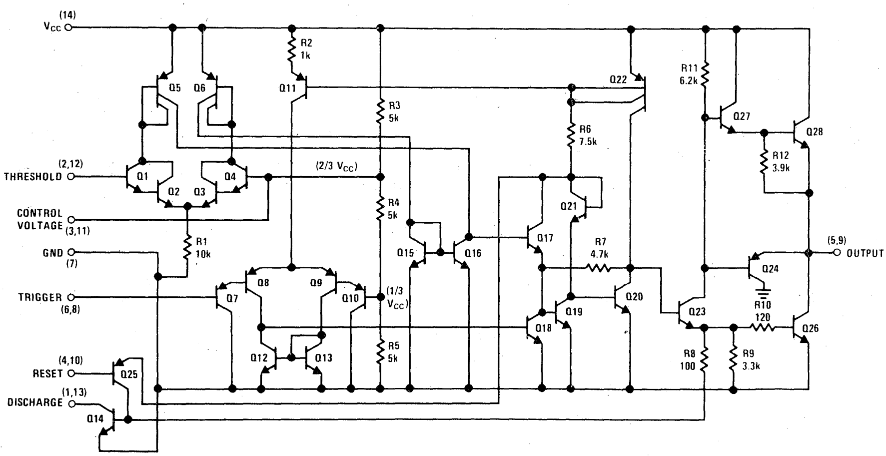
features

- Direct replacement for SE556/NE556
- Timing from microseconds through hours
- Operates in both astable and monostable modes
- Replaces two 555 timers

applications

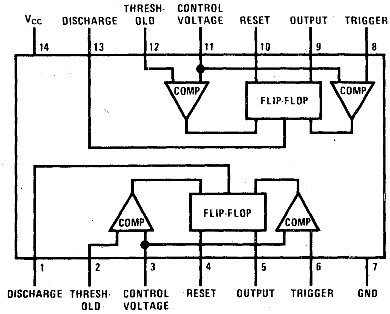
- Precision timing
- Pulse generation
- Sequential timing
- Time delay generation
- Pulse width modulation
- Pulse position modulation
- Linear ramp generator

schematic diagram



connection diagram

Dual-In-Line Package



TOP VIEW

Order Number LM556D or LM556CD
See Package 1
Order Number LM556CN
See Package 22
Order Number LM556J or LM556CJ
See Package 16

absolute maximum ratings

Supply Voltage	+18V
Power Dissipation (Note 1)	600 mW
Operating Temperature Ranges	
LM556C	0°C to +70°C
LM556	−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	LM556			LM556C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Supply Voltage		4.5		18	4.5		16	V
Supply Current (Each Timer Section)	V_{CC} = 5V, R_L = ∞		3	5		3	6	mA
	V_{CC} = 15V, R_L = ∞ (Low State) (Note 2)		10	11		10	14	mA
Timing Error, Monostable								
Initial Accuracy			0.5	1.5		0.75	5.0	%
Drift With Temperature	R_A, R_B = 1k to 100k, 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	0.4	%/V
Timing Error, Astable								
Initial Accuracy			1.5	5		2.25	7	%
Drift With Temperature			90			150		ppm/°C
Accuracy Over Temperature			2.5			3.0		%
Drift With Supply			0.15	0.2		0.30	0.5	%/V
Trigger Voltage	V_{CC} = 15V	4.8	5	5.2	4.5	5	5.5	V
	V_{CC} = 5V	1.45	1.67	1.9	1.25	1.67	2.0	V
Trigger Current			0.1	0.5		0.2	1.0	µA
Reset Voltage	(Note 4)	0.4	0.5	1	0.4	0.5	1	V
Reset Current			0.1	0.4		0.1	0.6	mA
Threshold Current	(Note 5)		0.03	0.1		0.03	0.1	µA
Control Voltage Level And Threshold Voltage	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 1, 13 Leakage Output High			1	100		1	100	nA
Pin 1, 13 Sat	(Note 6)							
Output Low	V_{CC} = 15V, I = 15 mA		150	240		180	300	mV
Output Low	V_{CC} = 4.5V, I = 4.5 mA		70	100		80	200	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	2.25		2	2.75	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
Matching Characteristics	(Note 7)							
Initial Timing Accuracy			0.05	0.2		0.1	2.0	%
Timing Drift With Temperature			±10			±10		ppm/°C
Drift With Supply Voltage			0.1	0.2		0.2	0.5	%/V

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 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: As reset voltage lowers, timing is inhibited and then the output goes low.

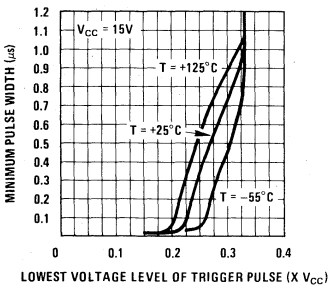
Note 5: This will determine the maximum value of $R_A + R_B$ for 15V operation. The maximum total $(R_A + R_B)$ is 20 MΩ.

Note 6: No protection against excessive pin 1, 13 current is necessary providing the package dissipation rating will not be exceeded.

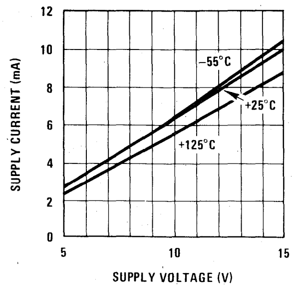
Note 7: Matching characteristics refer to the difference between performance characteristics of each timer section.

typical performance characteristics

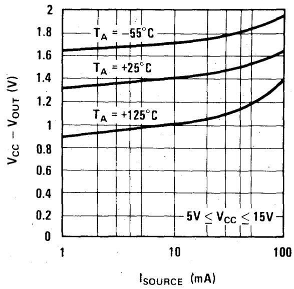
Minimum Pulse Width Required for Triggering



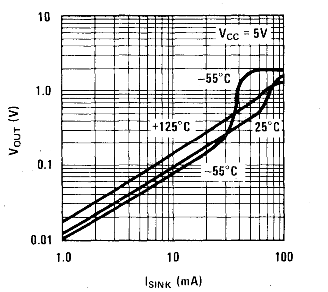
Supply Current vs Supply Voltage (Each Section)



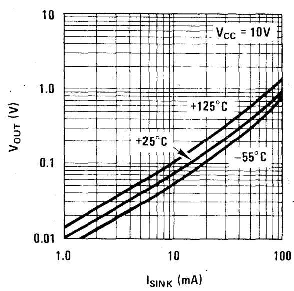
High Output Voltage vs Output Source Current



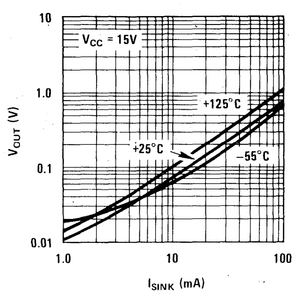
Low Output Voltage vs Output Sink Current



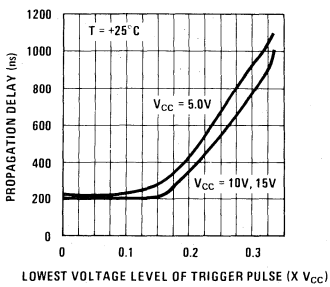
Low Output Voltage vs Output Sink Current



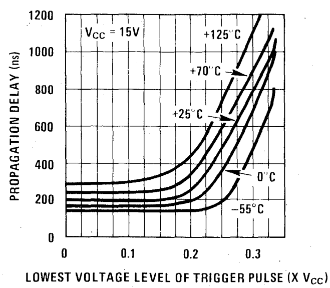
Low Output Voltage vs Output Sink Current



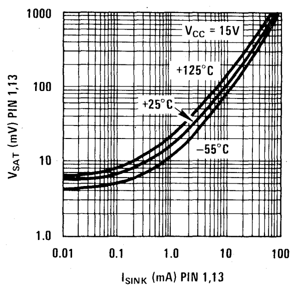
Output Propagation Delay vs Voltage Level of Trigger Pulse



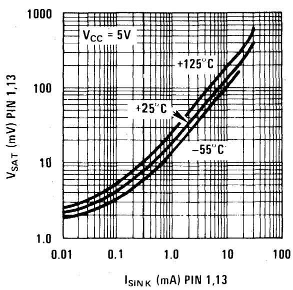
Output Propagation Delay vs Voltage Level of Trigger Pulse



Discharge Transistor (Pin 1,13) Voltage vs Sink Current



Discharge Transistor (Pin 1,13) Voltage vs Sink Current



9

Industrial/Automotive/Functional Blocks

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.

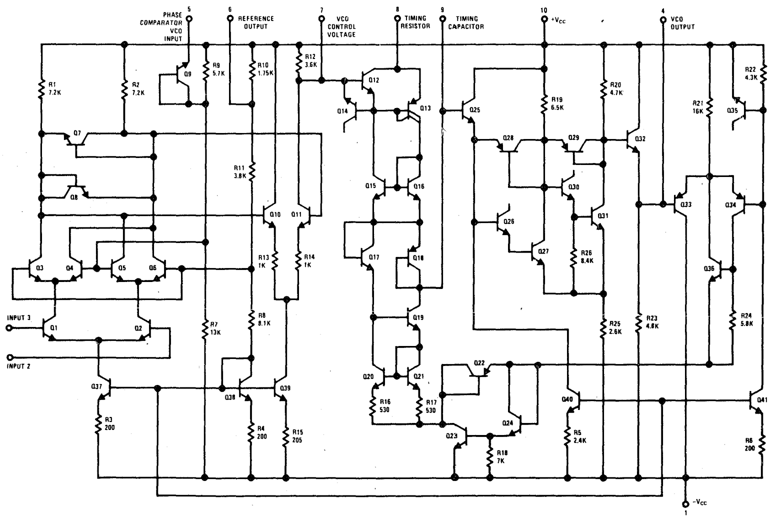
features

- 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%.

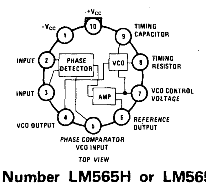
applications

- 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

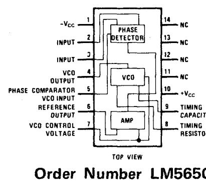


Metal Can Package



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

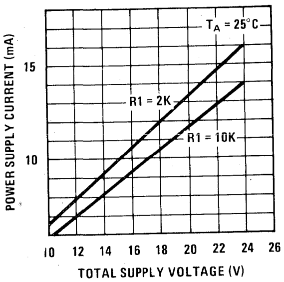
electrical characteristics (AC Test Circuit, T_A = 25°C, V_C = ±6V)

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		250	500		kHz
Operating Frequency Temperature Coefficient			−100	300		−200	500	ppm/°C
Frequency Drift with Supply Voltage			0.01	0.1		0.05	0.2	%/V
Triangle Wave Output Voltage		2	2.4	3	2	2.4	3	V_{p-p}
Triangle Wave Output Linearity			0.2	0.75		0.5	1	%
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	6400	6600	6800	6000	6600	7200	Hz/V
Demodulated Output Voltage (Pin 7)	±10% Frequency Deviation	250	300	350	200	300	400	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		0.6	.68	0.9	0.55	.68	0.95	V/radian

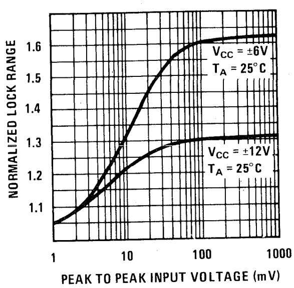
Note 1: The maximum junction temperature of the LM565 is 150°C, while that of the LM565C and LM565CN is 100°C. For operation at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W junction to ambient or 45°C/W junction to case. Thermal resistance of the dual-in-line package is 100°C/W.

typical performance characteristics

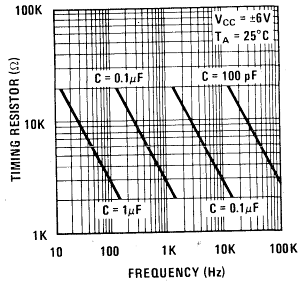
Power Supply Current as a Function of Supply Voltage



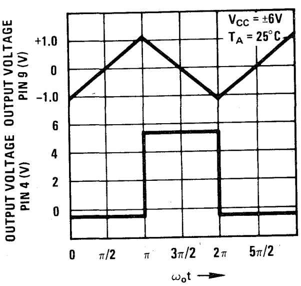
Lock Range as a Function of Input Voltage



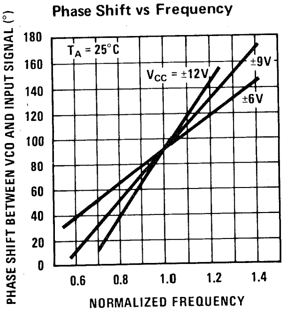
VCO Frequency



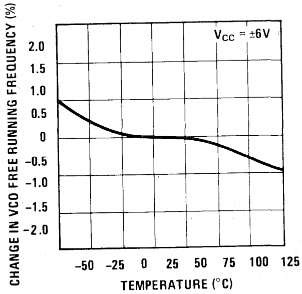
Oscillator Output Waveforms



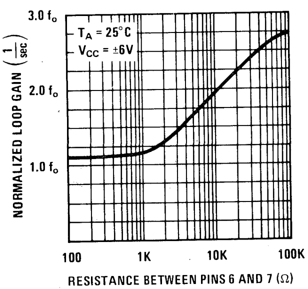
Phase Shift vs Frequency



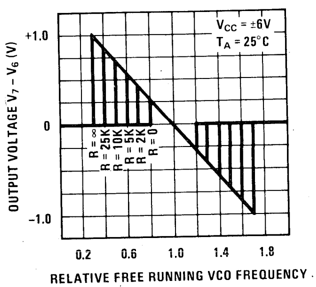
VCO Frequency as a Function of Temperature



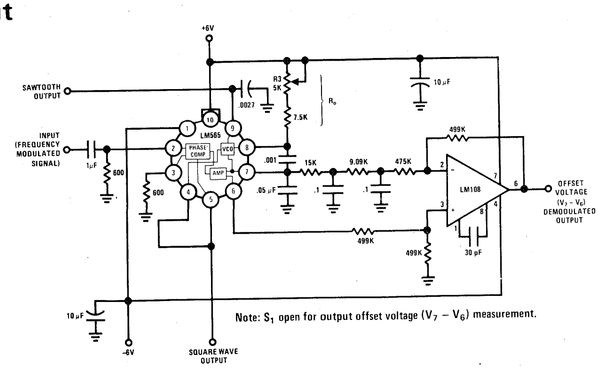
Loop Gain vs Load Resistance



Hold in Range as a Function of R_{6-7}

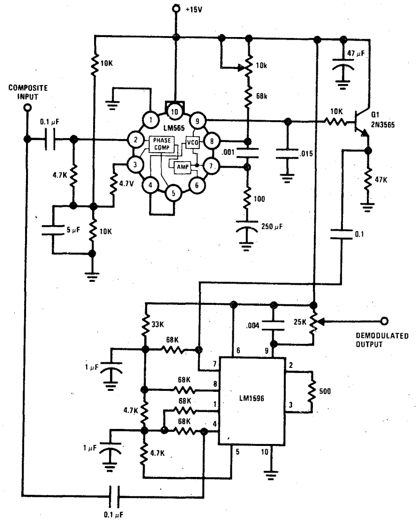


ac test circuit

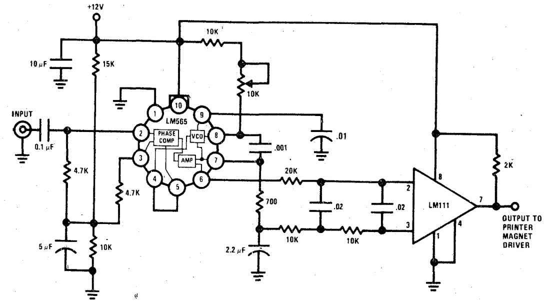


Note: S_1 open for output offset voltage $(V_7 - V_6)$ measurement.

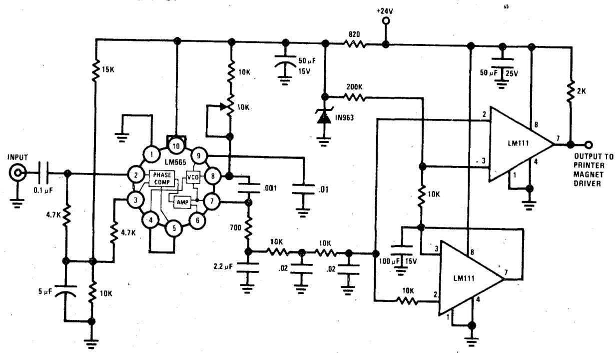
typical applications



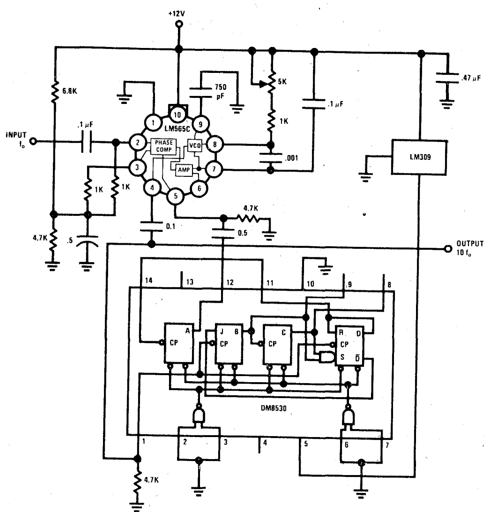
2400 Hz Synchronous AM Demodulator



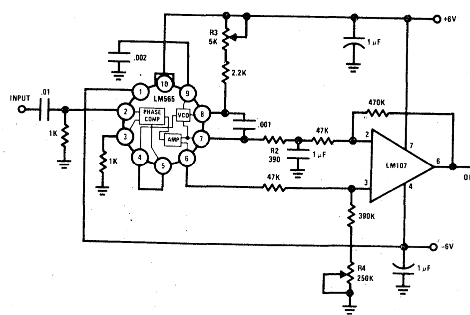
FSK Demodulator (2025-2225 cps)



FSK Demodulator with DC Restoration.



Frequency Multiplier (x10)



IRIG Channel 13 Demodulator

9

applications information

In designing with phase locked loops such as the LM565, the important parameters of interest are:

FREE RUNNING FREQUENCY

$$f_o \cong \frac{1}{3.7\ R_0C_0}$$

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".

$$\text{Loop gain} = K_oK_D \left(\frac{1}{\text{sec}}\right)$$

$$K_o = \text{oscillator sensitivity} \left(\frac{\text{radians/sec}}{\text{volt}}\right)$$

$$K_D = \text{phase detector sensitivity} \left(\frac{\text{volts}}{\text{radian}}\right)$$

The loop gain of the LM565 is dependent on supply voltage, and may be found from:

$$K_oK_D = \frac{33.6\ f_o}{V_c}$$

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.

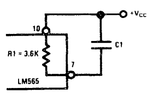
$$f_H = \pm \frac{8\ f_o}{V_c}$$

f_o = free running frequency of VCO

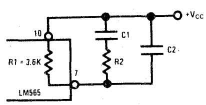
V_c = total supply voltage to the circuit.

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:

$$f_n = \frac{1}{2\pi}\sqrt{\frac{K_oK_D}{R_1C_1}}$$

Associated with this is a damping factor:

$$\delta = \frac{1}{2}\sqrt{\frac{1}{R_1C_1K_oK_D}}$$

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

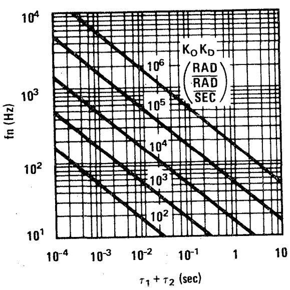
$$f_n = \frac{1}{2\pi}\sqrt{\frac{K_oK_D}{\tau_1 + \tau_2}}$$

$$\tau_1 + \tau_2 = (R_1 + R_2)\ C_1$$

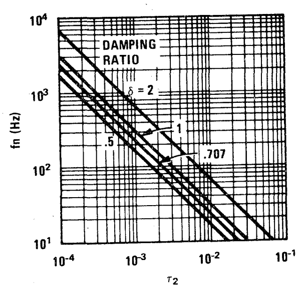
R_2 is selected to produce a desired damping factor δ, usually between 0.5 and 1.0. The damping factor is found from the approximation:

$$\delta \simeq \pi \tau_2 f_n$$

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 $C_2 \leq 0.1\ C_1$.

Industrial/Automotive/Functional Blocks

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.

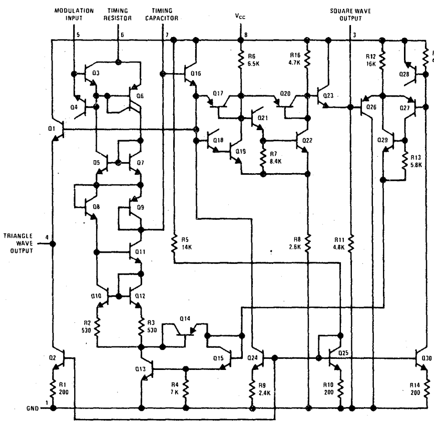
features

- 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.

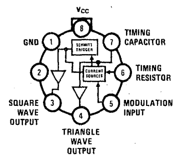
applications

- FM modulation
- Signal generation
- Function generation
- Frequency shift keying
- Tone generation

schematic and connection diagrams



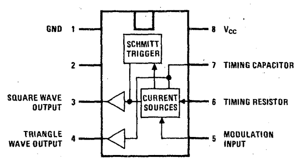
Metal Can Package



TOP VIEW

Order Number LM566H or LM566CH
See Package 11

Dual-In-Line Package

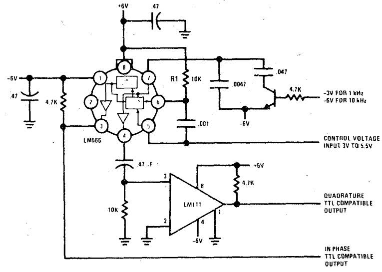


TOP VIEW

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

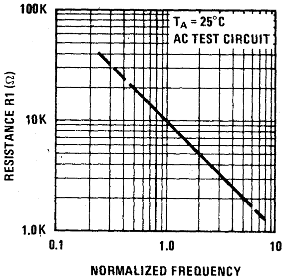
electrical characteristics V_{CC} = 12V, T_A = 25°C, AC Test Circuit

PARAMETER	CONDITIONS	LM566			LM566C			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Maximum Operating Frequency	R0 = 2k C0 = 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	10–20V		0.1	1		0.1	2	%/V
Input Impedance Pin 5		0.5	1		0.5	1		MΩ
VCO Sensitivity	For Pin 5, From 8–10V, f_O = 10 kHz	6.4	6.6	6.8	6.0	6.6	7.2	kHz/V
FM Distortion	±10% Deviation		0.2	0.75		0.2	1.5	%
Maximum Sweep Rate		800	1		500	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		Vp-p
Triangle Wave Output Level	R_{L2} = 10k	2.0	2.4		2.0	2.4		Vp-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	+1V Segment at 1/2 V_{CC}		0.2	0.75		0.5	1	%

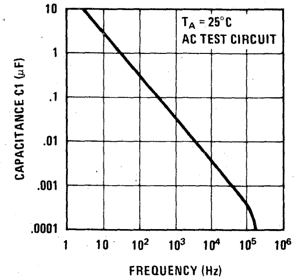
Note 1: The maximum junction temperature of the LM566 is 150°C, while that of the LM566C is 100°C. For operating at elevated junction temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W. The thermal resistance of the dual-in-line package is 100°C/W.

typical performance characteristics

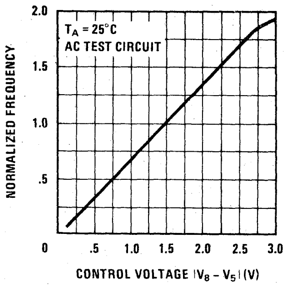
Operating Frequency as a Function of Timing Resistor



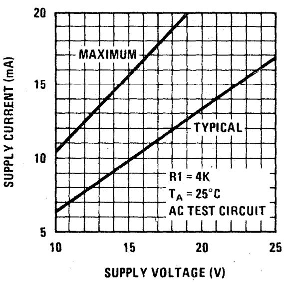
Operating Frequency as a Function of Timing Capacitor



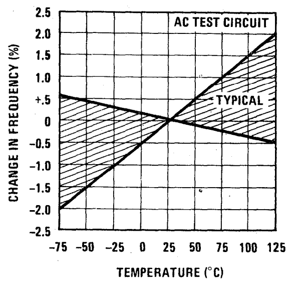
Normalized Frequency as a Function of Control Voltage



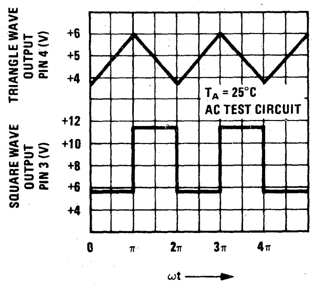
Power Supply Current



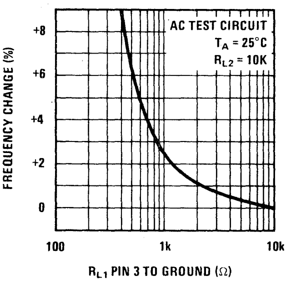
Temperature Stability



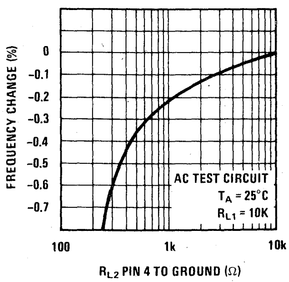
VCO Waveforms



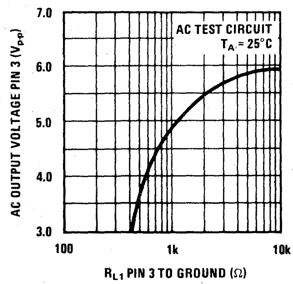
Frequency Stability vs Load Resistance (Square Wave Output)



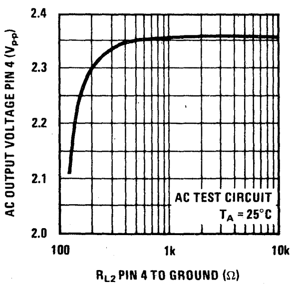
Frequency Stability vs Load Impedance (Triangle Output)



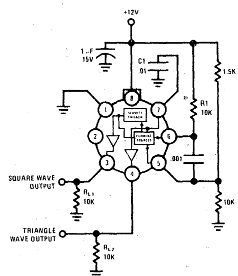
Square Wave Output Characteristics



Triangle Wave Output Characteristics



ac test circuit



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Industrial/Automotive/Functional Blocks

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

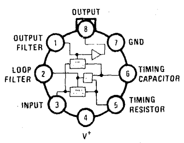
- 20 to 1 frequency range with an external resistor
- Logic compatible output with 100 mA current sinking capability
- Bandwidth adjustable from 0 to 14%
- High rejection of out of band signals and noise
- Immunity to false signals
- Highly stable center frequency
- Center frequency adjustable from 0.01 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

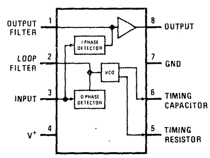
Metal Can Package



TOP VIEW

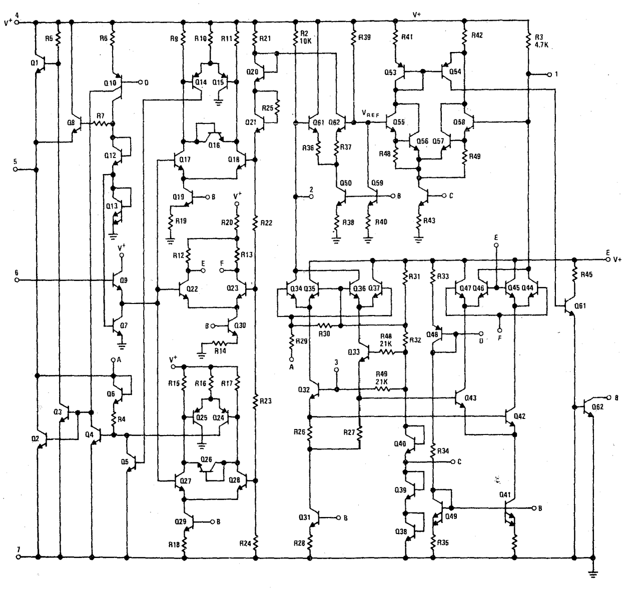
Order Number LM567H or LM567CH
See Package 11

Dual-In-Line Package



TOP VIEW

Order Number LM567CN
See Package 20



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

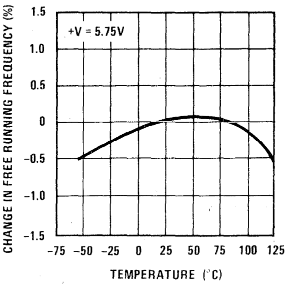
electrical characteristics (AC Test Circuit, T_A = 25°C, V_C = 5V)

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		18	20	22	15	20	25	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	0.25		±0.1	0.5	%/°C
Largest Detection Bandwidth Variation with Supply Voltage	4.75V – 6.75V		±1	±2		±1	±5	%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	4.75V – 6.75V		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

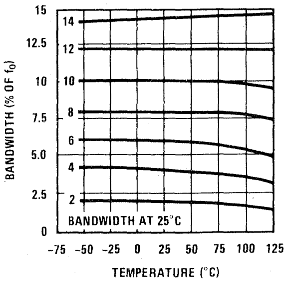
Note 1: The maximum junction temperature of the LM567 is 150°C, while that of the LM567C and LM567CN is 100°C. For operating at elevated temperatures, devices in the TO-5 package must be derated based on a thermal resistance of 150°C/W, junction to ambient or 45°C/W, junction to case. For the DIP the device must be derated based on a thermal resistance of 187°C/W, junction to ambient.

typical performance characteristics

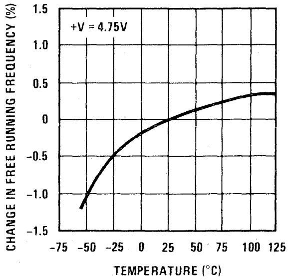
Typical Frequency Drift with Temperature (Mean and S.D.)



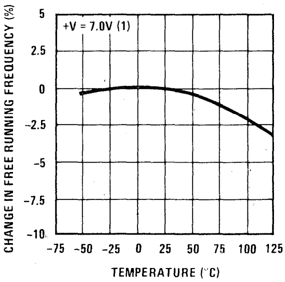
Typical Bandwidth Variation with Temperature



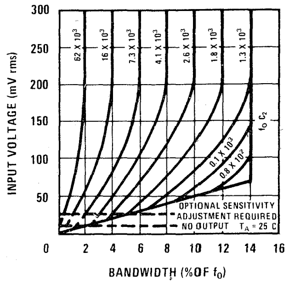
Typical Frequency Drift with (Mean and S.D.) Temperature



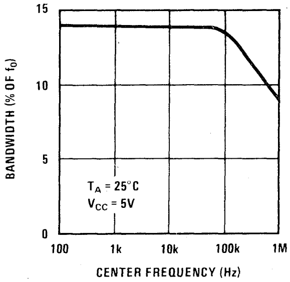
Typical Frequency Drift with Temperature (Mean and S.D.)



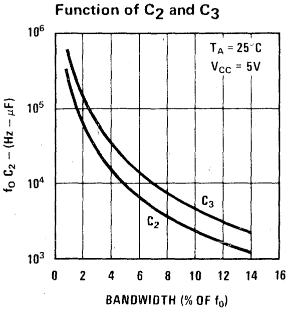
Bandwith vs Input Signal Amplitude



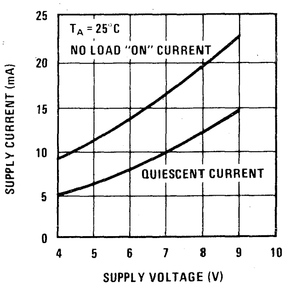
Largest Detection Bandwidth



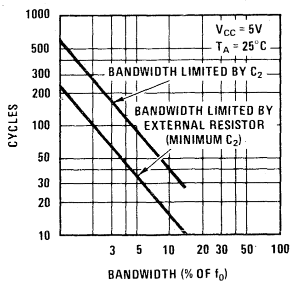
Detection Bandwidth as a Function of C_2 and C_3



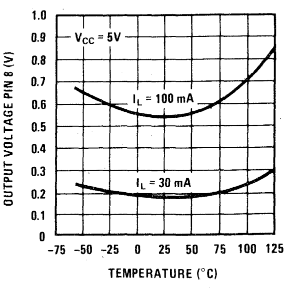
Typical Supply Current vs Supply Voltage



Greatest Number of Cycles Before Output

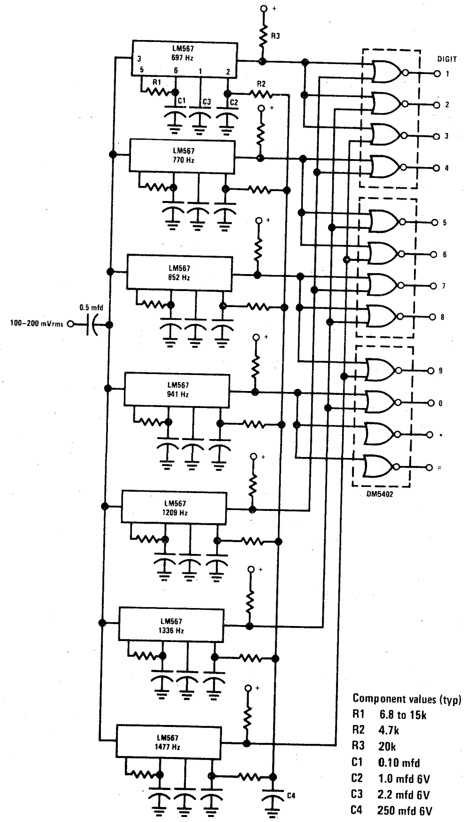


Typical Output Voltage vs Temperature



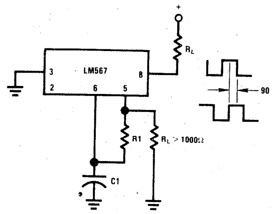
typical applications

Touch-Tone Decoder



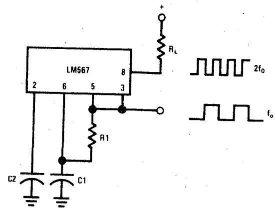
Component values (typ)
R1 6.8 to 15k
R2 4.7k
R3 20k
C1 0.10 mfd
C2 1.0 mfd 6V
C3 2.2 mfd 6V
C4 250 mfd 6V

Oscillator with Quadrature Output

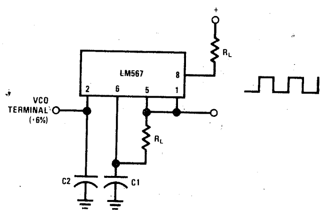


Connect pin 3 to 2.8V to invert output.

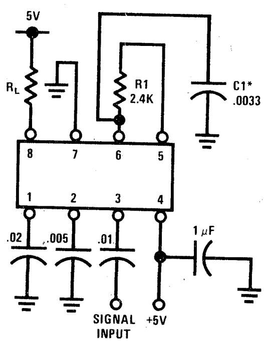
Oscillator with Double Frequency Output



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)

Industrial/Automotive/Functional Blocks

LM1812 ultrasonic transceiver

general description

The LM1812 is a special monolithic IC which consists of a 12W ultrasonic transmitter circuit, which uses novel circuitry to eliminate costly alignment adjustments, a selective receiver which uses only one external LC network, impulse noise rejection circuitry, a 10W display driver, and a keyed modulator.

The system operates from a 12V battery, drives power into a transducer, receives an echo and drives a display lamp.

A single LC network is time shared between the receiver and the transmitter to reduce external parts, to eliminate alignment labor and to guarantee that the received signal is always of the proper frequency.

Application areas include both sonar (distance measuring in water) and "sonic" radar (or "Sodar"—distance measuring in air) where a liquid level must be detected without actual immersion of a sensor or the presence of an object must be detected as in collision avoidance or an intrusion or burglar alarm system. As a sonar system, the presence of partially submerged objects can be detected, such as marine life, or the depth of a body of water can be determined (as for keel clearance or depth indicators). In addition, data transmission is possible for remote control applications such as in model submarines or hydroacoustic communication links.

unique characteristics

- RF transmitter design prevents "mode-hopping" of transducer
- Operates with interchangeable transducers without realignment
- Only one tuned circuit is used
- No additional transistors are needed
- A zero reference output, which "appears" the same as a normal return, is generated to coincide with the Tx. pulse
- Impulse noise is rejected
- Can be used with various displays

advantages

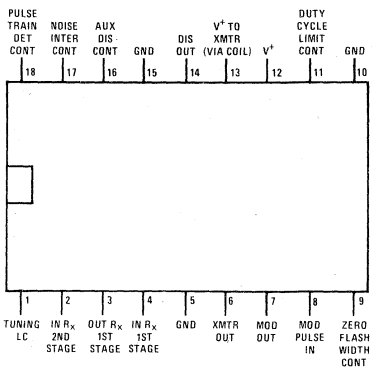
- Reduces assembly labor content
- Allows transducer replacement in the field without a factory return
- Allows multiple transducers to be used with the same electronics
- Provides for more consistent system performance in production

features

- Has special access pins (7 and 16) which allow adding an audible alarm feature to indicate an echo within a presettable maximum depth (or range)
- Does not require any heat sinking of the IC package
- Uses a built-in monostable multivibrator, with the capacitor on the chip, to pulse drive the transmitter for high efficiency and to minimize transducer interaction
- Has special circuitry to limit the maximum ON time of the display driver
- Can operate with a neon, a LED display device, a digital readout or a CRT

connection diagram

Dual-In-Line Package



TOP VIEW

Order Number LM1812N
See Package 29

absolute maximum ratings

Supply Voltage, V^+ (Pins 12, 6 and 14)	18 V_{DC}
Power Dissipation (Note 1)	600 mW
Operating Temperature Range (T_A)	0°C to +70°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 60 seconds)	300°C

PIN NO.	FUNCTION	R_{EXT} (MIN)	V_{MAX} (Total Inst. Peak)	I_{MAX} DC
1	Tuning LC		30V	
2	Input R_X – 2nd Stage			50 mA
3	Output R_X – 1st Stage		18 V_{DC}	
4	Input R_X – 1st Stage			50 mA
5	Ground			
6	XMTR Output		36V (When OFF)	1A for 1 µs
7	Modulator Output	75k	18V	
8	Modulator Pulse Input			50 mA
9	Zero Flash Width Control		7V	
10	Ground			
11	Duty Cycle Limit Control			50 mA
12	V^+		18V	
13	V^+ to XMTR (via Coil)		18V	
14	Display Output		25V (When OFF)	1A for 1 ms
15	Ground			
16	Auxiliary Display Control	2M	18V	
17	Noise Integrator Control			50 mA
18	Pulse Train Detector Control			50 mA

electrical characteristics (V^+ = +12 V_{DC} and T_A = 25°C, unless otherwise noted)

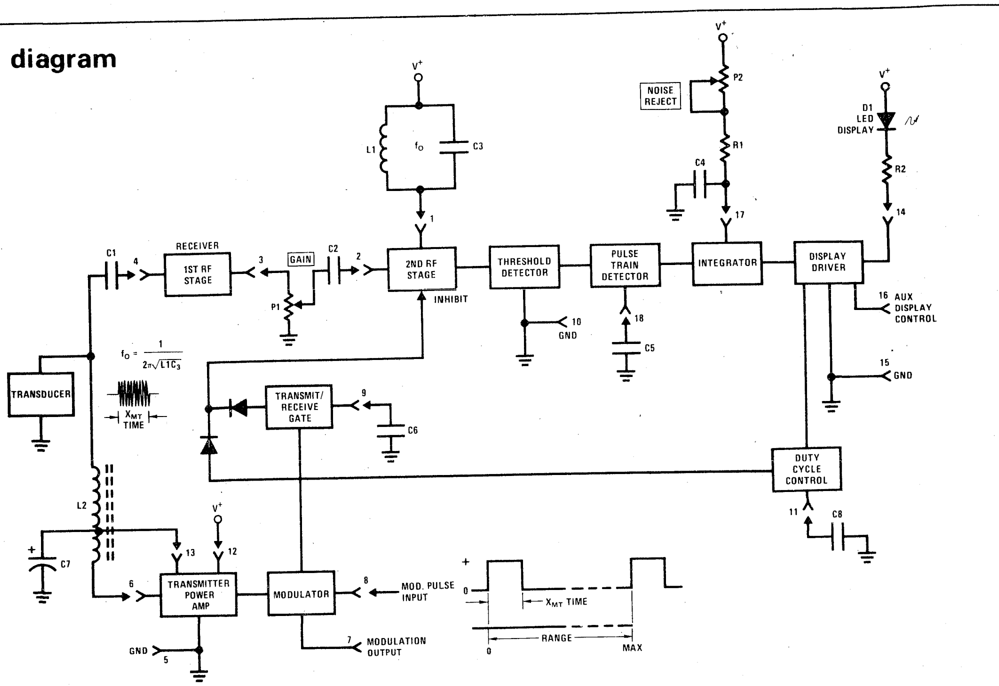
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Sensitivity	*(Figure 1)* (Note 2)		200	600	µVp-p
Transmitter (V_{SAT})	*(Figure 2)*, R_L = 10Ω (V_{SAT})		1.3	3	V_{DC}
Transmitter Leakage	Pin 6 = 32 V_{DC}, Pin 8 = Ground		0.01	1	mA_{DC}
Modulator Threshold	*(Figure 2)* (Note 3)	0.55	0.7	0.9	V_P
Supply Current	*(Figure 3)* (I_D)	5	8.5	20	mA_{DC}
Display Driver (V_{SAT})	*(Figure 4)* (V_{SAT})		1.5	3	V_{DC}
Display Driver Leakage	Pin 14 = 16 V_{DC}, Pin 17 = Ground		0.01	1	mA_{DC}

Note 1: For operating at high temperatures, the LM1812 must be derated based upon a +125°C maximum junction temperature and a thermal resistance of +167°C/W which applies for the device soldered in a printed circuit board and operating in a still air ambient. Due to the switching mode of operation, there is usually only a small power dissipation in the IC package.

Note 2: This sensitivity test uses the 500:1 attenuator to raise the input signal level for a more reliable reading and to reduce the chances for unintentional input-output coupling during the test.

Note 3: The "Modulator Threshold" is the voltage which must be applied to pin 8 to put the system in the transmit mode. The current input to pin 8 should be limited to 1–10 mA.

system diagram



ac test circuits

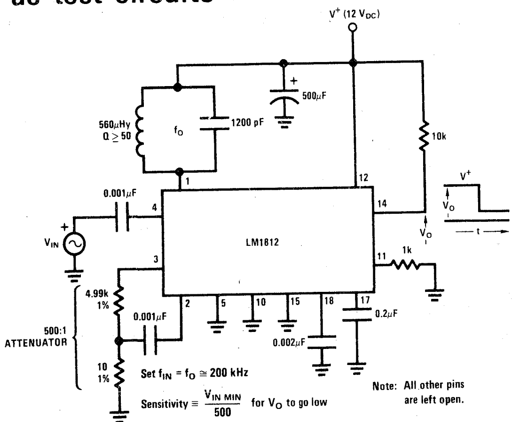


FIGURE 1. Sensitivity Test Circuit

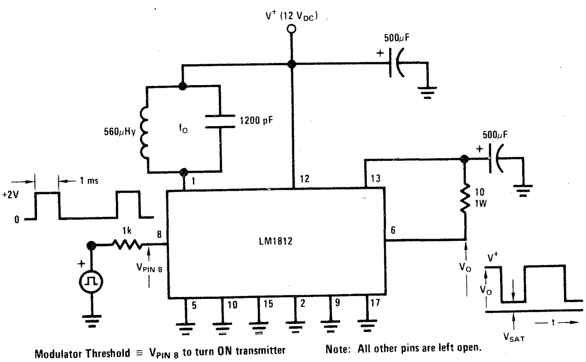


FIGURE 2. Transmitter V_{SAT} and Modulator Threshold Test Circuit

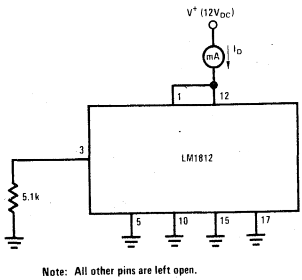


FIGURE 3. Current Drain Test Circuit

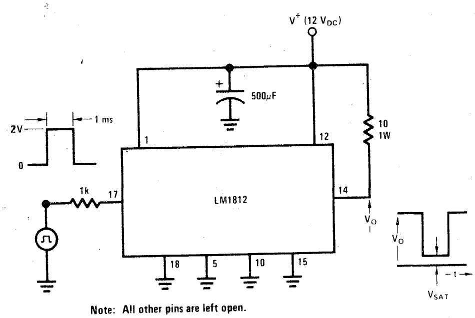


FIGURE 4. Neon Driver Test Circuit

application hints

As the LM1812 contains both a transmitter and a receiver in proximity, PC layouts or breadboarding has to be done with special attention to ground loops and common coupling paths. The use of three ground pins on the IC package helps reduce grounding problems, but at the time of transmission, with the display driver also ON, there can be 1–2A of peak current passed into the ground trace.

Local sources of high energy impulse noise, if not locally shielded, can cause an unwanted display "blip." This, for example, usually only occurs when using fly-ball governed dc display wheel drive motors and is due to the abrupt make-break action of the speed regulator contacts in combination with the large inductance of the lightly loaded motor. These "inductive kicks" can be locally filtered with a capacitor across the motor or a small valued capacitor (approximately 30 pF) can be connected across the first receive stage (between pins 3 and 4) to reduce the bandwidth and filter out these noise pulses.

For ranging applications, large transmit power levels are necessary due to the two-way path and the resulting received echo power falling as the fourth power of range (additional external receiver gain can be used to extend the range). One way communication links can use reduced power. Transmit power can be checked by measuring the voltage swing across the transducer (of known impedance) during the transmit mode. The magnitude of the transmitter power depends on the transducer impedance as presented to the transmitter power amplifier (usually a transformer is used to couple the transducer to the power amplifier). A minimum value of 10Ω causes approximately 1A peak current pulses out of this power amplifier. The inductance of the secondary should be designed to resonate with the sum of the capacitance associated with the cable feeding the transducer and that of the transducer. The low Q resonance allows transducer replacement without tuning.

An internal one-shot multivibrator with a fixed time of 1μs is used to drive the transmitter power amplifier into saturation for this time period once for each cycle of the transmit frequency. At a frequency of 200 kHz, this results in a high efficiency class-C type of operation for the power amplifier. The transmit frequency is equal to the natural resonance of the external LC network which is tied to pin 1. This network is also used to establish the center frequency and the selectivity of the receiver.

Impulse noise is rejected by the combined action of the "Pulse Train Detector" and the "Integrator" circuits. The integrator requires a number of cycles of valid returns to be received before turning ON the display driver. The pulse train detector will dump the integrator if a continuous train of pulses is not received (if 2 or 3 are missing, the integration capacitor is discharged to ground).

The collector of a grounded-emitter NPN transistor can be tied to pin 16 to allow an auxiliary control of the display driver. This transistor should normally be held OFF and should go ON for a time interval no longer than 1 ms if a neon display is used, due to the rapid current build-up in the primary of the step-up transformer. If a LED is used as a display device with a series limiting resistor, this ON time can be made longer as it is now limited only by the increased dissipation of the IC which results from the saturation voltage at pin 14 and the ON current of the LED.

The step-up transformer for the neon display lamp has to have a relatively large magnetizing inductance to prevent large current build-up for the time duration of the flash. For this reason, iron-cored transformers are generally used and the large number of turns on the primary, which is required to achieve a high magnetizing inductance, requires an even larger number of turns, on the secondary to step up the 12V to over 100V to guarantee that the neon lamp fires. Rapid flashing of the neon lamp can cause a current build-up in the primary. This is the reason for the RC filter which powers the transformer. Under rapid flashing conditions, the voltage available falls and both the IC and the neon are saved from degradation due to large power dissipation. With normal operation, this network can easily supply the low power requirements of the neon display.

An IC audio amplifier can be used to amplitude modulate the carrier for an AM communication link. A high input impedance detector and audio amplifier attach to pin 1 for the receiver. One audio amplifier can be switched between the modulator and the receiver section. FM or pulse modulation techniques can also be used to reduce the modulator power requirements.

A digital depth (or range) readout can be used with the LM1812. This eliminates the requirement for the constant speed dc motor. The modulator, pin 8, is electronically pulsed ON for approximately a 1 ms transmit time at a repetition rate which controls the updating of the displayed information. The "neon driver," pin 14, will provide a negative output pulse (from V^+ to approximately +1 V_{DC}) if a load resistor (5.1 kΩ) is used from pin 14 to V^+. This pulse is used to latch the output of a counter. This output is decoded and then drives a 7-segment LED display. The repetition rate of the clock input to the counter provides a direct conversion from elapsed time (total count) to depth (or range).

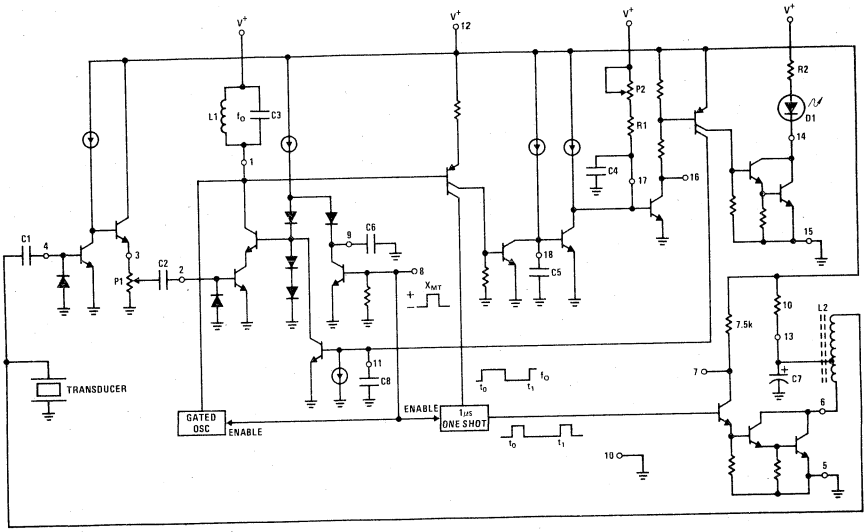
Transducers are available for use either in water or air. The appropriate transducer is important for proper functioning in the intended application; for example, the high frequency attenuation in air usually requires a lower operating frequency. The modifications for a 40 kHz system are shown in the applications section.

A simplified schematic diagram, complete with typical external components for a sonar system, is shown in *Figure 5.* This not only shows the operation of the system, but also indicates "what's on the other side of the IC pins" to aid the user in his application. When pin 8 is externally pulsed, the system is put in the transmit mode and a controlled amplitude sinewave oscillation waveform results across the LC resonator, pin 1. This is internally amplified and squared and each leading edge triggers the generation of a 1μs pulse. This pulse drives the RF power amplifier (output at pin 6) into saturation. During this transmit mode, the second RF stage is gated

application hints (con't)

OFF to disable the receiver. The receiver is also disabled if the display driver is ON for too long a time interval. The capacitor at pin 11 does the necessary integration for this control.

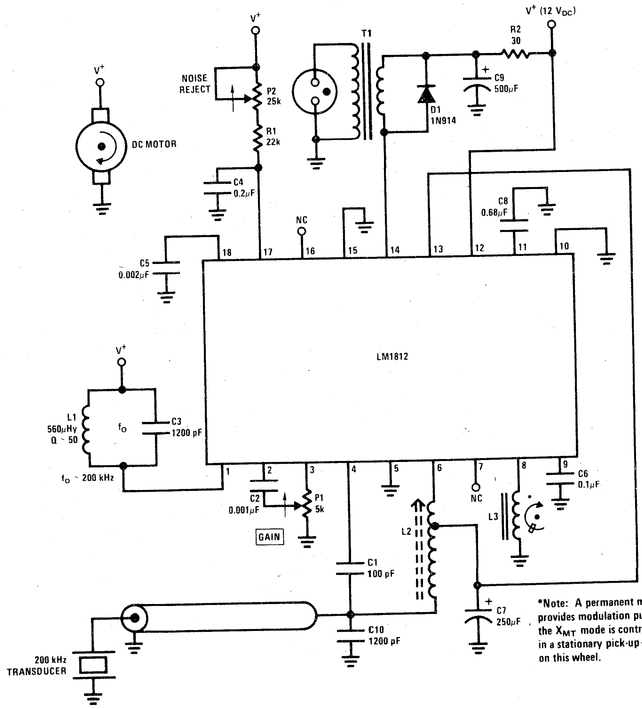
For additional information see *A Single-Chip Monolithic Sonar System,* T. M. Frederiksen and W. M. Howard, IEEE Journal of Solid State Circuits, Dec. 1974, Vol. SC-9, No. 6, pp. 394-403.



Note: Component numbering is the same as on the system and connection diagram.

FIGURE 5. Simplified Schematic Diagram in Typical Application

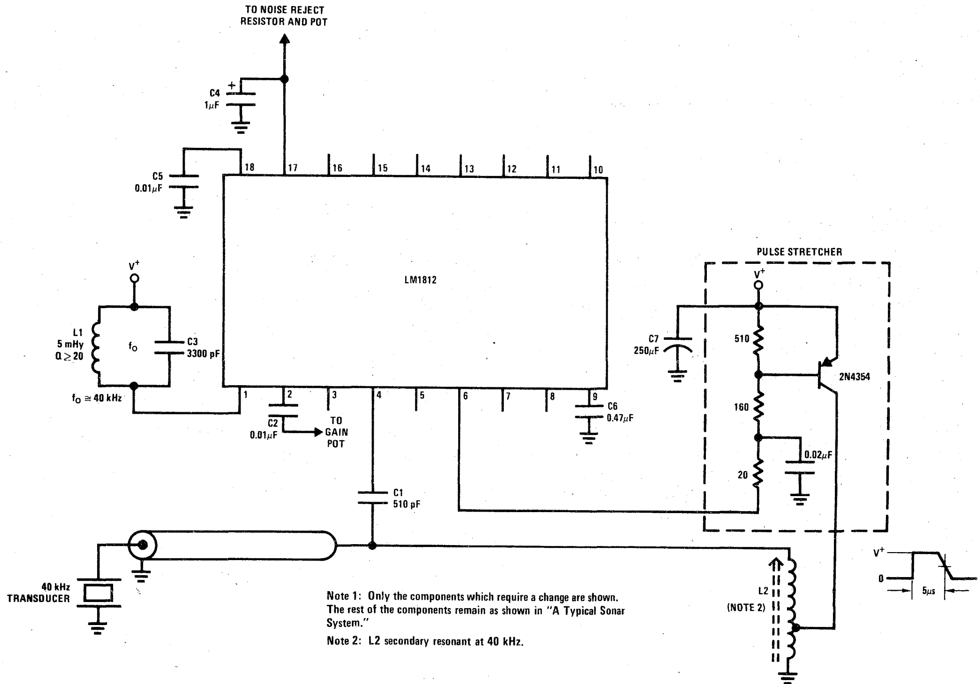
typical applications



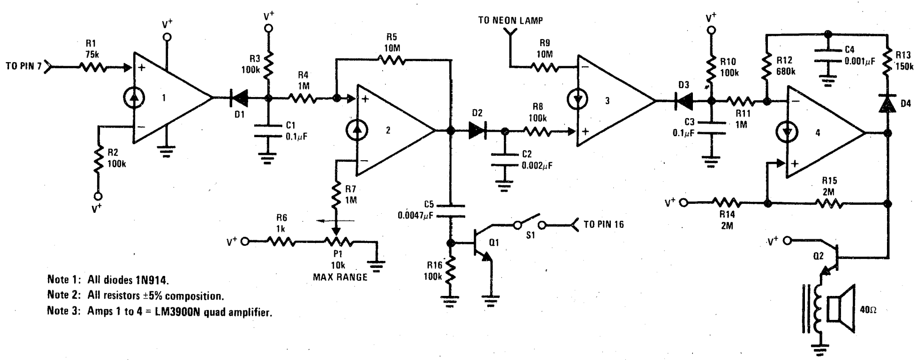
*Note: A permanent magnet attached to a rotating wheel provides modulation pulses to pin 8. The time duration for the X_{MT} mode is controlled by the voltage which is induced in a stationary pick-up coil. The neon display is also mounted on this wheel.

A Typical Sonar Application

typical applications (con't)



Component Changes for Operation in Air (40 kHz)



Electronics for Adding an Echo Annunciator

Industrial/Automotive/Functional Blocks

LM1815 adaptive sense amplifier

general description

The LM1815 is an adaptive sense amplifier and default gating circuit for motor control applications. The sense amplifier provides a one-shot pulse output whose leading edge coincides with the negative-going zero crossing of a ground referenced input signal such as from a variable reluctance magnetic pick-up coil.

In normal operation, this timing reference signal is processed (delayed) externally and returned to the LM1815. A logic input is then able to select either the timing reference or the processed signal for transmission to the output driver stage.

The adaptive sense amplifier operates with a positive-going threshold which is derived by peak detecting the incoming signal and dividing this down. Thus the input hysteresis varies with input signal amplitude. This enables the circuit to sense in situations where the high speed noise is greater than the low speed signal amplitude. Minimum input signal is 100 mVp-p.

features

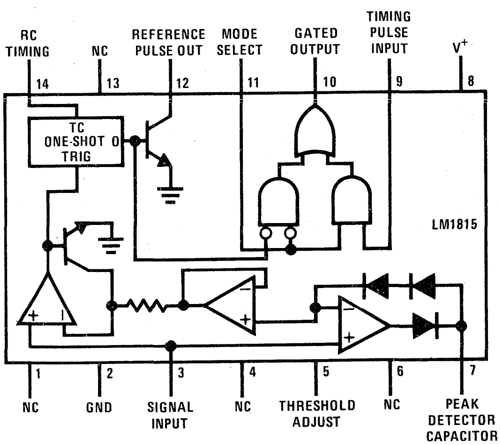
- Adaptive hysteresis
- Single supply operation
- Ground referenced input
- True zero crossing timing reference
- Operates from 2V to 16V supply voltage
- Handles inputs from 100 mV to over 120V with external resistor
- CMOS compatible logic

applications

- Position sensing with notched wheels
- Zero crossing switch
- Motor speed control
- Tachometer
- Engine testing

connection diagram

Dual-In-Line Package



TOP VIEW

Order Number LM1815N
See Package 22

absolute maximum ratings

Supply Voltage	18V
Power Dissipation (Note 1)	230 mW
Operating Temperature Range	−40°C to +125°C
Storage Temperature Range	−65°C to +150°C
Junction Temperature (Note 2)	125°C
Input Current	±30 mA

electrical characteristics (T_A = 25°C, V_{CC} = 10V, unless otherwise specified, see *Figure 1*)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Supply Voltage		2.5	10	18	V
Supply Current	f_{IN} = 500 Hz, Pin 9 = 2V, Pin 11 = 0.8V		3.6		mA
Reference Pulse Width	f_{IN} = 1 Hz to 2 kHz	70	100	130	μs
Input Bias Current	V_{IN} = 2V, (Pin 9 and Pin 11)			5	μA
Input Bias Current	V_{IN} = 0V dc, (Pin 3)		200		nA
Input Impedance	V_{IN} = 5Vrms, (Note 3)	12	20	28	kΩ
Zero Crossing Threshold	V_{IN} = 100 mVp-p, (Pin 3)			25	mV
Logic Threshold	(Pin 9 and Pin 11)	0.8	1.1	2.0	V
V_{OUT} High	R_L = 1 kΩ, (Pin 10)	7.5	8.6		V
V_{OUT} Low	I_{SINK} = 0.1 mA, (Pin 10)		0.3	0.4	V
Input Hysteresis	Pin 5 open	45	80% of V_3 Pk		mV
	Pin 5 to V^+	250	80% of V_3 Pk		mV
	Pin 5 to Gnd	0	80% of V_3 Pk		mV
Output Leakage Pin 12	V_{12} = 11V		0.01	10	μA
Saturation Voltage P12	I_{12} = 2 mA		0.2	0.4	V

Note 1: Derate at 5.7 mW/°C for ambient temperatures above 85°C. This applies when the device is soldered into a printed circuit board, operating in still air ambient.

Note 2: Temporary excursions to 150°C can be tolerated.

Note 3: Measured at input to external 18 kΩ resistor. IC contains 1 kΩ in series with a diode to attenuate the input signal.

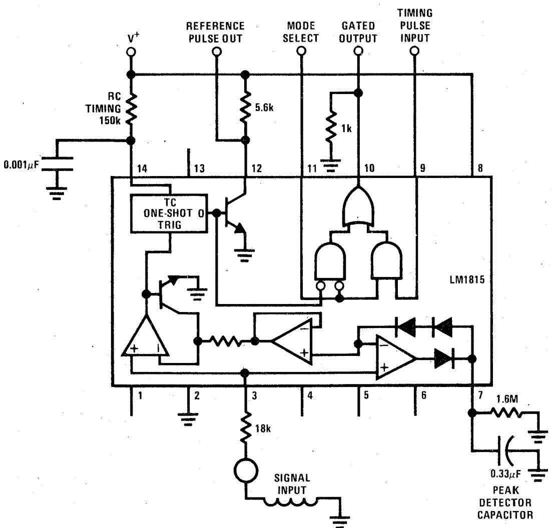


FIGURE 1. LM1815 Adaptive Sense Amplifier

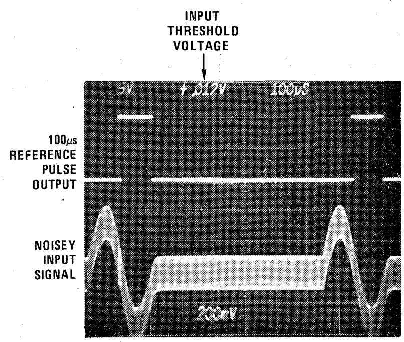
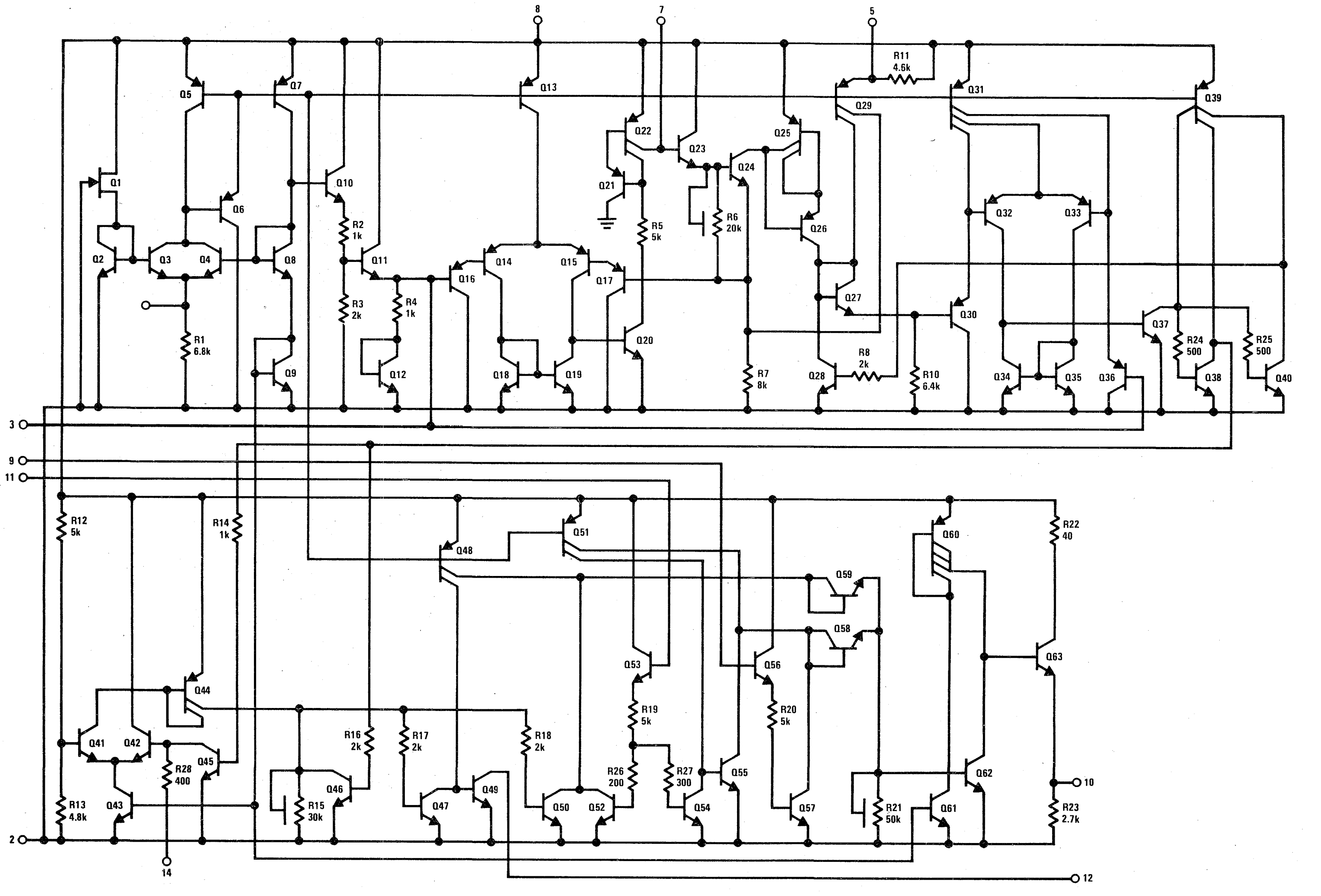


FIGURE 2. LM1815 Oscillograms

schematic diagram



Industrial/Automotive/Functional Blocks

Future Product

LM1823/LM1826 analog FDM modem

general description

The LM1823 and LM1826 are an integrated circuit pair for single channel station carrier systems. The LM1823 performs all the transmitter (modulator) functions while the LM1826 does the receiver (demodulator) functions using double side band AM. The pair forms a complete analog FDM modem. Duplex transmission is realized by using a frequency division multiplexing (FDM) technique. A functionally independent telephone channel can be added to an existing cable pair, doubling capacity. All the logic and delays needed for signaling, dialing and ringing are included so the set can be used in both the central office and the subscriber terminals. Although primarily for single channel systems, they can be adapted for multichannel applications.

The LM1823/LM1826 brings to station carrier telephony the unique advantages of integrated circuits: high reliability, low cost, availability in high volume, mechanical ruggedness, and small size. Per channel cost is significantly reduced by minimizing component count, saving PC board space and eliminating both factory and field adjustments. The modem pair can be powered from 6V batteries and operated over a −40°F (−40°C) to +140°F (60°C) temperature range.

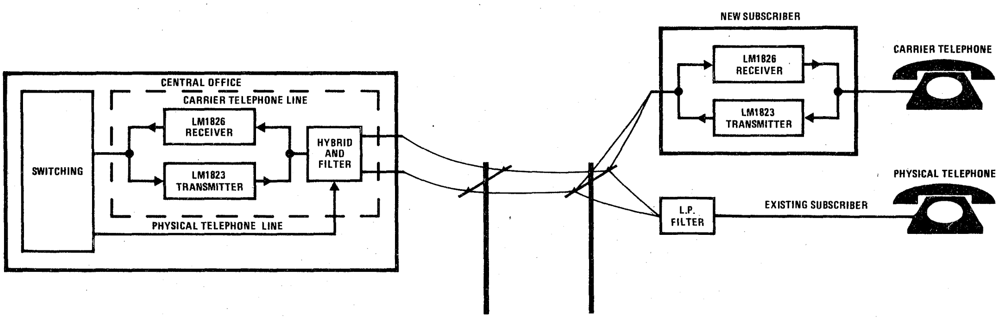
features

- Complete analog FDM modem in two IC's
- High IC reliability at low cost
- No factory or field adjustments
- Minimum component count and small size
- Used in both subscriber and central office terminals
- Low power drain; 6V battery powered operation
- Unique ringing circuit included
- Minimum design-to-production time
- One of a family of telecommunications IC's
- Coordinated transmit/receive AGC
- Simultaneous talk/listen, duplex operation
- Active RC filter for high carrier rejection

applications

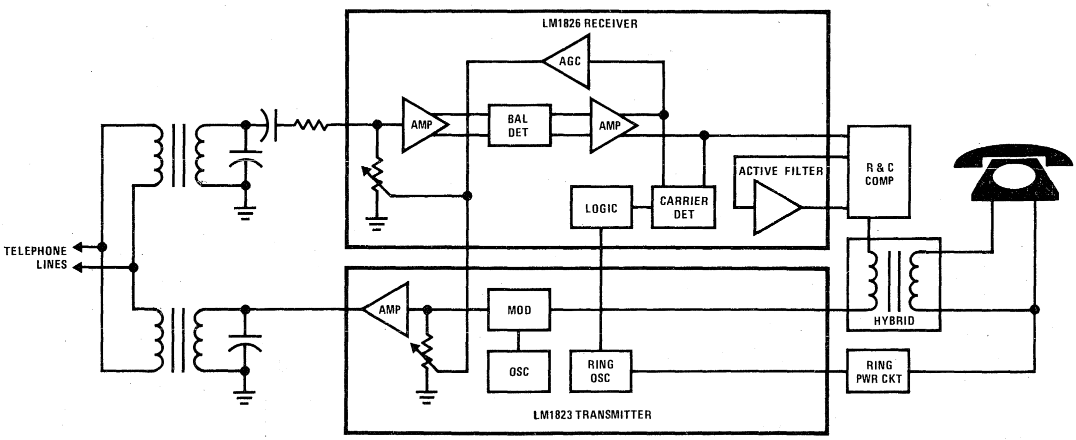
- Single channel (1 + 1) station carrier systems
- Multi-channel station carrier systems
- Simultaneous talk/listen communication links
- Single bus multi-station intercom with individual ringing
- Alarm systems
- Remote control loops

typical application



A Single Channel Station Carrier System Adds a New Subscriber to Existing Cable Plant

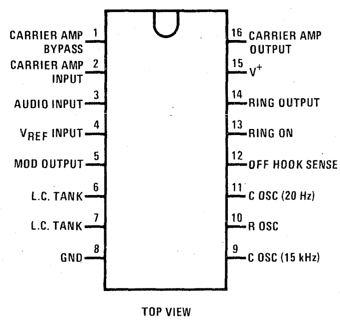
functional diagram



Simplified Functional Diagram of the Analog FDM Modem

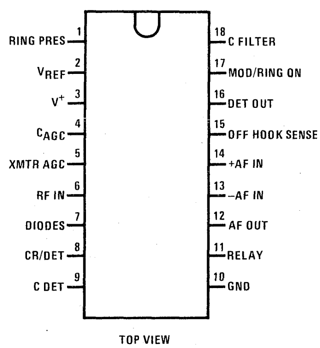
connection diagrams

Dual-In-Line Package



Order Number LM1823N
See Package 23

Dual-In-Line Package



Order Number LM1826N
See Package 29

LM1830 fluid detector

general description

The LM1830 is a monolithic bipolar integrated circuit designed for use in fluid detection systems. The circuit is ideal for detecting the presence, absence, or level of water, or other polar liquids. An ac signal is passed through two probes within the fluid. A detector determines the presence or absence of the fluid by comparing the resistance of the fluid between the probes with the resistance internal to the integrated circuit. An ac signal is used to overcome plating problems incurred by using a dc source. A pin is available for connecting an external resistance in cases where the fluid impedance is of a different magnitude than that of the internal resistor. When the probe resistance increases above the preset value, the oscillator signal is coupled to the base of the open-collector output transistor. In a typical application, the output could be used to drive a LED, loud speaker or a low current relay.

features

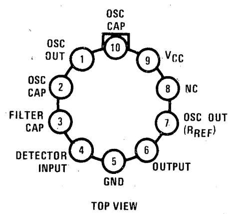
- Low external parts count
- Wide supply operating range
- One side of probe input can be grounded
- ac coupling to probe to prevent plating
- Internally regulated supply
- ac or dc output

applications

- Beverage dispensers
- Water softeners
- Irrigation
- Sump pumps
- Aquaria
- Radiators
- Washing machines
- Reservoirs
- Boilers

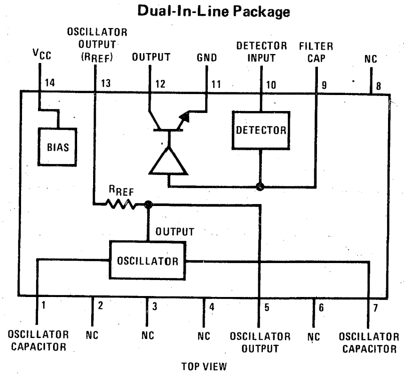
logic and connection diagrams

Metal Can Package



Order Number LM1830H
See Package 12

Dual-In-Line Package



Order Number LM1830N
See Package 22

absolute maximum ratings

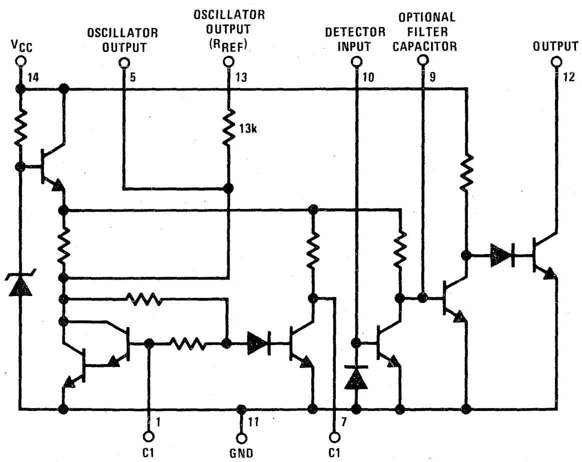
Supply Voltage	28V
Power Dissipation (Note 1)	300 mW
Output Sink Current	20 mA
Operating Temperature Range	−40°C to +85°C
Storage Temperature Range	−40°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics ($V^+ = 16V$, $T_A = 25°C$ unless otherwise specified)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Current			5.5	10	mA
Oscillator Output Voltage					
Low			1.1		V
High			4.2		V
Internal Reference Resistor		8	13	25	kΩ
Detector Threshold Voltage			680		mV
Detector Threshold Resistance		5	10	15	kΩ
Output Saturation Voltage	$I_O = 10$ mA		0.5	2.0	V
Output Leakage	$V_{PIN\ 12} = 16V$			10	μA
Oscillator Frequency	C1 = 0.001μF	4	7	12	kHz

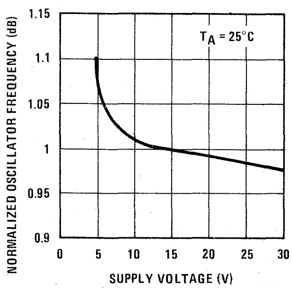
Note 1: The maximum junction temperature rating of the LM1830N is 100°C. For operation at elevated temperatures, devices in the dual-in-line plastic package must be derated based on a thermal resistance of 175°C/W.

schematic diagram

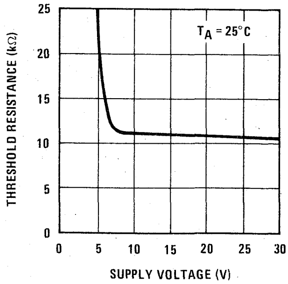


typical performance characteristics

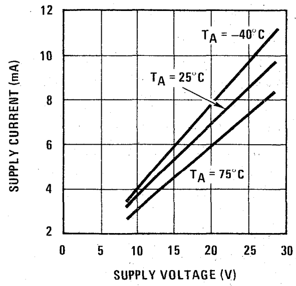
Normalized Oscillator Frequency vs Supply Voltage



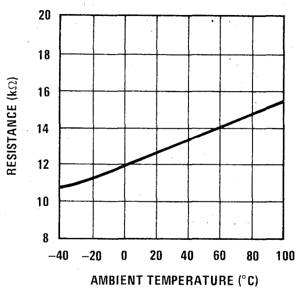
Threshold Resistance vs Supply Voltage



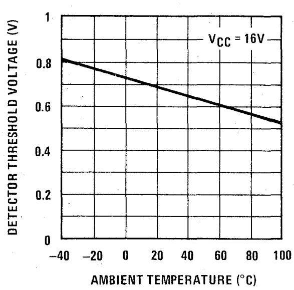
Power Supply Current vs Supply Voltage



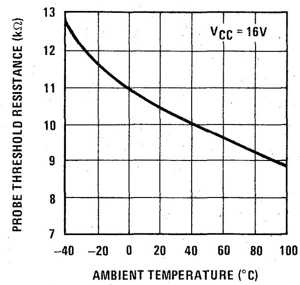
Reference Resistor vs Ambient Temperature



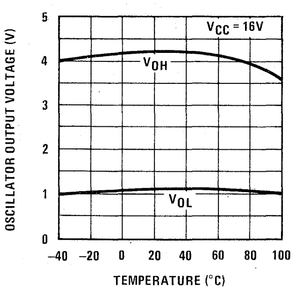
Detector Threshold Voltage vs Temperature



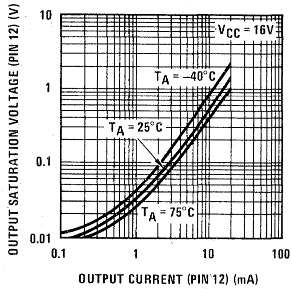
Probe Threshold Resistance vs Temperature



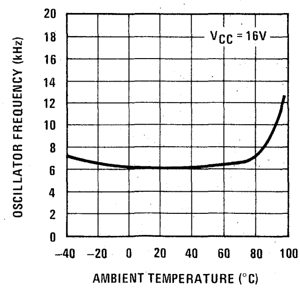
Oscillator V_{OH} and V_{OL} vs Ambient Temperature



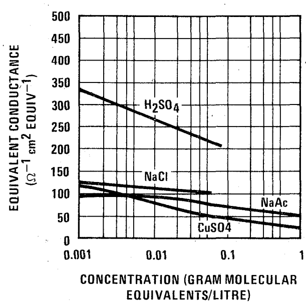
Output Saturation Voltage vs Output Current



Oscillator Frequency vs Ambient Temperature



Equivalent Resistance vs Concentration of Several Solutions



application hints

The LM1830 requires only an external capacitor to complete the oscillator circuit. The frequency of oscillation is inversely proportional to the external capacitor value. Using 0.001μF capacitor, the output frequency is approximately 6 kHz. The output from the oscillator is available at pin 5. In normal applications, the output is taken from pin 13 so that the internal 13k resistor can be used to compare with the probe resistance. Pin 13 is coupled to the probe by a blocking capacitor so that there is no net dc on the probe.

Since the output amplitude from the oscillator is approximately 4 V_{BE}, the detector (which is an emitter base junction) will be turned "ON" when the probe resistance to ground is equal to the internal 13 kΩ resistor. An internal diode across the detector emitter base junction provides symmetrical limiting of the detector input signal so that the probe is excited with ±2 V_{BE} from a 13 kΩ source. In cases where the 13 kΩ resistor is not compatible with the probe resistance range, an external resistor may be added by coupling the probe to pin 5 through the external resistor as shown in *Figure 2*. The collector of the detecting transistor is brought out to pin 9 enabling a filter capacitor to be connected so that the output will switch "ON" or "OFF" depending on the probe resistance. If this capacitor is omitted, the output will be switched at approximately 50% duty cycle when the probe resistance exceeds the reference resistance. This can be useful when an audio output is required and the output transistor can be used to directly drive a loud speaker. In addition, LED indicators do not require dc excitation. Therefore, the cost of a capacitor for filtering can be saved.

In the case of inductive loads or incandescent lamp loads, it is recommended that a filter capacitor be employed.

In a typical application where the device is employed for sensing low water level in a tank, a simple steel probe may be inserted in the top of the tank with the tank grounded. Then when the water level drops below the tip of the probe, the resistance will rise between the probe and the tank and the alarm will be operated. This is illustrated in *Figure 3*. In situations where a non-conductive container is used, the probe may be designed in a number of ways. In some cases a simple phono plug can be employed. Other probe designs include conductive parallel strips on printed circuit boards.

It is possible to calculate the resistance of any aqueous solution of an electrolyte for different concentrations, provided the dimensions of the electrodes and their spacing is known.

The resistance of a simple parallel plate probe is given by:

$$R = \frac{1000}{c.p} \cdot \frac{d}{A} \ \Omega$$

where A = area of plates (cm^2)
d = separation of plates (cm)
c = concentration (gm. mol. equivalent/litre)
p = equivalent conductance (Ω^{-1} cm^2 $equiv.^{-1}$)

(An equivalent is the number of moles of a substance that gives one mole of positive charge and one mole of negative charge. For example, one mole of NaCl gives $Na^+ + Cl^-$ so the equivalent is 1. One mole of $CaCl_2$ gives $Ca^{++} + 2Cl^-$ so the equivalent is 1/2.)

Usually the probe dimensions are not measured physically, but the ratio d/A is determined by measuring the resistance of a cell of known concentration c and equivalent conductance of 1. A graph of common solutions and their equivalent conductances is shown for reference. The data was derived from D.A. MacInnes, "The Principles of Electrochemistry," Reinhold Publishing Corp., New York., 1939.

In automotive and other applications where the power source is known to contain significant transient voltages, the internal regulator on the LM1830 allows protection to be provided by the simple means of using a series resistor in the power supply line as illustrated in *Figure 4*. If the output load is required to be returned directly to the power supply because of the high current required, it will be necessary to provide protection for the output transistor if the voltages are expected to exceed the data sheet limits.

Although the LM1830 is designed primarily for use in sensing conductive fluids, it can be used with any variable resistance device, such as light dependent resistor or thermistor or resistive position transducer.

The following table lists some common fluids which may and may not be detected by resistive probe techniques.

Conductive Fluids	Non-Conductive Fluids
City water	Pure water
Sea water	Gasoline
Copper sulphate solution	Oil
Weak acid	Brake fluid
Weak base	Alcohol
Household ammonia	Ethylene glycol
Water and glycol mixture	Paraffin
Wet soil	Dry soil
Coffee	Whiskey

application hints (con't)

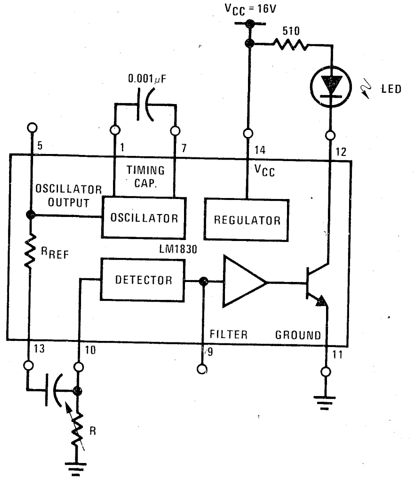


FIGURE 1. Test Circuit

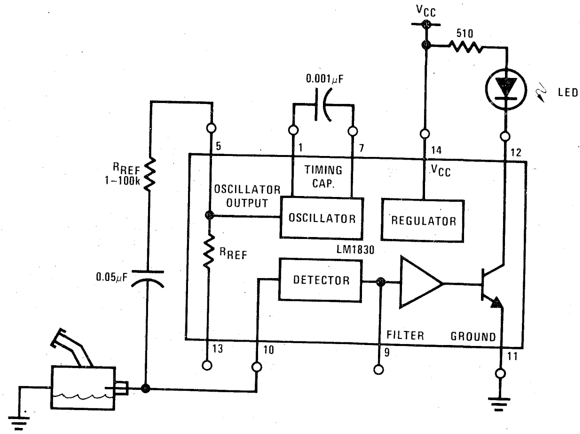


FIGURE 2. Application Using External Reference Resistor

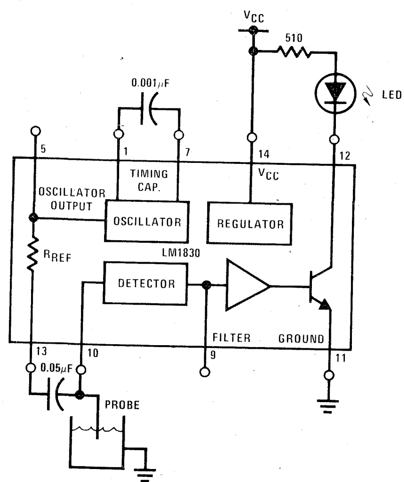
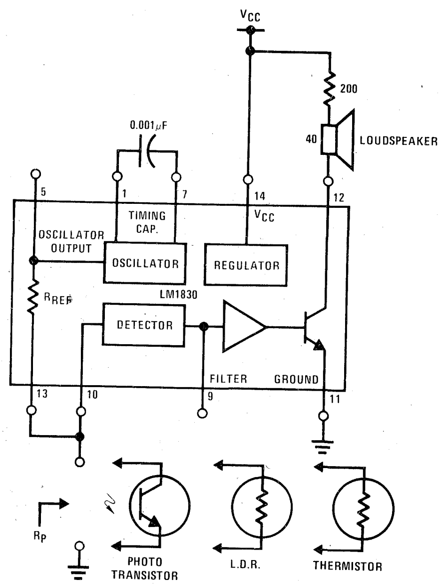


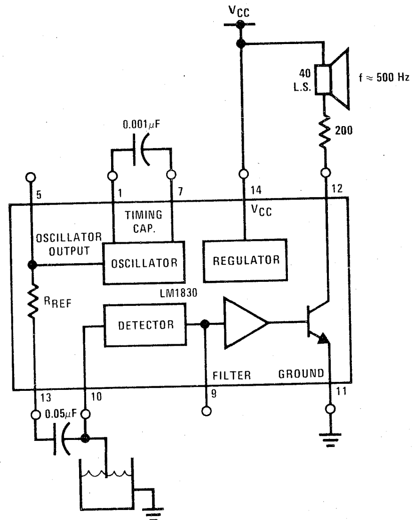
FIGURE 3. Basic Low Level Warning Device with LED Indication



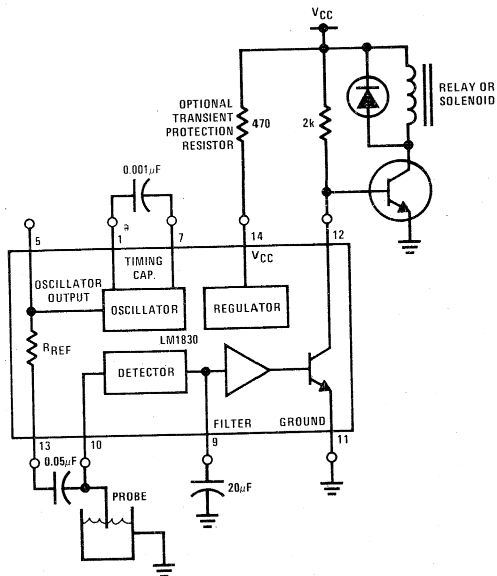
Output is activated when $R_P \gtrsim 1/3\ R_{REF}$

FIGURE 4. Direct Coupled Applications

typical applications



Low Level Warning with Audio Output



The output is suitable for driving a sump pump or opening a drain valve, etc.

High Level Warning Device

LM1850 ground fault interrupter

general description

The LM1850 is a monolithic circuit designed for ground fault protection from 120 V_{AC} household and industrial circuits. Its design takes full advantage of UL943 timing specifications giving the user high immunity to nuisance tripping.

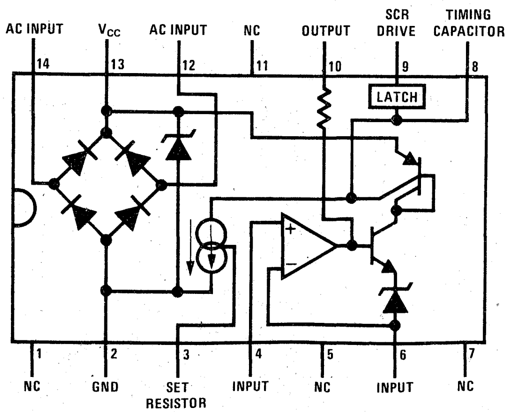
Special features include a non-permanent latch which assures opening even a sluggish breaker, rapid reset of the timing capacitor in the absence of input signal, and an internal full wave bridge power supply.

features

- Minimum external parts
- Internal full wave bridge
- Ability to take line reversal
- Wide temperature range
- Detects neutral line faults
- Trips at 5 mA ±1 mA

block and connection diagram

Dual-In-Line Package



TOP VIEW

Order Number LM1850N
See Package 22

absolute maximum ratings

Supply Current (ac Line)	25 mA
Power Dissipation (Note 1)	625 mW
Operating Temperature Range	−40°C to +70°C
Storage Temperature Range	−55°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics *(Figure 1)*

PARAMETER	MIN	TYP	MAX	UNITS
Regulator, Bridge Output Voltage (Pin 13)		24.5		V
Latch Trigger Voltage (Pin 8)		17.5		V
Gate Drive to SCR		25		mA
Internal SCR Gate Bleed Resistor (Pin 9–12)		500	1000	Ω
Heavy Fault 240 mA Trip Time (Note 4)		18	25	ms
Light Fault Trip Current (Notes 2 and 5)	4	5	6	mA
Neutral Fault (Grounded Neutral)	4	6		Ω

Note 1: For operation at elevated temperatures, the device must be derated based on a 150°C maximum junction temperature and a thermal devating of 5 mW/°C junction to ambient.

Note 2: Device meets UL943 requiring operation from −35°C to +66°C and line voltage variations from 102V to 132V_{AC}.

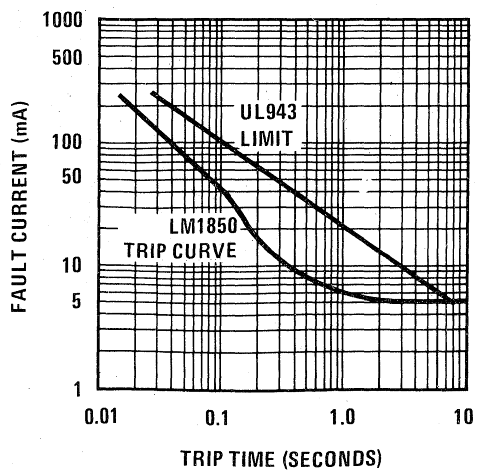
Note 3: Additional noise rejection can be had by using 50 pF from pin 2 to 4 or 120 pF pin 6 to 10 or both depending on severity of the noise.

Note 4: Average of 10, breaker time not included.

Note 5: Set resistor adjusted for 5.0 mA trip.

typical performance characteristics

Typical Trip Time vs Fault Current



typical applications *Figures 1, 2 and 3* show wall socket applications with reversable input wires and neutral ground detection.

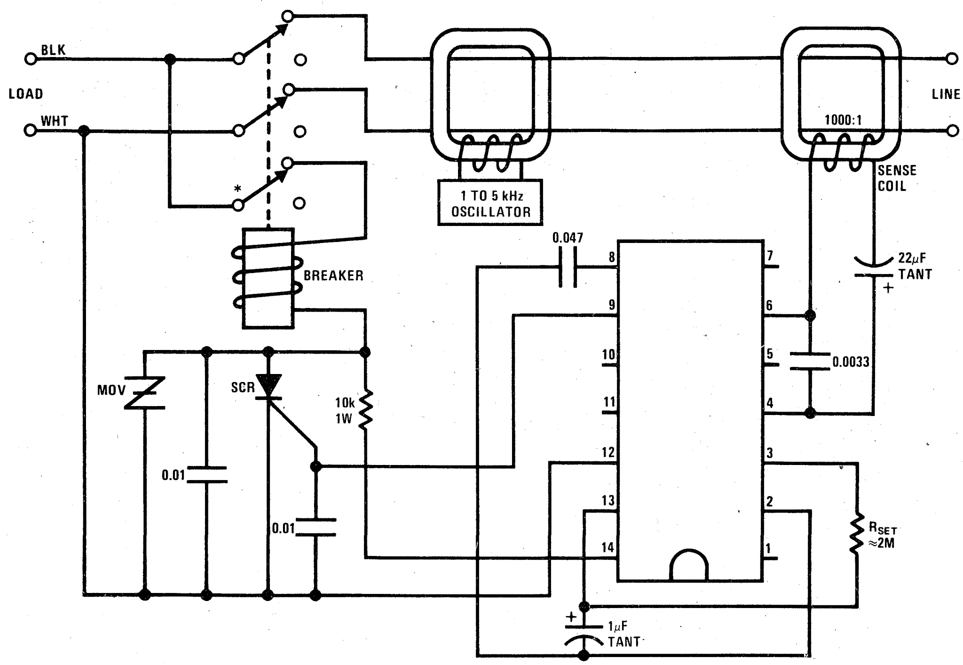


FIGURE 1. Grounded Neutral Detection Using External Oscillator

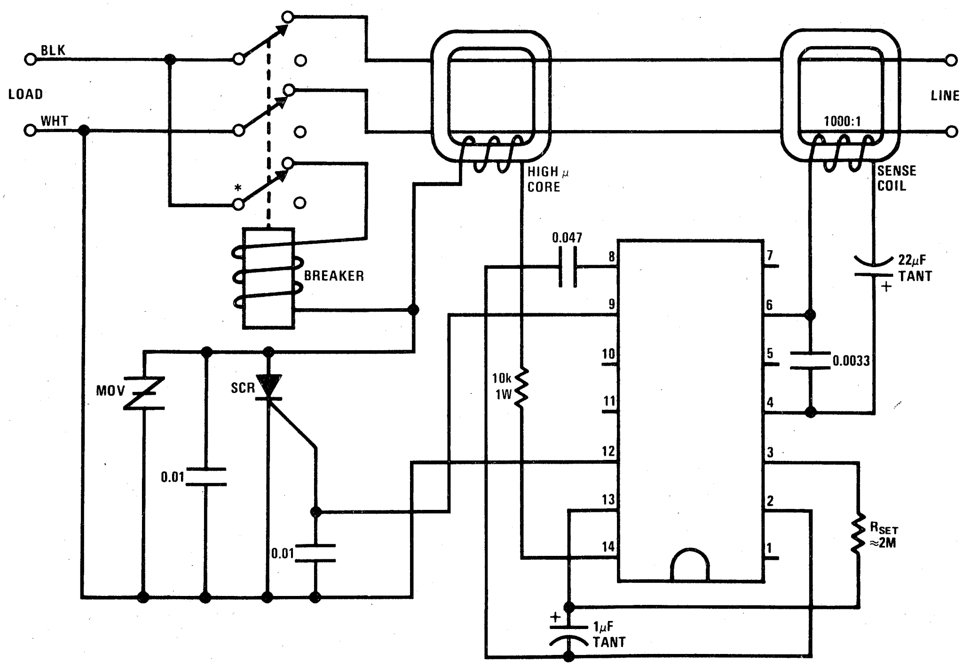
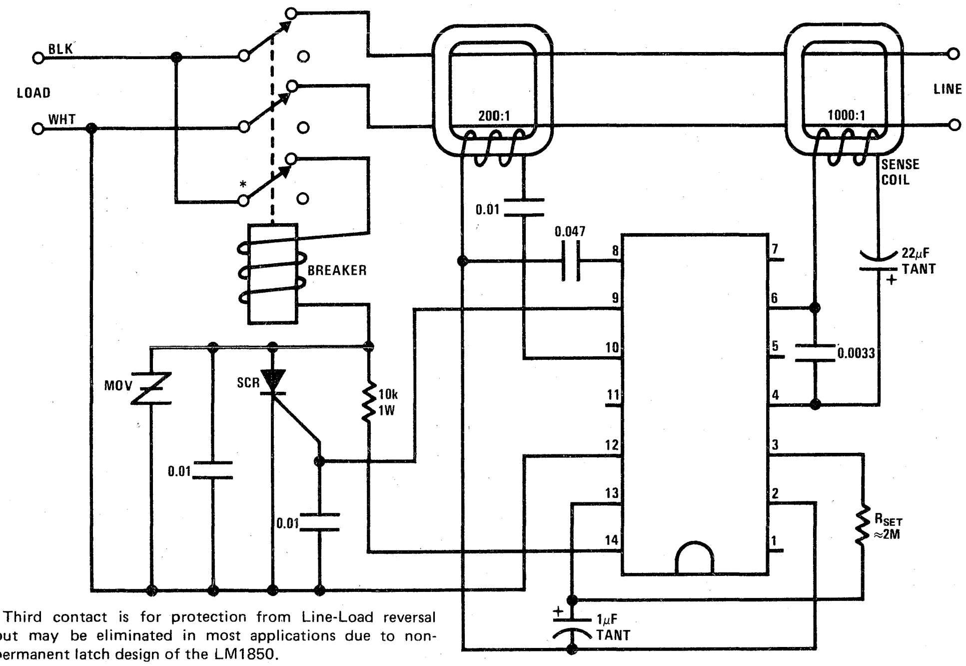


FIGURE 2. Grounded Neutral Detection Using 60 Hz Line

*Third contact is for protection from Line-Load reversal but may be eliminated in most applications due to non-permanent latch design of the LM1850.

Single contact breakers may be used in circuit breaker applications where input line is non-reversable.

typical applications (con't)



*Third contact is for protection from Line-Load reversal but may be eliminated in most applications due to non-permanent latch design of the LM1850.

Single contact breakers may be used in circuit breaker applications where input line is non-reversable.

FIGURE 3. Grounded Neutral Detection Using a Regenerative Oscillator

Industrial/Automotive/Functional Blocks

Future Product

LM2704, LM2705, LM2706, LM2707 analog compandors

LM2704/LM3704 programmable transfer function compandor
LM2705/LM3705 CCITT* transfer function compandor with electronic shutdown
LM2706/LM3706 CCITT* transfer function compandor
LM2707/LM3707 Bell† transfer function compandor

general description

This family of analog compandors greatly improves the signal-to-noise ratio in multi-channel FDM station carrier systems. These syllabic compandors reduce noise by compressing the dynamic range of speech allowing transmission at a high level above the noise of the channel. The received signal is then expanded back to the original level. Both compression and expansion functions can be configured by external connections around one IC.

These devices differ only in the unity gain level of the transfer function. Three have been internally set to meet either of two standard specifications – CCITT* or Bell†. By means of external resistors, the programmable version allows setting of the unity gain level to optimize system design. Tracking of the transfer function is precisely fixed so that any expandor will restore signals from any compressor. Also, the need for factory adjustments has been eliminated. These compandors simplify system design, reduce cost, size, and number of components, have low power drain and offer improved performance and reliability.

Although primarily for carrier telephony, these audio frequency compandors can be used where accurate dynamic amplitude range compression or expansion are needed: such as increasing modulation level, tape noise reduction, and expanding HiFi record playback. For less stringent tracking and temperatures, the LM3704, LM3705, LM3706 and LM3707 can be used.

features

- Up to 30 dB improvement in signal-to-noise ratio
- Complete companding function—a compressor and an expandor in one package
- Selectable functions—a compressor and expandor or two compressors or two expandors
- Either a programmable or fixed transfer function
- Accurate tracking: $< \pm 1$ dB
- Low distortion $< 0.5\%$
- Large dynamic range: > 70 dB
- Transfer function independent of temperature
- TTL compatible electronic shutdown saves power
- Low power drain for battery operation: < 5 mA
- Another of a family of telecommunications IC's

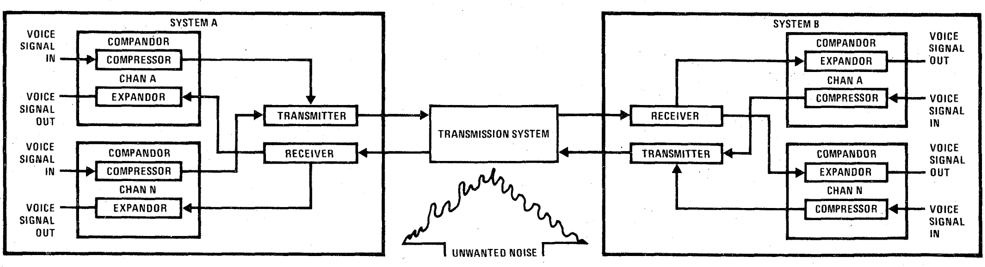
applications

- Telephone station carrier systems
- Tape recording/playback systems
- Noise reduction in CB radios
- Telephone trunk circuit electronics
- Expansion of HiFi record playback

The LM3704, LM3705, LM3706 and LM3707 provide identical functions to the LM2704, LM2075, LM2706 and LM2707 except its temperature range is 0°C to +70°C instead of −25°C to +85°C.

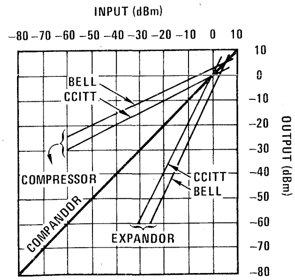
typical application

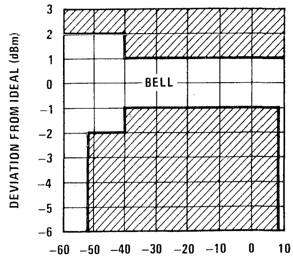
A Multichannel FDM Station **Carrier System Using Compandors for Noise Reduction**



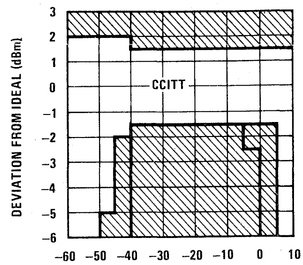
*CCITT Vol. III Rec. G 162
†Bell System N2/N3 Carrier System

transfer functions





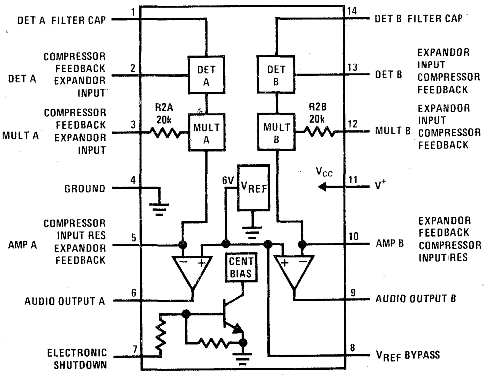
INPUT (dBm) ALLOWABLE COMPANDOR TRACKING ERROR



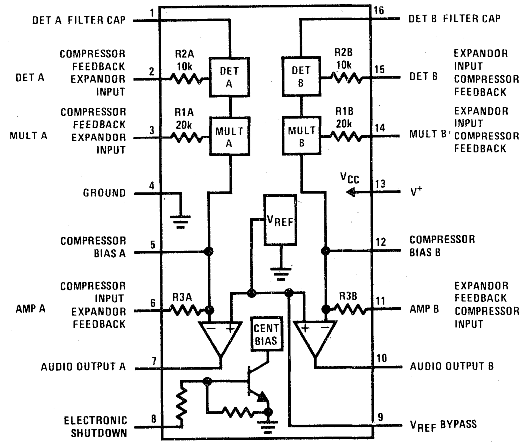
INPUT (dBm) ALLOWABLE COMPANDOR TRACKING ERROR

functional and connection diagrams

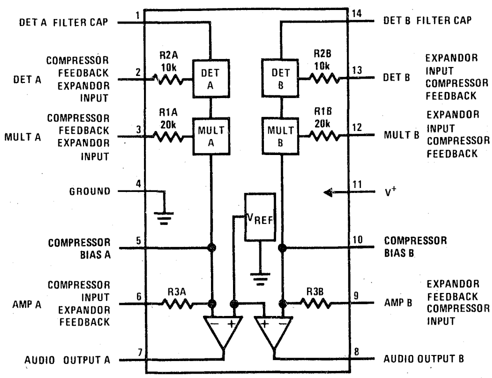
Programmable Transfer Function Compandors
LM2704, LM3704



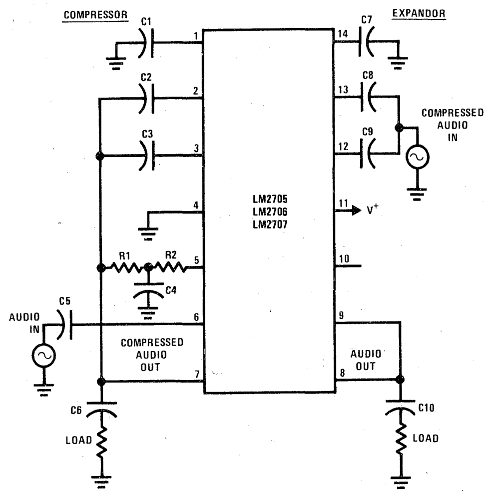
Fixed Transfer Function Compandors
LM2705, LM3705



Fixed Transfer Function Compandors
LM2706, LM2707, LM3706, LM3707



External Connections for Fixed Transfer Function Compandors



Industrial/Automotive/Functional Blocks

LM2907, LM2917 frequency to voltage converter

general description

The LM2907, LM2917 series are monolithic frequency to voltage converters with a high gain op amp/comparator designed to operate a relay, lamp, or other load when the input frequency reaches or exceeds a selected rate. The tachometer uses a charge pump technique and offers frequency doubling for low ripple, full input protection in two versions (LM2907-8, LM2917-8) and its output swings to ground for a zero frequency input. (continued on page 9-71)

advantages

- Output swings to ground for zero frequency input
- Easy to use; $V_{OUT} = f_{IN} \times V_{CC} \times R1 \times C1$
- Only one RC network provides frequency doubling
- Zener regulator on chip allows accurate and stable frequency to voltage or current conversion. (LM2917)

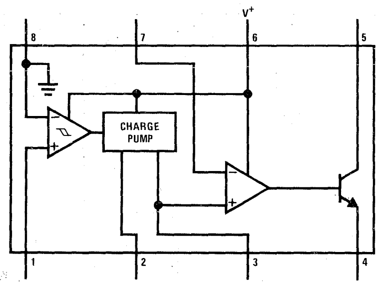
features

- Ground referenced tachometer input interfaces directly with variable reluctance magnetic pickups
- Op amp/comparator has floating transistor output
- 50 mA sink or source to operate relays, solenoids, meters, or LEDs
- Frequency doubling for low ripple
- Tachometer has built-in hysteresis with either differential input or ground referenced input
- Built-in zener on LM2917
- ±0.3% linearity typical
- Ground referenced tachometer is fully protected from damage due to swings above V_{CC} and below ground

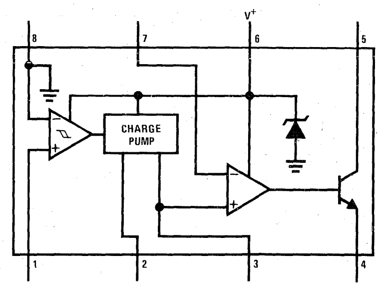
applications

- Over/under speed sensing
- Frequency to voltage conversion (tachometer)
- Speedometers
- Breaker point dwell meters
- Hand-held tachometer
- Speed governors
- Cruise control
- Automotive door lock control
- Clutch control
- Horn control
- Touch or sound switches

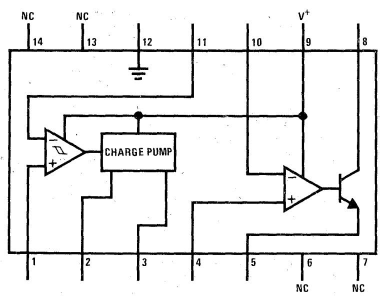
block and connection diagrams Dual-In-Line Package, Top Views



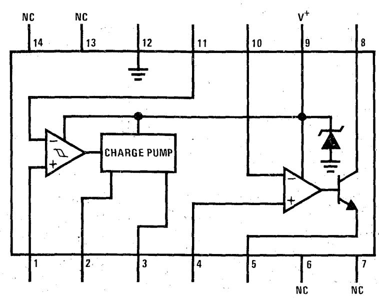
Order Number LM2907N-8
See Package 20



Order Number LM2917N-8
See Package 20



Order Number LM2907J
See Package 16
Order Number LM2907N
See Package 22



Order Number LM2917J
See Package 16
Order Number LM2917N
See Package 22

9

absolute maximum ratings (Note 1)

Supply Voltage	28V
Supply Current (Zener Options)	25 mA
Collector Voltage	28V
Differential Input Voltage	
Tachometer	28V
Op Amp/Comparator	28V
Input Voltage Range	
Tachometer LM2907-8, LM2917-8	±28V
LM2907, LM2917	0.0V to +28V
Op Amp/Comparator	0.0V to +28V
Power Dissipation	500 mW
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_{CC} = 12 V_{DC}, T_A = 25°C, see test circuit

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
TACHOMETER					
Input Thresholds	V_{IN} = 250 mVp-p @ 1 kHz (Note 2)	±10	±15	±40	mV
Hysteresis	V_{IN} = 250 mVp-p @ 1 kHz (Note 2)		30		mV
Offset Voltage	V_{IN} = 250 mVp-p @ 1 kHz (Note 2)				
LM2907/LM2917			3.5	10	mV
LM2907-8/LM2917-8			5	15	mV
Input Bias Current	V_{IN} = ±50 mV_{DC}		0.1	1	μA
V_{OH} Pin 2	V_{IN} = +125 mV_{DC} (Note 3)		8.3		V
V_{OL} Pin 2	V_{IN} = −125 mV_{DC} (Note 3)		2.3		V
Output Current; I_2, I_3	V2 = V3 = 6.0V (Note 4)	140	180	240	μA
Leakage Current; I_3	I2 = 0, V3 = 0			0.1	μA
Gain Constant, K	(Note 3)	0.9	1.0	1.1	
Linearity	f_{IN} = 1 kHz, 5 kHz, 10 kHz, (Note 5)	−1.0	0.3	+1.0	%
OP/AMP COMPARATOR					
V_{OS}	V_{IN} = 6.0V		3	10	mV
I_{BIAS}	V_{IN} = 6.0V		50	500	nA
Input Common-Mode Voltage		0		V_{CC}−1.5V	V
Voltage Gain			200		V/mV
Output Sink Current	V_C = 1.0	40	50		mA
Output Source Current	V_E = V_{CC} − 2.0		10		mA
Saturation Voltage	I_{SINK} = 5 mA		0.1	0.5	V
	I_{SINK} = 20 mA			1.0	V
	I_{SINK} = 50 mA		1.0	1.5	V
ZENER REGULATOR					
Regulator Voltage	R_{DROP} = 470Ω		7.56		V
Series Resistance			10.5	15	Ω
Temperature Stability			+1		mV/°C
TOTAL SUPPLY CURRENT			3.8	6	mA

Note 1: For operating at elevated temperatures the device must be derated based on a +125°C maximum junction temperature and a thermal resistance of +187°C/W junction to ambient for both packages.

Note 2: Hysteresis is the sum $+V_{TH}-(-V_{TH})$, offset voltage is their difference. See test circuit.

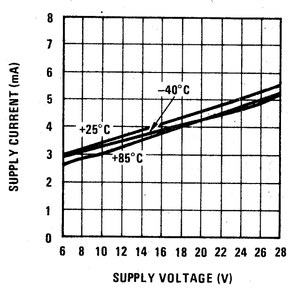
Note 3: V_{OH} is equal to 3/4 x V_{CC} − 1 V_{BE}, V_{OL} is equal to 1/4 x V_{CC} − 1 V_{BE} therefore $V_{OH} - V_{OL} = V_{CC}/2$. The difference, $V_{OH} - V_{OL}$, and the mirror gain, I_2/I_3, are the two factors that cause the tachometer gain constant to vary from 1.0.

Note 4: Be sure when choosing the time constant R1 x C1 that R1 is such that the maximum anticipated output voltage at pin 3 can be reached with I_3 x R1. The maximum value for R1 is limited by the output resistance of pin 3 which is greater than 10 MΩ typically.

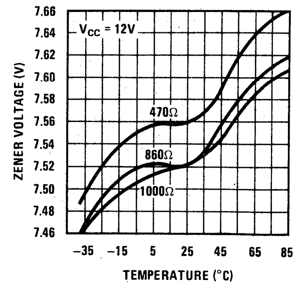
Note 5: Nonlinearity is defined as the deviation of V_{out} (@ pin 3) for f_{IN} = 5 kHz from a straight line defined by the V_{OUT} @ 1 kHz and V_{OUT} @ 10 kHz. C1 = 1000 pF, R1 = 68k and C2 = 0.22 mFd.

typical performance characteristics

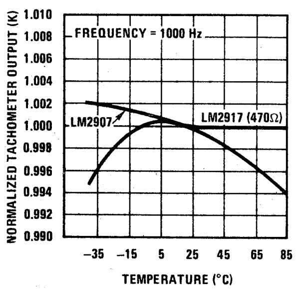
Total Supply Current



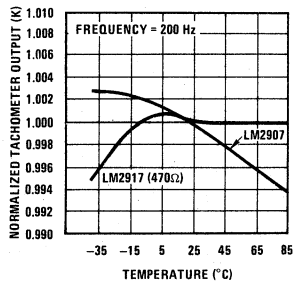
Zener Voltage vs Temperature



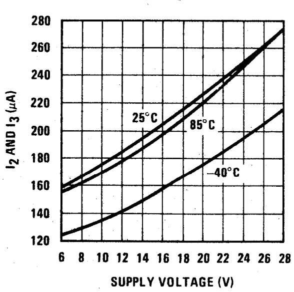
Normalized Tachometer Output vs Temperature



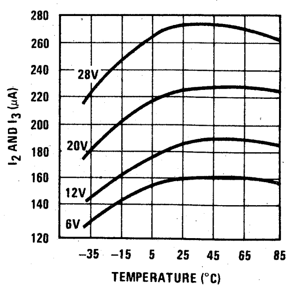
Normalized Tachometer Output vs Temperature



Tachometer Currents I_2 and I_3 vs Supply Voltage

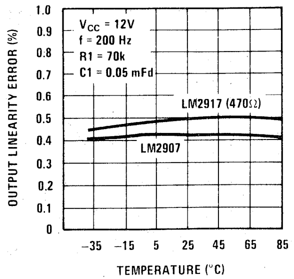


Tachometer Currents I_2 and I_3 vs Temperature

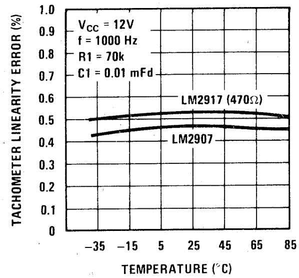


typical performance characteristics (con't)

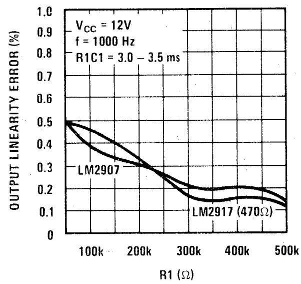
Tachometer Linearity vs Temperature



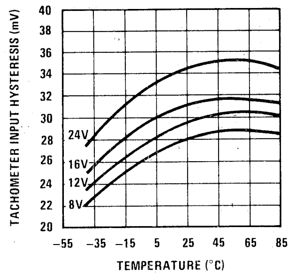
Tachometer Linearity vs Temperature



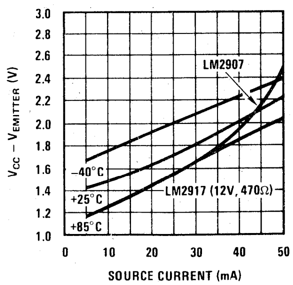
Tachometer Linearity vs R1



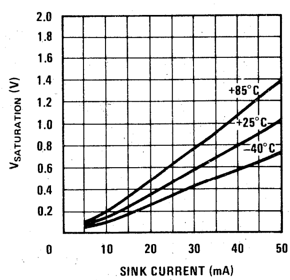
Tachometer Input Hysteresis vs Temperature



Op Amp Output Transistor Characteristics



Op Amp Output Transistor Characteristics



general description (con't)

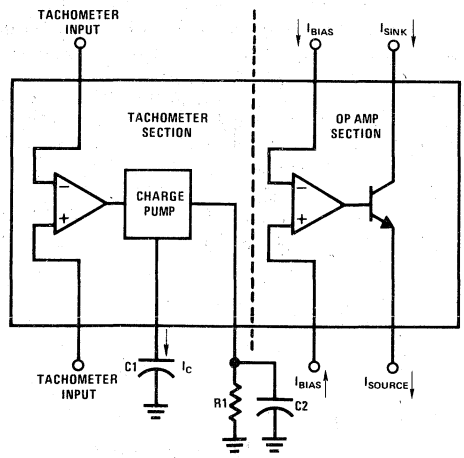
The op amp/comparator is fully compatible with the tachometer and has a floating transistor as its output. This feature allows either a ground or supply referred load of up to 50 mA. The collector may be taken above V_{CC} up to a maximum V_{CE} of 28V.

The two basic configurations offered include an 8-pin device with a *ground referenced tachometer* input and an internal connection between the tachometer output and the op amp non-inverting input. This version is well suited for single speed or frequency switching or fully buffered frequency to voltage conversion applications.

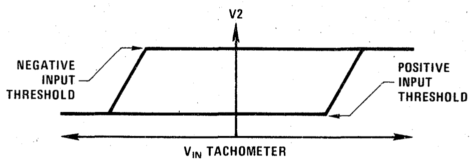
The more versatile configurations provide differential tachometer input and uncommitted op amp inputs. With this version the tachometer input may be floated and the op amp becomes suitable for active filter conditioning of the tachometer output.

Both of these configurations are available with an active shunt regulator connected across the power leads. The regulator clamps the supply such that stable frequency to voltage and frequency to current operations are possible with any supply voltage and a suitable resistor.

test circuit and waveform



Tachometer Input Threshold Measurement



applications information

The LM2907 series of tachometer circuits is designed for minimum external part count applications and maximum versatility. In order to fully exploit its features and advantages let's examine its theory of operation. The first stage of operation is a differential amplifier driving a positive feedback flip-flop circuit. The input threshold voltage is the amount of differential input voltage at which the output of this stage changes state. Two options (LM2907-8, LM2917-8) have one input internally grounded so that an input signal must swing above and below ground and exceed the input thresholds to produce an output. This is offered specifically for magnetic variable reluctance pickups which typically provide a single-ended ac output. This single input is also fully protected against voltage swings to ±28V, which are easily attained with these types of pickups.

The differential input options (LM2907, LM2917) give the user the option of setting his own input switching level and still have the hysteresis around that level for excellent noise rejection in any application. Of course in order to allow the inputs to attain common-mode voltages above ground, input protection is removed and neither input should be taken outside the limits of the supply voltage being used. It is very important that an input not go below ground without some resistance in its lead to limit the current that will then flow in the epi-substrate diode.

Following the input stage is the charge pump where the input frequency is converted to a dc voltage. To do this requires one timing capacitor, one output resistor, and an integrating or filter capacitor. When the input stage changes state (due to a suitable zero crossing or differential voltage on the input) the timing capacitor is either charged or discharged linearly between two voltages whose difference is $V_{CC}/2$. Then in one half cycle of the input frequency or a time equal to $1/2\ f_{IN}$ the change in charge on the timing capacitor is equal to $V_{CC}/2 \times C1$. The average amount of current pumped into or out of the capacitor then is:

$$\frac{\Delta Q}{T} = i_{c(AVG)} = C1 \times \frac{V_{CC}}{2} \times (2f_{IN}) = V_{CC} \times f_{IN} \times C1$$

The output circuit mirrors this current very accurately into the load resistor R1, connected to ground, such that if the pulses of current are integrated with a filter

applications information (con't)

capacitor, then, $V_o = i_c \times R1$, and the total conversion equation becomes:

$$V_O = V_{CC} \times f_{IN} \times C1 \times R1 \times K$$

Where K is the gain constant—typically 1.0.

The size of C2 is dependent only on the amount of ripple voltage allowable and the required response time.

CHOOSING R1 AND C1

There are some limitations on the choice of R1 and C1 which should be considered for optimum performance. The timing capacitor also provides internal compensation for the charge pump and should be kept larger than 100 pF for very accurate operation. Smaller values can cause an error current on R1, especially at low temperatures. Several considerations must be met when choosing R1. The output current at pin 3 is internally fixed and therefore $V_o/R1$ must be less than or equal to this value. If R1 is too large, it can become a significant fraction of the output impedance at pin 3 which degrades linearity. Also output ripple voltage must be considered and the size of C2 is affected by R1. An expression that describes the ripple content on pin 3 for a single R1C2 combination is:

$$V_{RIPPLE} = \frac{V_{CC}}{2} \times \frac{C1}{C2} \times \left(1 - \frac{V_{CC} \times f_{IN} \times C1}{I_2}\right) \text{pk—pk}$$

It appears R1 can be chosen independent of ripple, however response time, or the time it takes V_{OUT} to stabilize at a new voltage increases as the size of C2 increases so a compromise between ripple, response time, and linearity must be chosen carefully.

As a final consideration, the maximum attainable input frequency is determined by V_{CC}, C1 and I_2:

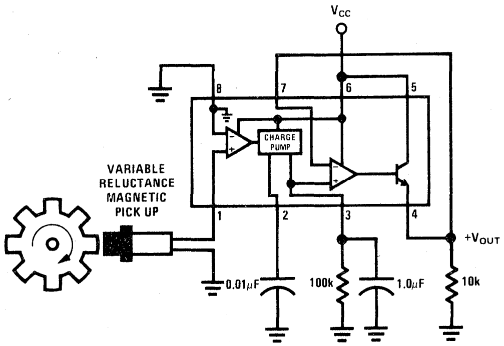
$$f_{MAX} = \frac{I_2}{C1 \times V_{CC}}$$

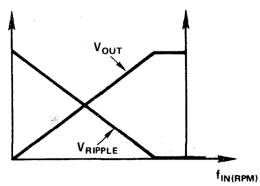
USING ZENER REGULATED OPTIONS (LM2917)

For those applications where an output voltage or current must be obtained independent of supply voltage variations, the LM2917 is offered. The most important consideration in choosing a dropping resistor from the unregulated supply to the device is that the tachometer and op amp circuitry alone require about 3 mA at the voltage level provided by the zener. At low supply voltages there must be some current flowing in the resistor above the 3 mA circuit current to operate the regulator. As an example, if the raw supply varies from 9 to 16V, a resistance of 470Ω will minimize the zener voltage variation to 160 mV. If the resistance goes under 400Ω or over 600Ω the zener variation quickly rises above 200 mV for the same input variation.

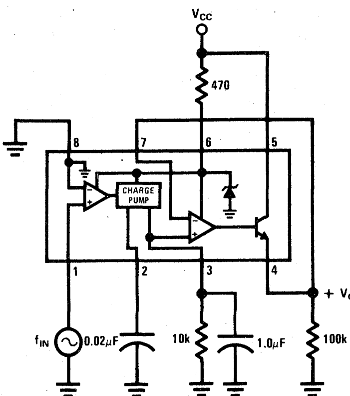
typical applications

Minimum Component Tachometer

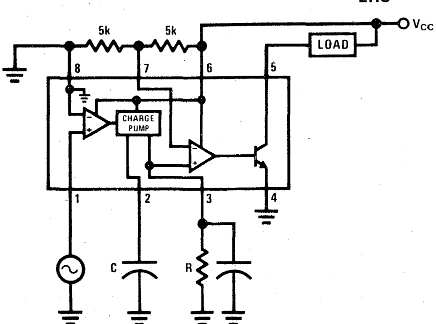




Zener Regulated Frequency to Voltage Converter

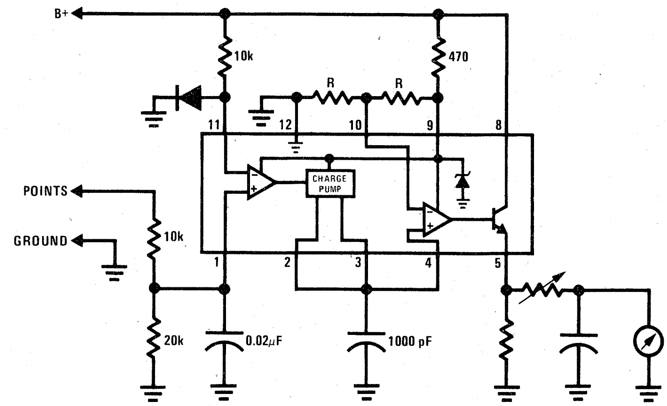


"Speed Switch" Load is Energized When $f_{IN} \geq \frac{1}{2RC}$

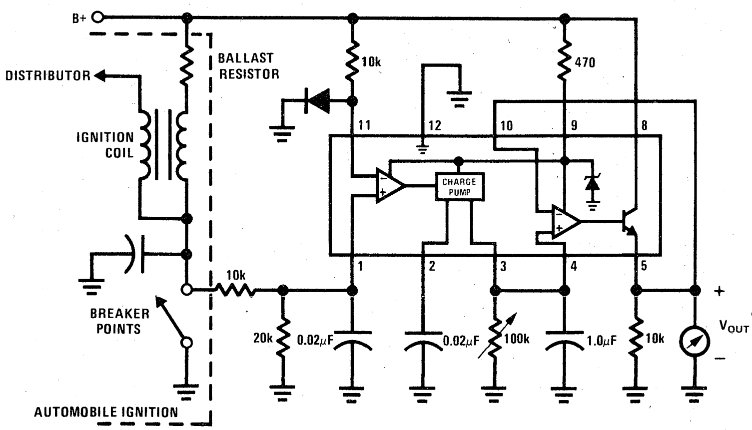


typical applications (con't)

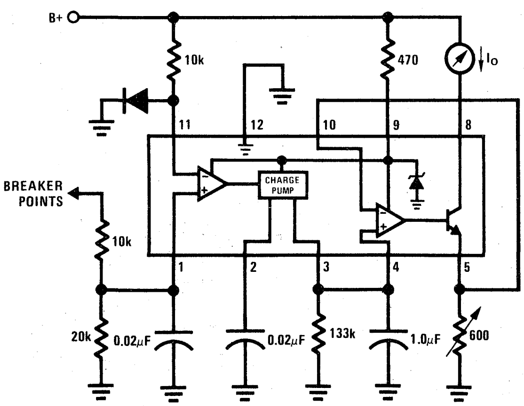
Breaker Point Dwell Meter



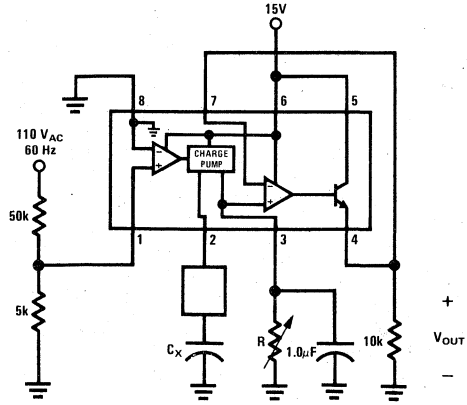
Voltage Driven Meter Indicating Engine RPM
V_O = 6V @ 400 Hz or 6000 ERPM (8 Cylinder Engine)



Current Driven Meter Indicating Engine RPM
I_O = 10 mA @ 300 Hz or 6000 ERPM (6 Cylinder Engine)



Capacitance Meter
V_{OUT} = 1–10V for C_X = 0.01 to 0.1 mFd
(R = 111k)



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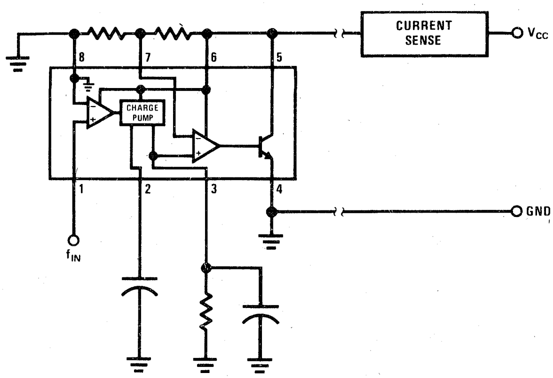
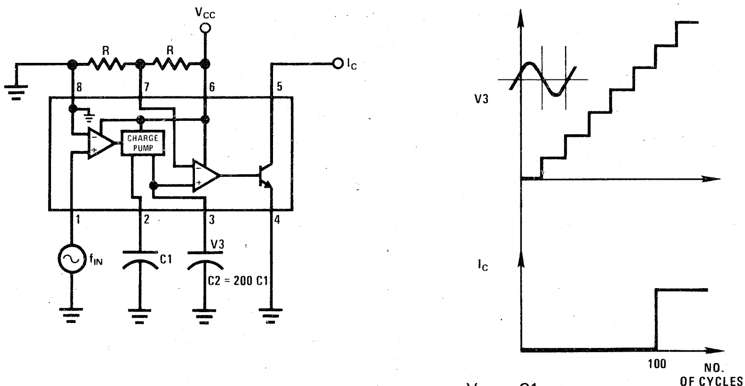
typical applications (con't)

Two-Wire Remote Speed Switch



100 Cycle Delay Switch



V3 steps up in voltage by the amount $\frac{V_{CC} \times C1}{C2}$

for each complete input cycle (2 zero crossings)

Example:

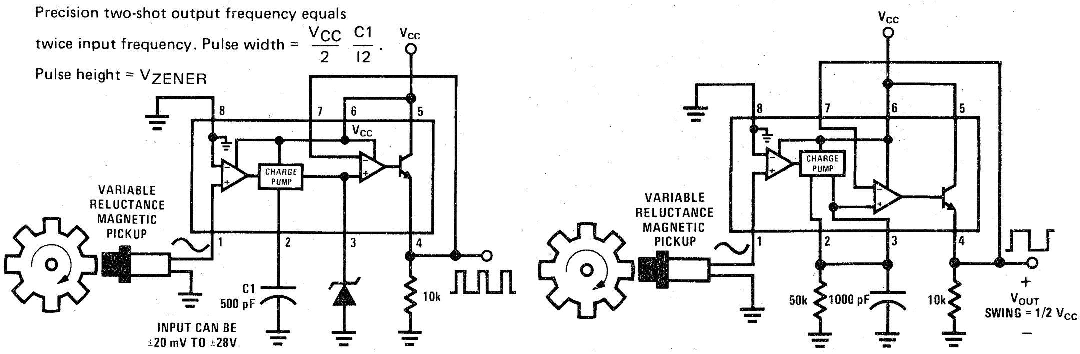
If C2 = 200 C1 after 100 consecutive input cycles.

$V3 = 1/2\ V_{CC}$

Variable Reluctance Magnetic Pickup Buffer Circuits

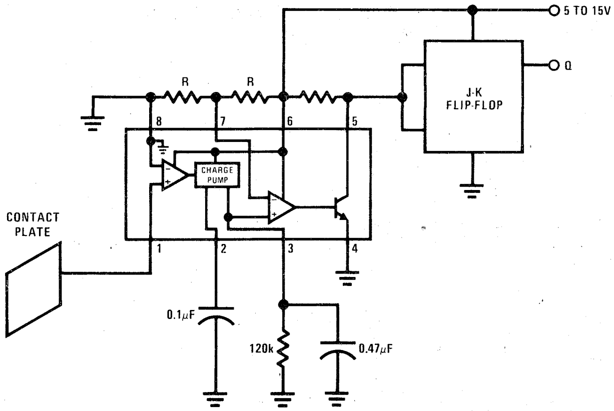
Precision two-shot output frequency equals twice input frequency. Pulse width = $\frac{V_{CC}}{2} \cdot \frac{C1}{I2}$.

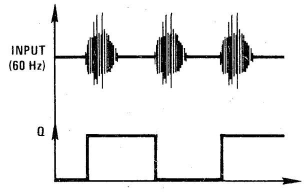
Pulse height = V_{ZENER}



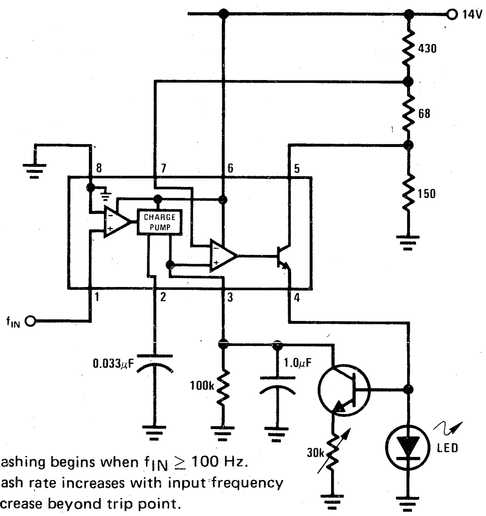
typical applications (con't)

Finger Touch or Contact Switch



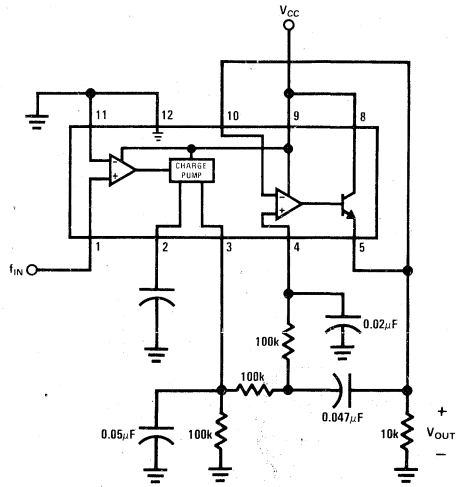


Flashing LED Indicates Overspeed



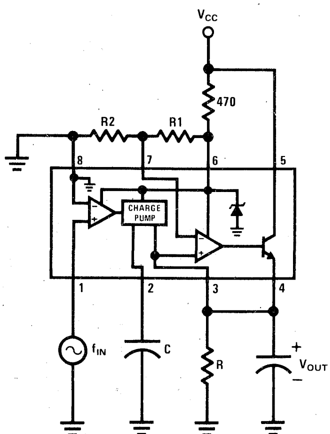
Flashing begins when $f_{IN} \geq 100$ Hz.
Flash rate increases with input frequency increase beyond trip point.

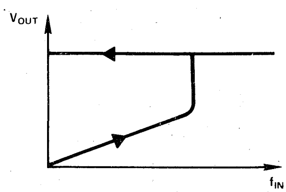
Frequency to Voltage Converter with 2 Pole Butterworth Filter to Reduce Ripple



f_{POLE} (Hz) = 52 Hz

Overspeed Latch





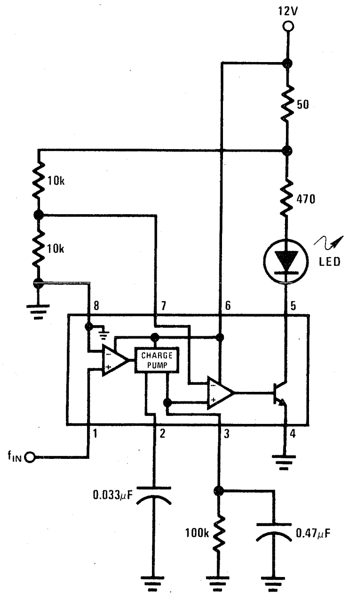
Output latches when

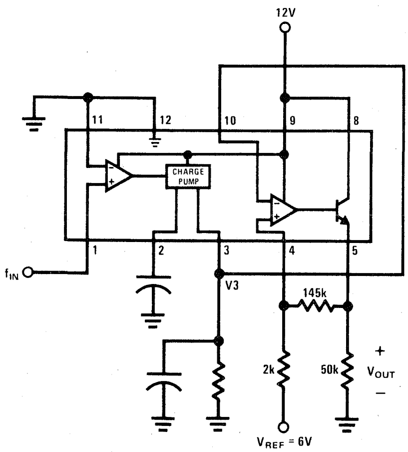
$$f_{IN} = \frac{R2}{R1 + R2} \cdot \frac{1}{RC}.$$

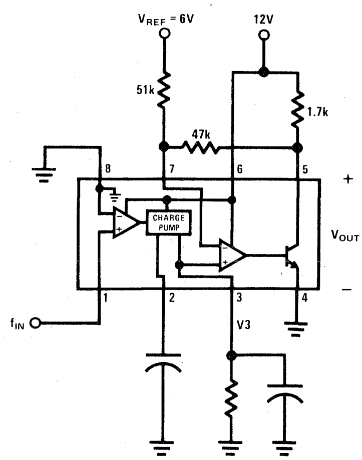
Reset by removing V_{CC}.

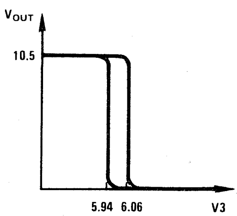
typical applications (con't)

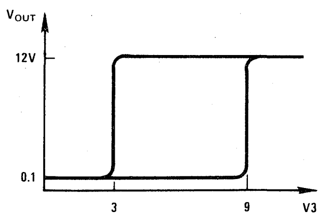
Some Frequency Switch Applications May Require Hysteresis in the Comparator Function Which Can Be Implemented in Several Ways:





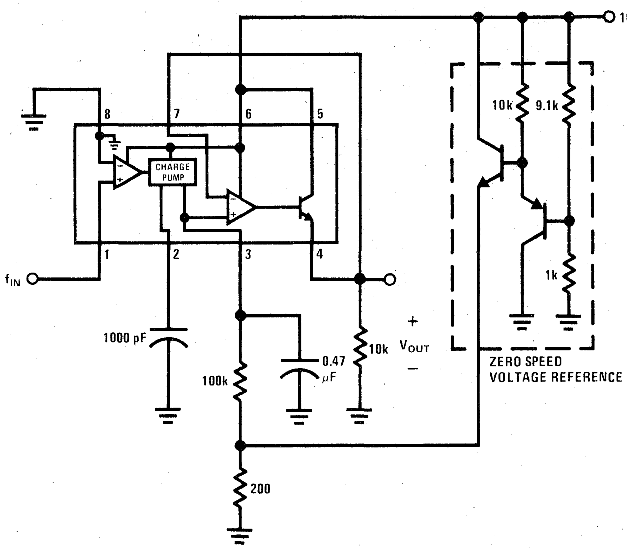


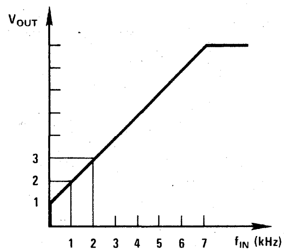




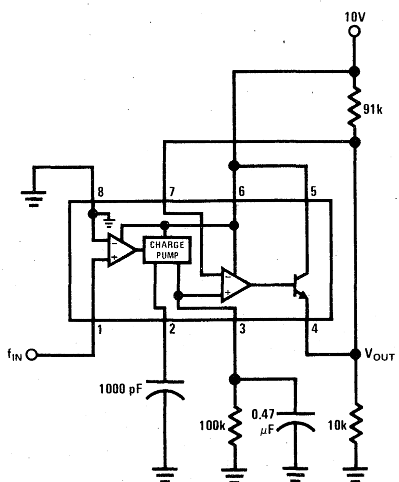
typical applications (con't)

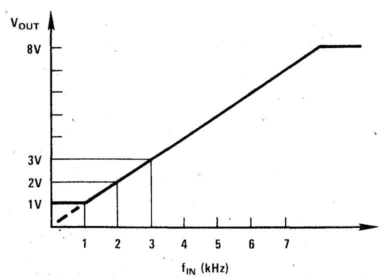
Changing the Output Voltage for an Input Frequency of Zero





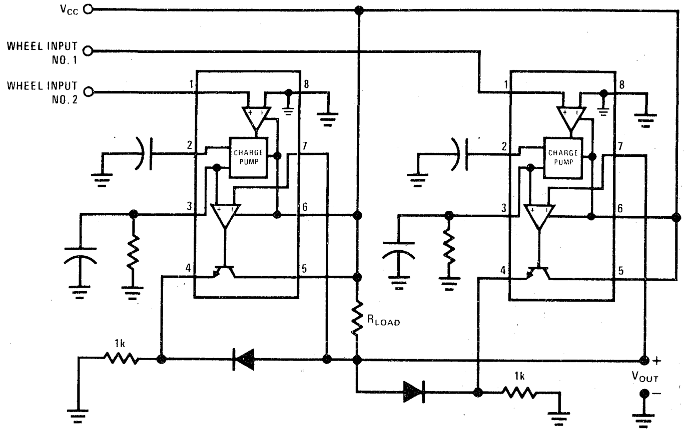
Changing Tachometer Gain Curve
or Clamping the Minimum Output Voltage

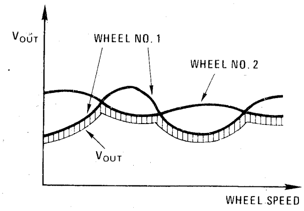




anti-skid circuit functions

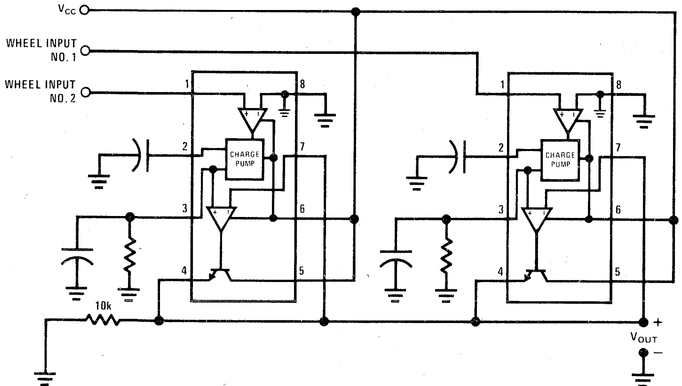
"Select-Low" Circuit

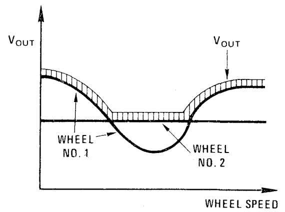




V_{OUT} is proportional to the lower of the two input wheel speeds.

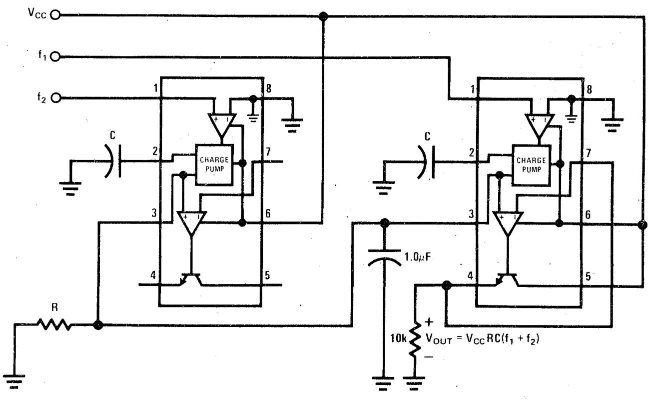
"Select-High" Circuit



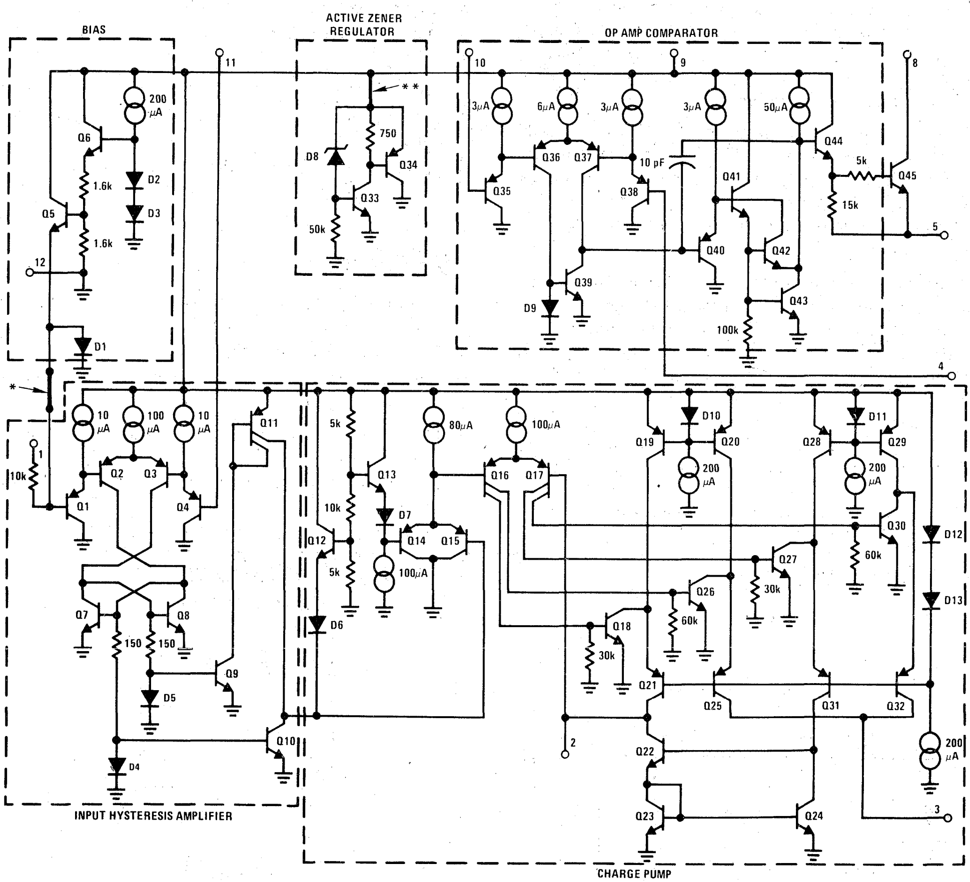


V_{OUT} is proportional to the higher of the two input wheel speeds.

"Select-Average" Circuit



equivalent schematic diagram



* **Note:** This connection made on LM2907-8 and LM2917-8 only.

* * **Note:** This connection made on LM2917 and LM2917-8 only.

Industrial/Automotive/Functional Blocks

LM3909 LED flasher/oscillator

general description

The LM3909 is a monolithic oscillator specifically designed to flash Light Emitting Diodes. By using the timing capacitor for voltage boost, it delivers pulses of 2 or more volts to the LED while operating on a supply of 1.5V or less. The circuit is inherently self-starting, and requires addition of only a battery and capacitor to function as a LED flasher.

Packaged in an 8-lead plastic mini-DIP, the LM3909 will operate over the extended consumer temperature range of −25°C to +70°C. It has been optimized for low power drain and operation from weak batteries so that continuous operation life exceeds that expected from battery rating.

Application is made simple by inclusion of internal timing resistors and an internal LED current limit resistor. As shown in the first two application circuits, the timing resistors supplied are optimized for nominal flashing rates and minimum power drain at 1.5V and 3V.

Timing capacitors will generally be of the electrolytic type, and a small 3V rated part will be suitable for any LED flasher using a supply up to 6V. However, when picking flash rates, it should be remembered that some electrolytics have very broad capacitance tolerances, for example −20% to +100%.

features

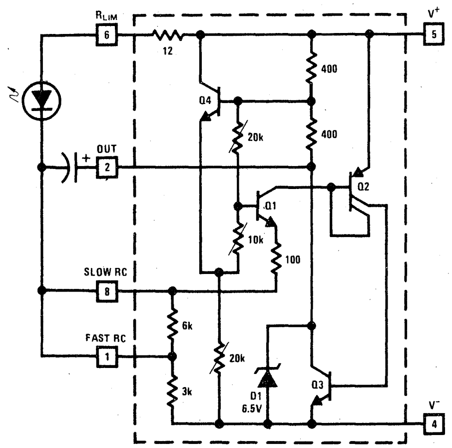
- Operation over one year from one C size flashlight cell
- Bright, high current LED pulse
- Minimum external parts
- Low cost
- Low voltage operation, from just over 1V to 5V
- Low current drain, averages under 0.5 mA during battery life
- Powerful; as an oscillator directly drives an 8Ω speaker
- Wide temperature range

applications

- Finding flashlights in the dark, or locating boat mooring floats
- Sales and advertising gimmicks
- Emergency locators, for instance on fire extinguishers
- Toys and novelties
- Electronic applications such as trigger and sawtooth generators
- Siren for toy fire engine, (combined oscillator, speaker driver)
- Warning indicators powered by 1.4 to 200V

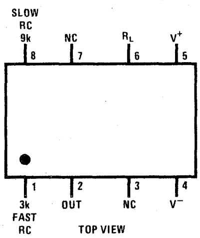
schematic diagram

Typical 1.5V Flasher



connection diagram

Dual-In-Line Package

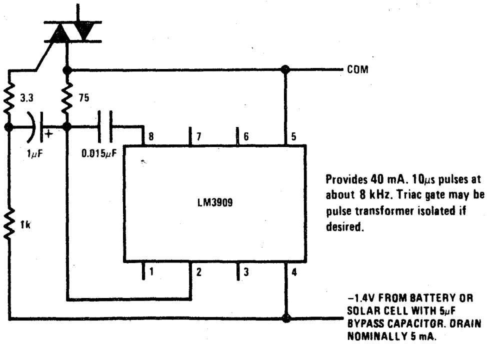


Order Number LM3909N
See Package 20

typical application

(See applications notes on page 2.)

Triac Trigger



absolute maximum ratings

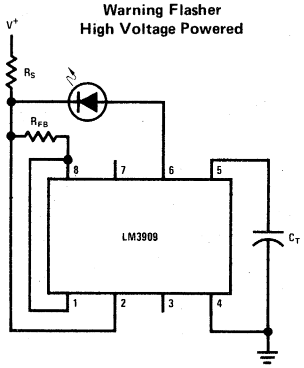
Power Dissipation	500 mW
V^+ Voltage	6.4V
Operating Temperature Range	–25°C to +70°C

electrical characteristics

PARAMETER	CONDITIONS (Applications Note 3)	MIN	TYP	MAX	UNITS
Supply Voltage	(In Oscillation)	1.15		6.0	V
Operating Current			0.55	0.75	mA
Flash Frequency	300μF, 5% Capacitor	0.65	1.0	1.3	Hz
High Flash Frequency	0.30μF, 5% Capacitor		1.1		kHz
Compatible LED Forward Drop	1 mA Forward Current	1.35		2.1	V
Peak LED Current	350μF Capacitor		45		mA
Pulse Width	350μF Capacitors at 1/2 Amplitude		6.0		ms

additional typical applications (See applications notes below.)

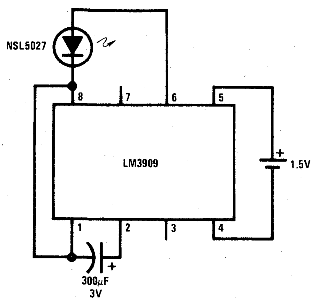
Warning Flasher
High Voltage Powered



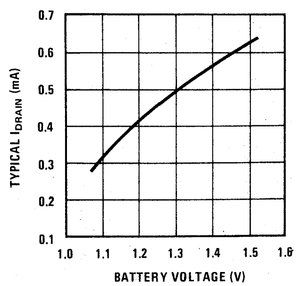
Typical Operating Conditions

V^+	NOMINAL FLASH Hz	C_T	R_S	R_{FB}	V^+_{RANGE}
6V	2	400μF	1k	1.5k	5–25V
15V	2	180μF	3.9k	1k	13–50V
100V	1.7	180μF	43k 1W	1k	85–200V

1.5V Flasher



Note: Nominal flash rate: 1 Hz.



Estimated Battery Life
(Continuous 1.5V Flasher Operation)

SIZE CELL	TYPE	
	STANDARD	ALKALINE
AA	3 months	6 months
C	7 months	15 months
D	1.3 years	2.6 years

Note: Estimates are made from our tests and manufacturers data. Conditions are fresh batteries and room temperature. Clad or "leak-proof" batteries are recommended for any application of five months or more. Nickel Cadmium cells are not recommended.

APPLICATIONS NOTES

Note 1: All capacitors shown are electrolytic unless marked otherwise.

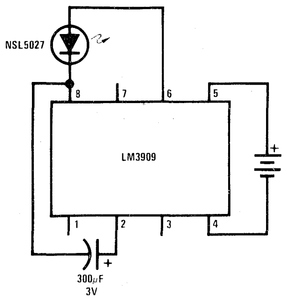
Note 2: Flash rates and frequencies assume a ±5% capacitor tolerance. Electrolytics may vary –20% to +100% of their stated value.

Note 3: Unless noted, measurements above are made with a 1.4V supply, a 25°C ambient temperature, and a LED with a forward drop of 1.5V to 1.7V at 1 mA forward current.

Note 4: Occasionally a flasher circuit will fail to oscillate due to a LED defect that may be missed because it only reduces light output 10% or so. Such LEDs can be identified by a large increase in conduction between 0.9V and 1.2V.

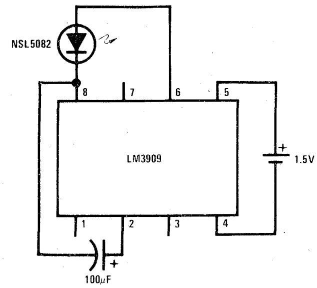
typical applications (con't) (See applications notes on page 9-81)

3V Flasher



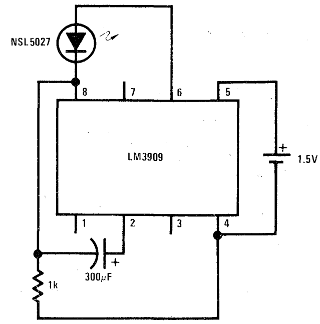
Note: Nominal flash rate: 1 Hz. Average I_{DRAIN} = 0.77 mA.

Minimum Power at 1.5V



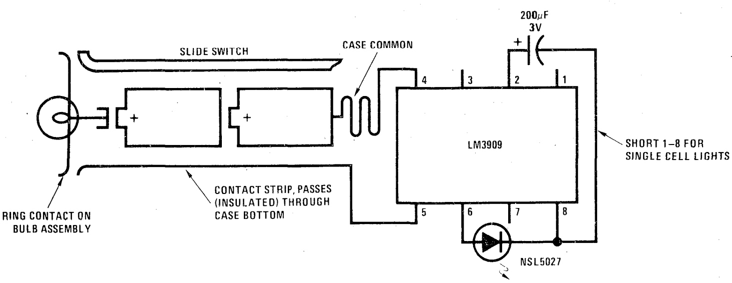
Note: Nominal flash rate: 1.1 Hz. Average I_{DRAIN} = 0.32 mA.

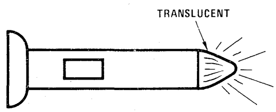
Fast Blinker



Note: Nominal flash rate: 2.6 Hz. Average I_{DRAIN} = 1.2 mA.

Flashlight Finder

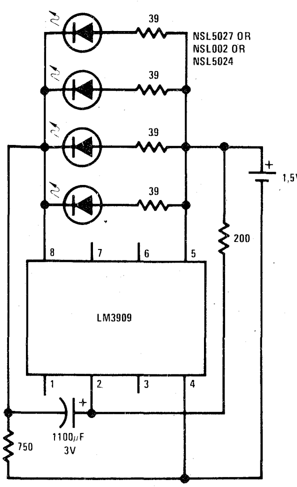




Note: Winking LED inside, locates light in total darkness.

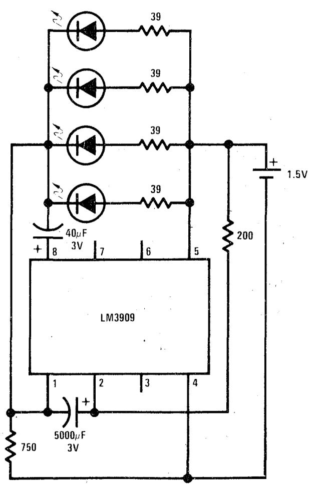
Note: LM3909, capacitor, and LED are installed in a white translucent cap on the flashlight's back end. Only one contact strip (in addition to the case connection) is needed for flasher power. Drawing current through the bulb simplifies wiring and causes negligible loss since bulb resistance cold is typically less than 2Ω.

4 Parallel LEDs



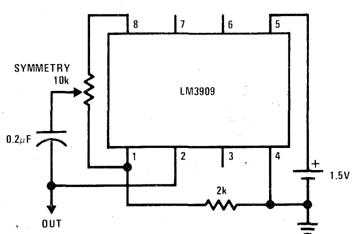
Note: Nominal flash rate: 1.3 Hz. Average I_{DRAIN} = 2 mA.

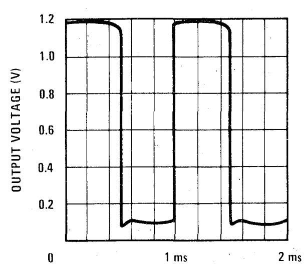
High Efficiency Parallel Circuit



Note. Nominal flash rate: 1.5 Hz. Average I_{DRAIN} = 1.5 mA.

1 kHz Square Wave Oscillator

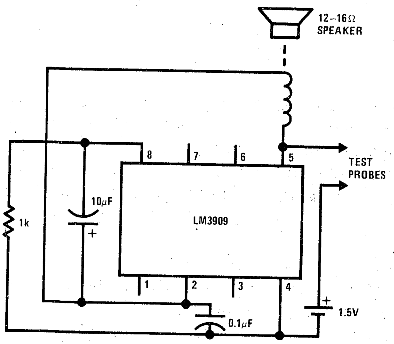




Note: Output voltage through a 10k load to ground.

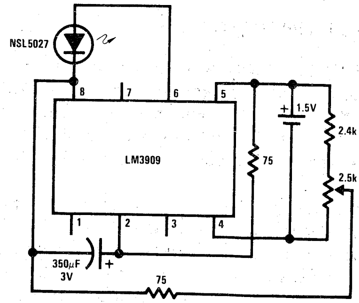
typical applications (con't) (See applications notes on page 9-81)

"Buzz Box" Continuity and Coil Checker



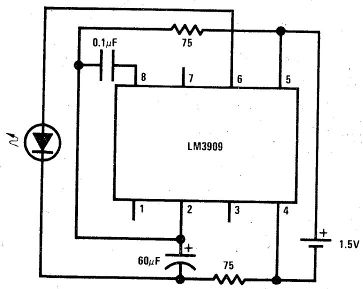
Note: Differences between shorts, coils, and a few ohms of resistance can be heard.

Variable Flasher



Note: Flash rate: 0–20 Hz.

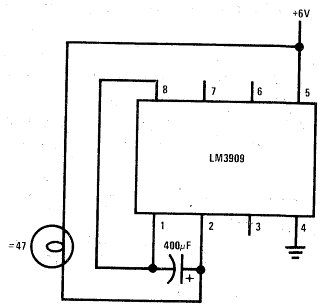
LED Booster



Note: High efficiency, 4 mA drain.

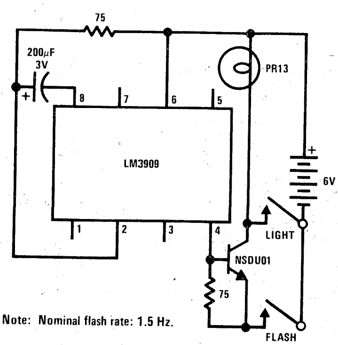
Note: Continuous appearing light obtained by supplying short, high current, pulses (2 kHz) to LEDs with higher than battery voltage available.

Incandescent Bulb Flasher



Note: Flash rate: 1.5 Hz.

Emergency Lantern/Flasher



Note: Nominal flash rate: 1.5 Hz.

Industrial/Automotive/Functional Blocks

LM3911 temperature controller

general description

The LM3911 is a highly accurate temperature measurement and/or control system for use over a −25°C to +85°C temperature range. Fabricated on a single monolithic chip, it includes a temperature sensor, a stable voltage reference and an operational amplifier.

The output voltage of the LM3911 is directly proportional to temperature in degrees Kelvin at 10 mV/°K. Using the internal op amp with external resistors any temperature scale factor is easily obtained. By connecting the op amp as a comparator, the output will switch as the temperature transverses the set-point making the device useful as an on-off temperature controller.

An active shunt regulator is connected across the power leads of the LM3911 to provide a stable 6.8V voltage reference for the sensing system. This allows the use of any power supply voltage with suitable external resistors.

The input bias current is low and relatively constant with temperature, ensuring high accuracy when high source impedance is used. Further, the output collector can be returned to a voltage higher than 6.8V allowing the LM3911 to drive lamps and relays up to a 35V supply.

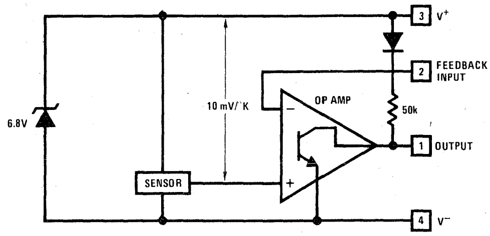
The LM3911 uses the difference in emitter-base voltage of transistors operating at different current densities as the basic temperature sensitive element. Since this output depends only on transistor matching the same reliability and stability as present op amps can be expected.

The LM3911 is available in three package styles—a metal can 4-lead TO-5, a metal can TO-46 and an 8-lead epoxy mini-DIP. In the epoxy package all electrical connections are made on one side of the device allowing the other 4 leads to be used for attaching the LM3911 to the temperature source. The LM3911 is rated for operation over a −25°C to +85°C temperature range.

features

- Uncalibrated accuracy ±10°C
- Internal op amp with frequency compensation
- Linear output of 10 mV/°K (10 mV/°C)
- Can be calibrated in degrees Kelvin, Celsius or Fahrenheit
- Output can drive loads up to 35V
- Internal stable voltage reference
- Low cost

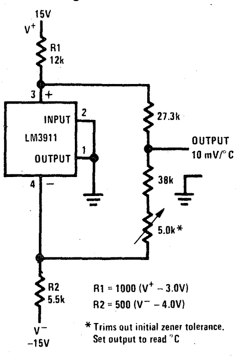
block diagram



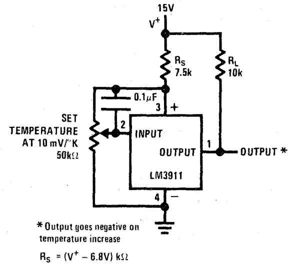
Note: Pin numbers refer to metal can.

typical applications

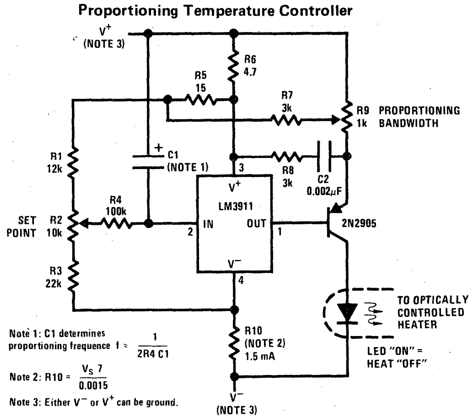
Ground Referred Centigrade Thermometer



Basic Temperature Controller



Proportioning Temperature Controller



absolute maximum ratings

Supply Current (Externally Set)	10 mA
Output Collector Voltage, V^{++}	36V
Feedback Input Voltage Range	0V to +7.0V
Output Short Circuit Duration	Indefinite
Operating Temperature Range	−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	MIN	TYP	MAX	UNITS
SENSOR					
Output Voltage	T_A = −25°C, (Note 2)	2.36	2.48	2.60	V
Output Voltage	T_A = 25°C, (Note 2)	2.88	2.98	3.08	V
Output Voltage	T_A = 85°C, (Note 2)	3.46	3.58	3.70	V
Linearity	ΔT = 100°C		0.5	2	%
Long-Term Stability			0.3		%
Repeatability			0.3		%
VOLTAGE REFERENCE					
Reverse Breakdown Voltage	1 mA $\leq I_Z \leq$ 5 mA	6.55	6.85	7.25	V
Reverse Breakdown Voltage Change With Current	1 mA $\leq I_Z \leq$ 5 mA		10	35	mV
Temperature Stability			20	85	mV
Dynamic Impedance	I_Z = 1 mA		3.0		Ω
RMS Noise Voltage	10 Hz ≤ f ≤ 10 kHz		30		μV
Long Term Stability	T_A = +85°C		6.0		mV
OP AMP					
Input Bias Current	T_A = +25°C		35	150	nA
Input Bias Current			45	250	nA
Voltage Gain	R_L = 36k, V^{++} = 36V	2500	15000		V/V
Output Leakage Current	T_A = 25°C (Note 3)		0.2	2	μA
Output Leakage Current	(Note 3)		1.0	8	μA
Output Source Current	$V_{OUT} \leq 3.70$	10			μA
Output Sink Current	1V $\leq V_{OUT} \leq$ 36V	2.0			mA

Note 1: These specifications apply for $-25°C \leq T_A \leq +85°C$ and $0.9 mA \leq I_{SUPPLY} \leq 1.1 mA$ unless otherwise specified.

Note 2: The output voltage applies to the basic thermometer configuration with the output and input terminals shorted and a load resistance of ≥ 1.0 MΩ. This is the feedback sense voltage and includes errors in both the sensor and op amp. This voltage is specified for the sensor in a rapidly stirred oil bath. The output is referred to V^+.

Note 3: The output leakage current is specified with ≥ 100 mV overdrive. Since this voltage changes with temperature, the voltage drive for turn-off changes and is defined as V_{OUT} (with output and input shorted) −100 mV. This specification applies for V_{OUT} = 36V.

application hints

Although the LM3911 is designed to be totally trouble-free, certain precautions should be taken to insure the best possible performance.

As with any temperature sensor, internal power dissipation will raise the sensor's temperature above ambient. Nominal suggested operating current for the shunt regulator is 1.0 mA and causes 7.0 mW of power dissipation. In free, still, air this raises the package temperature by about 1.2°K. Although the regulator will operate at higher reverse currents and the output will drive loads up to 5.0 mA, these higher currents will raise the sensor temperature to about 19°K above ambient—degrading accuracy. Therefore, the sensor should be operated at the lowest possible power level.

With moving air, liquid or surface temperature sensing, self-heating is not as great a problem since the measured media will conduct the heat from the sensor. Also, there are many small heat sinks designed for transistors which will improve heat transfer to the sensor from the surrounding medium. A small finned clip-on heat sink is quite effective in free-air. It should be mentioned that the LM3911 die is on the base of the package and therefore coupling to the base is preferrable.

The internal reference regulator provides a temperature stable voltage for offsetting the output or setting a comparison point in temperature controllers. However, since this reference is at the same temperature as the sensor temperature changes will also cause reference drift. For application where maximum accuracy is needed an external reference should be used. Of course, for fixed temperature controllers the internal reference is adequate.

typical performance characteristics

Temperature Conversion

$T_{CENTIGRADE} = T_C$

$T_{FAHRENHEIT} = T_F$

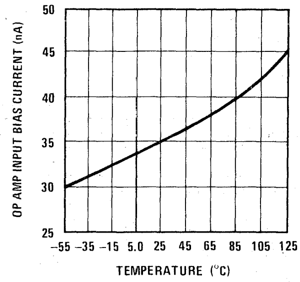
$T_{KELVIN} = T_K$

$T_K = T_C + 273$

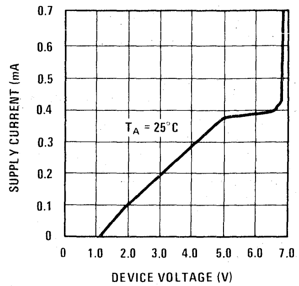
$$T_C = (40 + T_F)\ \frac{5}{9}\ - 40$$

$$T_F = (40 + T_C)\ \frac{9}{5}\ - 40$$

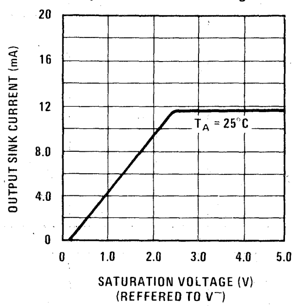
Op Amp Input Current



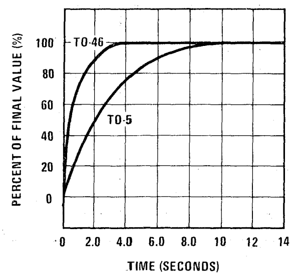
Power Supply Current



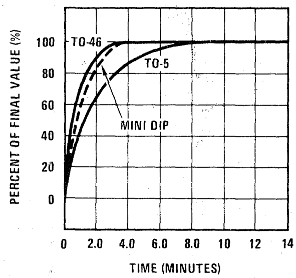
Output Saturation Voltage



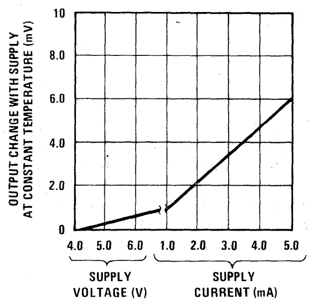
Thermal Time Constant in Stirred Oil Bath



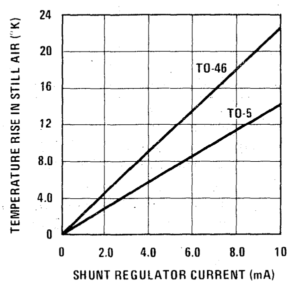
Thermal Time Constant in Still Air



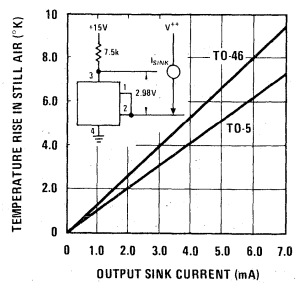
Supply Sensitivity



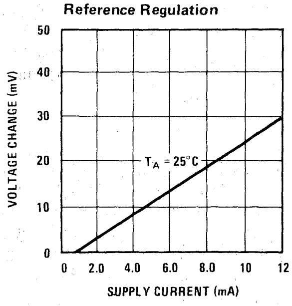
Device Temperature Rise



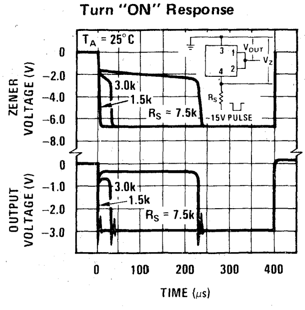
Device Temperature Rise



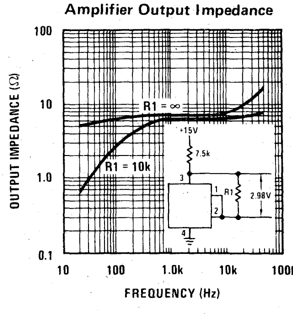
Reference Regulation



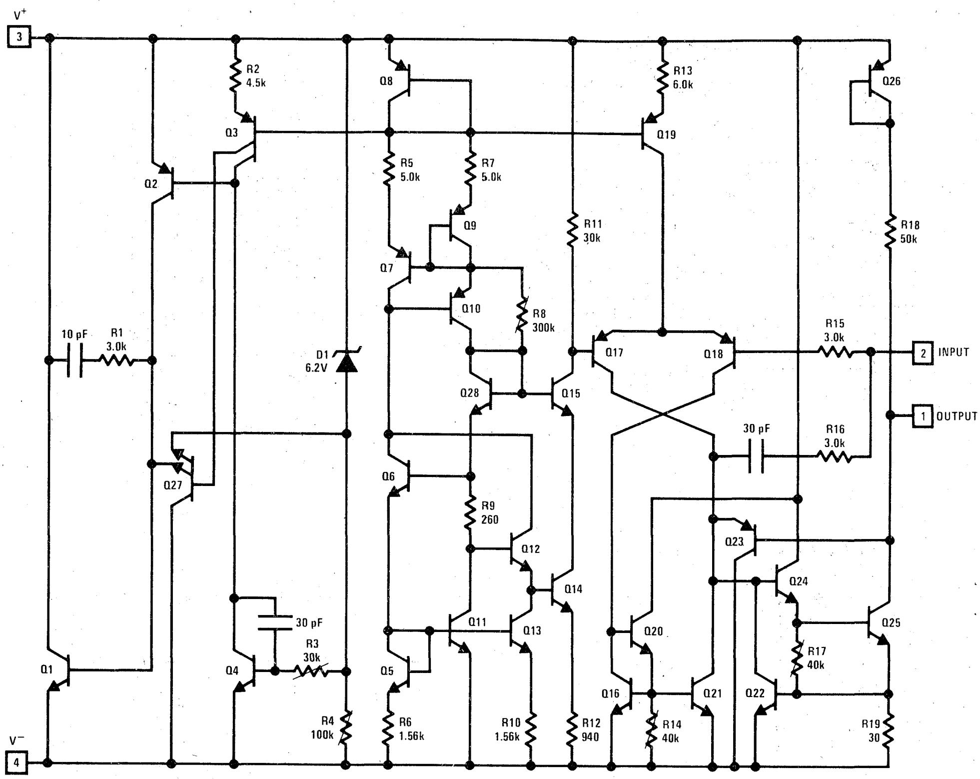
Turn "ON" Response



Amplifier Output Impedance

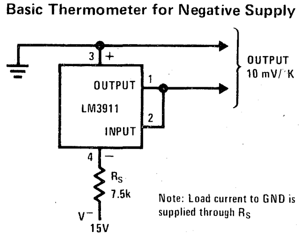


schematic diagram



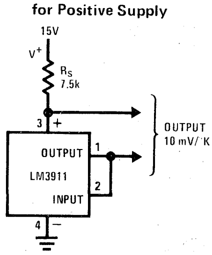
typical applications (con't)

Basic Thermometer for Negative Supply



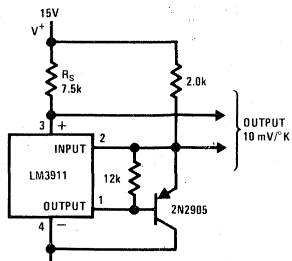
$R_S = (V^- - 6.8V) \times 10^3 \Omega$

Basic Thermometer for Positive Supply



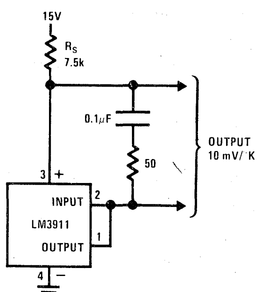
$R_S = (V^- - 6.8V) \times 10^3 \Omega$

Increasing Gain and Output Drive

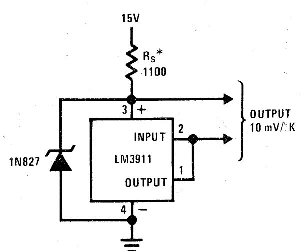


$R_S = (V^+ - 6.8V) \times 10^3 \Omega$

External Frequency Compensation for Greater Stability when Driving Capacitive Loads

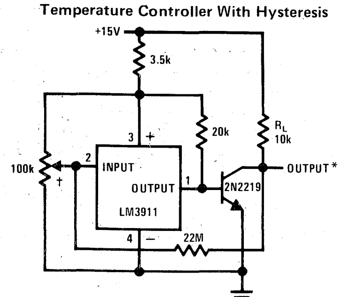


Operating With External Zener for Lower Power Dissipation and Ambient Reference



* Depends on Zener current.

Temperature Controller With Hysteresis

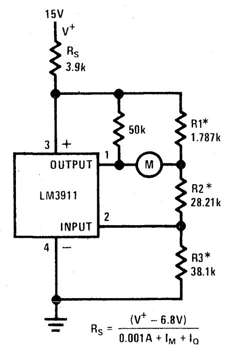


* Output goes positive on temperature increase

†Set temperature

typical applications (con't)

Thermometer With Meter Output



$$R_S = \frac{(V^+ - 6.8V)}{0.001A + I_M + I_Q}$$

$$R1^* = \frac{(V_Z)(10\,mV)(\Delta T)}{I_M (V_Z - 0.01\,T_O)}$$

$$R2 = \frac{0.01\,T_O - I_Q\,R1}{I_Q}$$

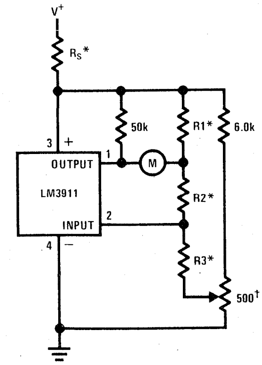
$$R3 = \frac{V_Z}{I_Q} - R1 - R2$$

$$\left(I_Q \le \frac{2V}{R1}\right)$$

V_Z = Shunt regulator voltage (use 6.85)
ΔT = Meter temperature span (°K)
I_M = Meter full scale current (A)
T_O = Meter zero temperature (°K)
I_Q = Current through R1, R2, R3 at zero meter current (10μA to 1.0 mA) (A)

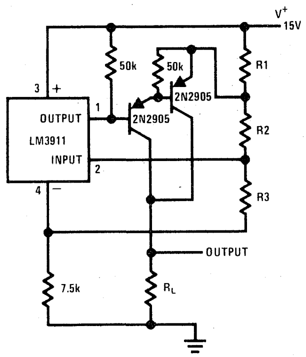
* Values shown for:
$T_O = 300°K$, $\Delta T = 100°K$,
$I_M = 1.0\,mA$, $I_Q = 100\mu A$

Meter Thermometer With Trimmed Output



*Selected as for meter thermometer except T_O should be 5°K more than desired and $I_Q = 100\mu A$
†Calibrates T_O

Ground Referred Thermometer



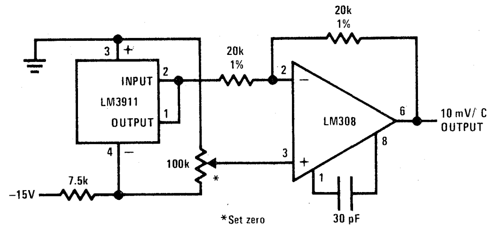
$$R1 = \frac{(V_Z)(10\,mV)(\Delta T)}{\frac{V_O}{R_L}(V_Z - 0.01\,T_O)}$$

$$R2 = \frac{0.01\,T_O - I_Q\,R1}{I_Q}$$

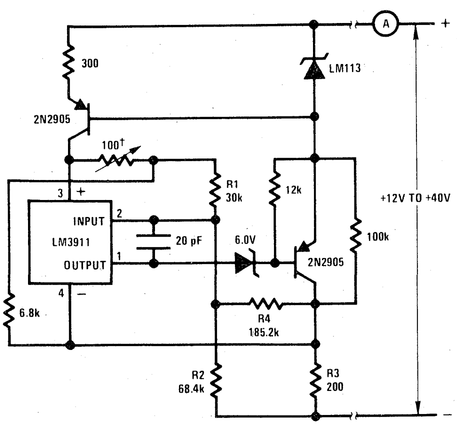
$$R3 = \frac{V_Z}{I_Q} - R1 - R2$$

V_Z = Shunt regulator voltage
ΔT = Temperature span (°K)
T_O = Temperature for zero output (°K)
V_O = Full scale output voltage ≤ 10V
I_Q = Current through R1, R2, R3 at zero output voltage (typically 100μA to 1.0 mA)

Ground Referred Centigrade Thermometer



Two Terminal Temperature to Current Transducer*



$$R2\,(\Omega) = \frac{\left(V_Z - 0.01\,T_L\right)\left(I_H - \frac{0.01\,T_H}{R1}\right) + \left(V_Z - 0.01\,T_H\right)\left(\frac{0.01\,T_L}{R1} - I_L\right)}{\frac{0.01}{R1\,R3}\left[T_H\,(V_Z - 0.01\,T_L) - T_L\,(V_Z - 0.01\,T_H)\right]}$$

$$R3\,(\Omega) \geqq \frac{V_Z\left(\frac{T_H}{T_L} - 1\right)}{I_H - \frac{I_L\,T_H}{T_L}}$$

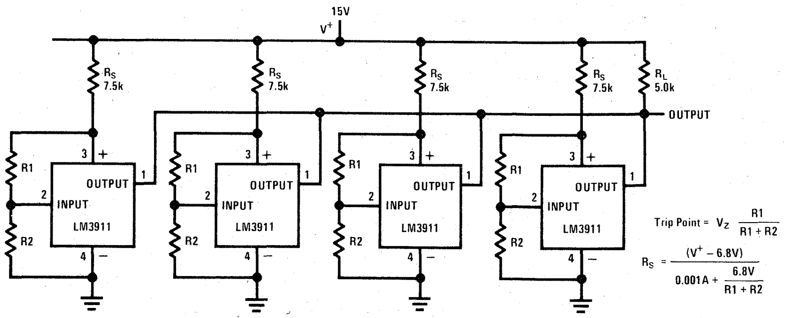
$$\frac{1}{R4} = \frac{1}{(V_Z - 0.01\,T_L)(R2)}\left[\frac{(R2)(0.01\,T_L)}{R1} + \frac{\left(\frac{V_Z - 0.01\,T_L}{R2} - I_L\right)}{\frac{1}{R2} + \frac{1}{R3}}\right] - \frac{1}{R2}$$

T_L = Temperature for I_L (°K)
T_H = Temperature for I_H (°K)
V_Z = Zener voltage (V)
I_L = Low temperature output current (A)
I_H = High temperature output current (A)

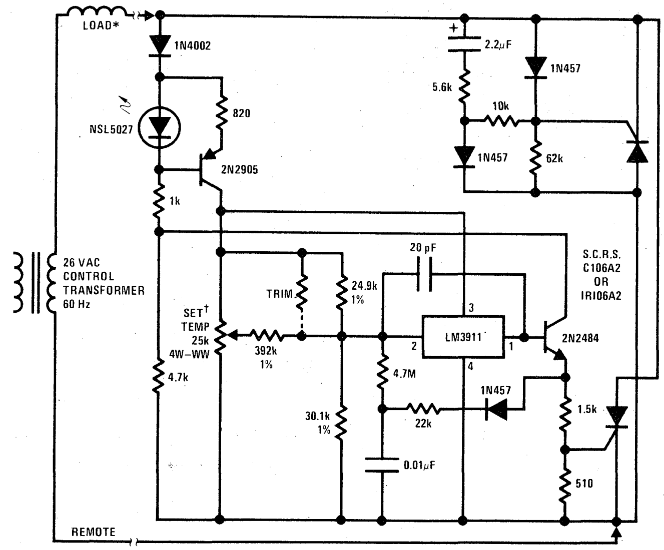
*Values shown for I_{OUT} = 1 mA to 10 mA for 10°F to 100°F
†Set temperature

typical applications (con't)

Over Temperature Detectors With Common Output



Two-Wire Remote A.C. Electronic Thermostat (Gas or Oil Furnace Control)

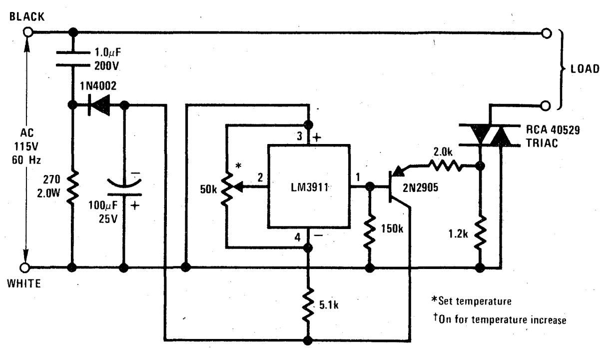


*Solenoid or 6–15W heater

†Pot will provide about a 50°F to 90°F setting range. The trim resistor (100k) is selected to bring 70°F near the middle of the pot rotation.

SCR heating, by proper positioning, can preheat the sensor giving control anticipation as is presently used in many home thermostats.

Temperature Controller Driving TRIAC

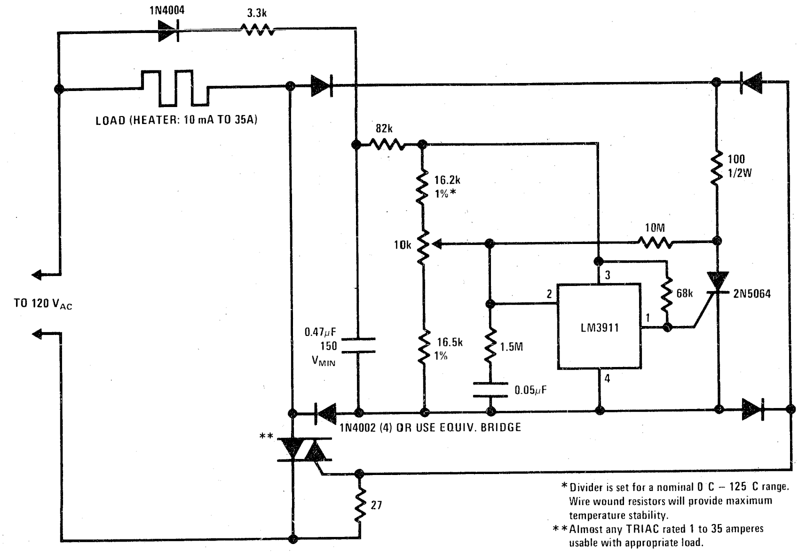


*Set temperature

†On for temperature increase

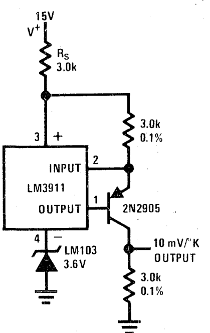
typical applications (con't)

Three-Wire Electronic Thermostat



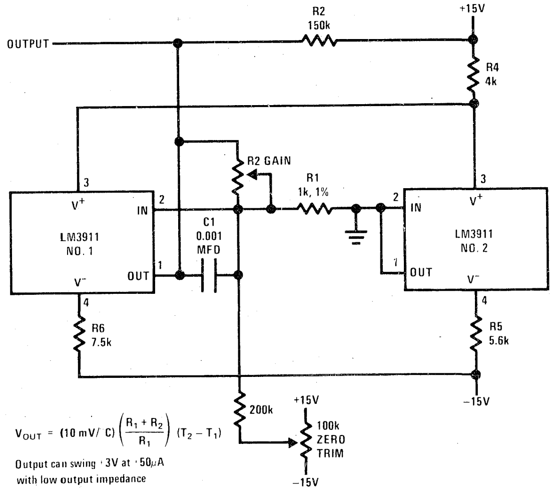
*Divider is set for a nominal 0 C – 125 C range. Wire wound resistors will provide maximum temperature stability.
**Almost any TRIAC rated 1 to 35 amperes usable with appropriate load.

Kelvin Thermometer With Ground Referred Output



$$R_S = \frac{V_S^+ - 6.8\text{V} \times 10^3\Omega}{2}$$

Differential Thermometer

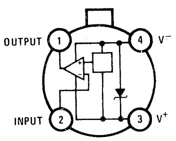


$$V_{OUT} = (10\text{ mV/ C})\left(\frac{R_1 + R_2}{R_1}\right)(T_2 - T_1)$$

Output can swing ±3V at ±50µA with low output impedance

connection diagrams

Metal Can Package

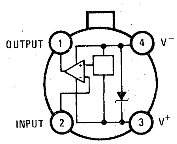


TOP VIEW

Note: Pin 4 connected to case.

Order Number LM3911H-05
See Package 9B

Metal Can Package

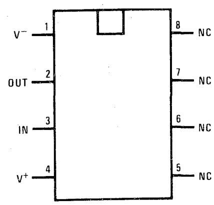


TOP VIEW

Note: Pin 4 connected to case.

Order Number LM3911H-46
See Package 9C

Dual-In-Line Package



TOP VIEW

Order Number LM3911N
See Package 20

Industrial/Automotive/Functional Blocks

LX5600/LX5600A, LX5700/LX5700A temperature transducers

general description

The LX5600/LX5700 series temperature transducers are highly accurate temperature measurement or control systems for use over a −55°C to +125°C temperature range. Fabricated on a single monolithic chip they include a temperature sensor, stable voltage reference and operational amplifier.

The output of the LX5600/LX5700 is directly proportional to temperature in degrees Kelvin at 10 mV/°K. Using the internal op amp with external resistors any temperature scale factor is easily obtained. By connecting the op amp as a comparator, the output will switch as the temperature transverses the set-point making the device useful as an on-off temperature controller.

An active shunt regulator is connected across the power leads to the LX5600/LX5700 to provide a stable voltage reference. In addition to providing a reference, it regulates the operating voltage to 6.8V. This allows the use of any power supply voltage with suitable external resistors.

The op amp can amplify the 10 mV/°K from the sensor to almost any desired output. The input bias current is low and relatively constant with temperature, ensuring high accuracy when high source impedance is used. Further, the output collector can be returned to a voltage higher than 6.8V allowing the LX5600/LX5700 to drive lamps and relays from a 28V supply.

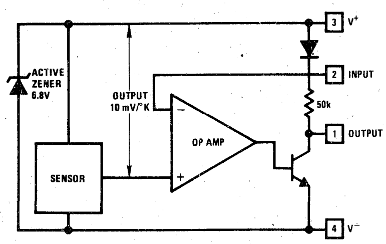
The LX5600 uses the difference in emitter-base voltage of transistors operating at different current densities as the basic temperature sensitive element. Since this output depends only on transistor matching the same reliability and stability as present op amps can be expected.

The LX5600 and LX5600A operate over a −55°C to +125°C range and are available in 4 lead TO-5 package. The LX5700 and LX5700A also operate over the −55°C to +125°C range and are available in the 4 lead TO-46 package.

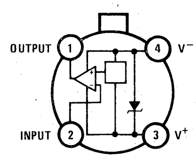
features

- Initial calibration accuracy of ±4°C over −55°C to +125°C
- Internal op amp with frequency compensation
- Linear output of 10 mV/°K (10 mV/°C)
- Directly calibrated in degrees Kelvin
- Output can drive loads up to 35V
- Internal stable voltage reference
- Four lead device—minimizing wiring

block and connection diagrams



Metal Can Package

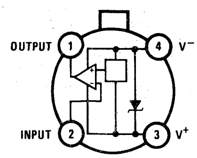


TOP VIEW

NOTE: PIN 4 CONNECTED TO CASE

Order Number LX5600AH or LX5600H
See Package 9B

Metal Can Package



TOP VIEW

NOTE: PIN 4 CONNECTED TO CASE

Order Number LX5700AH or LX5700H
See Package 9C

absolute maximum ratings

Supply Voltage	Internally Regulated	Output Short Circuit Duration	Indefinite
Supply Current (Externally Set)	10 mA	Operating Temperature Range	−55°C to +125°C
Output Collector Voltage	36V	Storage Temperature Range	−65°C to +150°C
Input Voltage Range	0V to +7.0V	Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (Note 1)

PARAMETER	CONDITIONS	LX5600A/LX5700A			LX5600/LX5700			UNITS
		TYP VOLTS	ERROR ±mV	ERROR ± % OF SPAN	TYP VOLTS	ERROR ±mV	ERROR ± % OF SPAN	
Output Voltage (Note 2)	T_A = +25°C	2.98	40	2.22	2.98	80	4.44	
Output Voltage (Note 2)	T_A = −55°C	2.18	40	2.22	2.18	80	4.44	
Output Voltage (Note 2)	T_A = +125°C	3.98	40	2.22	3.98	80	4.44	
Linearity	$\Delta T \leq +180°C$	0.018			0.018			
Long Term Stability	T_A = 125°C	±0.002			±0.002			
Repeatability	T_A = 125°C	±0.002			±0.002			
VOLTAGE REFERENCE		**MIN**	**TYP**	**MAX**	**MIN**	**TYP**	**MAX**	**UNITS**
Reverse Breakdown Voltage	$1\ mA \leq I_z \leq 5\ mA$	6.68	6.85	7.12	6.55	6.85	7.25	V
Reverse Breakdown Voltage Change With Current	$1\ mA \leq I_z \leq 5\ mA$		10	25		10	35	mV
Temperature Stability			20	60		20	85	mV
Dynamic Impedance	I_z = 1 mA		3.0			3.0		Ω
RMS Noise Voltage	$10\ Hz \leq f \leq 10\ kHz$		30			30		µV
Long Term Stability	T_A = +125°C		6.0			6.0		mV
OP AMP								
Input Bias Current	T_A = +25°C		35	75		35	150	nA
Input Bias Current			45	150		45	250	nA
Voltage Gain	R_L = 36k, V^{++} = 36V	2000	15000		1500	15000		V/V
Output Leakage Current	T_A = 25°C (Note 3)		0.2	1.0	2.0	0.2		µA
Output Leakage Current	(Note 3)		1.0	5.0	8.0	1.0		µA
Output Source Current	$V_{OUT} \leq 4.05$	10			10			µA
Output Sink Current	$1V \leq V_{OUT} \leq 36V$	2.0			2.0			mA

Note 1: These specifications apply for $-55°C \leq T_A \leq +125°C$ and $0.9\ mA \leq I_{SUPPLY} \leq 1.1\ mA$ unless otherwise specified.

Note 2: The output voltage applies to the basic thermometer configuration with the output and feedback terminals shorted and a load resistance of ≥ 1.0 MΩ. This is the feedback sense voltage and includes errors in both the sensor and op amp. This voltage is specified for the sensor in a rapidly stirred oil bath.

Note 2: The output leakage current is specified with ≥ 100 mV overdrive. Since this voltage changes with temperature, the voltage drive for turn-off changes and is defined as V_{OUT} (with output and input shorted) −100 mV. This specification applies for V_{OUT} = 36V.

application hints

Although the LX5600/LX5700 were designed to be as trouble-free as possible, certain precautions should be taken to insure the best possible performance.

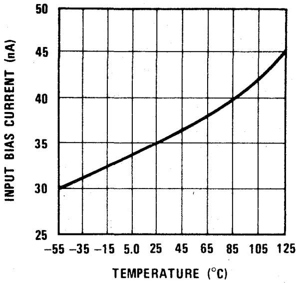
Like any temperature sensor, internal power dissipation will raise the sensor temperature above ambient. Nominal operating current for the shunt regulator is 1.0 mA and causes 7.0 mW of power dissipation. In free, still, air this raises the package temperature by about 1.2°K. Although the regulator will operate at higher reverse currents and the output will drive loads up to 5.0 mA, these higher currents can raise the sensor temperature over 19°K above ambient—degrading accuracy. Therefore, the sensor should be operated at the lowest possible power level.

With moving air, liquid or surface temperature sensing, self heating is not as great a problem since the measured media will conduct the heat from the sensor. Also, there are many small heat sinks designed for transistors which will improve heat transfer to the sensor from the surrounding medium. A small finned clip-on heat sink is quite effective in free-air. It should be mentioned that the LX5600 die is on the base of the package and therefore coupling to the base is preferrable.

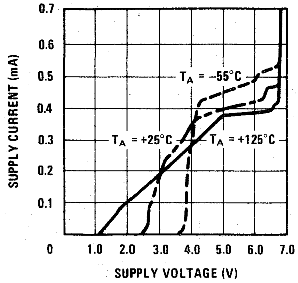
The internal reference regulator provides a temperature stable voltage for offsetting the temperature output or setting a comparison point in temperature controllers. However, since this reference is at the same temperature as the sensor temperature changes will also cause reference drift. For application where maximum accuracy is needed an external reference should be used. Of course, for fixed temperature controllers the internal reference is adequate.

typical performance characteristics

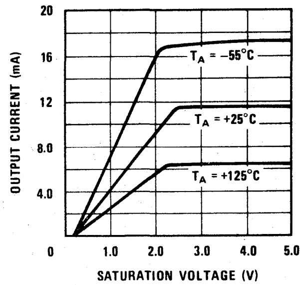
Input Current



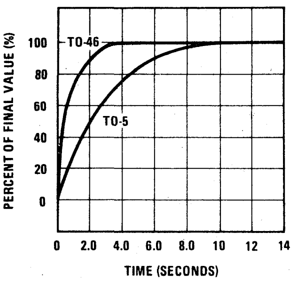
Start-Up



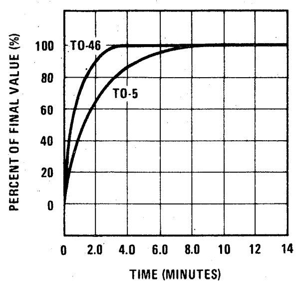
Output Saturation Voltage



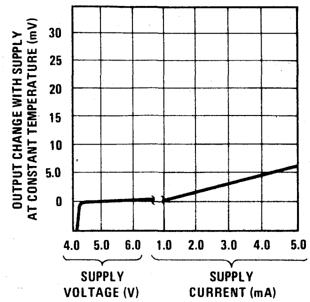
Thermal Time Constant in Stirred Oil Bath



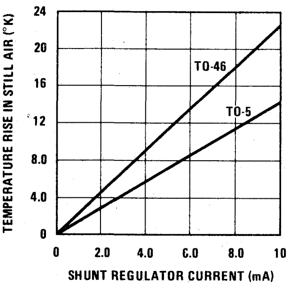
Thermal Time Constant in Still Air



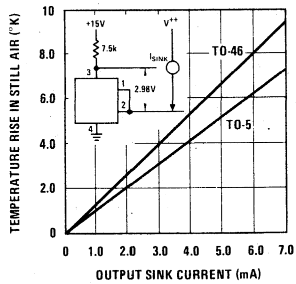
Supply Sensitivity



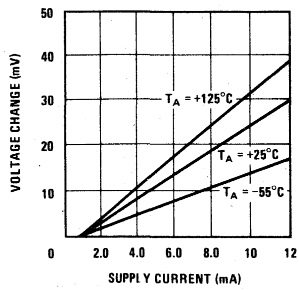
Temperature Rise



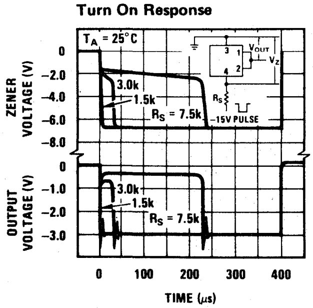
Temperature Rise



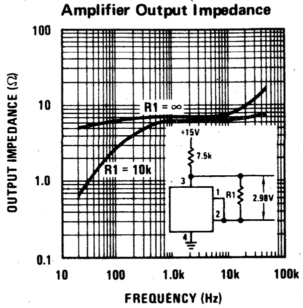
Reference Regulation



Turn On Response



Amplifier Output Impedance



Temperature Conversion

$T_{CENTIGRADE} = T_C$

$T_{FAHRENHEIT} = T_F$

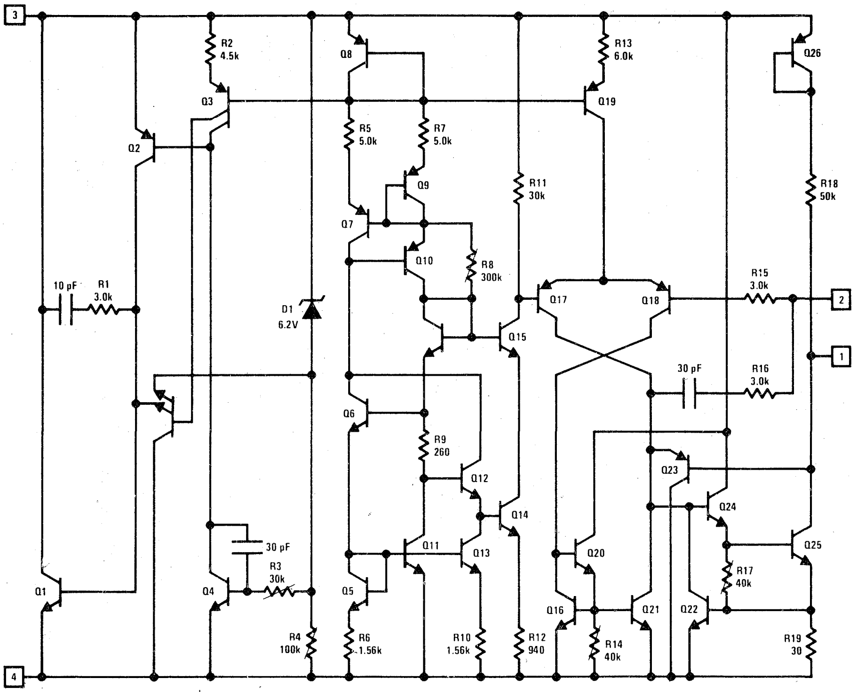
$T_{KELVIN} = T_K$

$T_K = T_C + 273$

$$T_C = (40 + T_F)\ \frac{5}{9} - 40$$

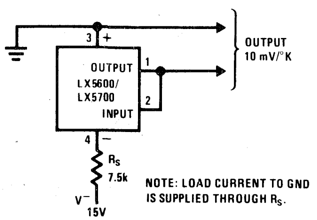
$$T_F = (40 + T_C)\ \frac{9}{5} - 40$$

schematic diagram



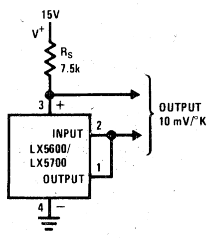
typical applications

Basic Thermometer for Negative Supply



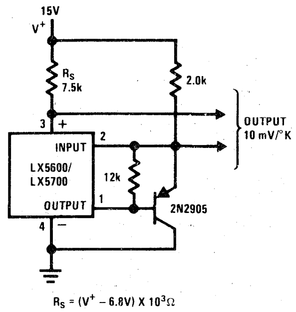
$R_S = (V^- - 6.8V) \times 10^3\Omega$

Basic Thermometer for Positive Supply



$R_S = (V^+ - 6.8V) \times 10^3\Omega$

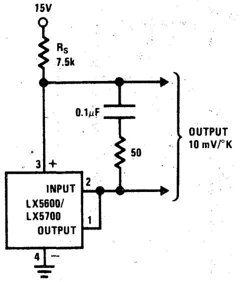
Increasing Gain and Output Drive



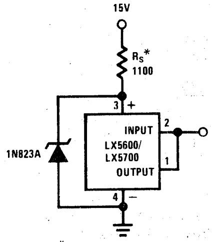
$R_S = (V^+ - 6.8V) \times 10^3\Omega$

typical applications (con't)

External Frequency Compensation for Greater Stability

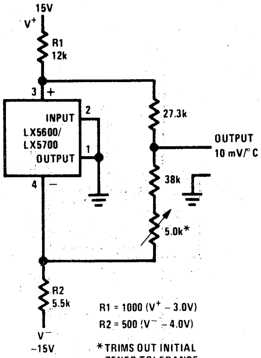


Operating With External Zener for Lower Power Dissipation and Better Reference Stability



*Depends on Zener current.

Ground Referred Centigrade Thermometer

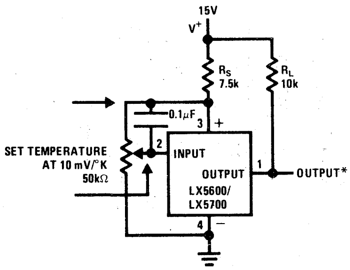


$R1 = 1000\ (V^+ - 3.0V)$

$R2 = 500\ (V^- - 4.0V)$

*TRIMS OUT INITIAL ZENER TOLERANCE. SET OUTPUT TO READ C

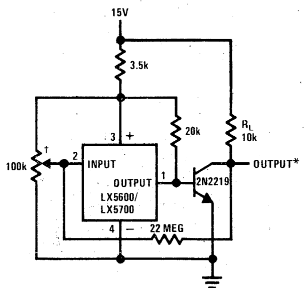
Basic Temperature Controller



*OUTPUT GOES NEGATIVE ON TEMPERATURE INCREASE

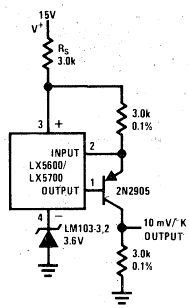
$R_S = (V^+ - 6.8V)\ k\Omega$

Temperature Controller With Hysteresis



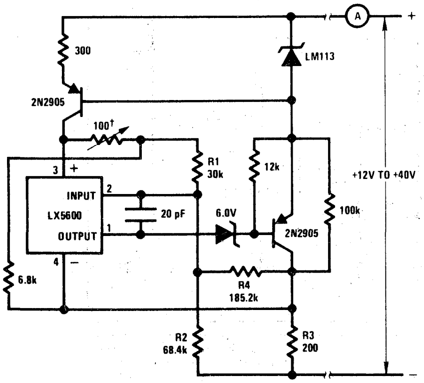
*OUTPUT GOES POSITIVE ON TEMPERATURE INCREASE
†SET TEMPERATURE

Kelvin Thermometer With Ground Referred Output



$$R_S = \frac{V_S^+ - 6.8V \times 10^3\Omega}{2}$$

Two Terminal Temperature to Current Transducer*



$$R2\ (\Omega) = \frac{\left(V_Z - 0.01\ T_L\right)\left(I_H - \frac{0.01\ T_H}{R1}\right) + \left(V_Z - 0.01\ T_H\right)\left(\frac{0.01\ T_L}{R1} - I_L\right)}{\frac{0.01}{R1\ R3}\left[T_H\ (V_Z - 0.01\ T_L) - T_L\ (V_Z - 0.01\ T_H)\right]}$$

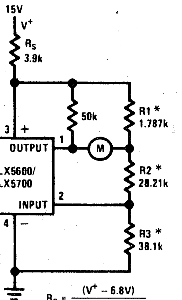
$$R3\ (\Omega) \geq \frac{V_Z\left(\frac{T_H}{T_L} - 1\right)}{I_H - \frac{I_L\ T_H}{T_L}}$$

$$\frac{1}{R4} = \frac{1}{(V_Z - 0.01\ T_L)(R2)}\left[\frac{(R2)(0.01\ T_L)}{R1} + \frac{\left(\frac{V_Z - 0.01\ T_L}{R2} - I_L\right)}{\frac{1}{R2} + \frac{1}{R3}}\right] - \frac{1}{R2}$$

T_L = TEMPERATURE FOR I_L (°K)
T_H = TEMPERATURE FOR I_H (°K)
V_Z = ZENER VOLTAGE (VOLTS)
I_L = LOW TEMPERATURE OUTPUT CURRENT (mA)
I_H = HIGH TEMPERATURE OUTPUT CURRENT (mA)
*VALUES SHOWN FOR I_{OUT} = 1 mA TO 10 mA FOR 10°F TO 100°F
†SET TEMPERATURE

typical applications (con't)

Thermometer With Meter Output



$R_S = \dfrac{(V^+ - 6.8V)}{0.001A + I_M + I_Q}$

* VALUES SHOWN FOR:
T_O = 300°K, ΔT = 100°K,
I_M = 1.0 mA, I_Q = 100μA

$R1^* = \dfrac{(V_Z)\,(10\text{ mV})\,(\Delta T)}{I_M\,(V_Z - 0.01\,T_O)}$

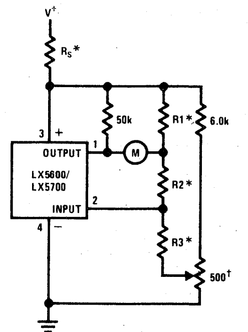
$R2 = \dfrac{0.01\,T_O - I_Q\,R1}{I_Q}$

$R3 = \dfrac{V_Z}{I_Q} - R1 - R2$

$\left(I_Q \le \dfrac{2V}{R1}\right)$

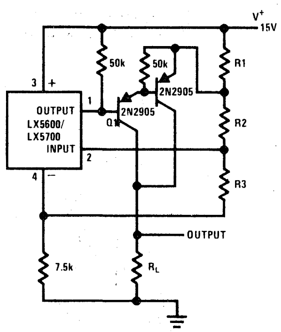
- V_Z = SHUNT REGULATOR VOLTAGE (USE 6.85)
- ΔT = METER TEMPERATURE SPAN (°K)
- I_M = METER FULL SCALE CURRENT (A)
- T_O = METER ZERO TEMPERATURE (°K)
- I_Q = CURRENT THROUGH R1 R2 R3 AT ZERO METER CURRENT (10μA TO 1.0 mA) (A)

Meter Thermometer With Trimmed Output



*SELECTED AS FOR METER THERMOMETER EXCEPT T_O SHOULD BE 5°K MORE THAN DESIRED AND I_Q = 100μA.
†CALIBRATES T_O.

Ground Referred Thermometer



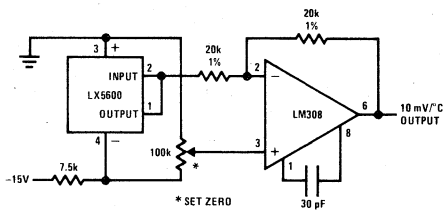
$R1 = \dfrac{(V_Z)(10\text{ mV})(\Delta T)}{\dfrac{V_O}{R_L}\,(V_Z - 0.01\,T_O)}$

$R2 = \dfrac{0.01\,T_O - I_Q\,R1}{I_Q}$

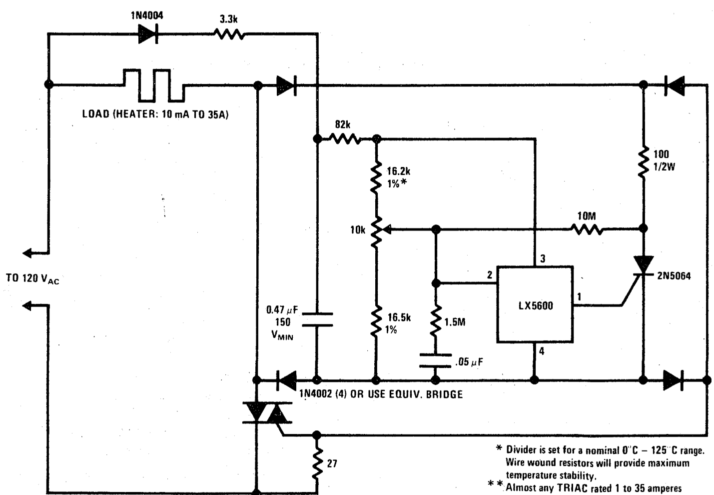
$R3 = \dfrac{V_Z}{I_Q} - R1 - R2$

- V_Z = SHUNT REGULATOR VOLTAGE
- ΔT = TEMPERATURE SPAN (°K)
- T_O = TEMPERATURE FOR ZERO OUTPUT (°K)
- V_O = FULL SCALE OUTPUT VOLTAGE ≤ 10V
- I_Q = CURRENT THROUGH R1, R2, R3, AT ZERO OUTPUT VOLTAGE (TYPICALLY 100μA TO 1.0 mA)

Ground Referred Centigrade Thermometer



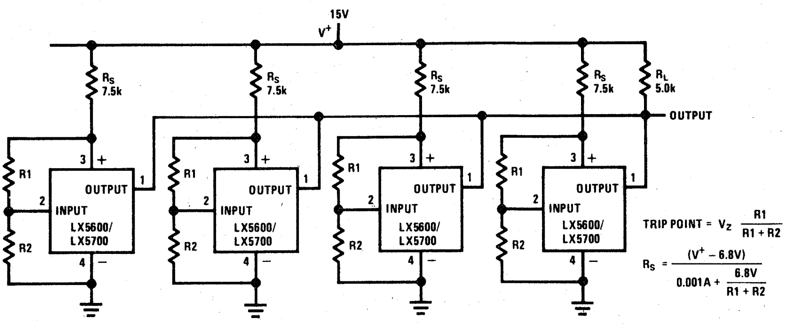
Three Wire Electronic Thermostat



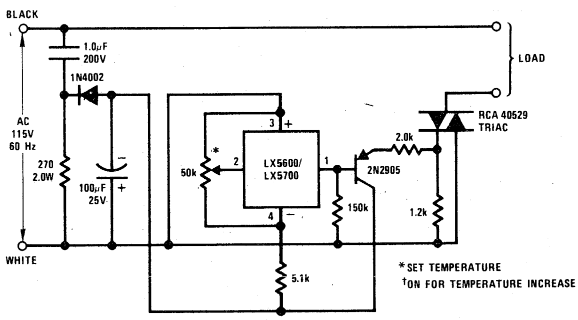
* Divider is set for a nominal 0°C – 125°C range. Wire wound resistors will provide maximum temperature stability.
** Almost any TRIAC rated 1 to 35 amperes usable with appropriate load.

typical applications (con't)

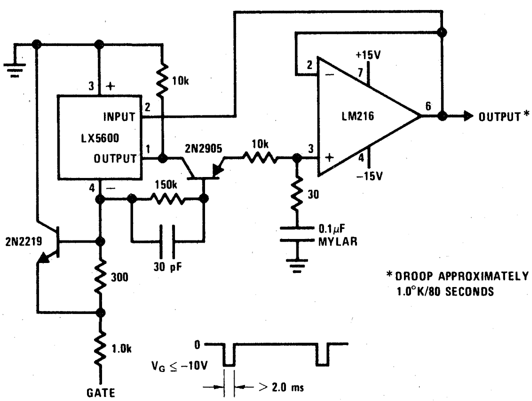
Over Temperature Detectors With Common Output



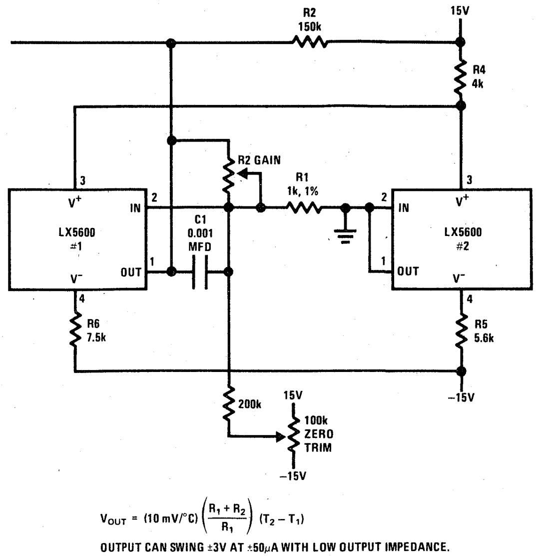
Temperature Controller Driving TRIAC



Low Duty Cycle Thermometer



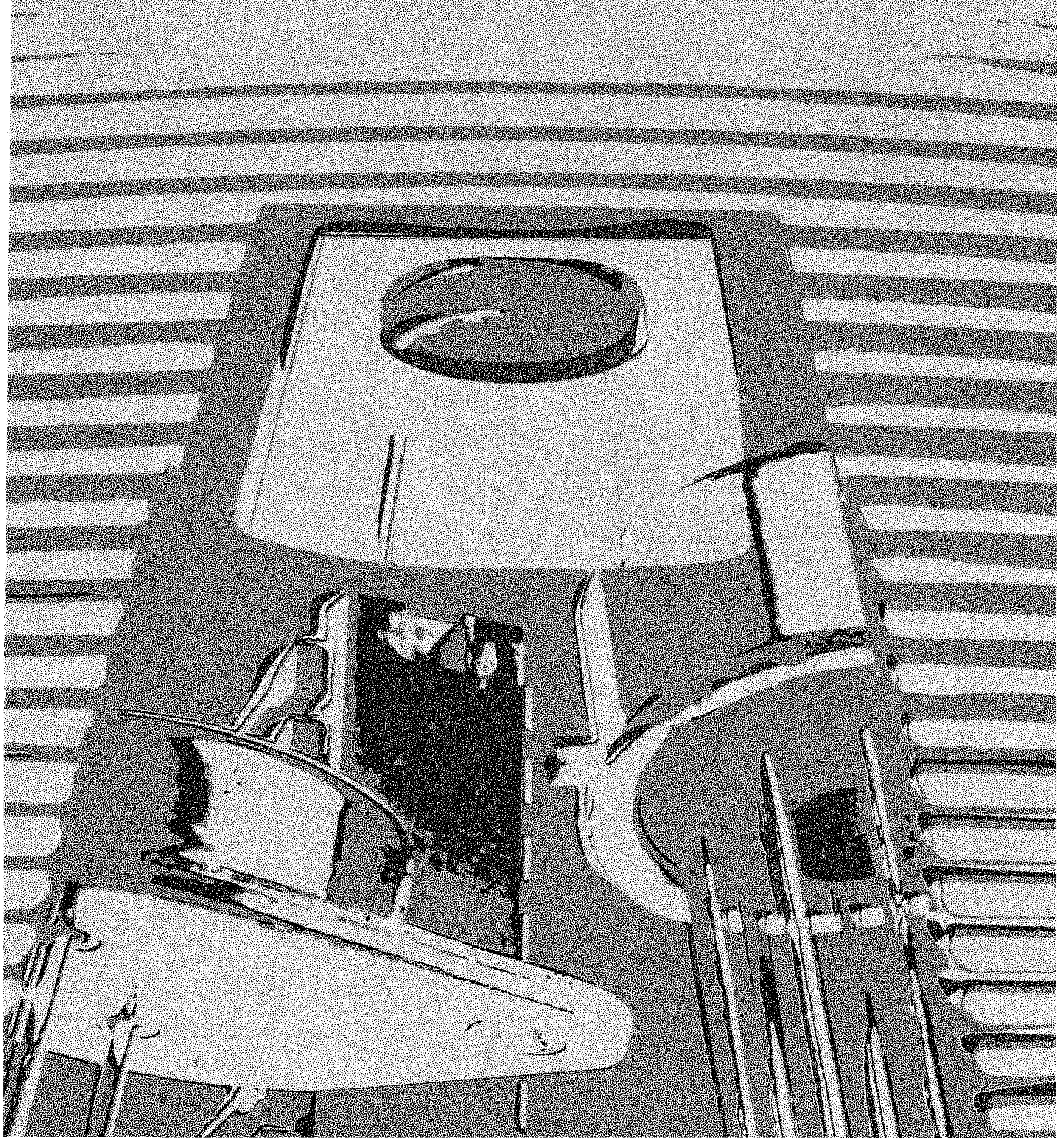
Differential Thermometer



$V_{OUT} = (10\ mV/°C)\left(\frac{R_1 + R_2}{R_1}\right)(T_2 - T_1)$

OUTPUT CAN SWING ±3V AT ±50μA WITH LOW OUTPUT IMPEDANCE.

National Semiconductor
AUDIO, RADIO AND TV CIRCUITS
Section 10



Audio, Radio and TV Circuits

Section Contents

AUDIO CIRCUITS

*Product added to this Data Book since last printing.

Introduction of three new mono power amplifiers and revision of eight device data sheets reflect National's continued effort to become the leader in audio integrated circuits. Continuing with the popular LM380 design concept, the new LM384 allows higher voltage operation to achieve a 5W output. For battery powered systems, the LM388 offers 1.5W output; likewise designed for low voltage applications is the versatile LM389 power amplifier and NPN transistor array.

Revisions of data sheets include up-date and modifications to the LM377, LM378 and LM386 devices; in addition, increased package dissipation limits appear for the LM380 power amplifier. A new power package for the LM379 is shown, along with several new applications. Minor modifications of the LM381 and LM382 data sheets, along with introduction of the LM387A selected low noise part complete the changes to the preamplifiers.

To make comparison between power amplifiers easier, this edition of the Linear Data Book includes audio device selection tables and graphs. National Semiconductor's line of audio power amplifiers consists of two major families; the "Duals," represented by the LM377, LM378 and LM379 family, and the "Monos," represented by six products. Available power output ranges from minuscule 320 mW battery operated systems to hefty 7W line operated systems. Designed for single supply operation, all devices may be operated from split supplies where required. Table I of the Audio Selection Guide summarizes the dual family for ease of selection, while Table II compares the six mono devices. *Figures 1–3* provide graphical comparison of power output versus supply voltage for loads of 4, 8 and 16Ω.

National Semiconductor's line of integrated circuits designed specifically to be used as audio preamplifiers consists of the LM381, LM382, LM387 and the LM1303. All are dual amplifiers in recognition of their major use in two-channel applications. In addition, there exists the LM389 which has three discrete NPN transistors that can be configured into a low noise monaural preamplifier for minimum parts count mono systems. Table III of the Audio Selection Guide shows the major electrical characteristics of each of the dual preamps offered. A detailed description of each amplifier follows, where the individual traits and operating requirements are presented.

Section Contents (con't)

RADIO CIRCUITS

*Product added to this Data Book since last printing.

Two new products add to National's broad line of radio circuits: the LM3089 FM receiver IF system, featuring all the major functions required for modern FM IF designs of automotive, high-fidelity and communications receivers; and the TBA120S IF amplifier/detector designed for audio detection in FM radio receivers. The TBA120S & TBA120U/T feature O.C. operated volume controls having 85 dB attennation range.

The revised LM1310 data sheet shows new external component values and increased absolute maximum power dissipation limits. Also changed in the stereo demodulator area is the popular LM1800 device. Improvements in pilot level sensitivity, total harmonic distortion and SCA rejection reflect circuit changes accomplished during the past year. Introduction of the LM1800A prime part marks the lowest guaranteed distortion figure available—allowing top-end hi-fi manufacturers previously unobtainable THD performance.

Section Contents (con't)

TV CIRCUITS

*Product added to this Data Book since last printing.

In the chroma area, the new LM1828, LM1848 devices complete the range of chroma demodulators offered. The LM1828 uses the standard output matrix, while the LM1848 features a revised output matrix to increase the red and green gains. Both demodulators have built-in ripple filters. The LM1829 phase-lock chroma processor has been renamed LM3126 to agree with other industry designations.

Also new in the TV area are the LM1391, LM1394 phase-lock blocks. Both devices feature a stable VCO, pulse phase detector, and variable duty cycle output. Although primarily aimed at TV horizontal synch applications, the versatility of these devices make them a cost effective alternative in other applications as well.

The LM1807, introduced at the 1975 I.E.E.E. Spring Conference, can form the heart of a complete TV phase-lock IF Synchronous detector system. The new data sheet includes all the specifications and applications information.

The LM1808 one-chip sound system is now available specified at a full 4W output. In order to handle the additional power it is being offered in a new socketable I.C. power package which has a factor of three improvements in Θ_{JA}.

Audio, Radio and TV Circuits

Audio Selection Guide

TABLE I. Dual Audio Amplifier Typical P_O @ 10% THD

SUPPLY	DEVICE			LOAD IMPEDANCE	
				8Ω	16Ω
12	LM377	LM378	LM379	1.6W	
16				2.2W	1.5W
18				3.0W	1.8W
20				3.8W	2.4W
22				4.6W	2.8W
24				5.4W(1) 1.5W(2)	3.6W 4.2W
26				6.0W	
28				7.0W	5.0W
30					5.5W

Note 1: LM379
Note 2: LM378 (Thermal Limit)

TABLE II. Mono Audio Amplifier Typical P_O @ 10% THD

SUPPLY	DEVICE	LOAD IMPEDANCE		
		4Ω	8Ω	16Ω
6V	LM386, LM389	320 mW	320 mW	180 mW
	LM388	600 mW	400 mW	200 mW
	LM390	1W	600 mW	340 mW
9V	LM386, LM389		500 mW	500 mW
	LM388	1.2W	1.0W	600 mW
	LM390	2.0W	1.2W	770 mW
12V	LM380	2.5W	1.5W	0.5W
	LM386, LM389		0.3W	0.9W
	LM388	2.0W	1.5W	1.1W
14V	LM380	3.3W	2.2W	1.0W
18V	LM380	4.2W	4.0W	2.2W
	LM384	4.2W	4.0W	2.2W
22V	LM384	3.5W	5.7W	3.5W

Audio Selection Guide (con't)

TABLE III. Dual Preamplifier Characteristics

PARAMETER	CONDITIONS	LM381N (14-PIN DIP)			LM382N (14-PIN DIP)			LM387N (8-PIN DIP)			LM1303N (14-PIN DIP)			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Supply Voltage		9		40	9		40	9		40	±4.5		±15	Vrms
Quiescent Supply Current			10			10	16		10				15	mA
Input Resistance (Open Loop)														
Positive Input			100k			100k		50k	100k			25k		Ω
Negative Input			200k			200k			200k			25k		Ω
Open Loop Gain			104			100k			104		76	80		dBV
Output Voltage Swing	$R_L = 10\ k\Omega$		V_S-2			V_S-2			V_S-2		11.3	15.6		Vp-p
Output Current														
Source			8(2)			8(2)			8(2)		0.6	0.8		mA
Sink			2			2			2		0.6	0.8		mA
Output Resistance (Open Loop)			150			150			150			4k		Ω
Slew Rate	(A_V = 40 dB)		4.7			4.7			4.7			5.0(7)		V/µs
Power Bandwidth	20 Vp-p (V_S = 24V)		75			75			75					kHz
	11.3 Vp-p (V_S = ±13V)											100		kHz
Unity Gain Bandwidth			15			15			15			20		MHz
Input Voltage														
Positive Input				300			300			300				mVrms
Either Input													±5	V
Supply Rejection Ratio	Input Referred, 1 kHz		120			120			110					dBV
Channel Separation	f = 1 kHz		60		40	60		40	60		60	70		dBV
Total Harmonic Distortion	f = 1 kHz (3)		0.1			0.1	0.3		0.1	0.5		0.1		%
Total Equivalent Input Noise	$R_S = 600\Omega$, 10–10 kHz		0.5(4)	1.0(4)		0.8	1.2		0.8	1.2				µVrms
	$R_S = 600\Omega$, 10–10 kHz		0.5(4,5)	0.7(4,5)					0.65(6)	0.9(6)				µVrms
Total NAB(8) Output Noise			190						230					µVrms
	$R_S = 600\Omega$, 10–10 kHz		140(5)						180(6)					µVrms

Note (1): Specifications apply for $T_A = 25°C$ with V_S = 14V for LM381, LM382, LM387 and V_S = ±13V for LM1303 unless otherwise noted.
Note (2): DC current; symmetrical ac current = 2 mAp-p.
Note (3): LM381 and LM387 gain = 60 dB; LM382 gain = 60 dB; LM1303 gain = 40 dB.
Note (4): Single ended input biasing.
Note (5): LM381AN.
Note (6): LM387AN.
Note (7): Frequency compensation: C = 0.0047µF, pins 3 to 4.
Note (8): NAB reference level: 37 dBV gain at 1 kHz. Tape playback circuit.

Audio Selection Guide (con't)

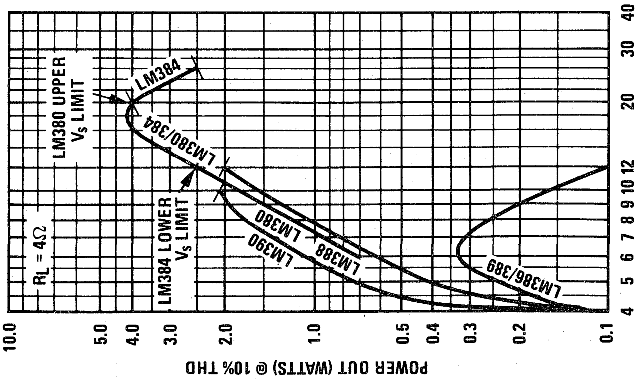


FIGURE 1. P_O vs V_S For $R_L = 4\Omega$

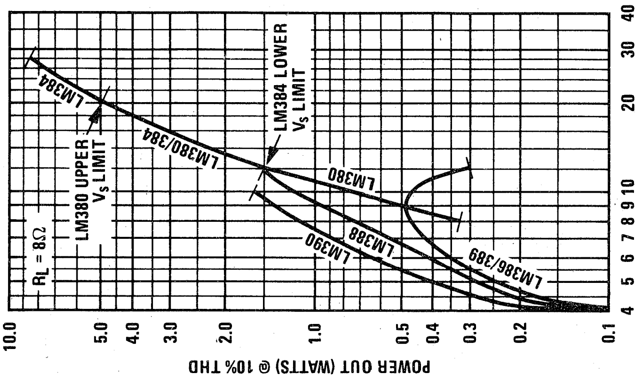


FIGURE 2. P_O vs V_S For $R_L = 8\Omega$

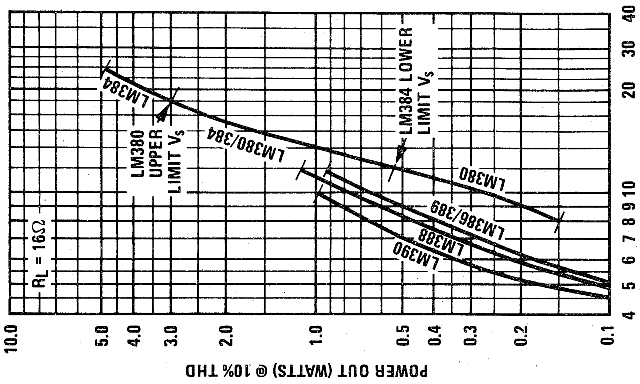


FIGURE 3. P_O vs V_S For $R_L = 16\Omega$

Definition of Terms

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.

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.

Audio, Radio and TV Circuits

LM170/LM270/LM370 agc/squelch amplifier

general description

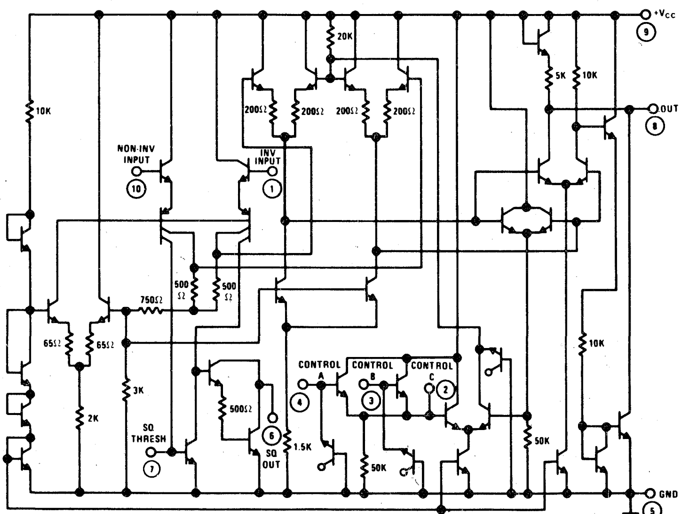
The LM170 is a direct coupled monolithic amplifier whose voltage gain is controlled by an external DC voltage. The device features:

- 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.

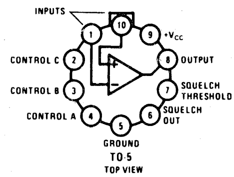
The LM170 is specified for operation over the −55°C to +125°C military temperature range. The LM270 is specified for operation over the −25°C to +75°C temperature range. The LM370 is specified for operation over the 0°C to +70°C temperature range.

schematic** and connection diagrams



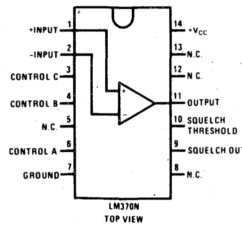
Circled numbers are pin connections.

Metal Can Package



Order Number LM170H or LM270H or LM370H
See Package 14

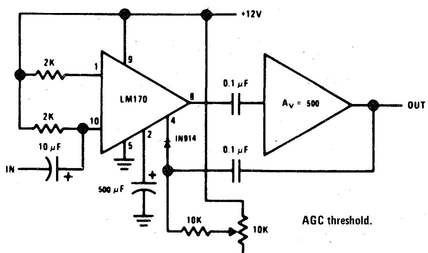
Dual-In-Line Package



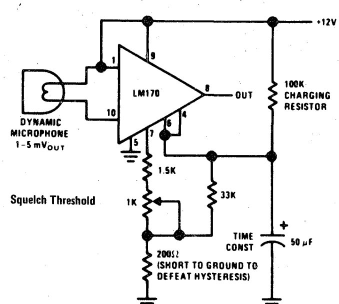
Order Number LM370N
See Package 22

typical applications**

AGC Using Built-in Detection, Driven By Additional System Gain



Squelched Preamplifier with Hysteresis



**Pin connections shown are for metal can.

10

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.

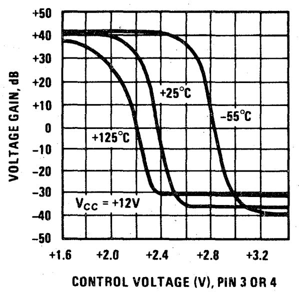
Input characteristics are similar to those of an operational amplifier, with common-mode input range extending from +4.5 volts up to and including the positive supply voltage. Lowest distortion occurs at input levels of 20 mV p-p or less. Outputs of several amplifiers, which will have quiescent DC levels 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.

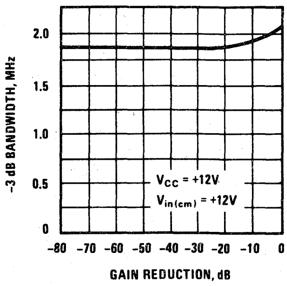
A sensitive squelch detector, independent of the amplifier's gain, provides fast-attack, slow release control at Pin 6, with threshold set by an external resistance from Pin 7 to ground. Injecting a portion of the control voltage at Pin 6 into this threshold results in a hysteresis, reducing response to erratic inputs. Since threshold is dependent on DC levels, differential DC input voltage should be held constant for squelch operation.

variable gain characteristics

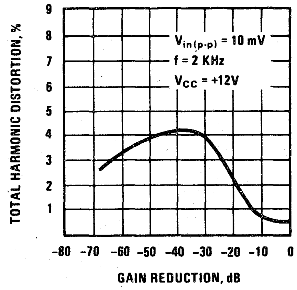
Voltage Gain vs Control Voltage



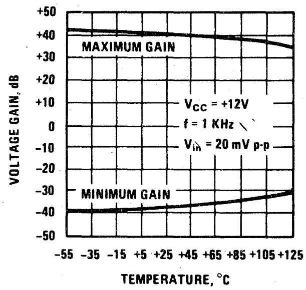
Bandwidth vs Gain Reduction



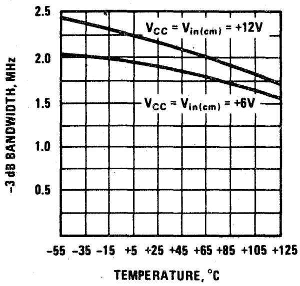
Total Harmonic Distortion vs Gain Reduction



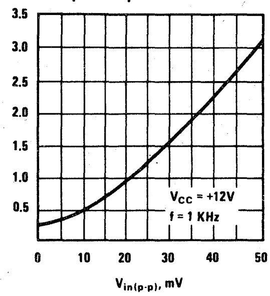
Maximum and Minimum Voltage Gain vs Temperature



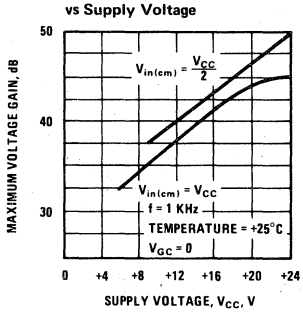
Bandwidth vs Temperature



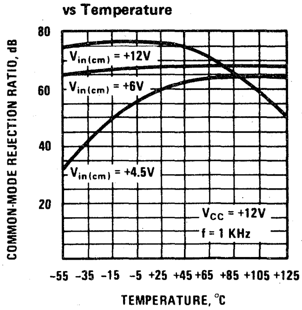
Total Harmonic Distortion vs Input Amplitude



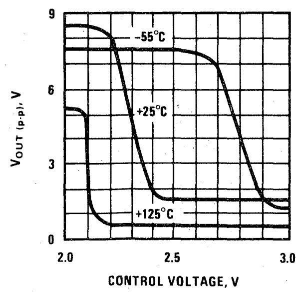
Maximum Voltage Gain vs Supply Voltage



Common-Mode Rejection Ratio vs Temperature

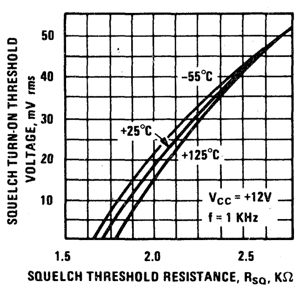


Output Dynamic Range vs Control Voltage

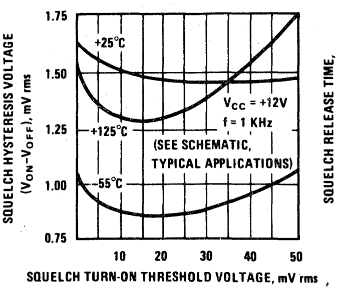


squelch characteristics

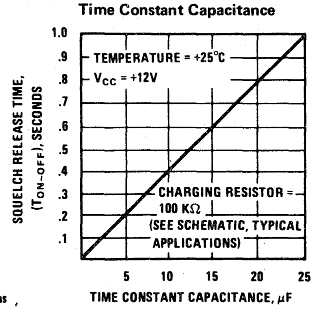
Squelch Threshold Voltage vs Threshold Resistance



Squelch Hysteresis Voltage vs Squelch Threshold Voltage

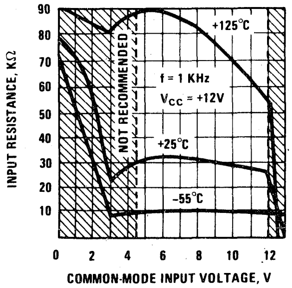


Squelch Release Time vs Time Constant Capacitance

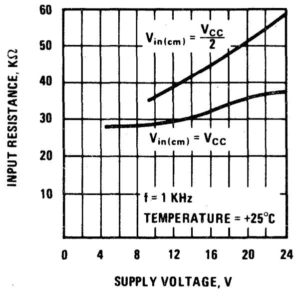


input and output characteristics

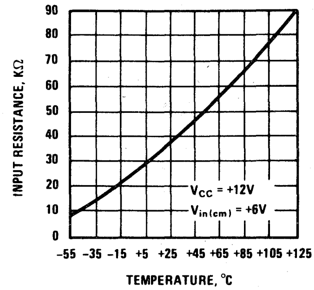
Input Resistance vs Common-Mode Input Voltage



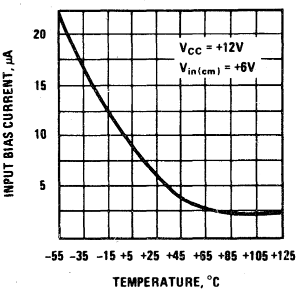
Input Resistance vs Supply Voltage



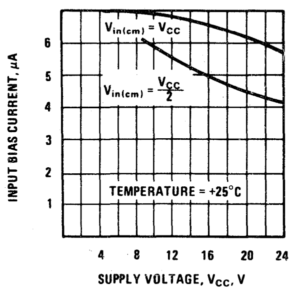
Input Resistance vs Temperature



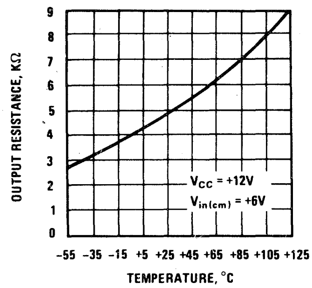
Input Bias Current vs Temperature



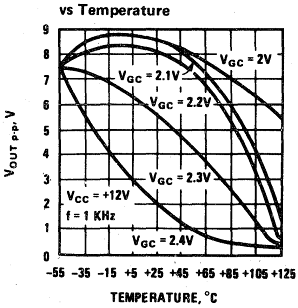
Input Bias Current vs Supply Voltage



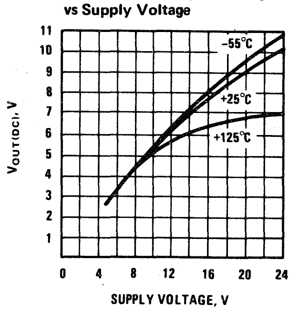
Output Resistance vs Temperature



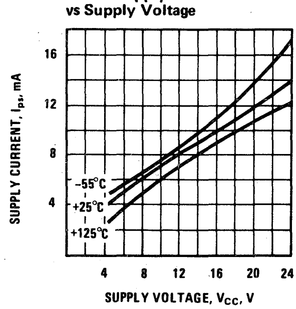
Output Dynamic Range vs Temperature



Quiescent DC Output Voltage vs Supply Voltage



Power Supply Current vs Supply Voltage



Audio, Radio and TV 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.

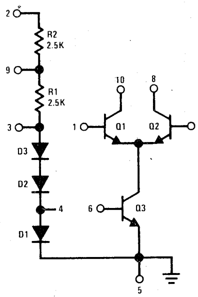
features

- 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

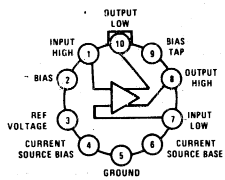
	(Emitter Coupled)	24.6 dB
	(Cascode)	27.5 dB

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



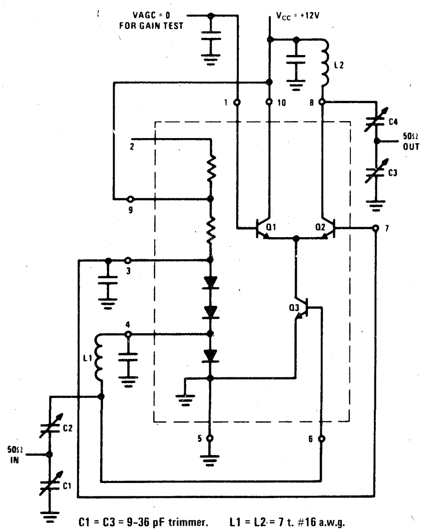
Metal Can Package



Order Number LM171H or LM271H or LM371H See Package 14

typical applications

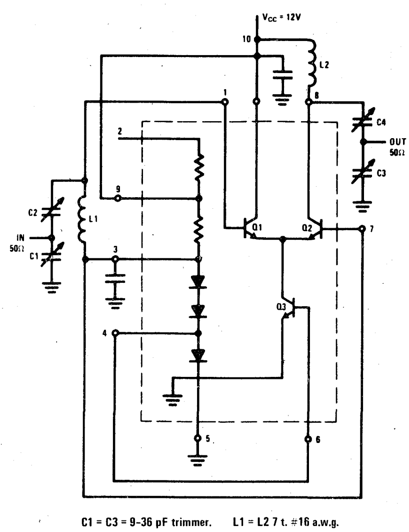
100 MHz Cascode Test Circuit



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 ($\lvert Y_{21}\rvert$)	455 kHz	17.0	27.0		mmhos
Magnitude of Reverse Transadmittance ($\lvert Y_{12}\rvert$)	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 ($\lvert Y_{21}\rvert$)	455 kHz Pin 1 GND	25.0	50.0		mmhos
Magnitude of Reverse Transadmittance ($\lvert Y_{12}\rvert$)	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) ($\lvert Y_{21}\rvert$)	455 kHz $e_{in} < 10$ mV rms	17.0			mmhos
Magnitude of Forward Transadmittance (Cascode) ($\lvert Y_{21}\rvert$)	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

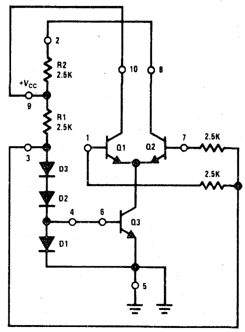
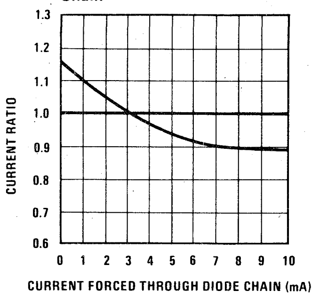
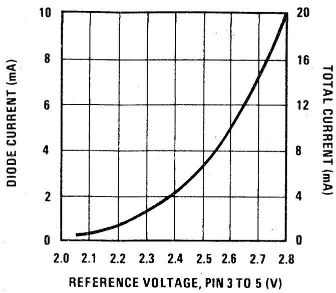


FIGURE 3

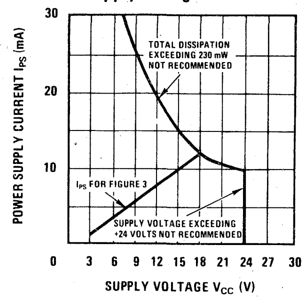
Current Source — Diode Current Ratio vs Current Forced Through Diode Chain



DC Reference Voltage (3 to 5) vs Diode Chain Current and Supply Current

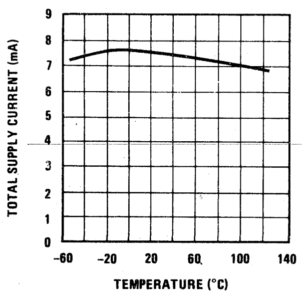


Total Supply Current vs Supply Voltage

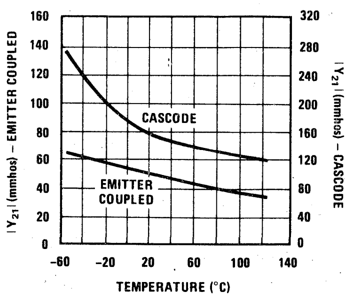


typical temperature characteristics

Total Supply Current vs Temperature, V_{CC} = +12V



Magnitude of Forward Transadmittance vs Temperature, V_{CC} = +12V, 455 kHz



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cascode configuration

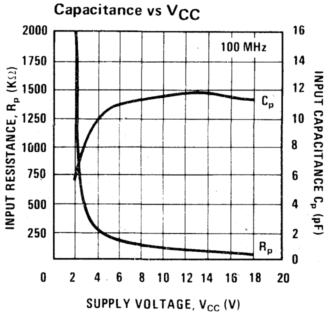
The common-emitter, common-base, or cascode, configuration is useful as a tuned RF or IF amplifier to 250 MHz. Two common-base stages are formed by the differential pair, Q1 and Q2, which may be used as a gain control system by applying a differential gain control voltage between pins 1 and 7. With Q1 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.

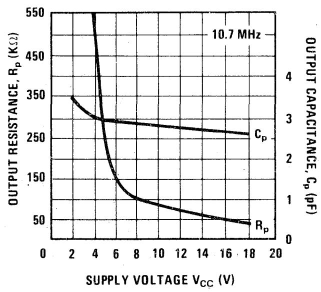
Pin 3 may be used as the DC reference for the AGC input, to assure adequate bias voltage for the collector of Q3. Where large AGC voltages are used, an external resistive divider, from pin 3 to 1 to the

AGC voltage may be used to optimize the DC AGC requirements. VAGC is defined as the voltage between pin 1 and 7.

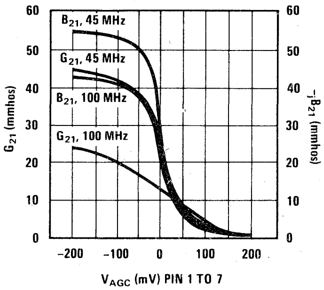
At some frequencies, bypassing may be required at pins 1, 3, 4 or the V_{CC} connection.



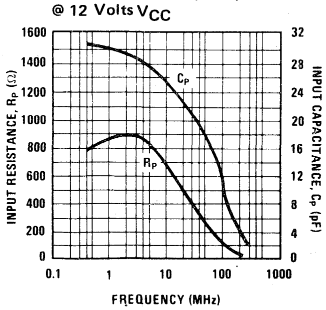
Input Resistance and Capacitance vs V_{CC}



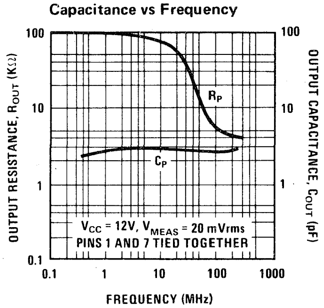
Output Resistance and Capacitance vs V_{CC}



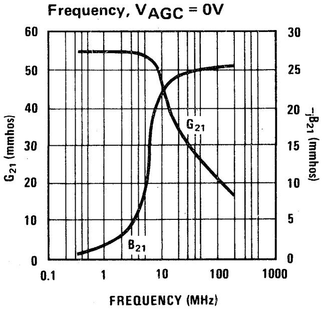
Forward Transadmittance vs AGC Voltage



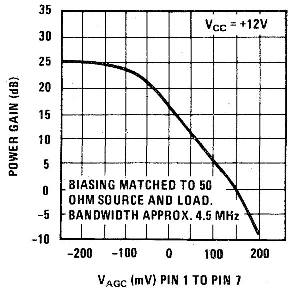
Input Resistance and Capacitance vs Frequency @ 12 Volts V_{CC}



Output Resistance and Capacitance vs Frequency



Forward Transadmittance vs Frequency, V_{AGC} = 0V



Tuned Power Gain vs AGC Voltage

emitter coupled configuration

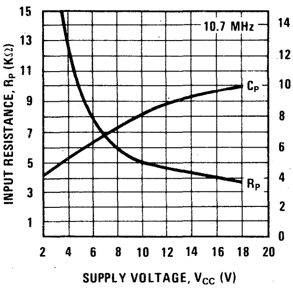
The common-collector, common-base, or emitter-coupled configuration is useful as a symmetrically non-saturated limiting RF or IF amplifier to 150 MHz. Basically a differential amplifier, this configuration is especially suited to FM IF strips using conventional interstage tuning. While available gain 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.

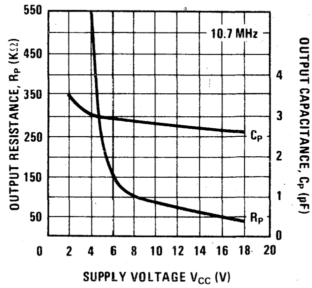
For non-saturated operation, the output load must be chosen so that the collector voltage of the output transistor is higher than the DC reference voltage, with all source current shunted into the output, for the particular bias levels used.

At some frequencies, bypassing of pins 3, 6, 7, or the V_{CC} connection may be required.

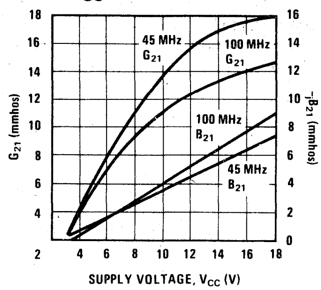
Input Resistance and Capacitance vs V_{CC}



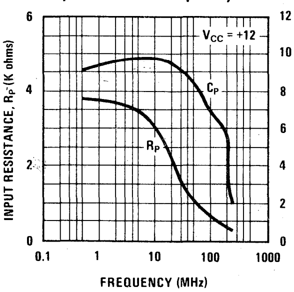
Output Resistance and Capacitance vs V_{CC}



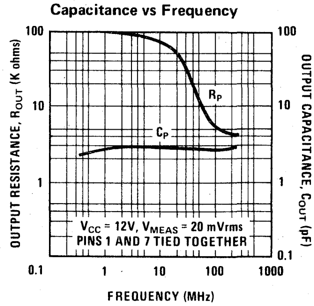
Forward Transadmittance vs V_{CC}



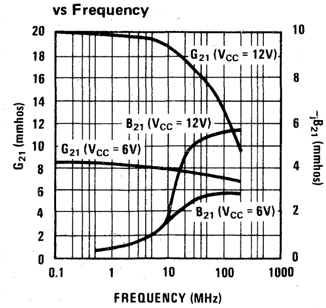
Input Resistance and Capacitance vs Frequency



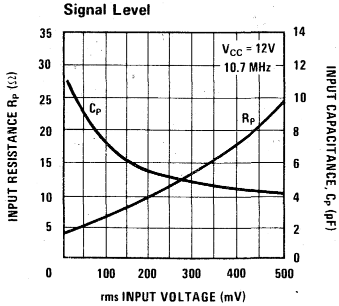
Output Resistance and Capacitance vs Frequency



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)

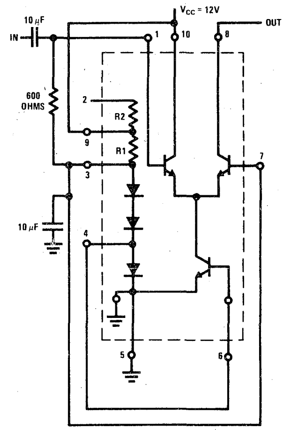
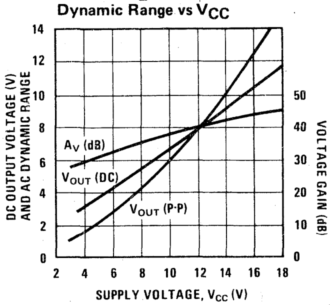
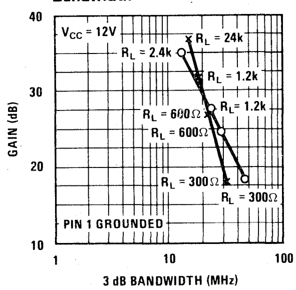


FIGURE 4

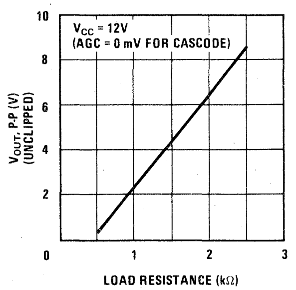
Voltage Gain, DC Output Voltage (R_L = R2) & Dynamic Range vs V_{CC}



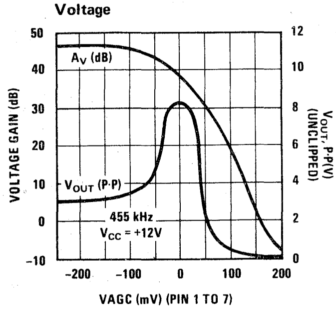
Cascode and Emitter Coupled Video Amplifiers Voltage Gain and Load Resistance vs Bandwidth



Cascode & Emitter Coupled Video Amplifiers Dynamic Range vs Load Resistance



Cascode Video Amplifier Voltage Gain & Dynamic Range vs AGC Voltage



Audio, Radio and TV Circuits

LM172/LM272/LM372 am if strip

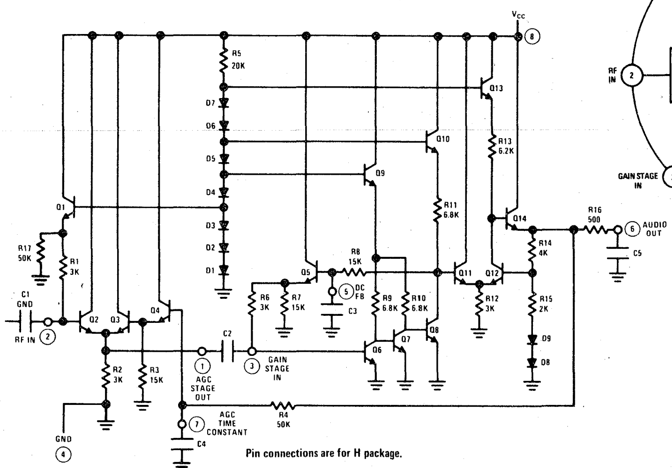
general description

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 individuai stage decoupling.
- AGC voltage available to drive receiver "front end."

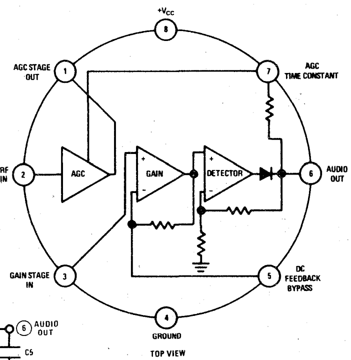
The LM172 is specified for operation over the $-55°C$ to $+125°C$ military temperature range. The LM272 is specified for operation over the $-25°C$ to $+75°C$ temperature range. The LM372 is specified for operation over the $0°C$ to $+70°C$ temperature range.

schematic and connection diagrams



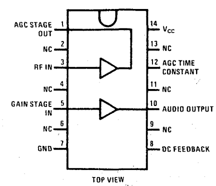
Pin connections are for H package.

Metal Can Package



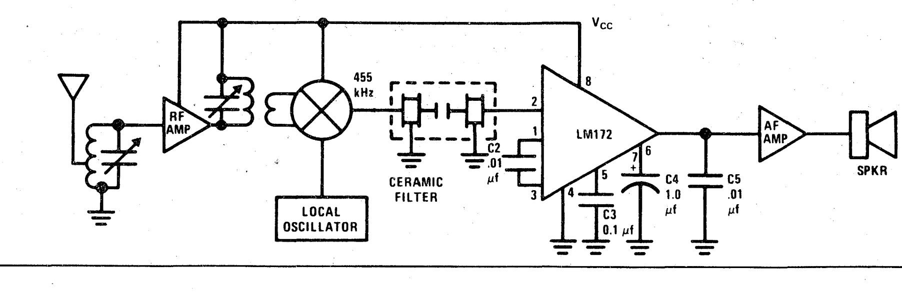
Order Number LM172H or LM272H or LM372H
See Package 11

Dual-In-Line Package



Order Number LM272N or LM372N
See Package 22

typical application



10

absolute maxium ratings

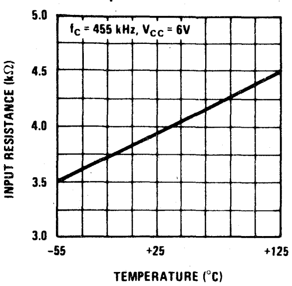
Supply Voltage Range		+6V to +15V
Storage Temperature		−65°C to +150°C
Operating Temperature	LM172	−55°C to +125°C
	LM272	−25°C to +75°C
	LM372	0°C to +70°C
RF Input Level, Pin 2		500 mV rms

electrical characteristics (T_A = 25°C)

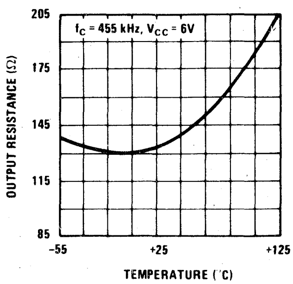
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Power Supply Drain	I_{ps}	V_{CC} = 6V, Input = 50 mV f = 455 kHz		1.4		mA
		V_{CC} = 6V, Input = 50 μV f = 455 kHz		1.7		mA
		V_{CC} = 15V, Input = 50 mV f = 455 kHz				
		LM172/272		2.5	2.65	mA
		LM372		2.5	3.2	mA
AGC Range	AGCR	V_{CC} = 6V, f = 455 kHz				
		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

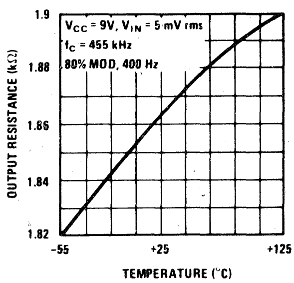
AGC Stage Input Resistance vs Temperature



AGC Stage Output Resistance vs Temperature

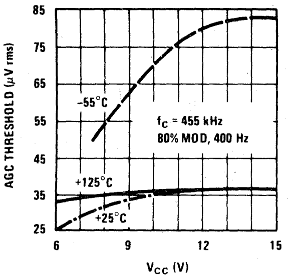


Detector Output Resistance vs Temperature

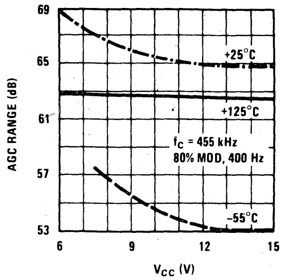


typical characteristics

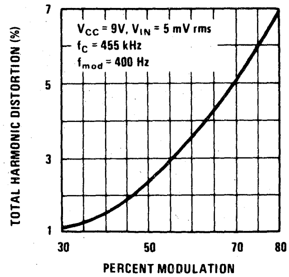
AGC Threshold vs V_{CC}



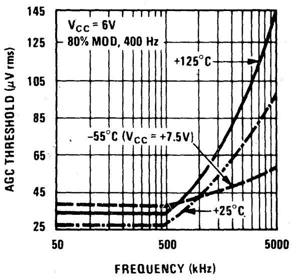
AGC Range vs V_{CC}



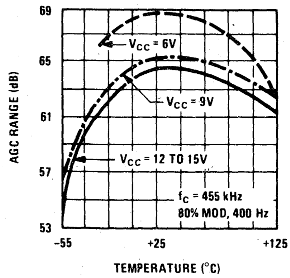
Audio Distortion vs % Modulation



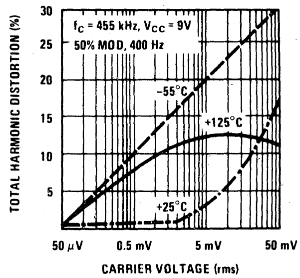
AGC Threshold vs Carrier Frequency



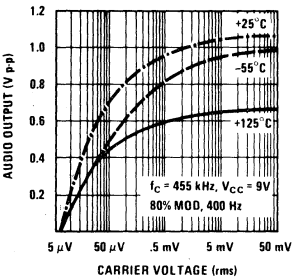
AGC Range vs Temperature



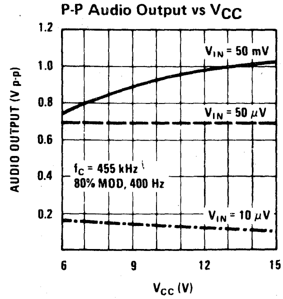
Audio Distortion vs Input Carrier Voltage



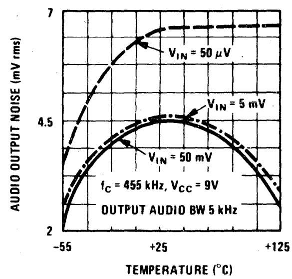
P-P Audio Output vs Input Carrier Voltage



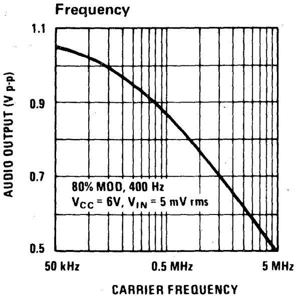
P-P Audio Output vs V_{CC}



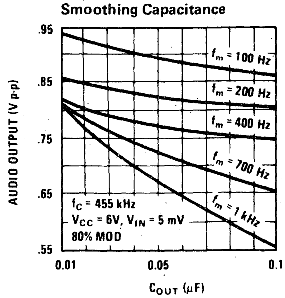
Audio Output Noise vs Temperature



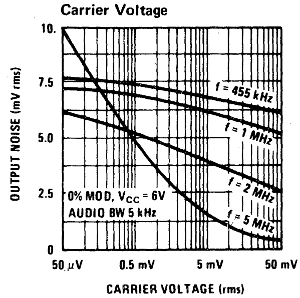
P-P Audio Output vs Carrier Frequency



P-P Audio Output vs Output Smoothing Capacitance

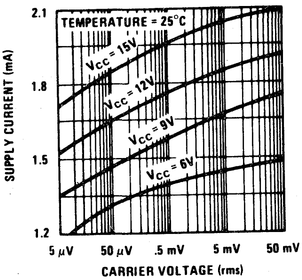


Audio Output Noise vs Input Carrier Voltage

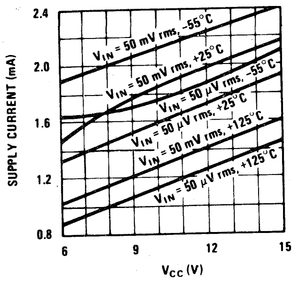


power supply characteristics

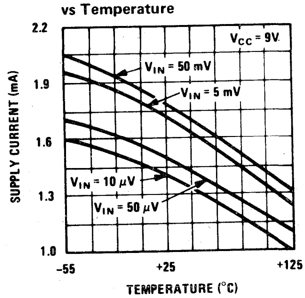
Power Supply Current vs Input Carrier Voltage



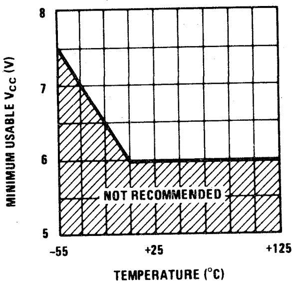
Power Supply Current vs V_{CC}



Power Supply Current vs Temperature



Minimum Operating V_{CC} vs Temperature



Audio, Radio and TV 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

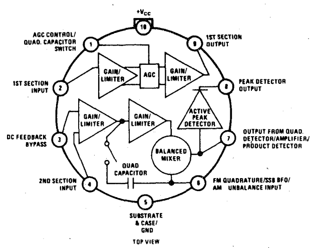
- Internal video peak detector for video AGC
- High and low level video outputs
- Gated video AGC capability

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

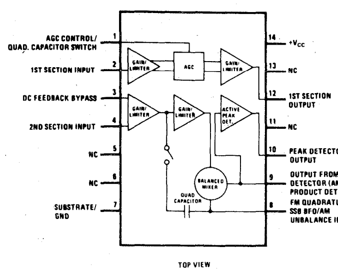
connection diagrams

Metal Can Package



Order Number LM273H or LM373H
LM274H or LM374H
See Package 14

Dual-In-Line Package



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
		$-20°C \le T_A \le +100°C$			21				mA
AGC Input Current	I_1	$V_{AGC} \le 5V$		50	110		50	110	μA
		$-20°C \le T_A \le +100°C$			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	MIN	TYP	MAX	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
		$-20°C \le T_A \le 100°C$ LM273/LM373	28						dB
AGC Section Transconductance	$g_{m2-9(11)}$	V_{AGC} = 0V, f = 455 kHz	28	40		28	40		mmhos
		$-20°C \le T_A \le 100°C$ 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		$V_{p\text{-}p}$
		$-20°C \le T_A \le 100°C$	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		$V_{p\text{-}p}$
		$-20°C \le T_A \le 100°C$	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

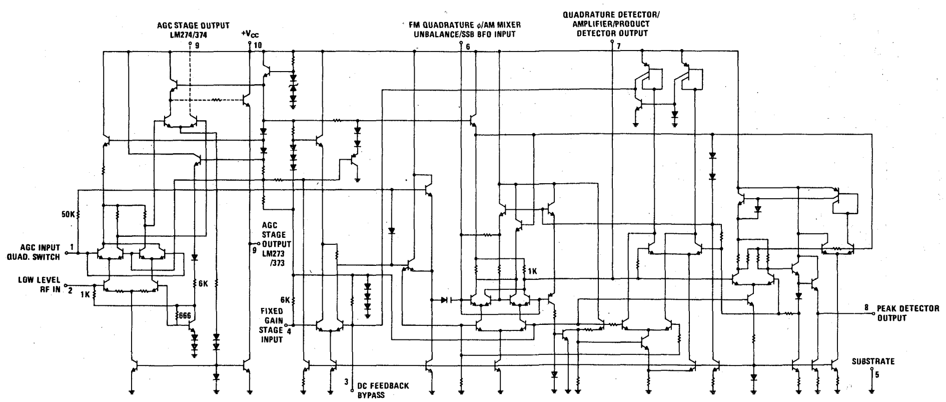
Note 1: For operation at elevated temperatures, derate devices based on 150°C maximum junction temperature and 150°C/W junction to ambient or 45°C/W junction to case thermal coefficients for the metal can.

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)					
Limiting Threshold	$e_O = 3$ dB from value at $e_{IN} = 100$ mVrms				
	$\Delta f = \pm 75$ kHz		800	–	μVrms
	$\Delta f = \pm 5$ kHz	800	800	–	μVrms
AM Rejection Ratio	$M_{fm} = 1$, $M_{am} = 0.3$ $e_{IN} = 10$ mVrms				
	$\Delta f = \pm 75$ kHz		45	–	dB
	$\Delta f = \pm 5$ kHz	35		–	dB
Audio Output	$e_{IN} = 10$ mVrms				
	$\Delta f = \pm 75$ kHz		80	–	mVrms
	$\Delta f = \pm 5$ kHz	70	38	–	mVrms
	@ $T_A = 100°C$, $\Delta f = \pm 75$ kHz		50	–	mVrms
	@ $T_A = 100°C$, $\Delta f = \pm 5$ kHz LM273 and LM274 only	40	19	–	mVrms
Audio Distortion	$e_{IN} = 10$ mVrms				
	$\Delta f = \pm 75$ kHz		1.5	–	%
	$\Delta f = \pm 5$ kHz	2	1.0	–	%
TYPICAL SSB PERFORMANCE (See Figures 5 and 6)					
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

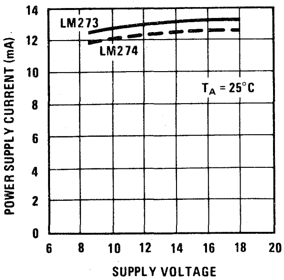
schematic diagram



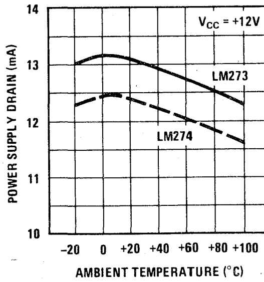
Pin connections shown are for TO-5 package only.

typical performance characteristics

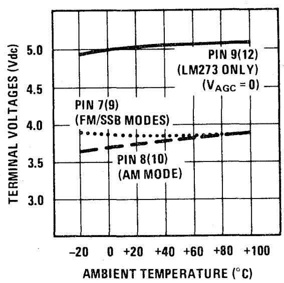
Power Supply Current vs Supply Voltage



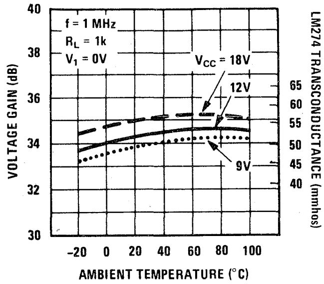
Power Supply Current vs Ambient Temperature



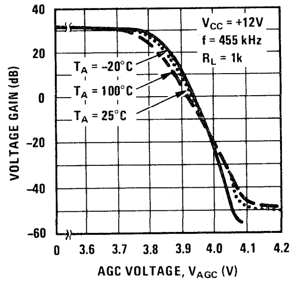
Output Terminal Voltage vs Temperature



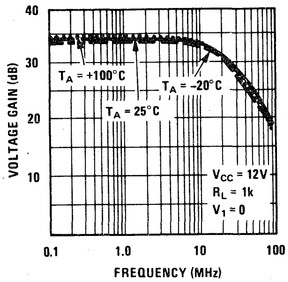
First Section Voltage Gain or Transconductance vs Temperature



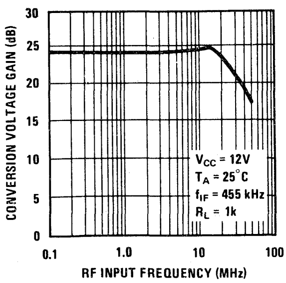
First Section Voltage Gain vs AGC Voltage



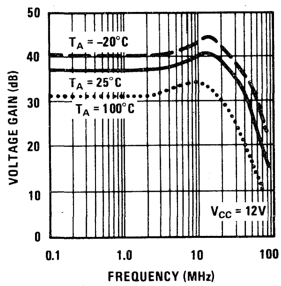
First Section Voltage Gain vs Frequency



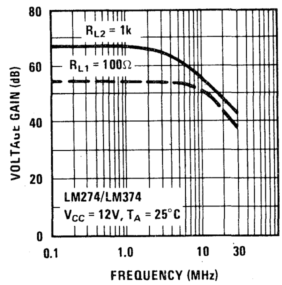
First Section Conversion Voltage Gain vs Frequency



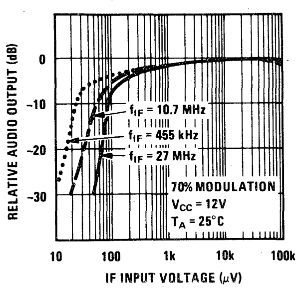
Second Section Voltage Gain vs Frequency



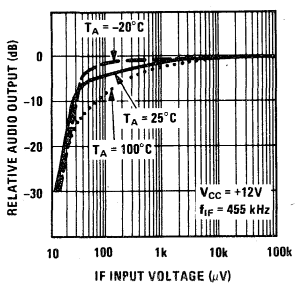
Cascaded Sections Video Gain vs Frequency, LM274/LM374 Only



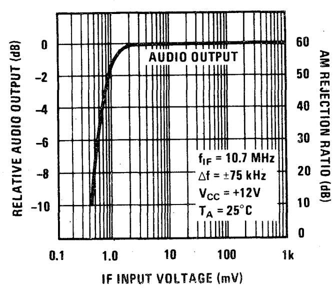
AM IF Audio Output vs IF Input Voltage



Relative AM Audio Output vs IF Input Voltage, Referred to 100 mV Inputs

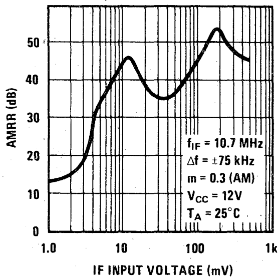


Wide Band FM Audio Output vs IF Input Voltage

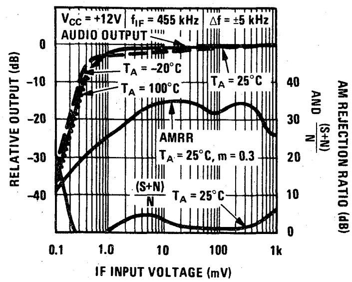


typical performance characteristics (con't)

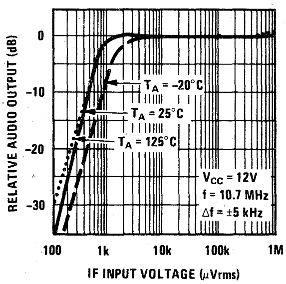
AM Rejection Ratio vs IF Input Voltage for Wide Band FM



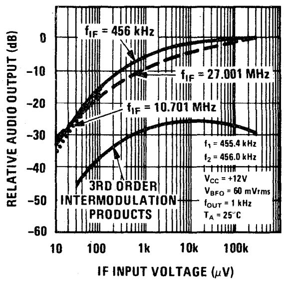
455 kHz NFM IF Audio Output, AM Rejection Ratio, and Signal to Noise vs IF Input Voltage



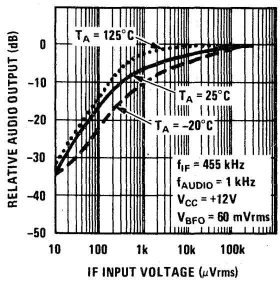
10.7 MHz NFM IF Audio Output vs IF Input Voltage



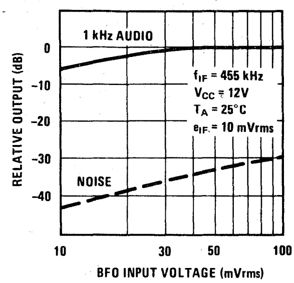
SSB IF Audio Output and Intermodulation Products vs IF Input Level



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

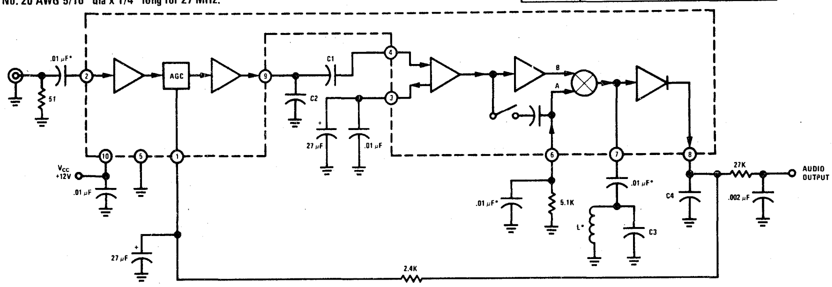
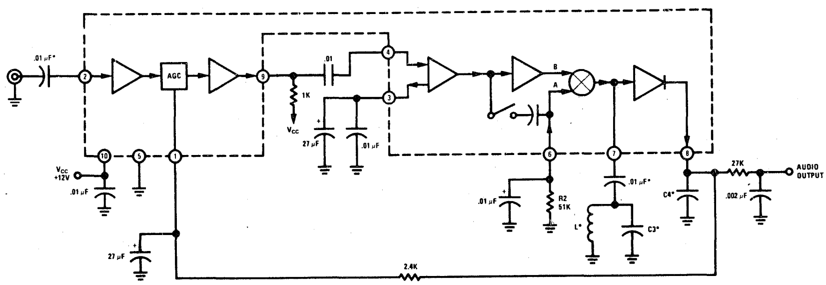


FIGURE 1. LM273/LM373 AM IF Connection



*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).

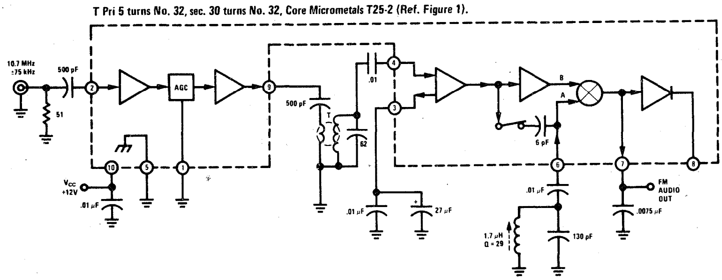


FIGURE 3. LM273/LM373 Wide Band FM IF Connection

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

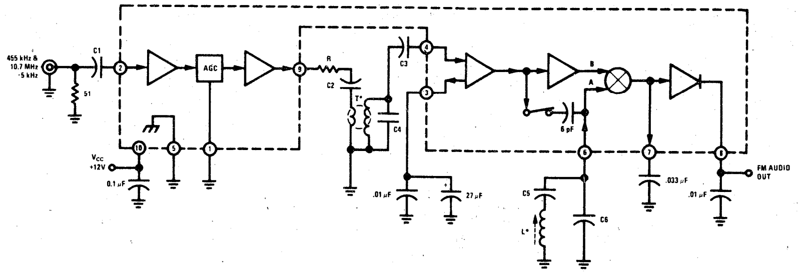
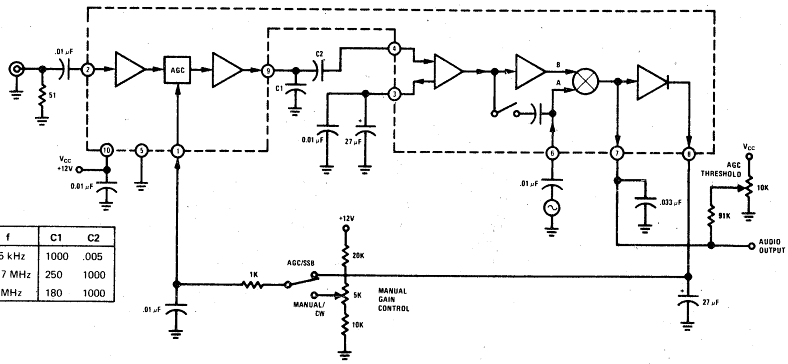


FIGURE 4. LM273/LM373 Narrow Band FM IF Connection



f	C1	C2
455 kHz	1000	.005
10.7 MHz	250	1000
27 MHz	180	1000

FIGURE 5. LM273/LM373 SSB & CW IF Connection

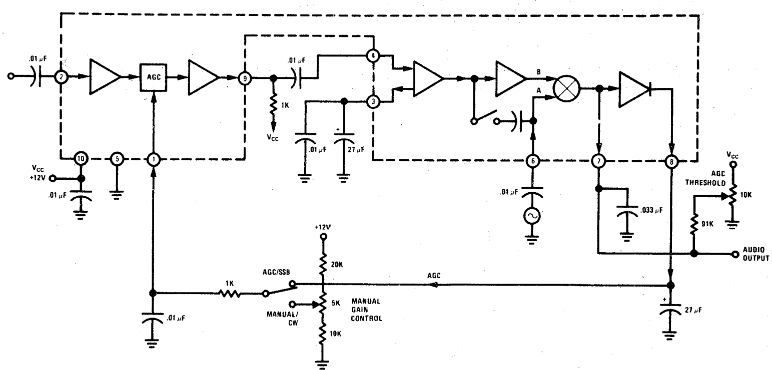


FIGURE 6. LM274/LM374 SSB & CW IF Connection

typical applications (con't)

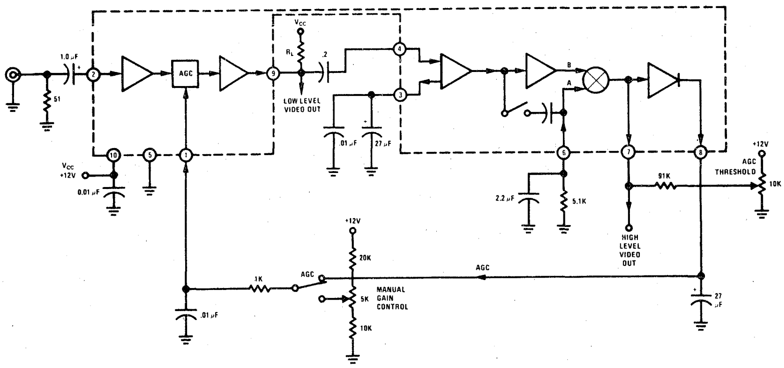
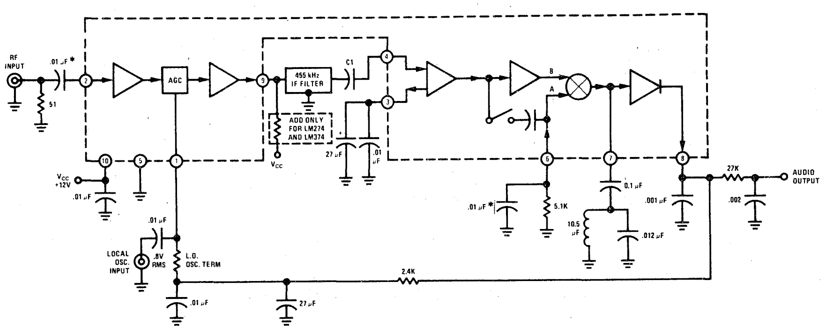


FIGURE 7. LM274/LM374 Video Amplifier Configuration



*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

Audio, Radio and TV Circuits

LM175/LM275/LM375 oscillator and buffer with TTL output

general description

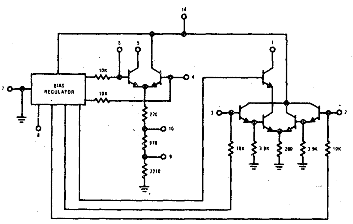
The LM175/LM275/LM375 is a monolithic, differential pair, general purpose oscillator. It may be used with crystal control or with LC or RC tanks. Two output configurations are possible. It may be connected to the internal isolating buffer to provide sine or square wave outputs, or to the internal logic 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.

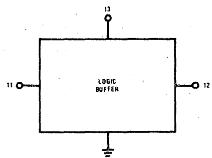
The LM175 is specified for operation over the −55°C to +125°C military temperature range. The LM275 is specified for operation over the −25°C to +85°C temperature range. The LM375 is specified for operation over the 0°C to +70°C temperature range.

features

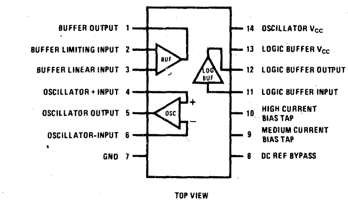
- Oscillation up to 200 MHz
- Operation from supplies from 4.5V to 24V (Logic buffer maximum supply at 7.0V)
- High supply voltage rejection, typically 0.1 ppm/V
- Low temperature coefficient, typically 0.05 ppm/°C
- Variable drive to crystal to limit dissipation
- Capable of fundamental or overtone, 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



Order Number LM175D, LM275D or LM375D
See Package 1

Order Number LM175J, LM275J or LM375J
See Package 16

Order Number LM375N
See Package 22

typical applications

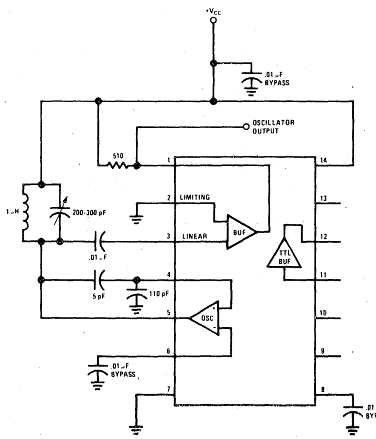


FIGURE 1. 10 MHz L–C Sine Wave Oscillator

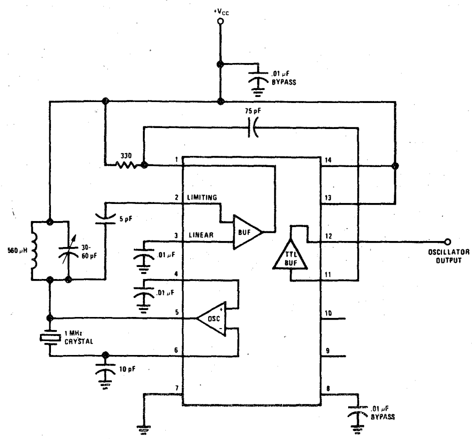


FIGURE 2. 1 MHz Crystal Oscillator with TTL Output

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		$\mu A_{p\text{-}p}$
		Pin 9 Tied to Pin 10	160	190		$\mu A_{p\text{-}p}$
		Pin 9 Grounded, Pin 10 Open	300	360		$\mu A_{p\text{-}p}$
		Pin 10 Grounded, Pin 9 Open	750	1000		$\mu A_{p\text{-}p}$
Buffer Output Current	I_{BUF}		2.5	3.0		$mA_{p\text{-}p}$
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			$\mu A_{p\text{-}p}$
		Pin 9 Tied to Pin 10	130			$\mu A_{p\text{-}p}$
		Pin 9 Grounded, Pin 10 Open	250			$\mu A_{p\text{-}p}$
		Pin 10 Grounded, Pin 9 Open	600			$\mu A_{p\text{-}p}$
Buffer Ouptut Current	I_{BUF}		2.0			$mA_{p\text{-}p}$
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

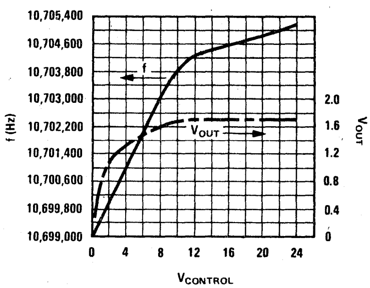
Note 1: For operation at elevated temperatures, the device must be operated based on a 150°C maximum junction temperature with a thermal resistance of 140°C/W for the metal DIP package and 100°C maximum junction temperature with a thermal resistance of 150°C/W for the plastic DIP package.

electrical characteristics (con't)

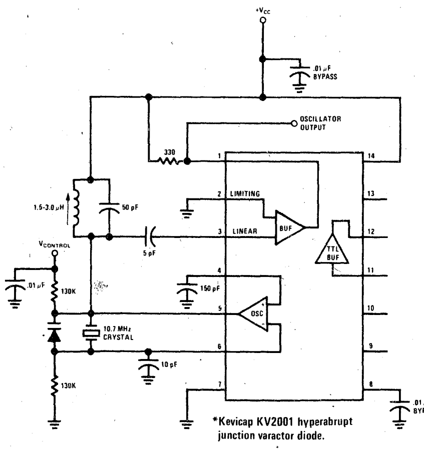
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
OSCILLATOR CHARACTERISTICS (See Oscillator Circuit)						
Frequency vs Power Supply Rejection		$5V < V_{CC} < 10V$		0.1		ppm/V
Frequency vs Temperature Rejection		$-55°C < T_A < +125°C$		0.05		ppm/°C
Load Pull (Change in Frequency vs Change in Buffer Load Impedance)		$0 \le R_{L\ BUF} \le \infty$		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

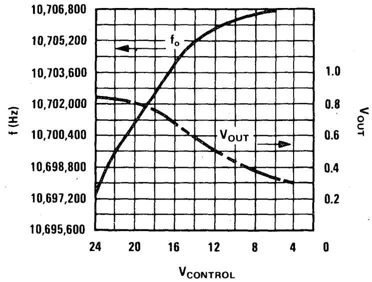


10.7 MHz Voltage-Controlled Crystal Oscillator Parallel Tuning

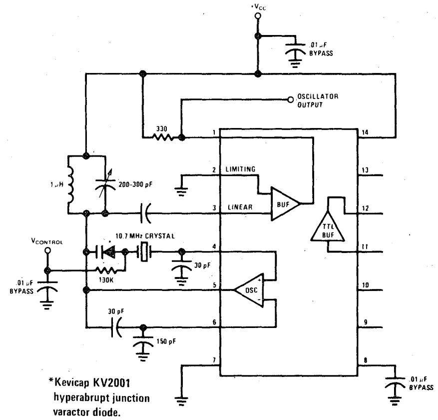


typical oscillator circuit connections (con't)

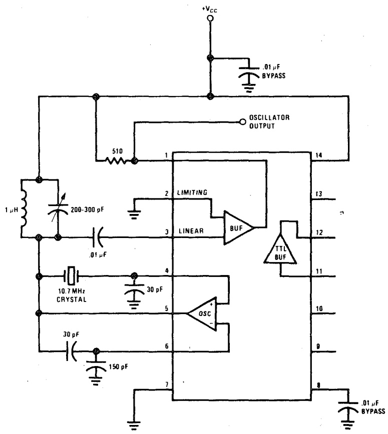
Frequency and Output Voltage for Series Tuned VCXO



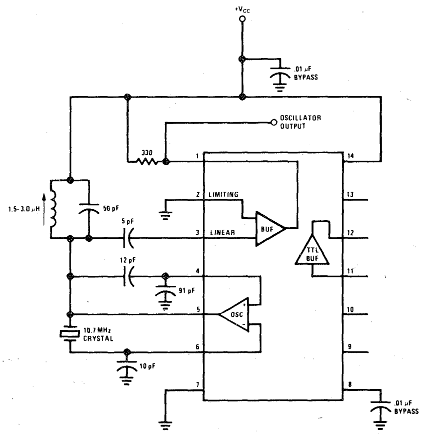
10.7 MHz Voltage Controlled Crystal Oscillator Series Tuning



10.7 MHz Series Resonant Crystal Oscillator

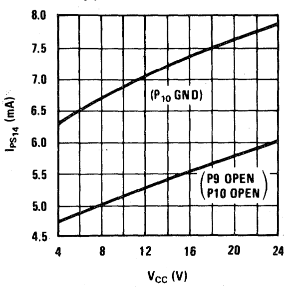


10.7 MHz Parallel Resonant Crystal Oscillator

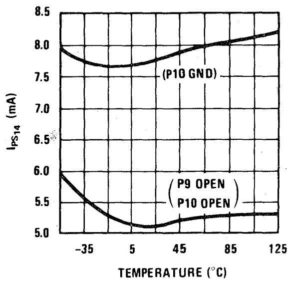


typical performance characteristics

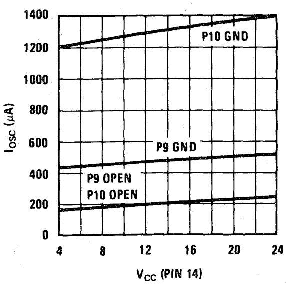
I_{PS14} vs V_{CC} (T_A = 25°C)



I_{PS14} vs Temperature (V_{CC} = 12V)

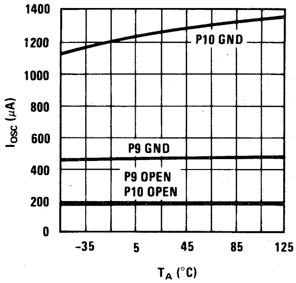


I_{OSC} vs V_{CC} T_A = 25°C

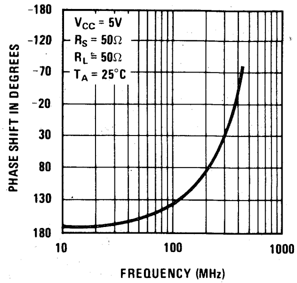


typical performance characteristics (con't)

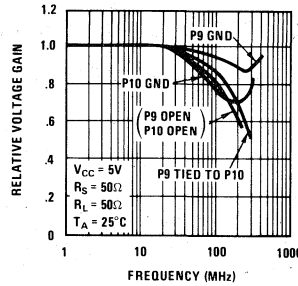
I_{OSC} vs Temperature
V_{CC} = 12V



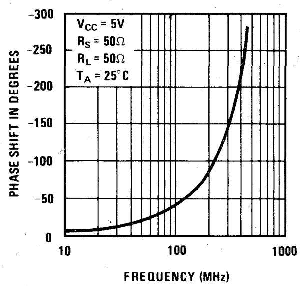
Phase Shift from Pin 6 to Pin 5



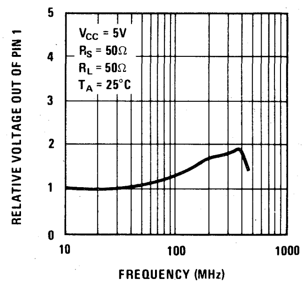
OSC Stage Bandwidth



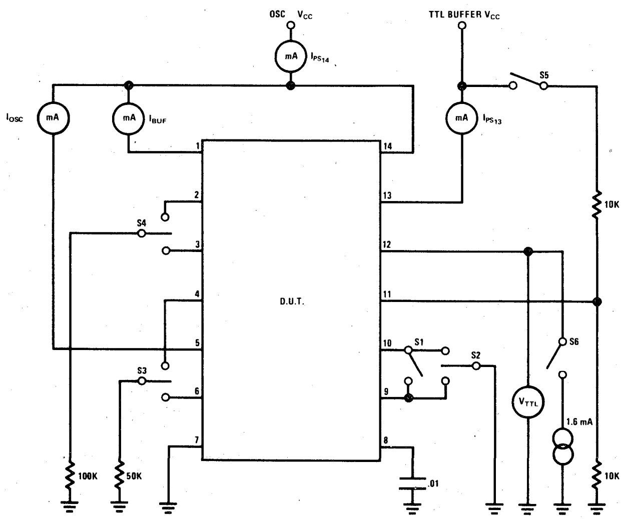
Phase Shift from Pin 4 to Pin 5



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.

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. For more information, see AN-125.

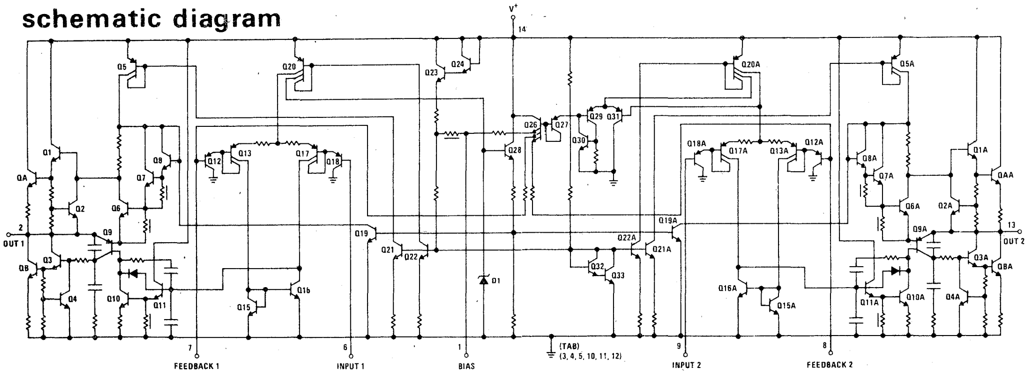
features

- 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

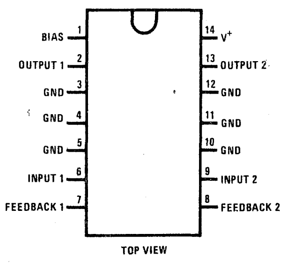
- Multi-channel audio systems
- Tape recorders and players
- Movie projectors
- Automotive systems
- Stereo phonographs
- Bridge output stages
- AM-FM radio receivers
- Intercoms
- Servo amplifiers
- Instrument systems

schematic diagram



connection diagram

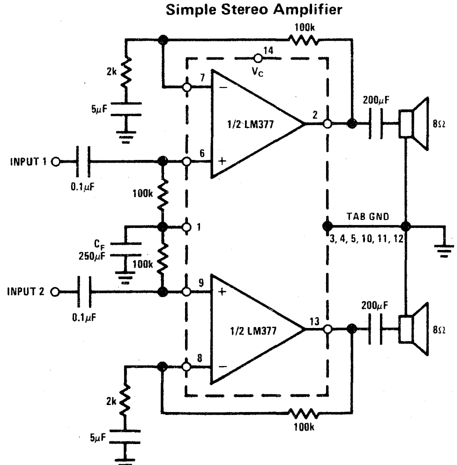
Dual-In-Line Package



Order Number LM377N
See Package 22

typical applications

Simple Stereo 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 P_{OUT} = 1.5W/Channel		15 430	50 500	mA 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 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
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

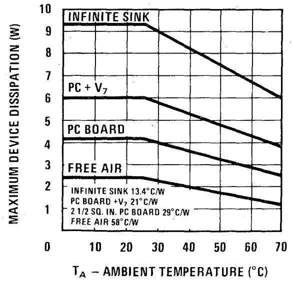
b. P.C. board +V_7 sink – 21°C/W. P.C. board is 2 1/2 square inches. Staver V_7 sink is 0.02 inch thick copper and has a radiating surface area of 10 square inches.

c. P.C. board only – 29°C/W. Device soldered to 2 1/2 square inch P.C. board.

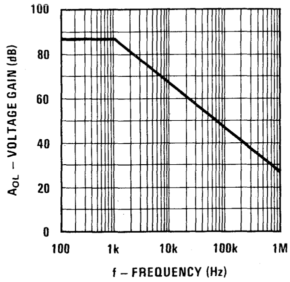
d. Free air – 58°C/W.

typical performance characteristics

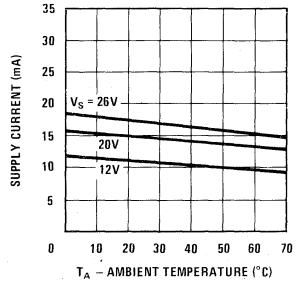
Maximum Dissipation vs Ambient Temperature



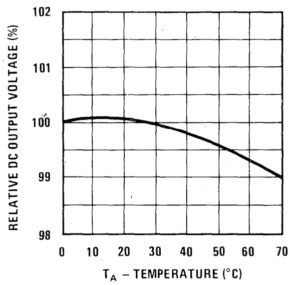
Open Loop Gain



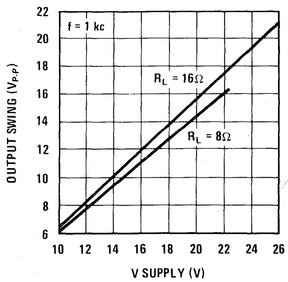
Supply Current vs Temperature



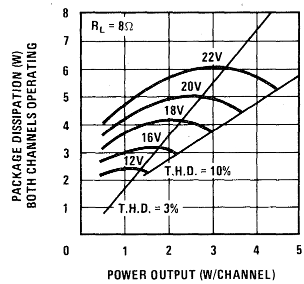
DC Output Level vs Temperature



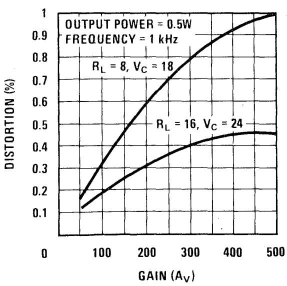
Output Swing vs V_S



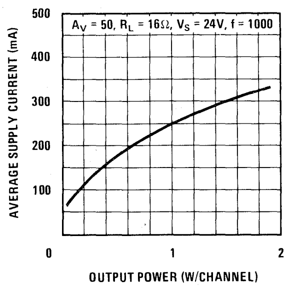
Power Dissipation vs Power Output



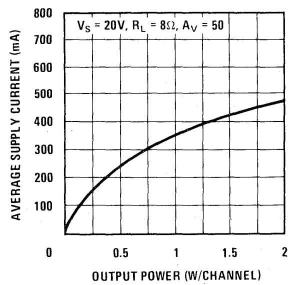
Distortion vs Gain



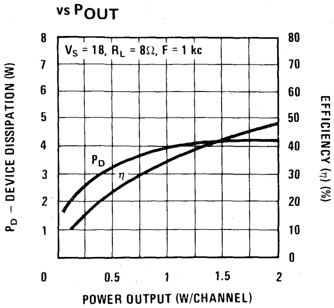
Supply Current vs Output Power



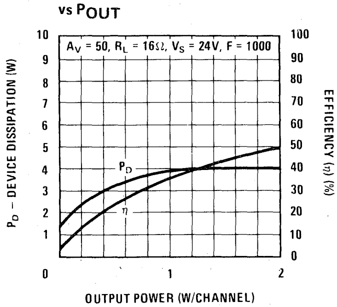
Supply Current vs P_{OUT}



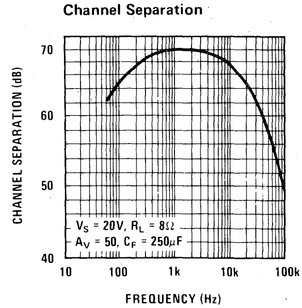
Dissipation and Efficiency vs P_{OUT}



Dissipation and Efficiency vs P_{OUT}

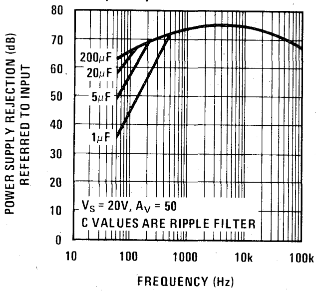


Channel Separation

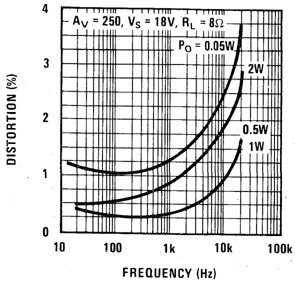


typical performance characteristics (con't)

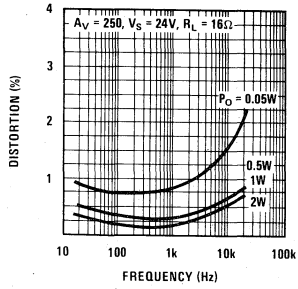
Supply Rejection vs Frequency



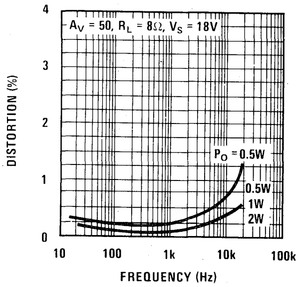
Distortion vs Frequency



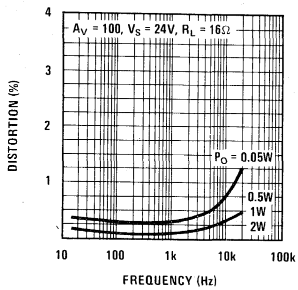
Distortion vs Frequency



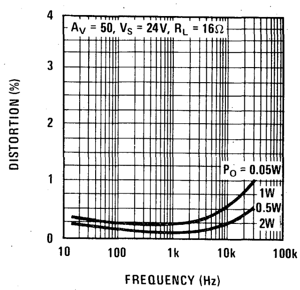
Distortion vs Frequency



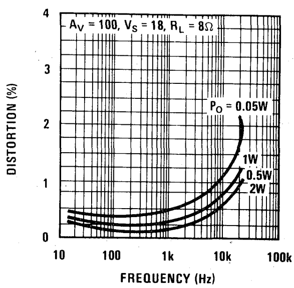
Distortion vs Frequency



Distortion vs Frequency

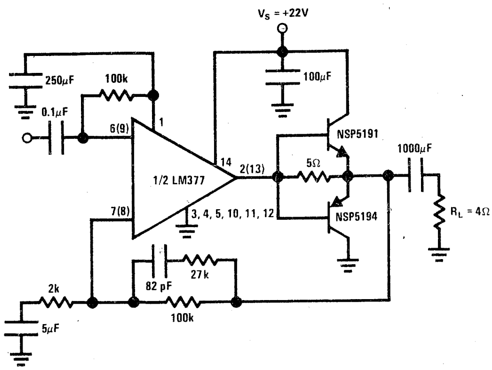


Distortion vs Frequency

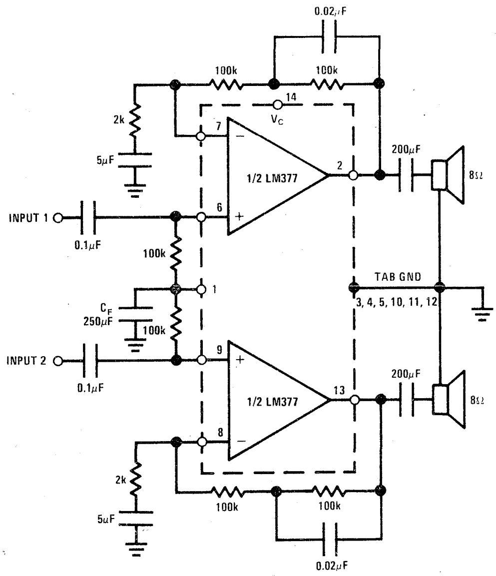


typical applications (con't)

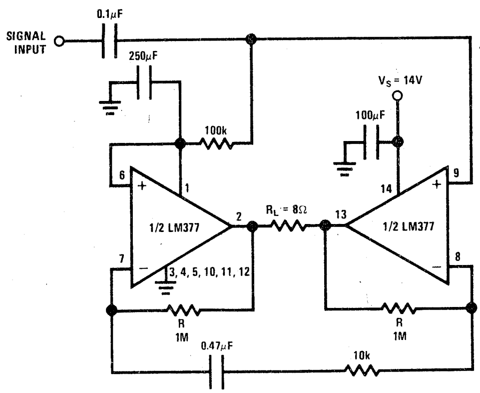
10W Per Channel Audio Amplifier



Simple Stereo Amplifier with Bass Boost



4W Bridge Amplifier



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. For more information see AN-125.

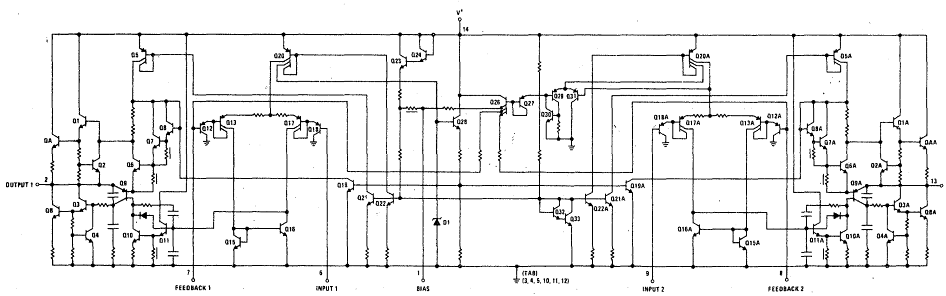
features

- 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

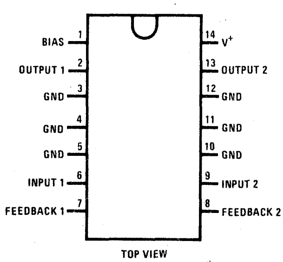
- Multi-channel audio systems
- Tape recorders and players
- Movie projectors
- Automotive systems
- Stereo phonographs
- Bridge output stages
- AM-FM radio receivers
- Intercoms
- Servo amplifiers
- Instrument systems

schematic diagram



connection diagram

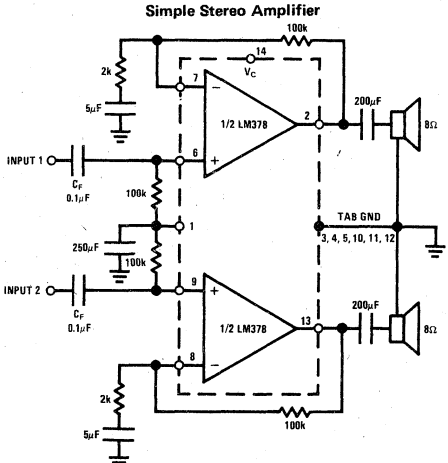
Dual-In-Line Package



Order Number LM378N
See Package 22

typical applications

Simple Stereo 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		15	50	mA
	P_{OUT} = 1.5W/Channel		430	500	mA
DC Output Level			12		V
Supply Voltage		10			V
Output Power	T.H.D. = < 5%, R_L = 8Ω	4	5		W
	T.H.D. = < 5%, R_L = 16Ω	4	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
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.

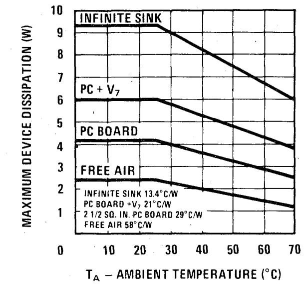
c. P.C. board only – 29°C/W. Device soldered to 2 1/2 square inch P.C. board.

d. Free air – 58°C/W.

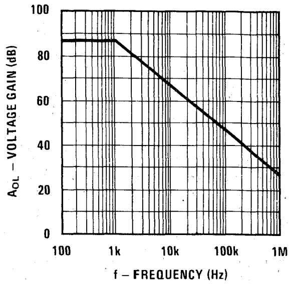
*Tested at V_S = 30V.

typical performance characteristics

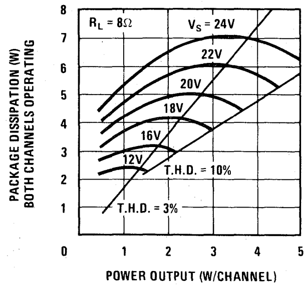
Maximum Dissipation vs Ambient Temperature



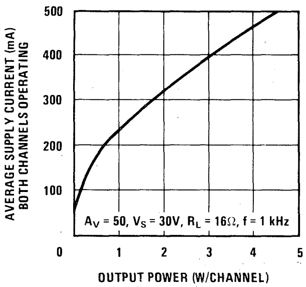
Open Loop Gain



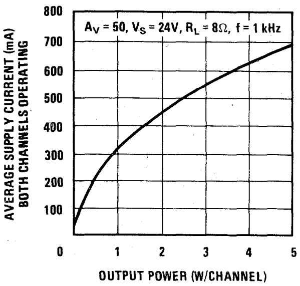
Power Dissipation vs Power Output



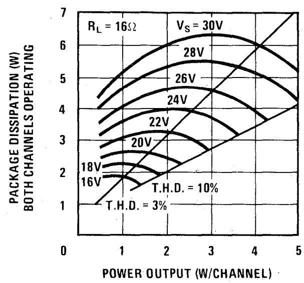
Supply Current vs Output Power



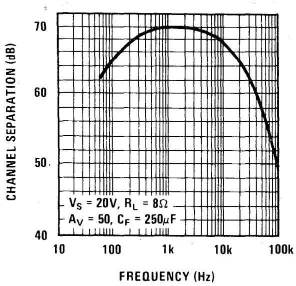
Supply Current vs Output Power



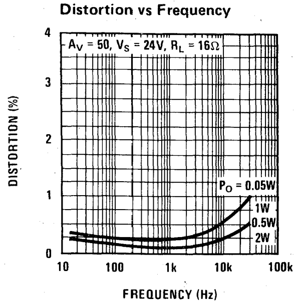
Power Dissipation vs Power Output



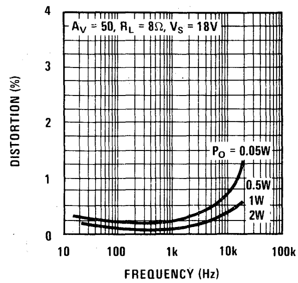
Channel Separation



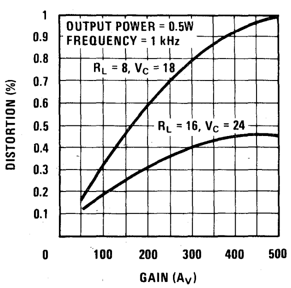
Distortion vs Frequency



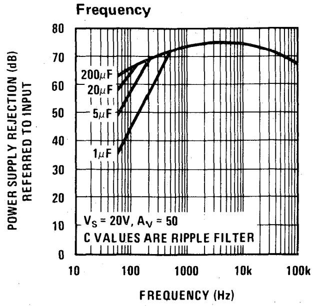
Distortion vs Frequency



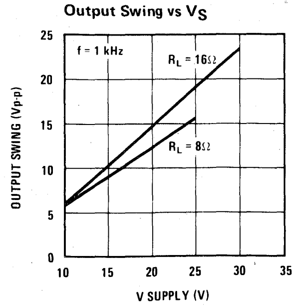
Distortion vs Gain



Supply Rejection vs Frequency

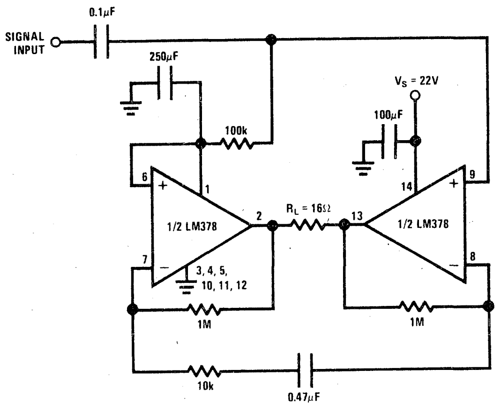


Output Swing vs V_S

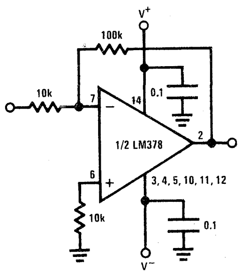


10

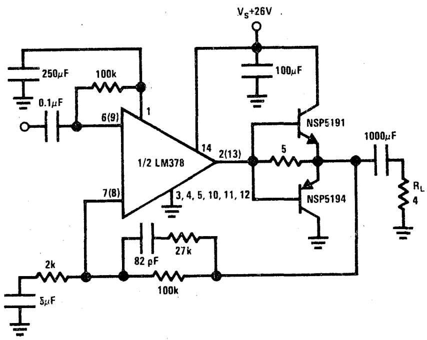
typical applications (con't)



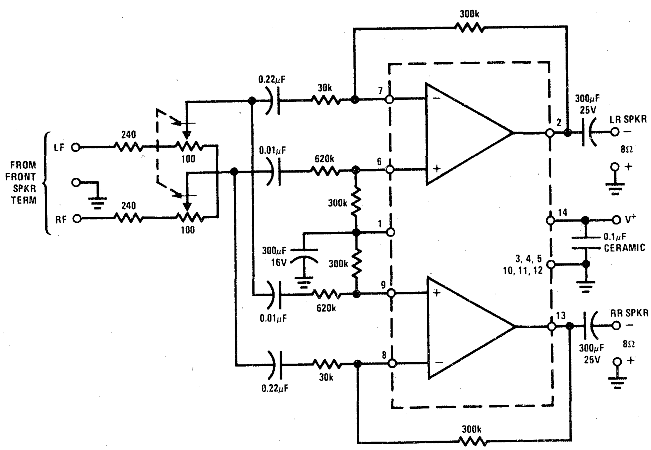
8W Bridge Amplifier



Power Op Amp (Using Split Supplies)



15W Per Channel Audio Amplifier



Rear Speaker Ambience (4-Channel) Amplifier

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 6W/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. For more information, see AN-125.

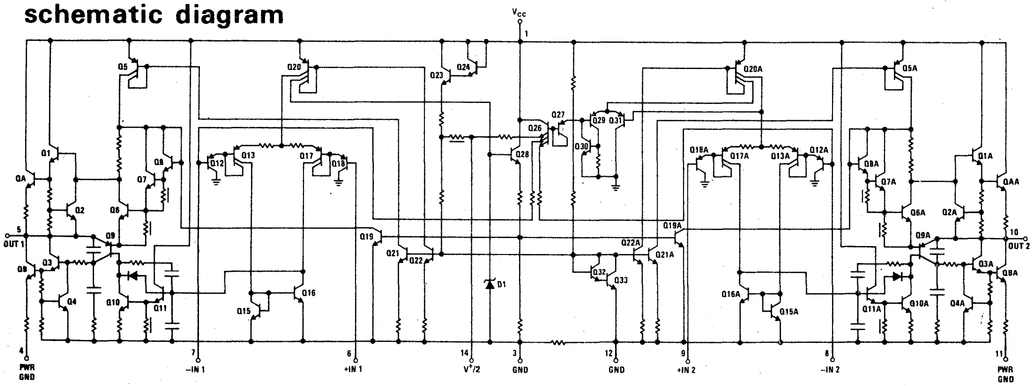
features

- A_{VO} typical 90 dB
- 6W 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

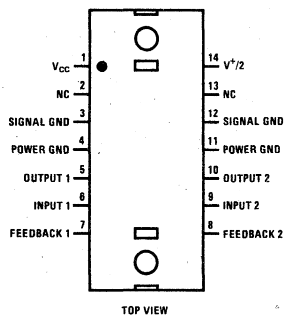
- Multi-channel audio systems
- Tape recorders and players
- Movie projectors
- Automotive systems
- Stereo phonographs
- Bridge output stages
- AM-FM radio receivers
- Intercoms
- Servo amplifiers
- Instrument systems

schematic diagram



connection diagram

Dual-In-Line Power Package

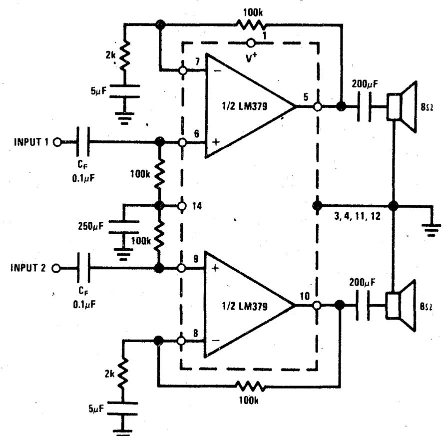


TOP VIEW

Order Number LM379S
See Package 39

typical applications

Simple Stereo 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

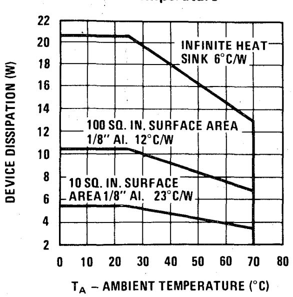
V_S = 28V, T_{TAB} = 25°C, R_L = 8Ω, A_V = 50 (34 dB), unless otherwise specified.

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

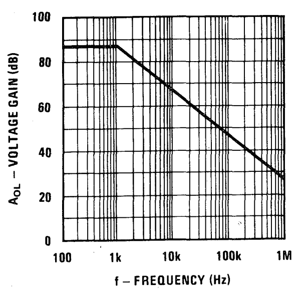
Note 1: For operation at ambient temperatures greater than 25°C the LM379 must be derated based on a maximum 150°C junction temperature using a thermal resistance which depends upon device mounting techniques. In most applications it is advisable to heat sink to the chassis. See curves.

typical performance characteristics

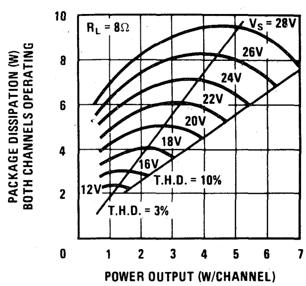
Maximum Dissipation vs Ambient Temperature



Open Loop Gain

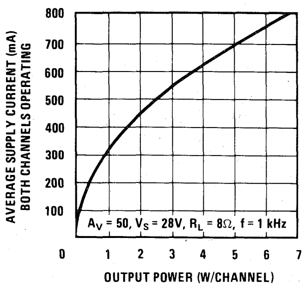


Power Dissipation vs Power Output

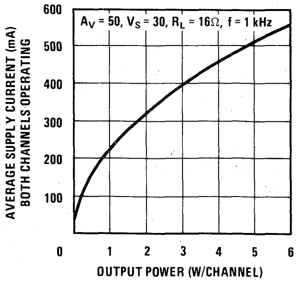


typical performance characteristics (con't)

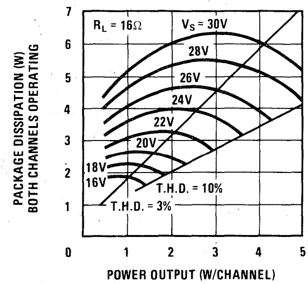
Supply Current vs Output Power



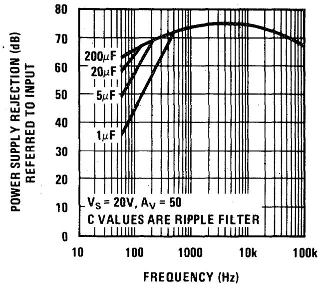
Supply Current vs P_{OUT}



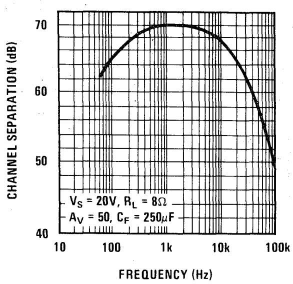
Power Dissipation vs Power Output



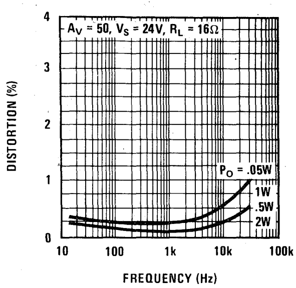
Supply Rejection vs Frequency



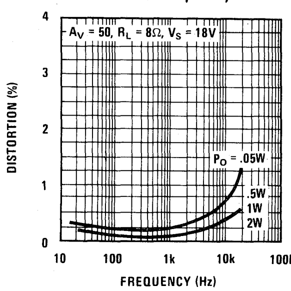
Channel Separation



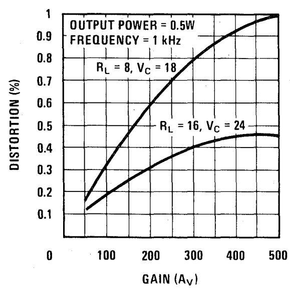
Distortion vs Frequency



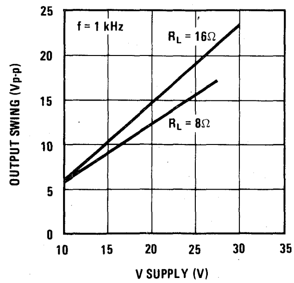
Distortion vs Frequency



Distortion vs Gain

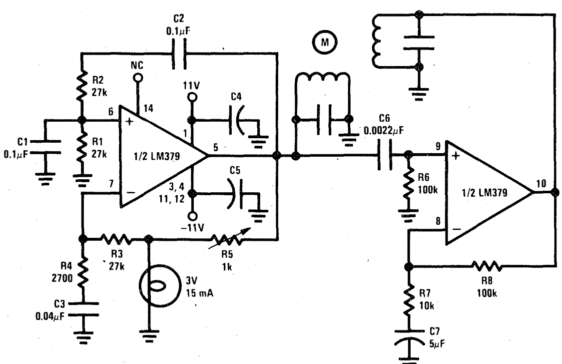


Output Swing vs V_S

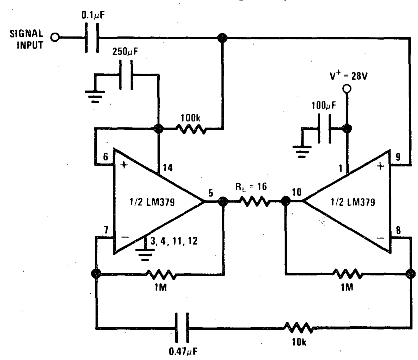


typical applications (con't)

Two-Phase Motor Drive

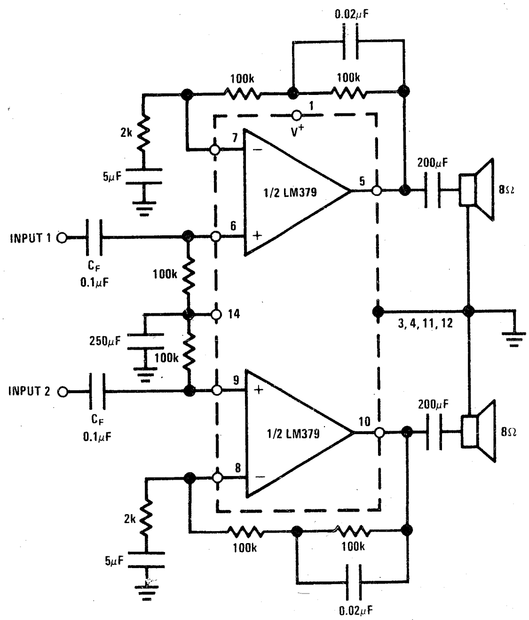


12W Bridge Amplifier

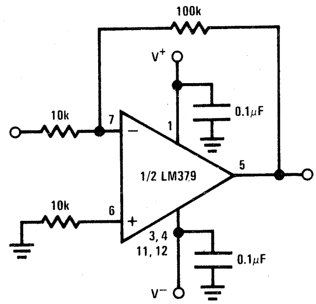


typical applications (con't)

Simple Stereo Amplifier with Bass Boost



Power Op Amp (Using Split Supplies)



Audio, Radio and TV 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.

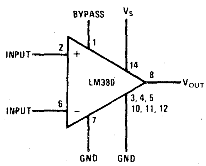
Uses include simple phonograph amplifiers, intercoms, line drivers, teaching machine outputs, alarms, ultrasonic drivers, TV sound systems, AM-FM radio, small servo drivers, power converters,etc.

A selected part for more power on higher supply voltages is available as the LM384. For more information see AN-69.

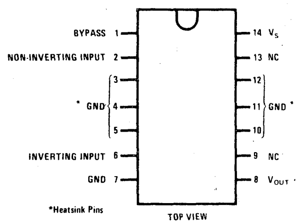
features

- 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

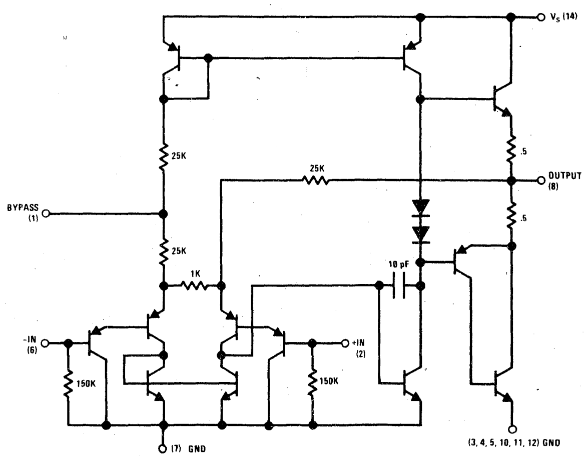


Dual-In-Line Package



Order Number LM380N
See Package 22

schematic diagram



absolute maximum ratings

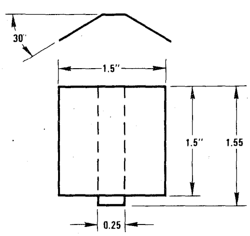
Supply Voltage	22V
Peak Current	1.3A
Package Dissipation 14-Pin DIP (Notes 6 and 7)	10W
Input Voltage	±0.5V
Storage Temperature	−65°C to +150°C
Operating Temperature	0°C to +70°C
Junction Temperature	+150°C
Lead Temperature (Soldering, 10 sec)	+300°C

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: The maximum junction temperature of the LM380 is 150°C.
Note 7: The package is to be derated at 12°C/W junction to heat sink pins.

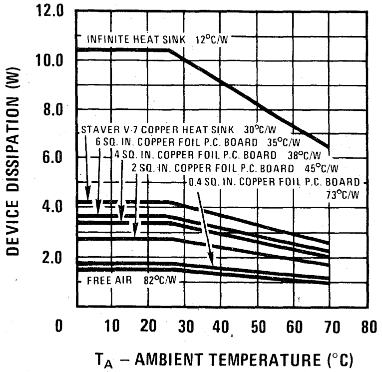
heat sink dimensions



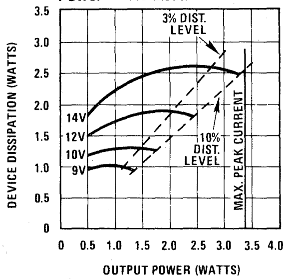
COPPER WINGS
2 REQUIRED
SOLDERED TO
PINS 3, 4, 5,
10, 11, 12
THICKNESS 0.04
INCHES

typical performance characteristics

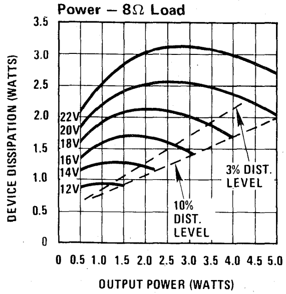
Device Dissipation vs Ambient Temperature



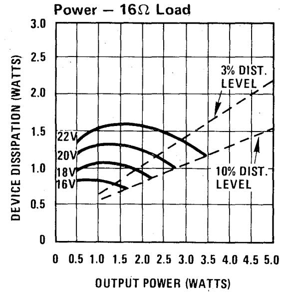
Device Dissipation vs Output Power — 4Ω Load



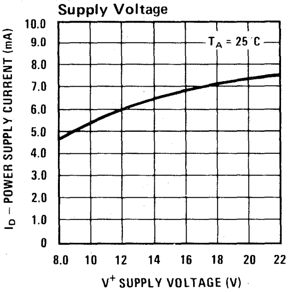
Device Dissipation vs Output Power — 8Ω Load



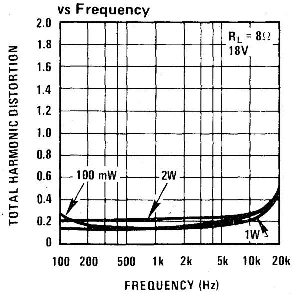
Device Dissipation vs Output Power — 16Ω Load



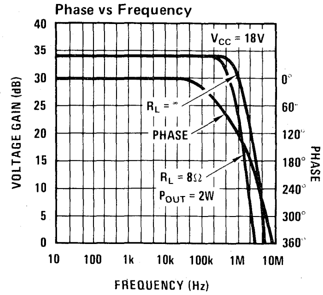
Power Supply Current vs Supply Voltage



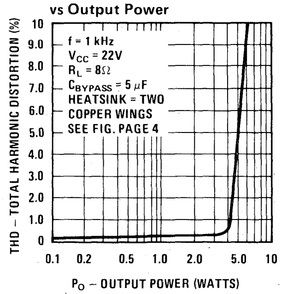
Total Harmonic Distortion vs Frequency



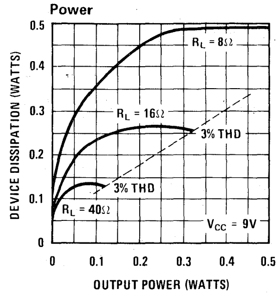
Output Voltage Gain and Phase vs Frequency



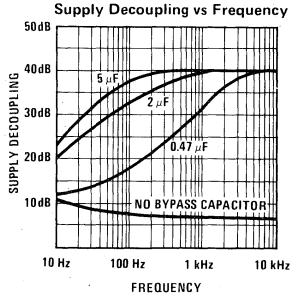
Total Harmonic Distortion vs Output Power



Device Dissipation vs Output Power

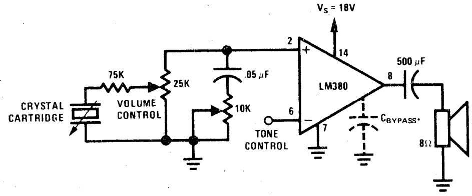


Supply Decoupling vs Frequency

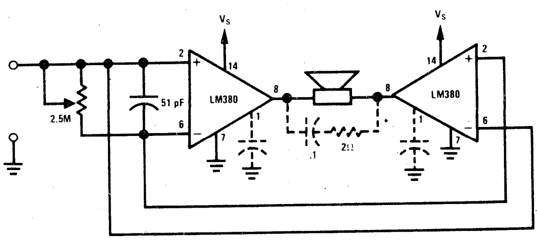


typical applications

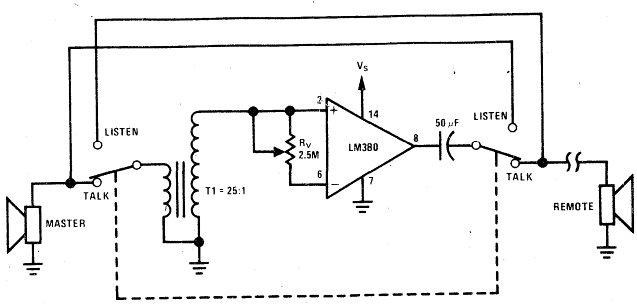
Phono Amplifier



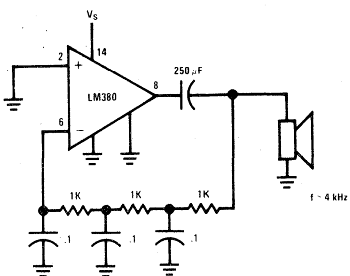
Bridge Amplifier



Intercom



Phase Shift Oscillator



Audio, Radio and TV Circuits

LM381/LM381A low noise dual preamplifier

general description

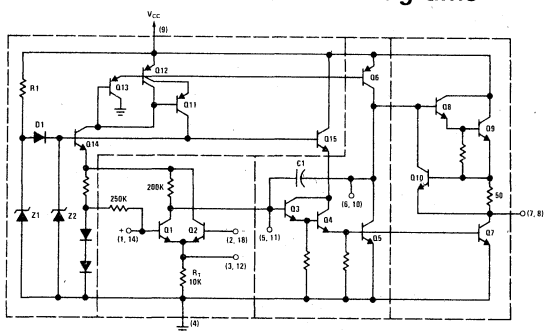
The LM381/LM381A is a dual preamplifier for the amplication of low level signals in applications requiring optimum noise performance. Each of the two amplifiers is completely independent, with individual internal power supply decoupler-regulator, providing 120 dB supply rejection and 60 dB channel separation. 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. For additional information see AN-64, AN-70, and AN-104.

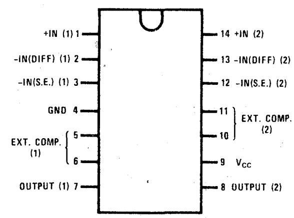
features

- 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



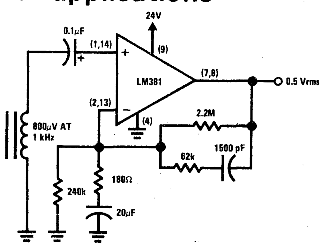
Dual-In-Line Package



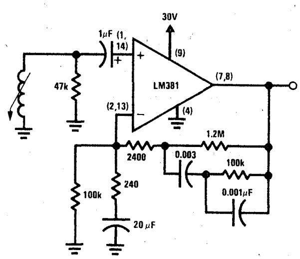
TOP VIEW

Order Number LM381N or LM381AN
See Package 22

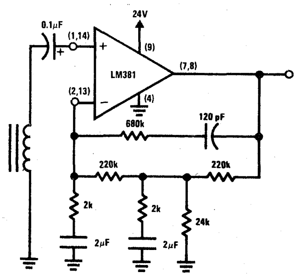
typical applications



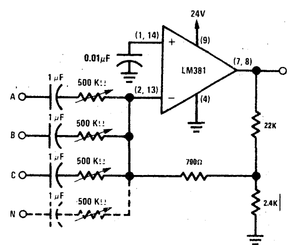
Typical Tape Playback Amplifier



Typical Magnetic Phono Preamp.



Two-Pole Fast Turn-On NAB Tape Preamp



Audio Mixer

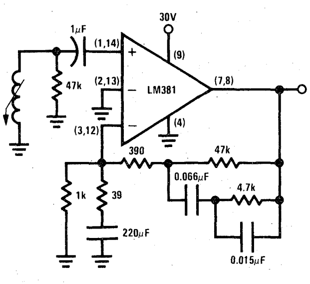
absolute maximum ratings

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

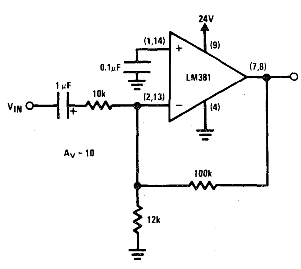
electrical characteristics T_A = 25°C, V_{CC} = 14V, unless otherwise stated.

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Voltage Gain	Open Loop (Differential Input), f = 100 Hz		160,000		V/V
	Open Loop (Single Ended), f = 100 Hz		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
Unity Gain 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		60		dB
Total Harmonic Distortion	60 dB Gain, f = 1 kHz		0.1		%
Total Equivalent Input Noise	R_S = 600Ω, 10 – 10,000 Hz (Single Ended Input, Flat Gain Circuit, A_V = 1000)				
LM381A			0.5	0.7	μVrms
LM381			0.5	1.0	μVrms

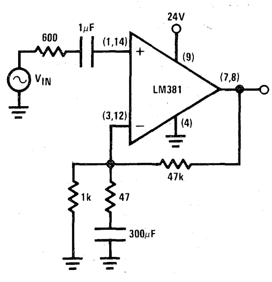
typical applications (con't)



Single-Ended Phono Preamp



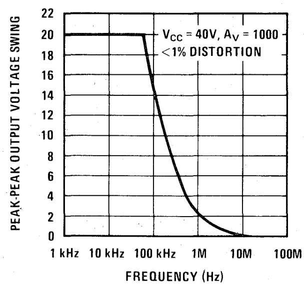
Ultra-Low Distortion Amplifier (A_V = 10, THD < 0.05%, V_{OUT} = 3 V_{RMS})



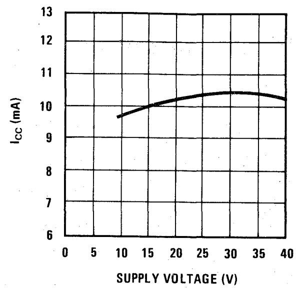
Flat Gain Circuit (A_V = 1000)

typical performance characteristics

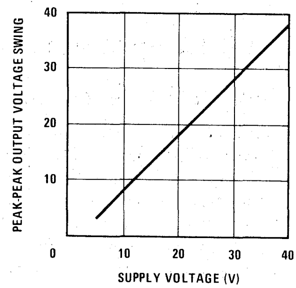
Large Signal Frequency Response



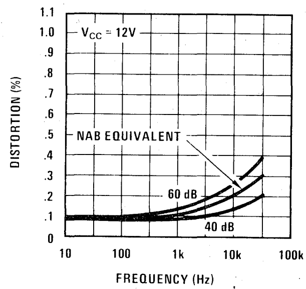
V_{CC} vs I_{CC}



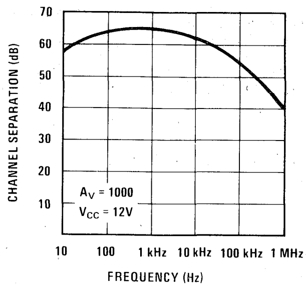
P–P Output Voltage Swing vs V_{CC}



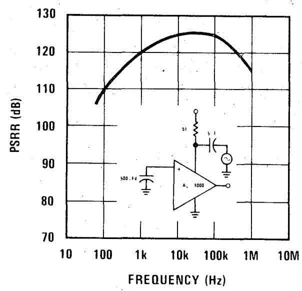
% Distortion



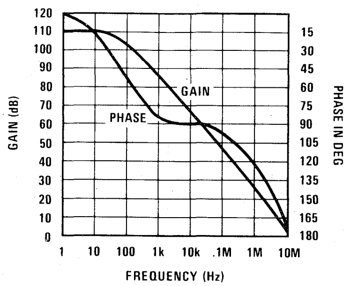
Channel Separation



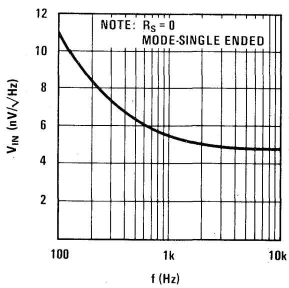
PSRR vs Frequency



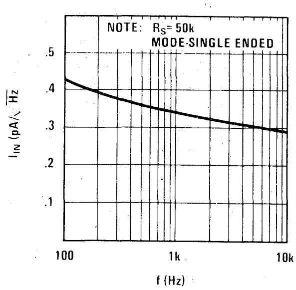
Gain and Phase Response



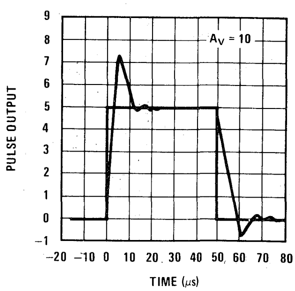
Noise Voltage vs Frequency



Noise Current vs Frequency



Pulse Response



Audio, Radio and TV Circuits

LM382 low noise dual preamplifier

general description

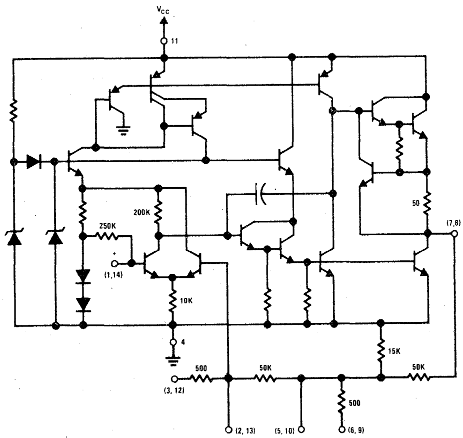
The LM382 is a dual preamplifier for the amplication of low level signals in applications requiring optimum noise performance. Each of the two amplifiers is completely independent, with individual internal power supply decoupler-regulator, providing 120 dB supply rejection and 60 dB channel separation. Other outstanding features include high gain (100 dB), and wide power bandwidth (75 kHz, 20 Vp-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.

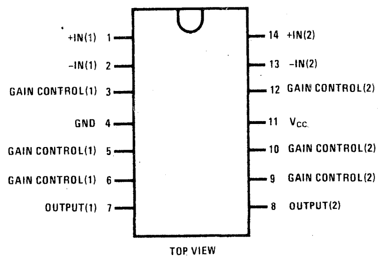
features

- 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

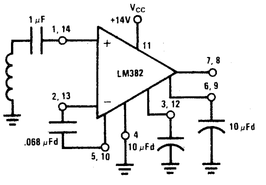


Dual-In-Line Package

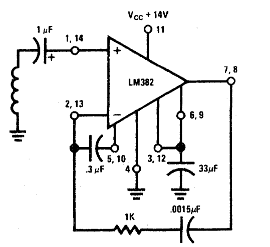


Order Number LM382N
See Package 22

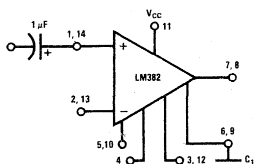
typical applications



Tape Pre-Amp (NAB Equalization)



Phono Pre-Amp (RIAA Equalization)



CAPACITOR	GAIN
C1 Only	40 dB
C2 Only	55 dB
C1 & C2	80 dB

Flat Response — Fixed Gain Configuration

absolute maximum ratings

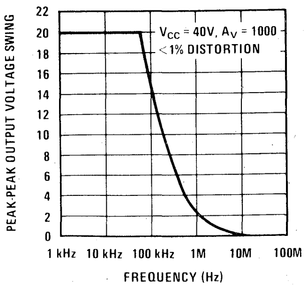
Supply Voltage	+40V
Power Dissipation	800 mW
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec)	300°C

electrical characteristics T_A = 25°C, V_{CC} = 14V, unless otherwise stated.

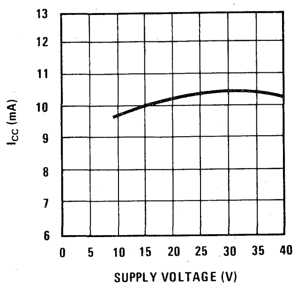
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Voltage Gain	Open Loop, f = 100 Hz		100,000		V/V
Supply Current	V_{CC} 9 to 40V, $R_L = \infty$		10	16	mA
Output DC Voltage			6		V
Input Resistance					
(Positive Input)			100		kΩ
(Negative Input)			200		kΩ
Input Current					
(Negative Input)			0.5		μA
Output Resistance	Open Loop		150		Ω
Output Current	Source		8		mA
	Sink		2		mA
Output Voltage Swing	Peak-to-Peak, R_L = 10k		12		V
Unity Gain 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		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 (Flat Response Circuit)		0.8	1.2	μVrms

typical performance characteristics

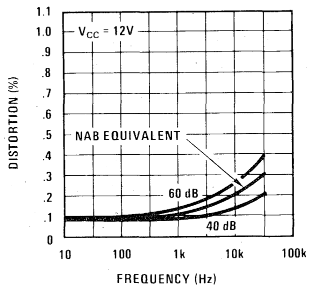
Large Signal Frequency Response



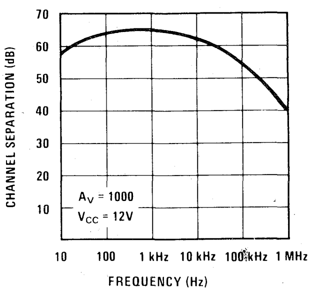
V_{CC} vs I_{CC}



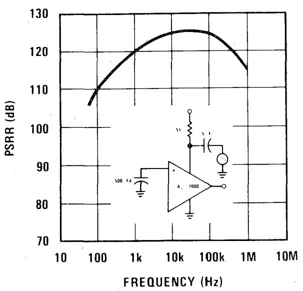
% Distortion



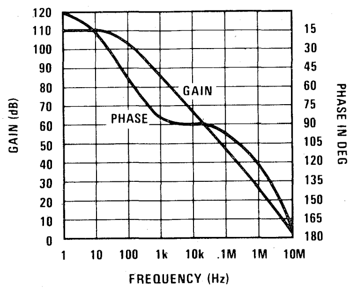
Channel Separation



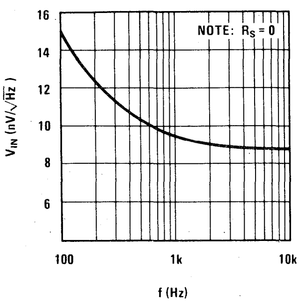
PSRR vs Frequency



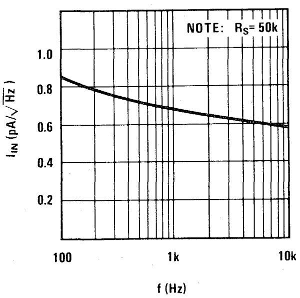
Gain and Phase Response



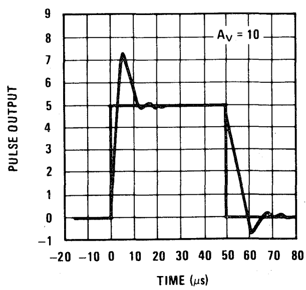
Noise Voltage vs Frequency



Noise Current vs Frequency



Pulse Response



Audio, Radio and TV Circuits

LM384 5 watt audio power amplifier

general description

The LM384 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-centering to one half the supply voltage.

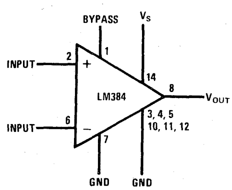
The output is short-circuit proof with internal thermal limiting. The package outline is standard dual-in-line. A copper lead frame is used with the center three pins on either side comprising a heat sink. This makes the device easy to use in standard p-c layout.

Uses include simple phonograph amplifiers, intercoms, line drivers, teaching machine outputs, alarms, ultrasonic drivers, TV sound systems, AM-FM radio, sound projector systems, etc. See AN-69 for circuit details.

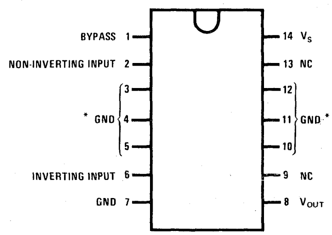
features

- 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

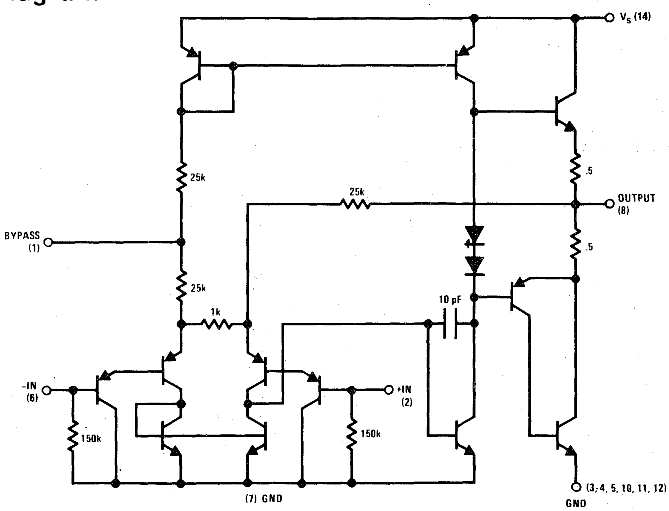


*Heatsink Pins

TOP VIEW

Order Number LM384N
See Package 22

schematic diagram



absolute maximum ratings

Supply Voltage	28V
Peak Current	1.3A
Power Dissipation	(See Notes 3 and 4)
Input Voltage	±0.5V
Storage Temperature	−65°C to +150°C
Operating Temperature	0°C to +70°C
Lead Temperature (Soldering, 10 seconds)	300°C

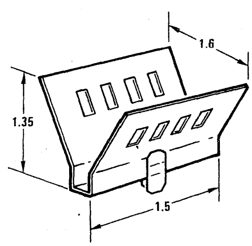
electrical characteristics (Note 1)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Input Resistance (Z_{IN})			150		kΩ
Bias Current (I_{BIAS})	Inputs Floating		100		nA
Gain (A_V)		40	50	60	V/V
Output Power (P_{OUT})	THD = 10%, R_L = 8Ω	5	5.5		W
Quiescent Supply Current (I_Q)			8.5	25	mA
Quiescent Output Voltage ($V_{OUT\ Q}$)			11		V
Bandwidth (BW)	P_{OUT} = 2W, R_L = 8Ω		450		kHz
Supply Voltage (V^+)		12		26	V
Short Circuit Current (I_{SC})			1.3		A
Power Supply Rejection Ratio ($PSRR_{RTO}$) (Note 2)			31		dB
Total Harmonic Distortion (THD)	P_{OUT} = 4W, R_L = 8Ω		0.25	1.0	%

Note 1: V^+ = 22V and T_A = 25°C operating with a Staver V7 heat sink for 30 seconds.
Note 2: Rejection ratio referred to the output with C_{BYPASS} = 5μF, freq = 120 Hz.
Note 3: The maximum junction temperature of the LM384 is 150°C.
Note 4: The package is to be derated at 12°C/W junction to heat sink pins.
Note 5: Output is fully protected against a shorted speaker condition at all voltages up to 22V.

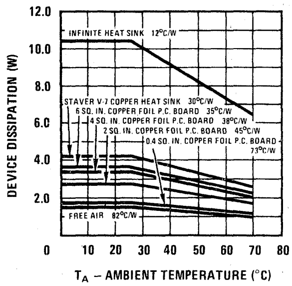
heat sink dimensions

Staver "V7" Heat Sink

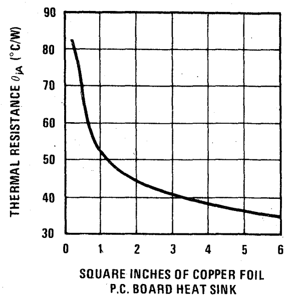


typical performance characteristics

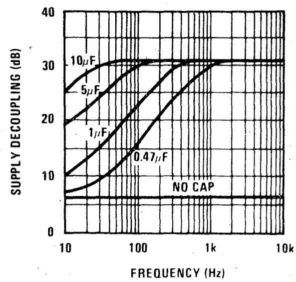
Device Dissipation vs Ambient Temperature



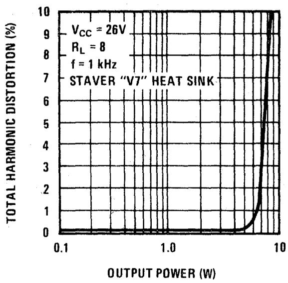
Thermal Resistance vs Square Inches



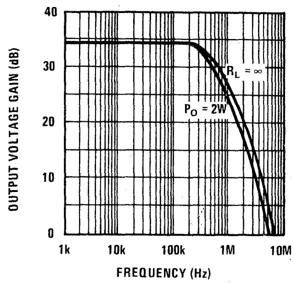
Supply Decoupling vs Frequency



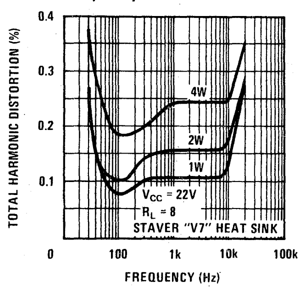
Total Harmonic Distortion vs Output Power



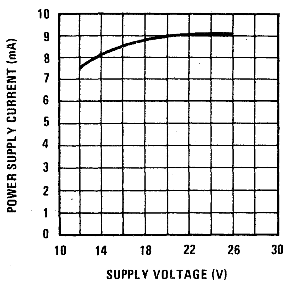
Output Voltage Gain vs Frequency



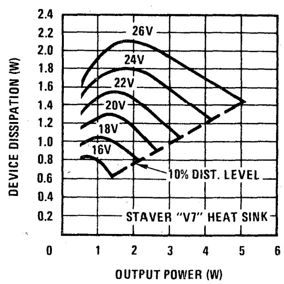
Total Harmonic Distortion vs Frequency



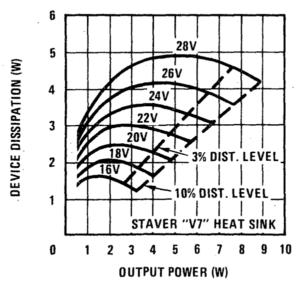
Power Supply Current vs Supply Voltage



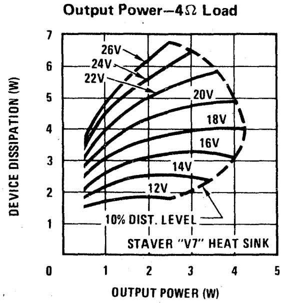
Device Dissipation vs Output Power—16Ω Load



Device Dissipation vs Output Power—8Ω Load



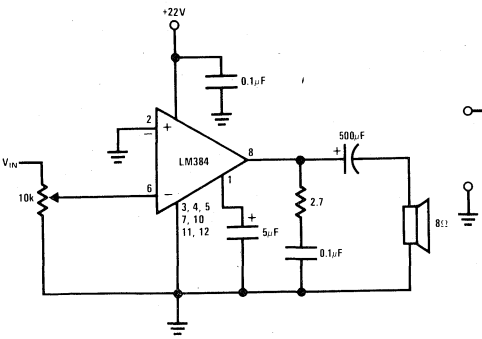
Device Dissipation vs Output Power—4Ω Load



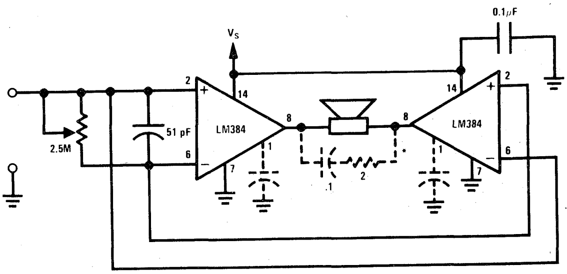
10

typical applications

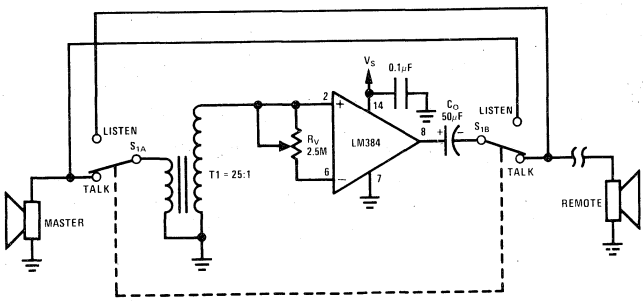
Typical 5W Amplifier



Bridge Amplifier

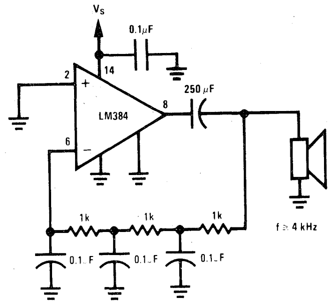


Intercom



*For stability with high current loads

Phase Shift Oscillator



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 24 milliwatts when operating from a 6 volt supply, making the LM386 ideal for battery operation.

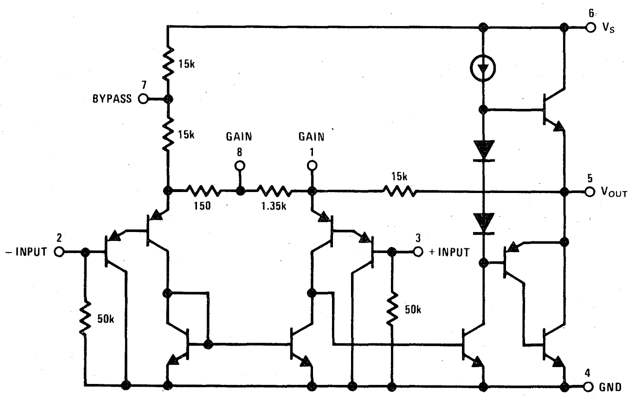
features

- Battery operation
- Minimum external parts
- Wide supply voltage range 4–12 Volts
- Low quiescent current drain 4 mA
- Voltage gains from 20 to 200
- Ground referenced input
- Self-centering output quiescent voltage
- Low distortion
- Eight pin dual-in-line package

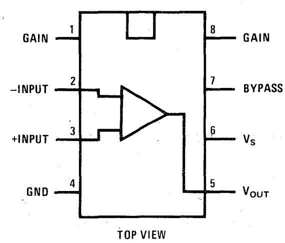
applications

- 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

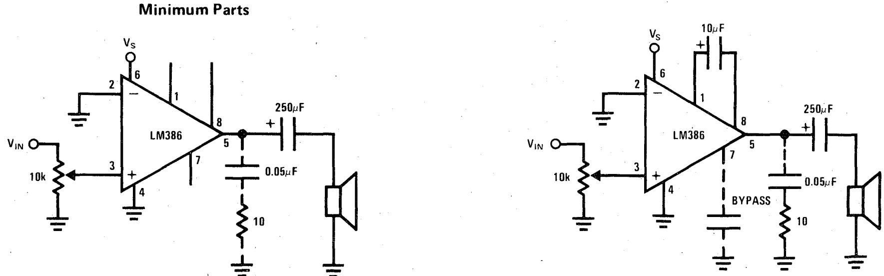


Dual-In-Line Package



Order Number LM386N
See Package 20

typical applications



absolute maximum ratings

Supply Voltage (Note 1)	15V
Package Dissipation 8 Pin DIP (Note 2)	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		4	8	mA
Output Power (P_{OUT}) (Note 3)	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: Parts selected for higher absolute maximum supply voltage available on special request.

Note 2: 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 3: 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.

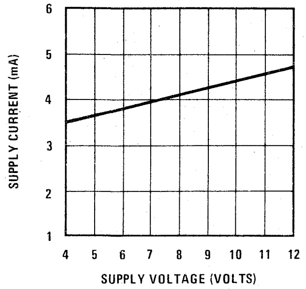
INPUT BIASING

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.

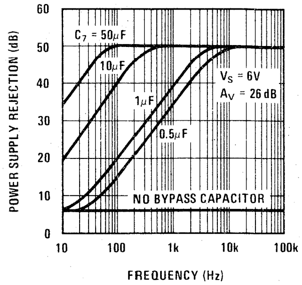
When using the LM386 with higher gains (bypassing the 1.35 kΩ resistor between pins 1 and 8) it is necessary to bypass the unused input, preventing degradation of gain and possible instabilities. This is done with a 0.1μF capacitor or a short to ground depending on the dc source resistance on the driven input.

typical performance characteristics

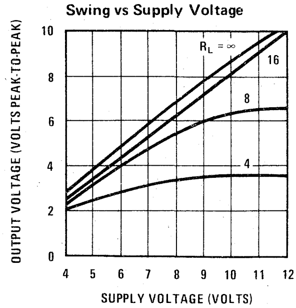
Quiescent Supply Current vs Supply Voltage



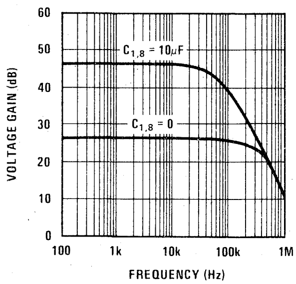
Power Supply Rejection Ratio (Referred to the Output) vs Frequency



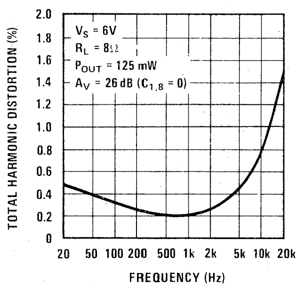
Peak-to-Peak Output Voltage Swing vs Supply Voltage



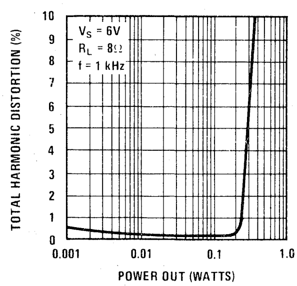
Voltage Gain vs Frequency



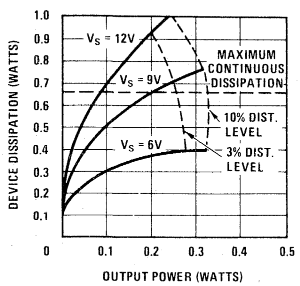
Distortion vs Frequency



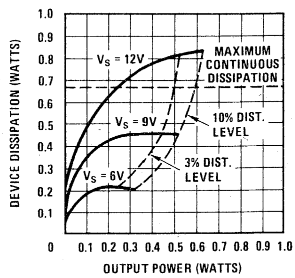
Distortion vs Output Power



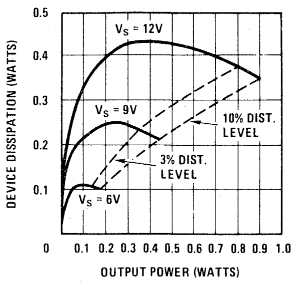
Device Dissipation vs Output Power — 4Ω Load



Device Dissipation vs Output Power — 8Ω Load

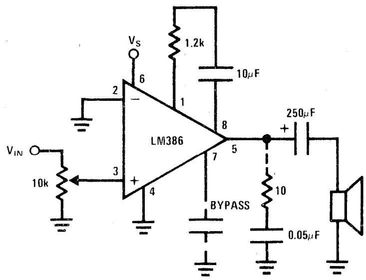


Device Dissipation vs Output Power — 16Ω Load

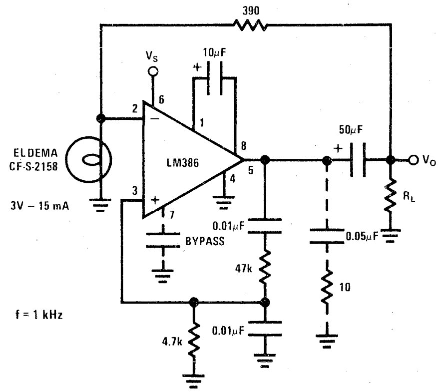


typical applications (con't)

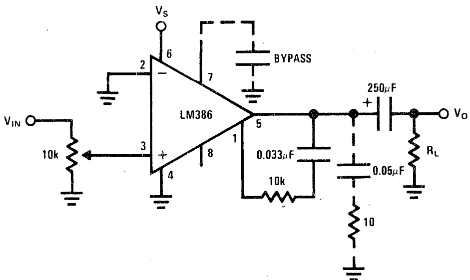
Amplifier with Gain = 50



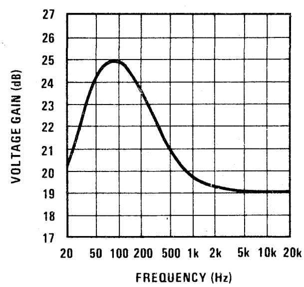
Low Distortion Power Wien Bridge Oscillator



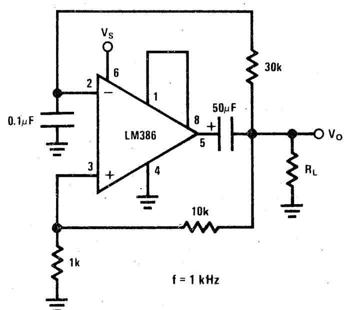
Amplifier with Bass Boost



Frequency Response with Bass Boost



Square Wave Oscillator



LM387/LM387A low noise dual preamplifier

general description

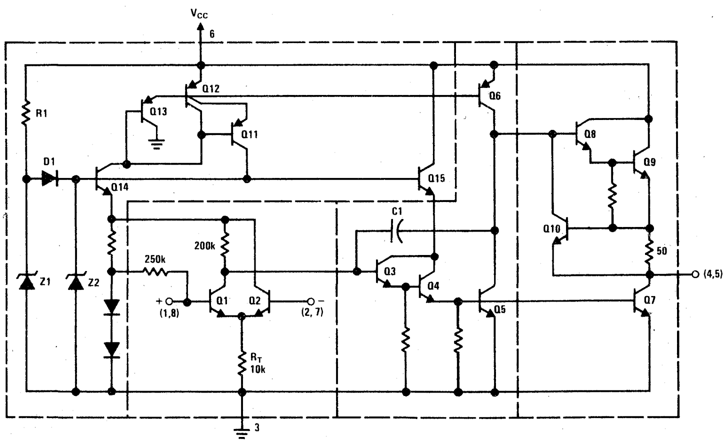
The LM387 is a dual preamplifier for the amplification of low level signals in applications requiring optimum noise performance. Each of the two amplifiers is completely independent, with an internal power supply decoupler-regulator, providing 110 dB supply rejection and 60 dB channel separation. Other 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 LM387A is a selected version of the LM387 that has lower noise and can operate on a larger supply voltage. The LM387 operates from a single supply across the wide range of 9V to 30V, the LM387A operates on a supply of 9V to 40V.

The amplifiers are internally compensated for gains greater than 10. The LM387, LM387A is available in an 8-lead dual-in-line package. The LM387, LM387A is biased like the LM381. See AN-64 and AN-104.

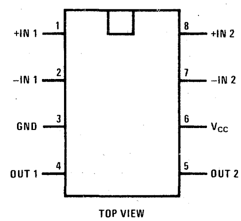
features

- Low noise LM387 — 0.8μV total input noise
  LM387A — 0.65 total input noise
- High gain — 104 dB open loop
- Single supply operation
- Wide supply range LM387 — 9 to 30V
  LM387A — 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
- Performance similar to LM381

schematic and connection diagrams



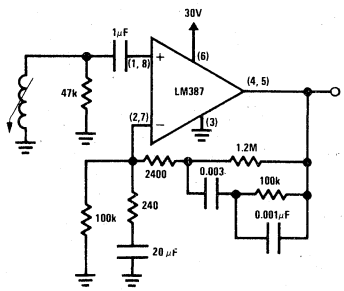
Dual-In-Line Package



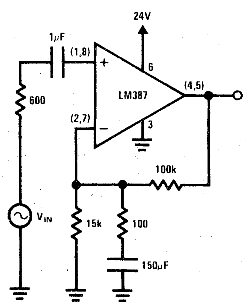
Order Number LM387N or LM387AN
See Package 20

typical applications

Typical Magnetic Phono Preamplifier



Flat Gain Circuit (A_V = 1000)



absolute maximum ratings

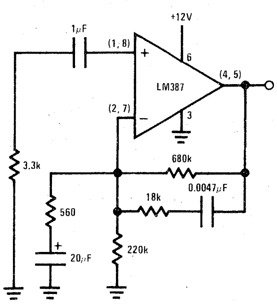
Supply Voltage	
LM387	+30V
LM387A	+40V
Power Dissipation	660 mW
Operating Temperature Range	0°C to +70°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics $T_A = 25°C$, $V_{CC} = 14V$, unless otherwise stated.

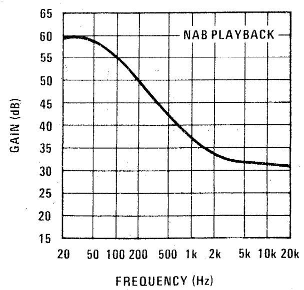
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Voltage Gain	Open Loop, f = 100 Hz		160,000		V/V
Supply Current	LM387, V_{CC} 9–30V, $R_L = \infty$		10		mA
	LM387A, V_{CC} 9–40V, $R_L = \infty$		10		mA
Input Resistance					
Positive Input		50	100		kΩ
Negative Input			200		kΩ
Input Current					
Negative Input			0.5	3.1	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
Unity Gain Bandwidth			15		MHz
Power Bandwidth	20 Vp-p (V_{CC} = 24V)		75		kHz
Maximum Input Voltage	Linear Operation			300	mVrms
Supply Rejection Ratio Input Referred	f = 1 kHz		110		dB
Channel Separation	f = 1 kHz	40	60		dB
Total Harmonic Distortion	60 dB Gain, f = 1 kHz		0.1	0.5	%
Total Equivalent Input	R_S = 600Ω, 10–10,000 Hz				
Noise (Flat Gain Circuit)	LM387		0.8	1.2	μVrms
	LM387A		0.65	0.9	μVrms
Output Noise NAB Tape	10–10,000 Hz				
Playback Circuit	LM387		230		μVrms
	LM387A		180		μVrms

typical applications (con't)

NAB Tape Circuit

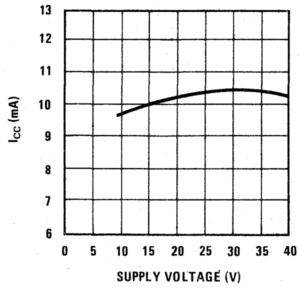


Frequency Response of NAB Circuit

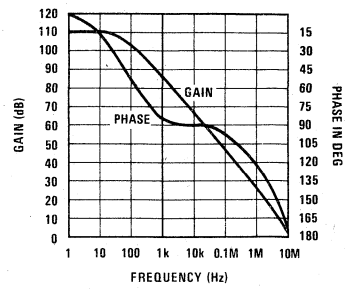


typical performance characteristics

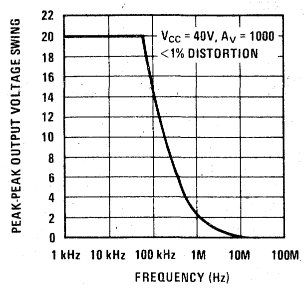
V_{CC} vs I_{CC}



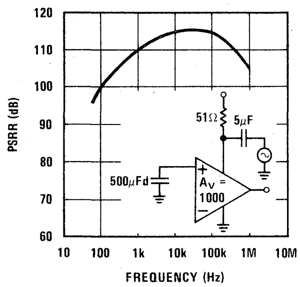
Gain and Phase Response



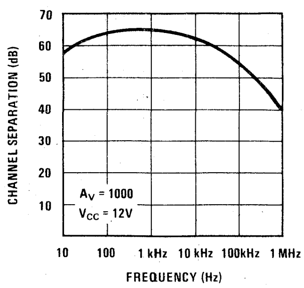
Large Signal Frequency Response



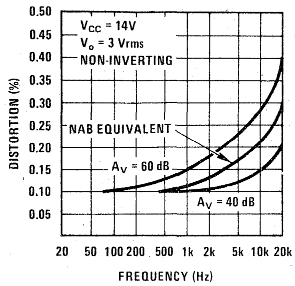
PSRR vs Frequency (Input Referred)



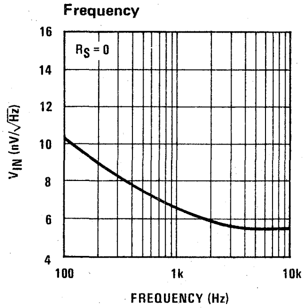
Channel Separation



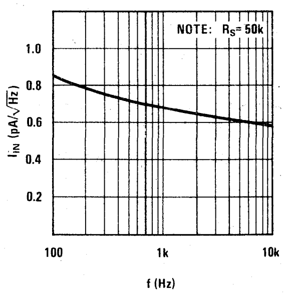
Distortion vs Frequency Non-Inverting Amplifier



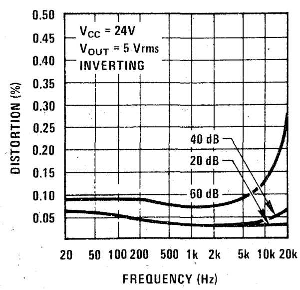
Noise Voltage vs Frequency



Noise Current vs Frequency

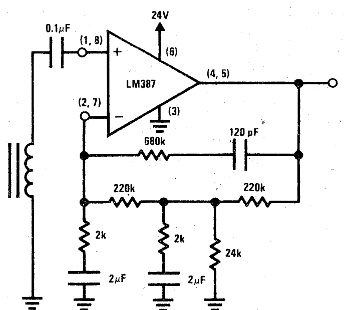


Distortion vs Frequency Inverting Amplifier

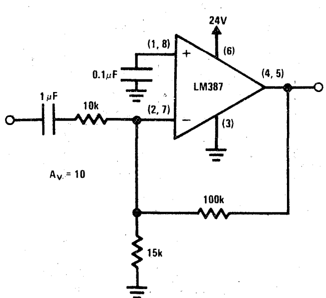


typical applications (con't)

Two-Pole Fast Turn-On NAB Tape Preamplifier



Inverting Amplifier Ultra-Low Distortion



Audio, Radio and TV Circuits

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.

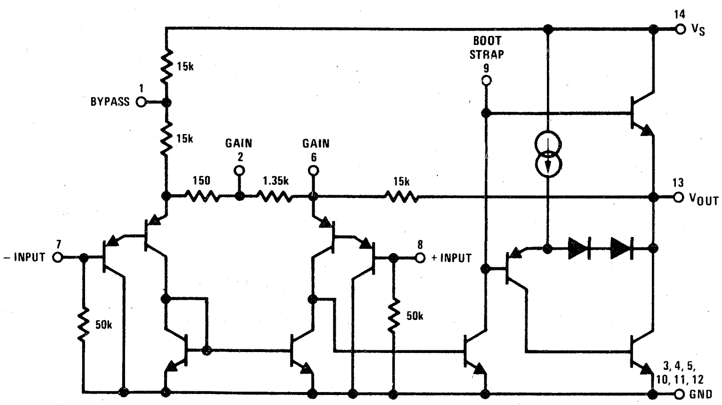
features

- Minimum external parts
- Wide supply voltage range
- Excellent supply rejection
- Ground referenced input
- Self-centering output quiescent voltage
- Variable voltage gain
- Low distortion
- Fourteen pin dual-in-line package
- Low voltage operation, 4V

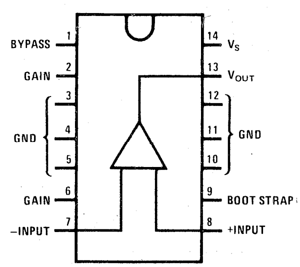
applications

- 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



TOP VIEW

Order Number LM388N
See Package 22

typical applications

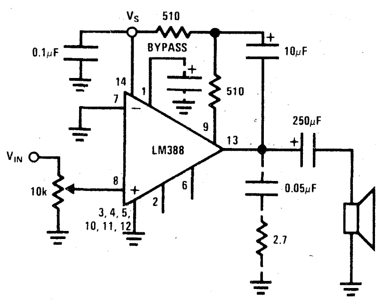


FIGURE 1. Load Returned to Ground (Amplifier with Gain = 20)

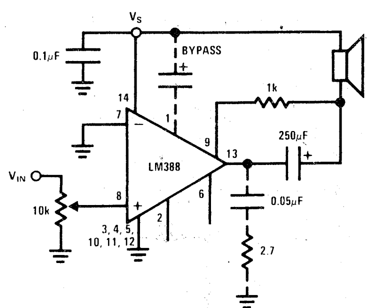


FIGURE 2. Load Returned to V_S (Amplifier with Gain = 20)

absolute maximum ratings

Supply Voltage (Note 1)	15V
Package Dissipation 14-Pin DIP (Note 2)	8.3W
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

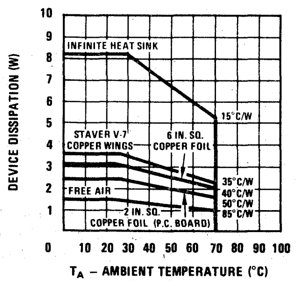
electrical characteristics $T_A = 25°C$, *(Figure 1)*

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Supply Voltage (V_S)		4		12	V
Quiescent Current (I_Q)	$V_S = 12V$, $V_{IN} = 0$		10	20	mA
Output Power (P_{OUT}) (Note 3)	$V_S = 12V$, $R_L = 8\Omega$, THD = 10% $V_S = 6V$, $R_L = 4\Omega$, THD = 10%, R1 + R2 = 440Ω	1.0 0.45	1.5 0.6		W W
Voltage Gain (A_V)	$V_S = 12V$, f = 1 kHz 10μF from Pin 2 to 6	23	26 46	30	dB dB
Bandwidth (BW)	$V_S = 12V$, Pins 2 and 6 Open		300		kHz
Total Harmonic Distortion (THD)	$V_S = 12V$, $R_L = 8\Omega$, $P_{OUT} = 500$ mW f = 1 kHz, Pins 2 and 6 Open		0.1	1	%
Power Supply Rejection Ratio (PSRR) (Note 4)	$V_S = 12V$, f = 1 kHz, $C_{BYPASS} = 10\mu F$, Pins 2 and 6 Open, Referred to Output		50		dB
Input Resistance (R_{IN})		10	50		kΩ
Input Bias Current (I_{BIAS})	$V_S = 12V$, Pins 7 and 8 Open		250		nA

Note 1: Parts selected for higher absolute maximum supply voltage available on special request.
Note 2: Pins 3, 4, 5, 10, 11, 12 at 25°C. Derate at 15°C/W above 25°C case.
Note 3: If oscillation exists under some load conditions, add 2.7Ω and 0.05μF series network from pin 13 to ground.
Note 4: If load and bypass capacitor are returned to V_S *(Figure 2)*, rather than ground *(Figure 1)*, PSRR is typically 30 dB.

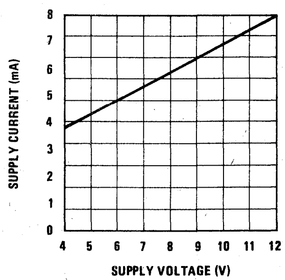
typical performance characteristics

Maximum Device Dissipation vs Ambient Temperature

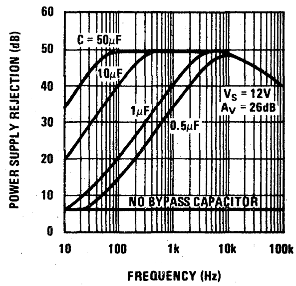


Note: 2 oz. copper foil, single-sided PC board.

Quiescent Supply Current vs Supply Voltage

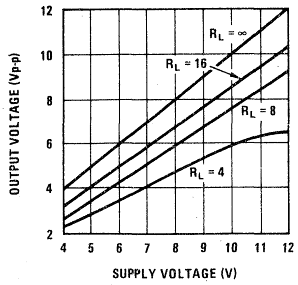


Power Supply Rejection Ratio (Referred to the Output) vs Frequency

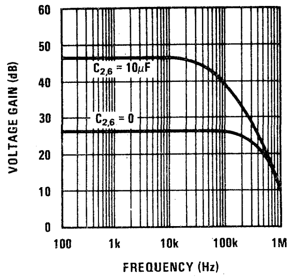


typical performance characteristics (con't)

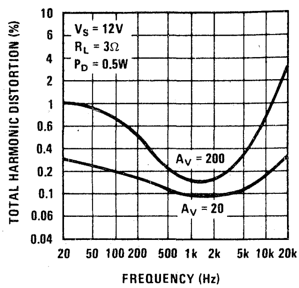
Peak-to-Peak Output Voltage Swing vs Supply Voltage



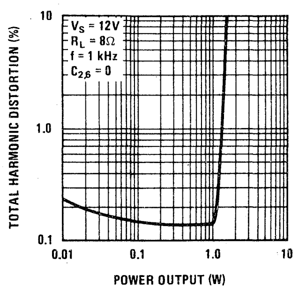
Voltage Gain vs Frequency



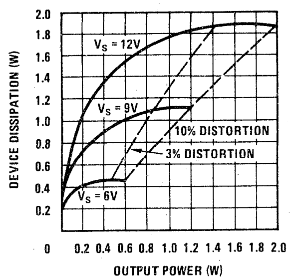
Distortion vs Frequency



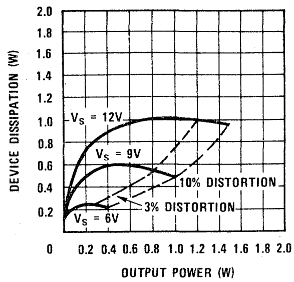
Distortion vs Output Power



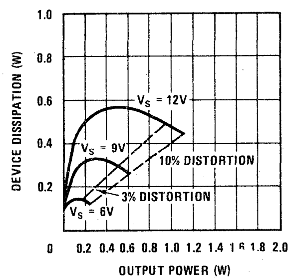
Device Dissipation vs Output Power — 4Ω Load



Device Dissipation vs Output Power — 8Ω Load



Device Dissipation vs Output Power — 16Ω Load



application hints

Gain Control

To make the LM388 a more versatile amplifier, two pins (2 and 6) are provided for gain control. With pins 2 and 6 open, the 1.35 kΩ resistor sets the gain at 20 (26 dB). If a capacitor is put from pin 2 to 6, 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. A low frequency pole in the gain response is caused by the capacitor working against the external resistor in series with the 150Ω internal resistor. If the capacitor is eliminated and a resistor connects pin 2 to 6 then the output dc level may shift due to the additional dc gain. Gain control can also be done by capacitively coupling a resistor (or FET) from pin 6 to ground, as in *Figure 7.*

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 6 to 13 (paralleling the internal 15 kΩ resistor). For 6 dB effective bass boost: R ≅

application hints (con't)

15 kΩ, the lowest value for good stable operation is R = 10 kΩ if pin 2 is open. If pins 2 and 6 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 V/V.

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 LM388 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 LM388 with higher gains (bypassing the 1.35 kΩ resistor between pins 2 and 6) 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.

Bootstrapping

The base of the output transistor of the LM388 is brought out to pin 9 for Bootstrapping. The output stage of the amplifier during positive swing is shown in *Figure 3* with its external circuitry.

R1 + R2 set the amount of base current available to the output transistor. The maximum output current divided by Beta is the value required for the current in R1 and R2:

$$(R1 + R2) = \beta_O \frac{(V_S/2) - V_{BE}}{I_{O\ MAX}}$$

Good design values are V_{BE} = 0.7V and β_O = 100.

Example: 1_{WATT} into 8Ω load with V_S = 12V.

$$I_{O\ MAX} = \sqrt{\frac{2\ P_O}{R_L}} = 500\ \text{mA}$$

$$(R1 + R2) = 100 \left(\frac{(12/2) - 0.7}{0.5}\right) = 1060\Omega$$

To keep the current in R2 constant during positive swing capacitor C_B is added. As the output swings positive C_B lifts R1 and R2 above the supply, maintaining a constant voltage across R2. To minimize the value of C_B, R1 = R2. The pole due to C_B and R1 and R2 is usually set equal to the pole due to the output coupling capacitor and the load. This gives:

$$C_B \simeq \frac{4C_c}{\beta_O} \simeq \frac{C_c}{25}$$

Example: for 100 Hz pole and R_L = 8Ω; C_c = 200μF and C_B = 8μF, if R1 is made a diode and R2 increased to give the same current, C_B can be decreased by about a factor of 4, as in *Figure 4.*

For reduced component count the load can replace R1. The value of (R1 + R2) is the same, so R2 is increased. Now C_B is both the coupling and the bootstrapping capacitor (see *Figure 2).*

typical applications (con't)

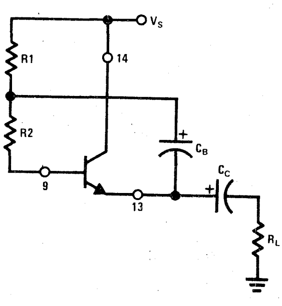


FIGURE 3.

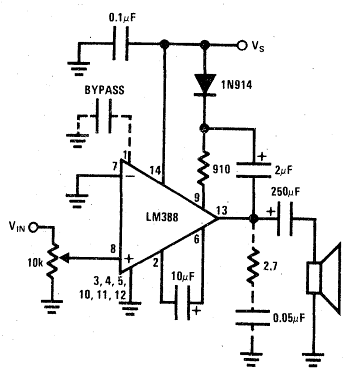
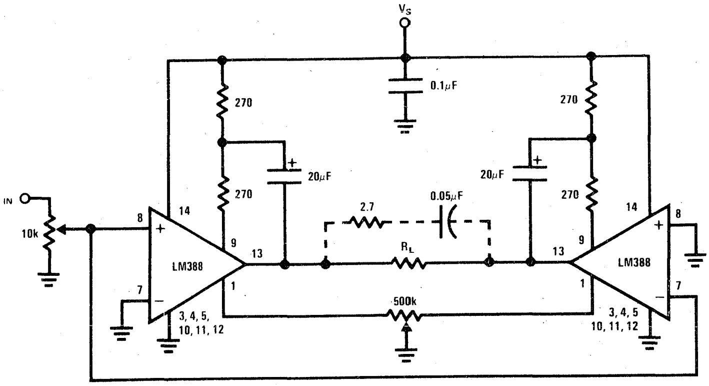


FIGURE 4. Amplifier with Gain = 200 and Minimum C_B

typical applications (con't)



$V_S = 6V$ $R_L = 4\Omega$ $P_O = 1.0W$
$V_S = 12V$ $R_L = 8\Omega$ $P_O = 3.5W$

FIGURE 5. Bridge Amp

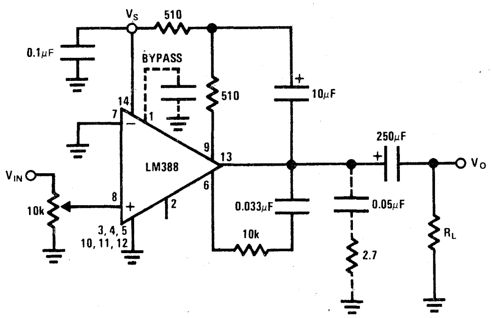


FIGURE 6a. Amplifier with Bass Boost

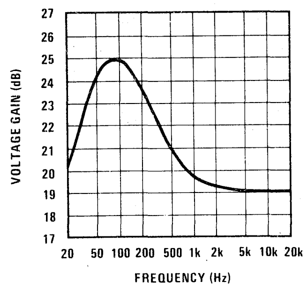


FIGURE 6b. Frequency Response with Bass Boost

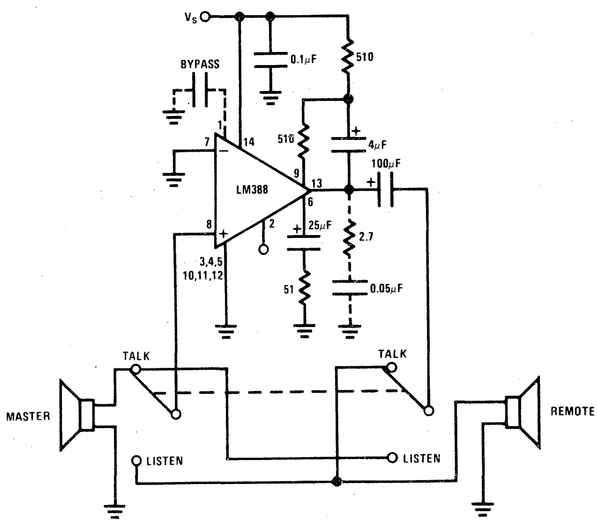


FIGURE 7. Intercom

LM389 low voltage audio power amplifier with NPN transistor array

general description

The LM389 is an array of three NPN transistors on the same substrate with an audio power amplifier similar to the LM386.

The amplifier inputs are ground referenced while the output is automatically biased to one half the supply voltage. The gain is internally set at 20 to minimize external parts, but the addition of an external resistor and capacitor between pins 4 and 12 will increase the gain to any value up to 200.

The three transistors have high gain and excellent matching characteristics. They are well suited to a wide variety of applications in dc through VHF systems.

features

Amplifier

- Battery operation
- Minimum external parts
- Wide supply voltage range
- Low quiescent current drain
- Voltage gains from 20 to 200
- Ground referenced input
- Self-centering output quiescent voltage
- Low distortion

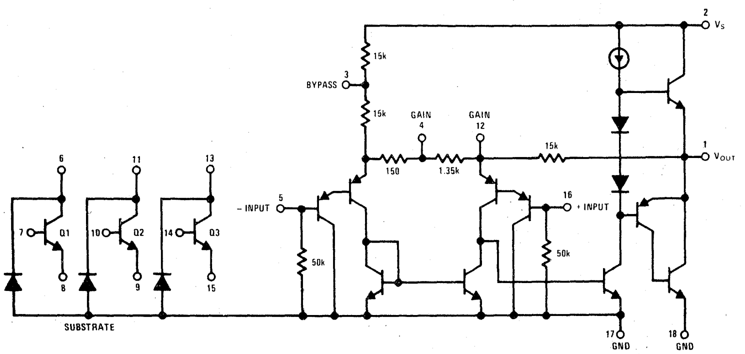
Transistors

- Operation from 1μA to 25 mA
- Frequency range from dc to 100 MHz
- Excellent matching

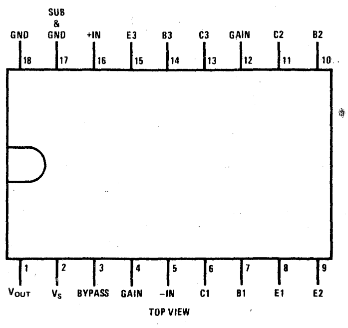
applications

- AM-FM radios
- Portable tape recorders
- Intercoms
- Toys and games
- Walkie-talkies
- Portable phonographs
- Power converters

equivalent schematic and connection diagrams



Dual-In-Line Package



Order Number LM389N
See Package 29

absolute maximum ratings

Supply Voltage	15V
Package Dissipation (Note 1)	825 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
Collector to Emitter Voltage, V_{CEO}	12V
Collector to Base Voltage, V_{CBO}	15V
Collector to Substrate Voltage, V_{CIO} (Note 2)	15V
Collector Current, I_C	25 mA
Emitter Current, I_E	25 mA
Base Current, I_B	5 mA
Power Dissipation (Each Transistor) $T_A \leq +70°C$	150 mW

electrical characteristics $T_A = 25°C$

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
AMPLIFIER						
V_S	Operating Supply Voltage		4		12	V
I_Q	Quiescent Current	$V_S = 6V$, $V_{IN} = 0V$		6	12	mA
P_{OUT}	Output Power (Note 3)	THD = 10% $V_S = 6V$, $R_L = 8\Omega$	250	325		mW
		THD = 10% $V_S = 9V$, $R_L = 16\Omega$		500		mW
A_V	Voltage Gain	$V_S = 6V$, f = 1 kHz	23	26	30	dB
		10μF From Pins 4 to 12		46		dB
BW	Bandwidth	$V_S = 6V$, Pins 4 and 12 Open		250		kHz
THD	Total Harmonic Distortion	$V_S = 6V$, $R_L = 8\Omega$, $P_{OUT} = 125$ mW, f = 1 kHz, Pins 4 and 12 Open		0.2	3.0	%
PSRR	Power Supply Rejection Ratio	$V_S = 6V$, f = 1 kHz, $C_{BYPASS} = 10\mu F$, Pins 4 and 12 Open, Referred to Output	30	50		dB
R_{IN}	Input Resistance		10	50		kΩ
I_{BIAS}	Input Bias Current	$V_S = 6V$, Pins 5 and 16 Open		250		nA
TRANSISTORS						
V_{CEO}	Collector to Emitter Breakdown Voltage	$I_C = 1$ mA, $I_B = 0$	12	20		V
V_{CBO}	Collector to Base Breakdown Voltage	$I_C = 10\mu A$, $I_E = 0$	15	40		V
V_{CIO}	Collector to Substrate Breakdown Voltage	$I_C = 10\mu A$, $I_E = I_B = 0$	15	40		V
V_{EBO}	Emitter to Base Breakdown Voltage	$I_E = 10\mu A$, $I_C = 0$	6.4	7.1	7.8	V
H_{FE}	Static Forward Current Transfer Ratio (Static Beta)	$I_C = 10\mu A$		100		
		$I_C = 1$ mA	100	275		
		$I_C = 10$ mA		275		
h_{oe}	Open-Circuit Output Admittance	$I_C = 1$ mA, $V_{CE} = 5V$, f = 1.0 kHz		20		μmho
V_{BE}	Base to Emitter Voltage	$I_E = 1$ mA		0.7	0.85	V
$\lvert V_{BE1} - V_{BE2} \rvert$	Base to Emitter Voltage Offset	$I_E = 1$ mA		1	5	mV
V_{CESAT}	Collector to Emitter Saturation Voltage	$I_C = 10$ mA, $I_B = 1$ mA		0.15	0.5	V
C_{EB}	Emitter to Base Capacitance	$V_{EB} = 3V$		1.5		pF
C_{CB}	Collector to Base Capacitance	$V_{CB} = 3V$		2		pF
C_{CI}	Collector to Substrate Capacitance	$V_{CI} = 3V$		3.5		pF
h_{fe}	High Frequency Current Gain	$I_C = 10$ mA, $V_{CE} = 5V$, f = 100 MHz	1.5	5.5		

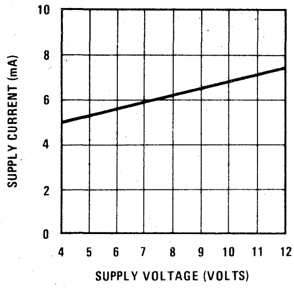
Note 1: For operating at elevated temperatures, the device must be derated based on a 150°C maximum junction temperature and a thermal resistance of 150°C/W junction to ambient.

Note 2: The collector of each transistor is isolated from the substrate by an integral diode. Therefore, the collector voltage should remain positive with respect to pin 17 at all times.

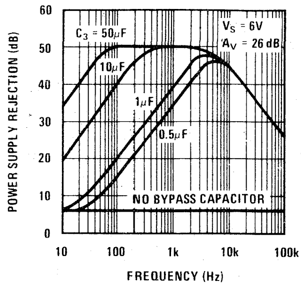
Note 3: If oscillation exists under some load conditions, add 2.7Ω and 0.05μF series network from pin 1 to ground.

typical amplifier performance characteristics

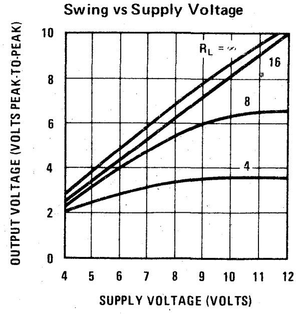
Quiescent Supply Current vs Supply Voltage



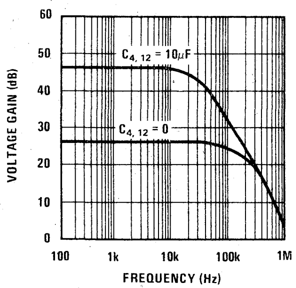
Power Supply Rejection Ratio (Referred to the Output) vs Frequency



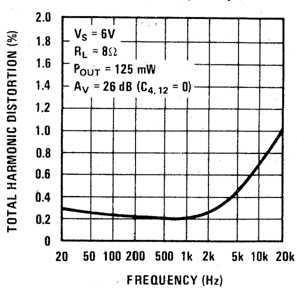
Peak-to-Peak Output Voltage Swing vs Supply Voltage



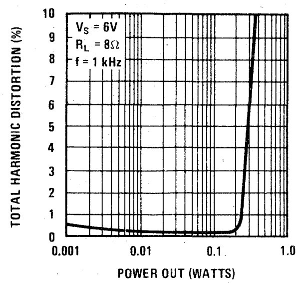
Voltage Gain vs Frequency



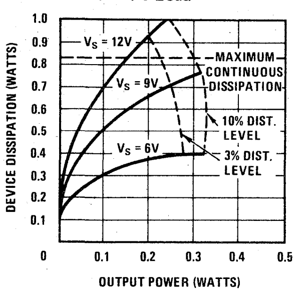
Distortion vs Frequency



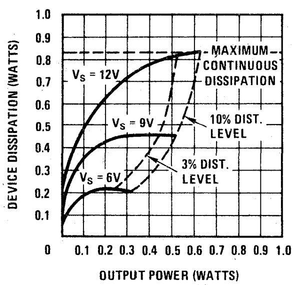
Distortion vs Output Power



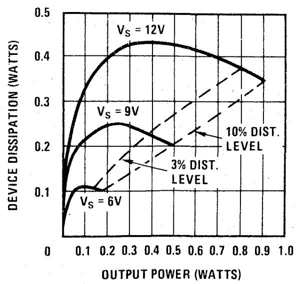
Device Dissipation vs Output Power — 4Ω Load



Device Dissipation vs Output Power — 8Ω Load

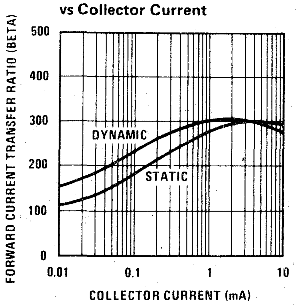


Device Dissipation vs Output Power — 16Ω Load

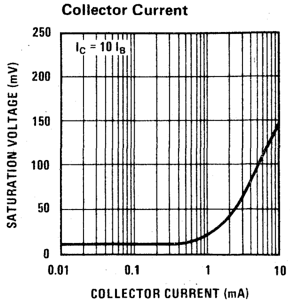


typical transistor performance characteristics

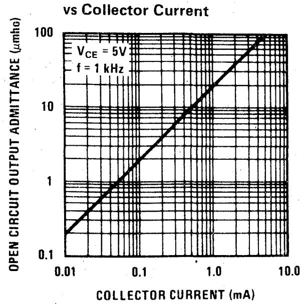
Forward Current Transfer Ratio vs Collector Current



Saturation Voltage vs Collector Current

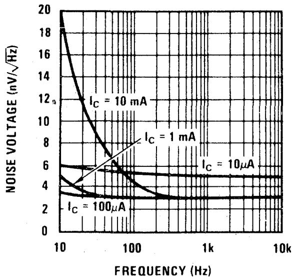


Open Circuit Output Admittance vs Collector Current

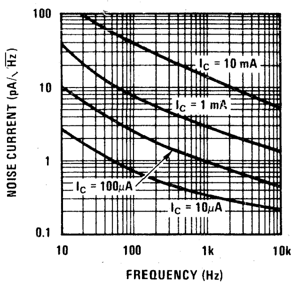


typical transistor performance characteristics (con't)

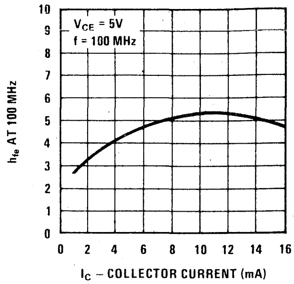
Noise Voltage vs Frequency



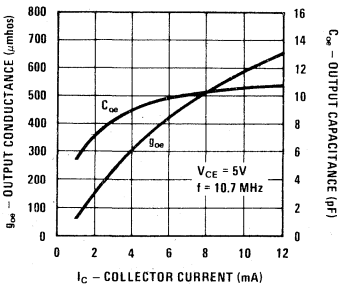
Noise Current vs Frequency



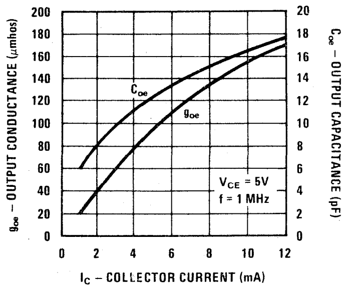
High Frequency Current Gain vs Collector Current



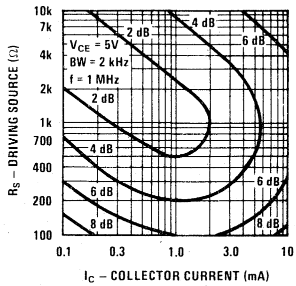
g_{oe} and C_{oe} vs Collector Current



g_{oe} and C_{oe} vs Collector Current



Contours of Constant Noise Figure



application hints

Gain Control

To make the LM389 a more versatile amplifier, two pins (4 and 12) are provided for gain control. With pins 4 and 12 open, the 1.35 kΩ resistor sets the gain at 20 (26 dB). If a capacitor is put from pin 4 to 12, 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. A low frequency pole in the gain response is caused by the capacitor working against the external resistor in series with the 150Ω internal resistor. If the capacitor is eliminated and a resistor connects pin 4 to 12, then the output dc level may shift due to the additional dc gain. Gain control can also be done by capacitively coupling a resistor (or FET) from pin 12 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 12 (paralleling the internal 15 kΩ resistor). For 6 dB effective bass boost: R ≅ 15 kΩ, the lowest value for good stable operation is R = 10 kΩ if pin 4 is open. If pins 4 and 12 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 9V/V.

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 LM389 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 LM389 with higher gains (bypassing the 1.35 kΩ resistor between pins 4 and 12) 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 of the driven input.

Supplies and Grounds

The LM389 has excellent supply rejection and does not require a well regulated supply. However, to eliminate possible high frequency stability problems, the supply should be decoupled to ground with a 0.1μF capacitor. The high current ground of the output transistor, pin 18, is brought out separately from small signal ground, pin 17. If the two ground leads are returned separately to supply then the parasitic resistance in the power ground lead will not cause stability problems. The parasitic resistance in the signal ground can cause stability problems and it should be minimized. Care should also be taken to insure that the power dissipation does not

application hints (con't)

exceed the maximum dissipation of the package for a given temperature. There are two ways to mute the LM389 amplifier. Shorting pin 3 to the supply voltage, or shorting pin 12 to ground will turn the amplifier off without affecting the input signal.

Transistors

The three transistors on the LM389 are general purpose devices that can be used the same as other small signal transistors. As long as the currents and voltages are kept within the absolute maximum limitations, and the collectors are never at a negative potential with respect to pin 17, there is no limit on the way they can be used. For example, the emitter-base breakdown voltage of 7.1V can be used as a zener diode at currents from 1μA to 5 mA. These transistors make good LED driver devices, V_{SAT} is only 150 mV when sinking 10 mA.

In the linear region, these transistors have been used in AM and FM radios, tape recorders, phonographs, and many other applications. Using the characteristic curves on noise voltage and noise current, the level of the collector current can be set to optimize noise performance for a given source impedance. Some of the circuits that have been built are shown in *Figures 1–7*. This is by no means a complete list of applications, since that is limited only by the designers imagination.

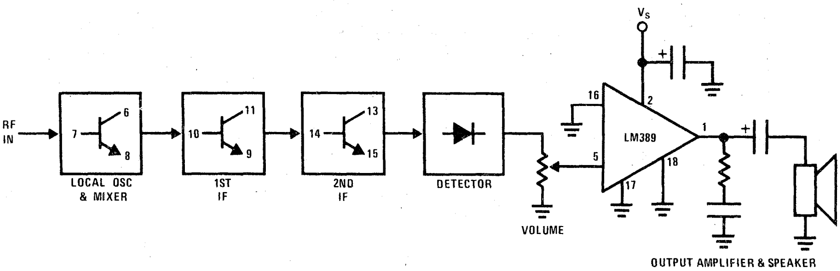


FIGURE 1. AM Radio

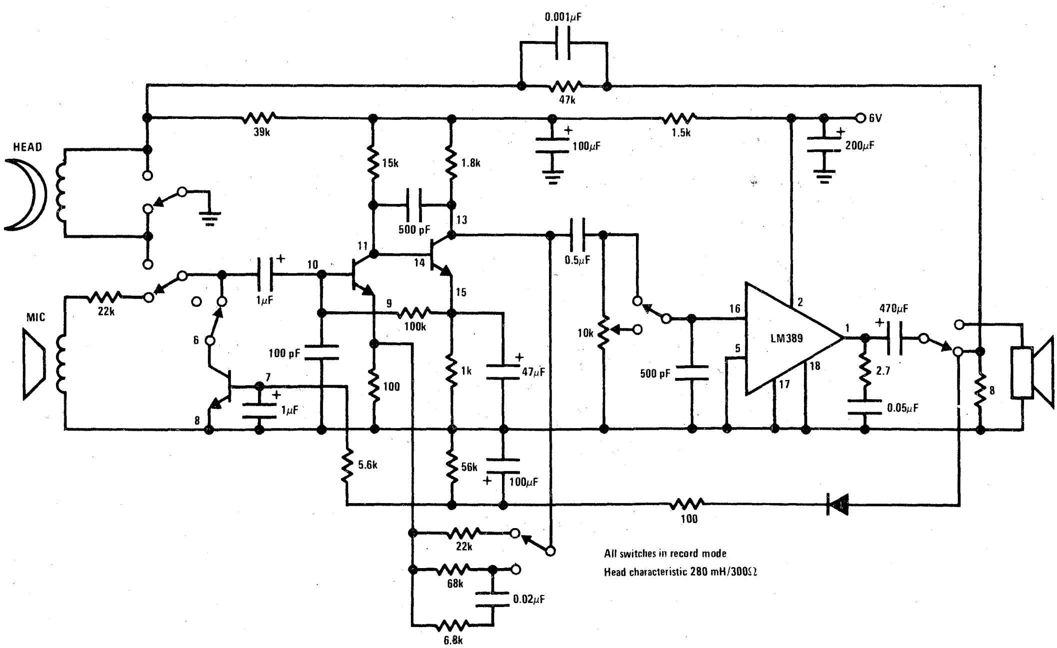


FIGURE 2. Tape Recorder

application hints (con't)

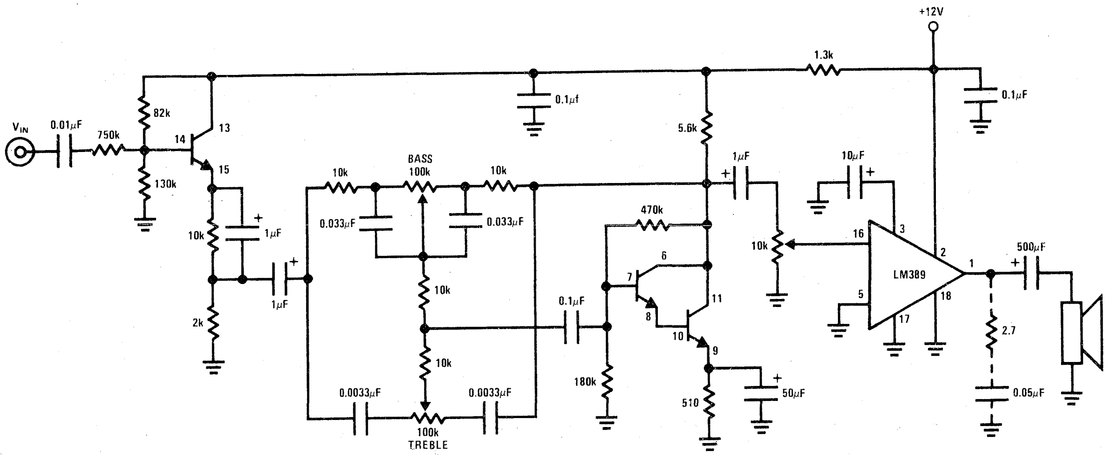


FIGURE 3. Ceramic Phono Amplifier with Tone Controls

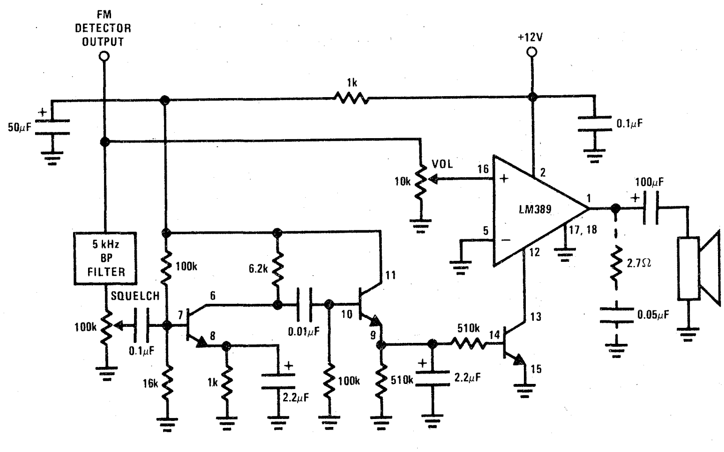


FIGURE 4. FM Scanner Noise Squelch Circuit

application hints (con't)

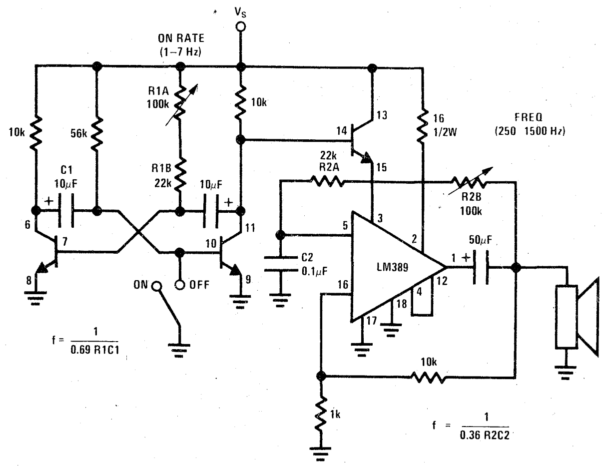


FIGURE 5. Siren

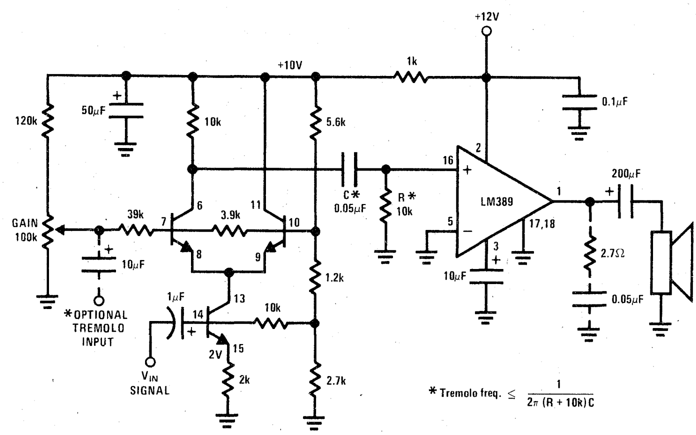


FIGURE 6. Voltage-Controlled Amplifier or Tremolo Circuit

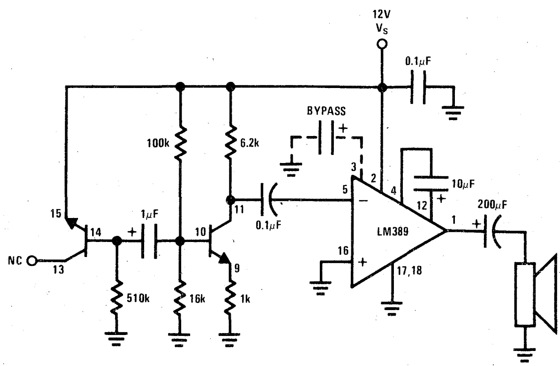


FIGURE 7. Noise Generator Using Zener Diode

10

Audio, Radio and TV Circuits

LM390 1 watt battery operated audio power amplifier

general description

The LM390 Power Audio Amplifier is optimized for 6V, 7.5V, 9V operation into low impedance loads. The gain is internally set at 20 to keep the 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.

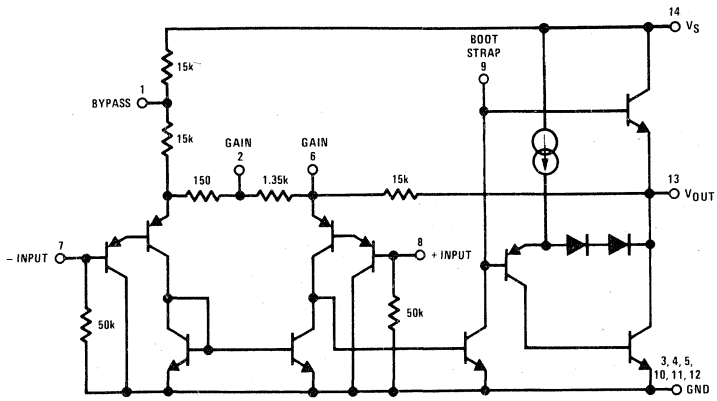
features

- Battery operation
- 1W output power
- Minimum external parts
- Excellent supply rejection
- Ground referenced input
- Self-centering output quiescent voltage
- Variable voltage gain
- Low distortion
- Fourteen pin dual-in-line package

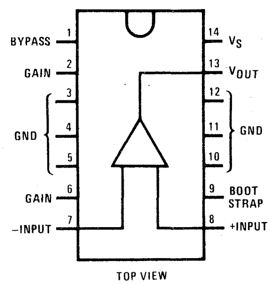
applications

- 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



Order Number LM390N
See Package 22

typical applications

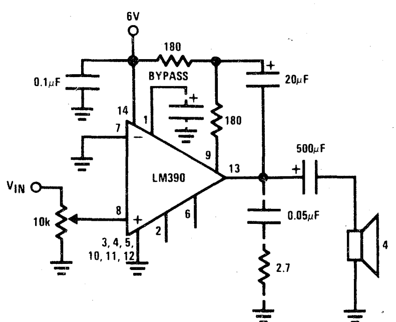


FIGURE 1. Load Returned to Ground (Amplifier with Gain = 20)

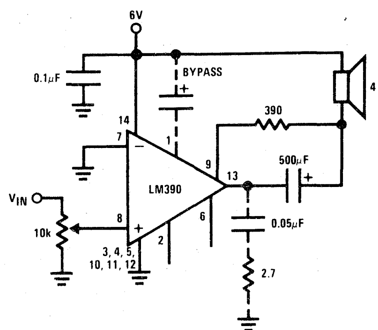


FIGURE 2. Load Returned to Supply (Amplifier with Gain = 20)

absolute maximum ratings (Note 1)

Supply Voltage	10V
Package Dissipation 14-Pin DIP	8.3W
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 $T_A = 25°C$, *(Figure 1)*

	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_S	Operating Supply Voltage		4		9	V
I_Q	Quiescent Current	$V_S = 6V$, $V_{IN} = 0$		10	20	mA
P_{OUT}	Output Power	$V_S = 6V$, $R_L = 4\Omega$, THD = 10%, (Note 2)	0.8	1.0		W
A_V	Voltage Gain	$V_S = 6V$, f = 1 kHz	23	26	30	dB
		10µF from Pin 2 to 6		46		dB
BW	Bandwidth	$V_S = 6V$, Pins 2 and 6 Open		300		kHz
THD	Total Harmonic Distortion	$V_S = 6V$, $R_L = 4\Omega$, $P_{OUT} = 500$ mW f = 1 kHz, Pins 2 and 6 Open		0.2	1	%
PSRR	Power Supply Rejection Ratio	$V_S = 6V$, f = 1 kHz, $C_{BYPASS} = 10\mu F$, Pins 2 and 6 Open, Referred to Output (Note 3)		50		dB
R_{IN}	Input Resistance		10	50		kΩ
I_{BIAS}	Input Bias Current	$V_S = 6V$, Pins 7 and 8 Open		250		nA

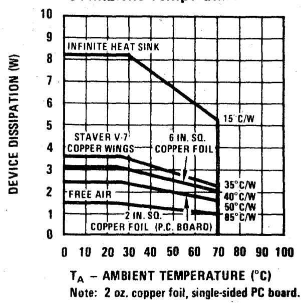
Note 1: Pins 3, 4, 5, 10, 11, 12 at 25°C. Derate at 15°C/W above 25°C case.

Note 2: If oscillation exists under some load conditions, add 2.7Ω and 0.05µF series network from pin 13 to ground.

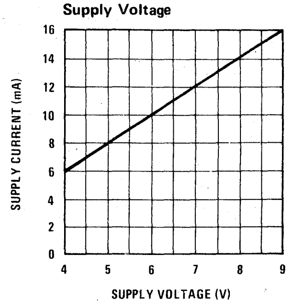
Note 3: If load and bypass capacitor are returned to V_S *(Figure 2)*, rather than ground *(Figure 1)*, PSRR is typically 30 dB.

typical performance characteristics

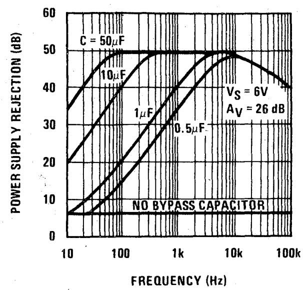
Maximum Device Dissipation vs Ambient Temperature



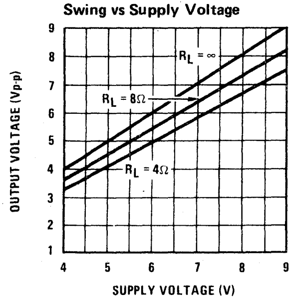
Quiescent Supply Current vs Supply Voltage



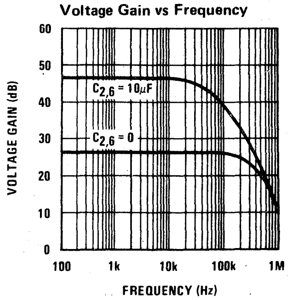
Power Supply Rejection Ratio (Referred to the Output) vs Frequency



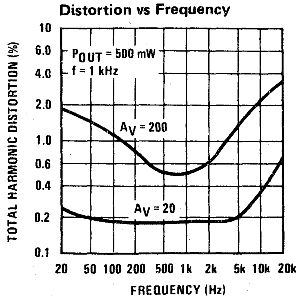
Peak-to-Peak Output Voltage Swing vs Supply Voltage



Voltage Gain vs Frequency

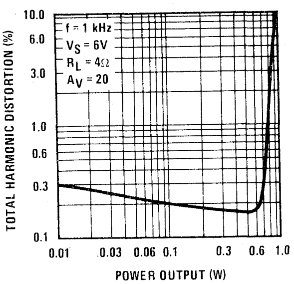


Distortion vs Frequency

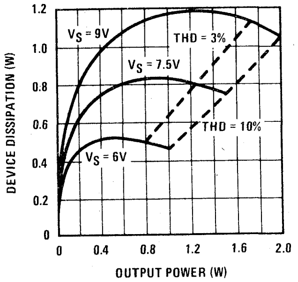


typical performance characteristics (con't)

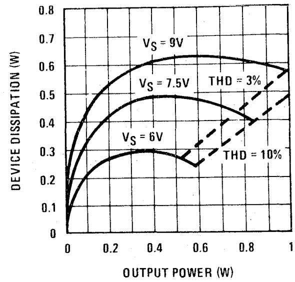
Distortion vs Output Power



Device Dissipation vs Output Power 4Ω Load



Device Dissipation vs Output Power 8Ω Load



application hints

Gain Control

To make the LM390 a more versatile amplifier, two pins (2 and 6) are provided for gain control. With pins 2 and 6 open, the 1.35 kΩ resistor sets the gain at 20 (26 dB). If a capacitor is put from pin 2 to 6, 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. A low frequency pole in the gain response is caused by the capacitor working against the external resistor in series with the 150Ω internal resistor. If the capacitor is eliminated and a resistor connects pin 2 to 6 then the output dc level may shift due to the additional dc gain. Gain control can also be done by capacitively coupling a resistor (or FET) from pin 6 to ground, as in *Figure 7.*

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 6 to 13 (paralleling the internal 15 kΩ resistor). For 6 dB effective bass boost: R ≅ 15 kΩ, the lowest value for good stable operation is R = 10 kΩ if pin 2 is open. If pins 2 and 6 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 V/V.

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 LM390 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 LM390 with higher gains (bypassing the 1.35 kΩ resistor between pins 2 and 6) 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.

Bootstrapping

The base of the output transistor of the LM390 is brought out to pin 9 for Bootstrapping. The output stage of the amplifier during positive swing is shown in *Figure 3* with its external circuitry.

typical applications (con't)

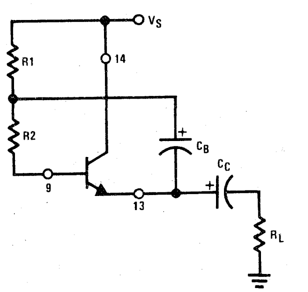


FIGURE 3.

application hints (con't)

R1 + R2 set the amount of base current available to the output transistor. The maximum output current divided by Beta is the value required for the current in R1 and R2:

$$(R1 + R2) = \beta_O \frac{(V_S/2) - V_{BE}}{I_{O\ MAX}}$$

Good design values are V_{BE} = 0.7V and β_O = 100.

Example 0.8_{WATT} into 4Ω load with V_S = 6V.

$$I_{O\ MAX} = \sqrt{\frac{2\ P_O}{R_L}} = 632\ mA$$

$$(R1 + R2) = 100 \left(\frac{(6/2) - 0.7}{0.632}\right) = 364\Omega$$

To keep the current in R2 constant during positive swing capacitor C_B is added. As the output swings positive C_B lifts R1 and R2 above the supply, maintaining a constant voltage across R2. To minimize the value of C_B, R1 = R2. The pole due to C_B and R1 and R2 is usually set equal to the pole due to the output coupling capacitor and the load. This gives:

$$C_B \simeq \frac{4C_c}{\beta_O} \simeq \frac{C_c}{25}$$

Example: for 100 Hz pole and R_L = 4Ω; C_c = 400μF and C_B = 16μF, if R1 is made a diode and R2 increased to give the same current, C_B can be decreased by about a factor of 4, as in *Figure 4*.

For reduced component count the load can replace R1. The value of (R1 + R2) is the same, so R2 is increased. Now C_B is both the coupling and the bootstrapping capacitor (see *Figure 2*).

typical applications (con't)

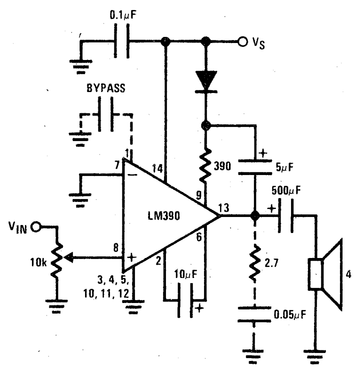


FIGURE 4. Amplifier with Gain = 200 and Minimum C_B

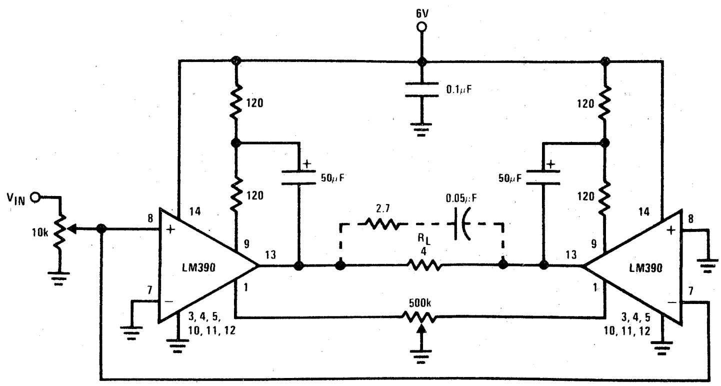


FIGURE 5. 2.5W Bridge Amplifier

typical applications (con't)

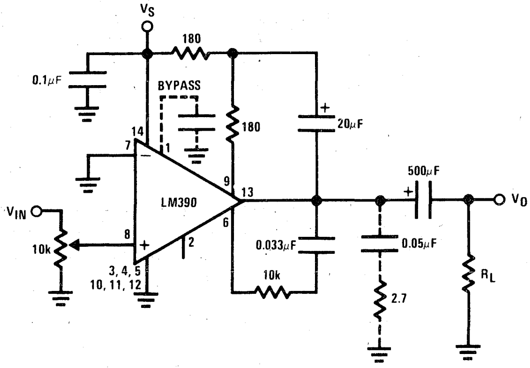


FIGURE 6(a). Amplifier with Bass Boost

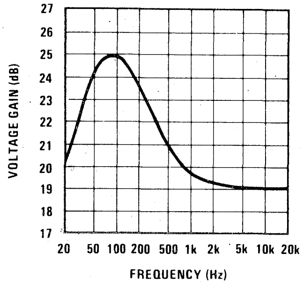


FIGURE 6(b). Frequency Response with Bass Boost

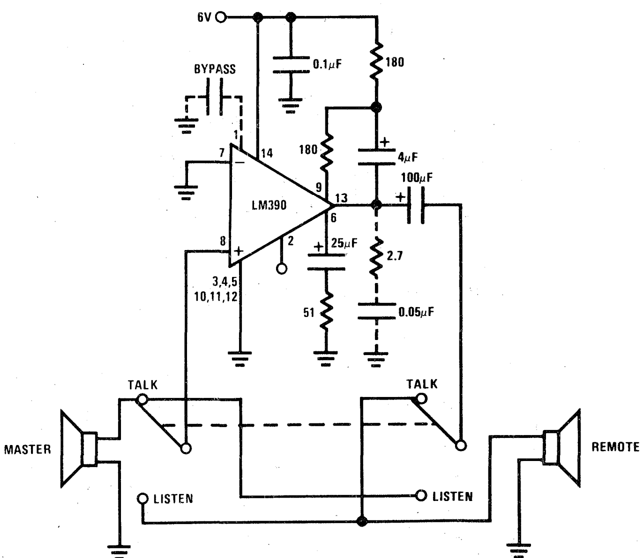


FIGURE 7. Intercom

Audio, Radio and TV Circuits

LM703L low power drain rf/if amplifier

general description

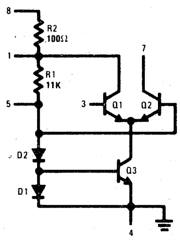
The LM703L is a monolithic RF-IF amplifier, having an efficient DC biasing system, reducing demands upon power supply and decoupling elements. Its low internal feedback guarantees a high stability-limited gain.

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

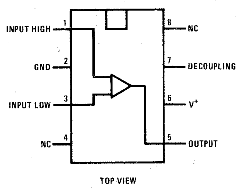
- Power Consumption 96 mW (max.)
- Forward Transadmittance 33 mmhos
- Input Conductance 0.35 mmhos
- Output Conductance 0.03 mmhos
- Peak-to-Peak Output Current 5.0 mA

schematic and connection diagrams



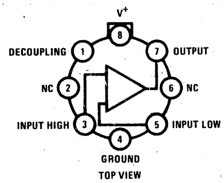
Pin connections are for H package.

Dual-In-Line Package



Order Number LM703LN
See Package 20.

Metal Can Package

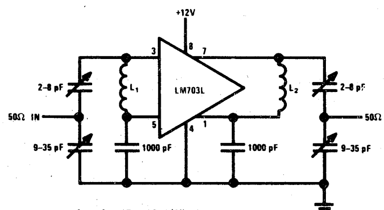


Note: Pin 4 connected to case.

Order Number LM703LH
See Package 11

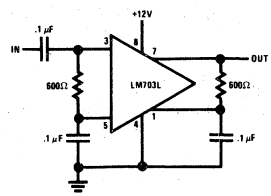
typical applications

100 MHz Narrow Band Amplifier

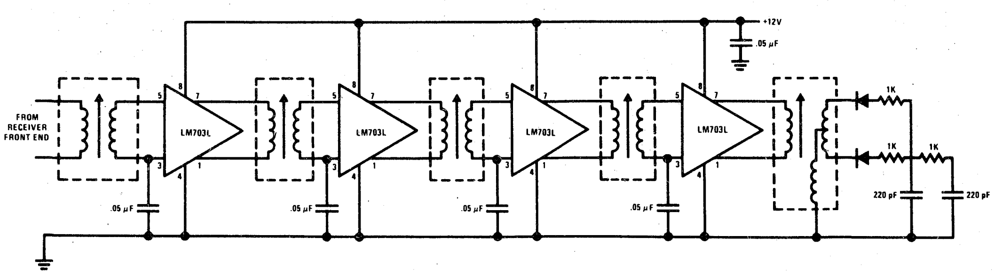


$L_1 = L_2$ = 7t #16, 1/4" i.d., spaced 1 turn.

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

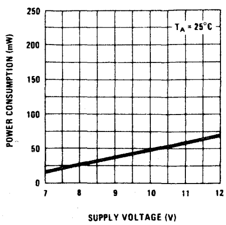
electrical characteristics (Note 1)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
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 = 500Ω, f = 10.7 MHz R_S = 500Ω, f = 100 MHz		6.0 8.0		dB dB
Maximum Stable Gain	f = 100 MHz		28.0		dB

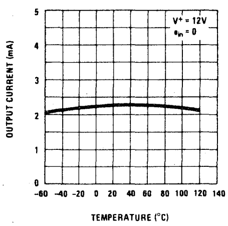
Note 1: These specifications apply for T_A = 25°C, V^+ = 12V unless otherwise specified.

typical performance characteristics

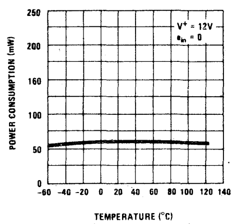
Power Consumption as a Function of Supply Voltage



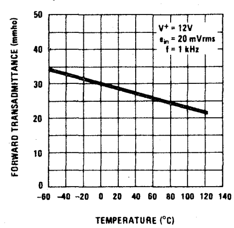
Output Current as a Function of Ambient Temperature



Power Consumption as a Function of Ambient Temperature



Forward Transadmittance as a Function of Ambient Temperature



Audio, Radio and TV 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.

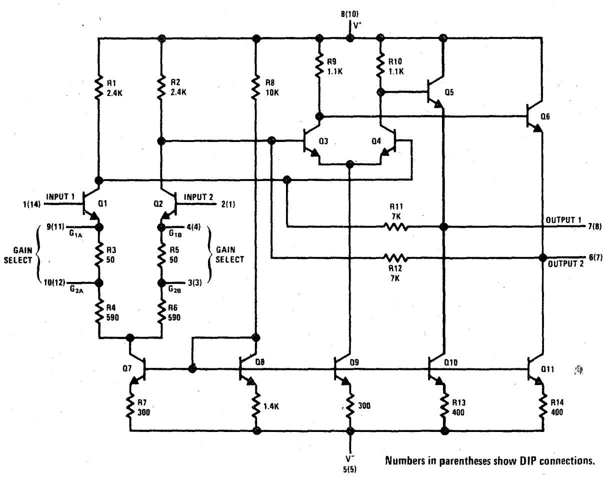
features

- 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

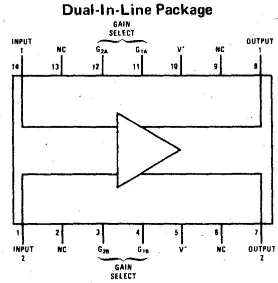
- Magnetic tape systems
- Disk file memories
- Thin and thick film memories
- Woven and plated wire memories
- Wide band video amplifiers.

schematic and connection diagrams



Numbers in parentheses show DIP connections.

Dual-In-Line Package



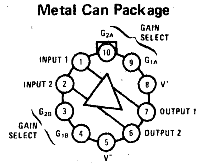
TOP VIEW

Order Number LM733D or LM733CD
See Package 2B

Order Number LM733CN
See Package 22

Order Number LM733J or LM733CJ
See Package 16

Metal Can Package



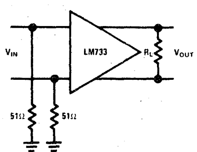
Note: Pin 5 connected to case.

TOP VIEW

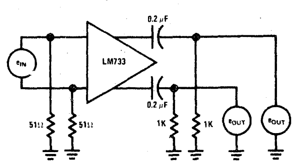
Order Number LM733H or LM733CH
See Package 14

test circuits

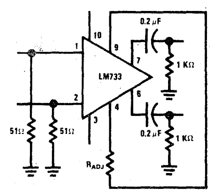
Test Circuit 1



Test Circuit 2



Voltage Gain Adjust Circuit



$V_S = 6V$, $T_A = 25°C$

(Pin numbers apply to TO-5 package)

10

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			LM733C			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
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 = ∞		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 = ∞	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 = ∞		18	24		18	24	mA

electrical characteristics (con't)

(The following specifications apply for $-55°C < T_A < 125°C$ for the LM733 and $0°C < T_A < 70°C$ for the LM733C, $V_S = ±6.0V$)

CHARACTERISTICS	TEST CIRCUIT	TEST CONDITIONS	LM733			LM733C			UNITS
			MIN	TYP	MAX	MIN	TYP	MAX	
Differential Voltage Gain									
Gain 1			200		600	250		600	
Gain 2	1	$R_L = 2 kΩ, V_{OUT} = 3 V_{p-p}$	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	$V_{CM} = ±1V, f \leq 100 kHz$	50			50			dB
Supply Voltage Rejection Ratio									
Gain 2	1	$ΔV_S = ±0.5V$	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.

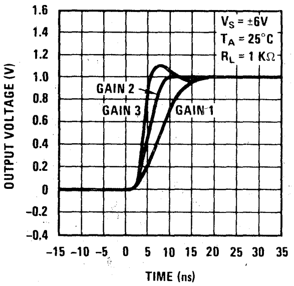
Note 2: Pins G1A and G1B connected together.

Note 3: Pins G2A and G2B connected together.

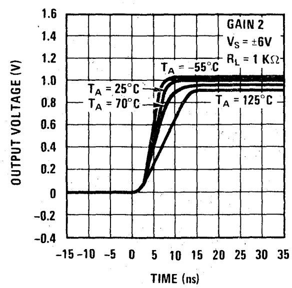
Note 4: Gain select pins open.

typical performance characteristics

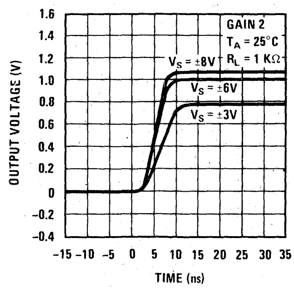
Pulse Response



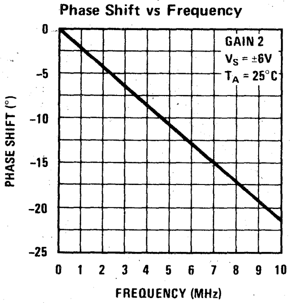
Pulse Response vs Temperature



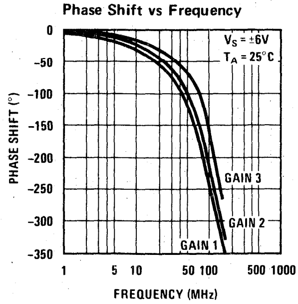
Pulse Response vs Supply Voltage



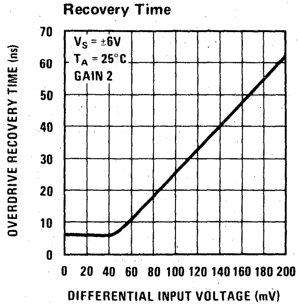
Phase Shift vs Frequency



Phase Shift vs Frequency

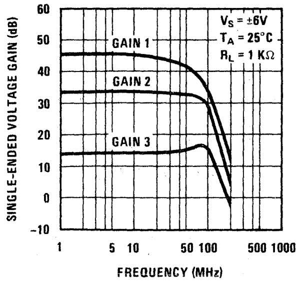


Differential Overdrive Recovery Time

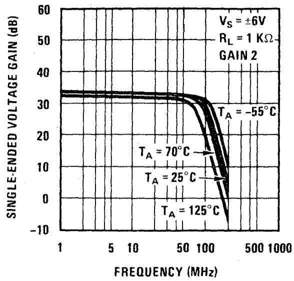


typical performance characteristics (con't)

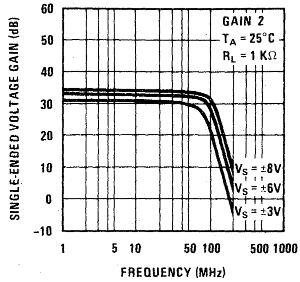
Voltage Gain vs Frequency



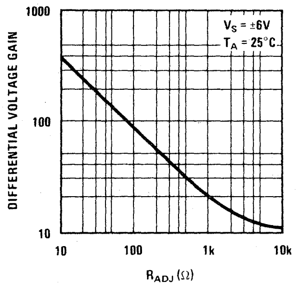
Gain vs Frequency Temperature



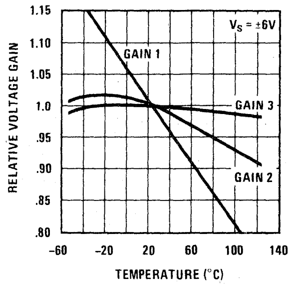
Gain vs Frequency vs Supply Voltage



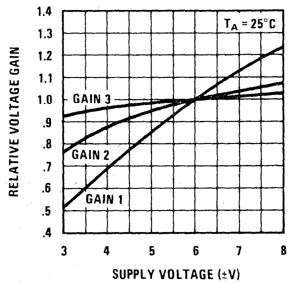
Voltage Gain vs R_{ADJ}



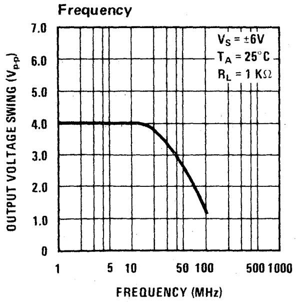
Voltage Gain vs Temperature



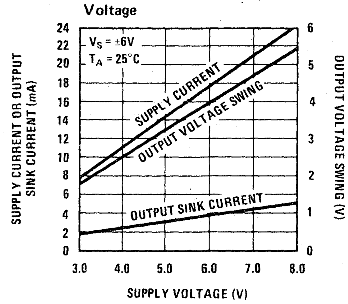
Voltage Gain vs Supply Voltage



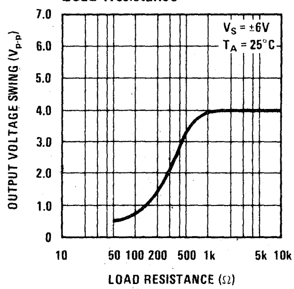
Output Voltage Swing vs Frequency



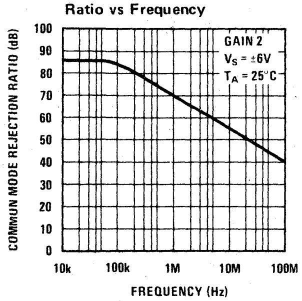
Supply Current, Output Voltage and Current Swing vs Supply Voltage



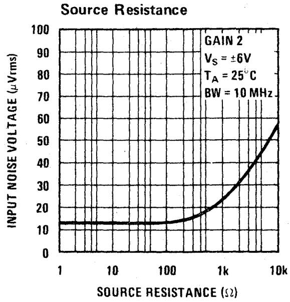
Output Voltage Swing vs Load Resistance



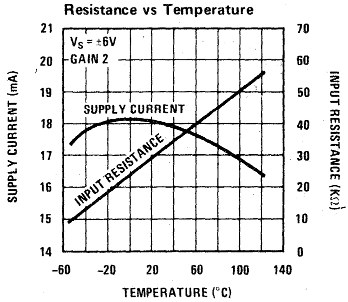
Common Mode Rejection Ratio vs Frequency



Input Noise Voltage vs Source Resistance



Supply Current and Input Resistance vs Temperature



LM746 color television chroma demodulator

general description

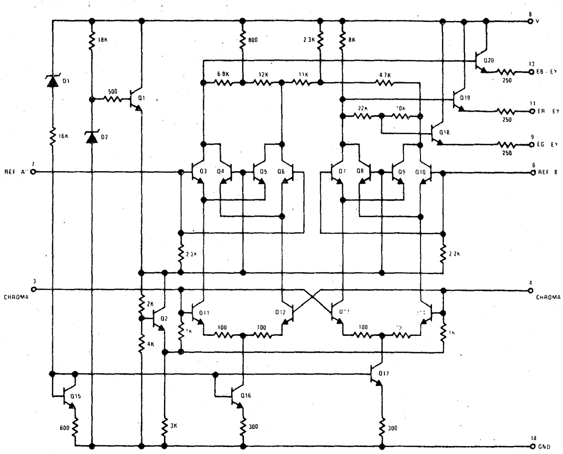
The LM746 is a monolithic silicon integrated circuit which demodulates the chroma subcarrier information contained in a color television video signal and provides color-difference signals at the outputs

The low DC voltage drift of the outputs insures excellent performance in direct-coupled chrominance output circuitry.

features

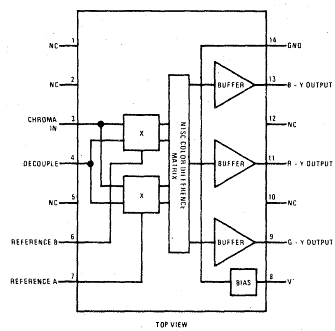
- Low output voltage drift with temperature
- Doubly balanced demodulation
- Internal color-difference matrix for NTSC color television
- 10V peak-to-peak $E_B - E_Y$ output

schematic and block diagrams



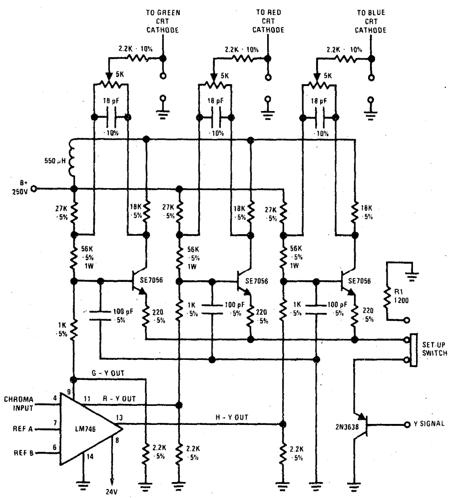
Pin numbers shown for Dual-In-Line Package.

Dual-In-Line Package



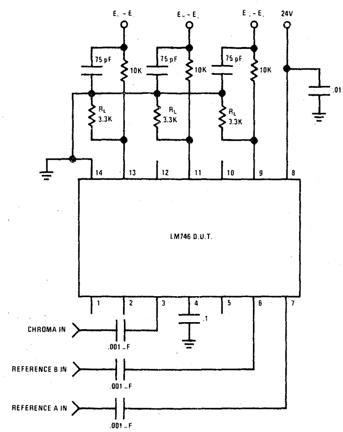
Order Number LM746N or LM746N-01
See Packages 22 and 24

typical application



Pin numbers shown for Dual-In-Line Package.

test circuit 1



103°C from reference A.

10

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	$\|\Delta V_O\|$		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	$V_{p\text{-}p}$

Audio, Radio and TV Circuits

LM1303 stereo preamplifier

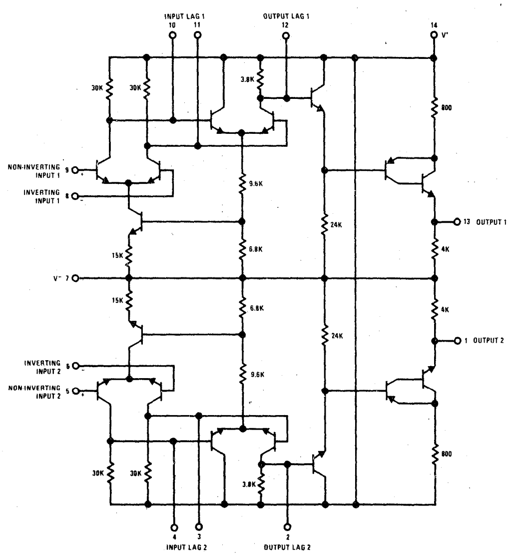
general description

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.

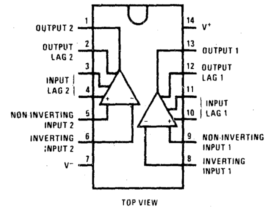
features

- 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



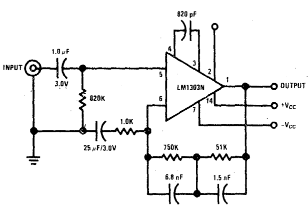
Dual-In-Line Package

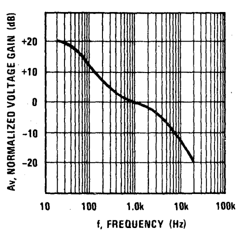


Order Number LM1303N
See Package 22

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

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 (con't)

Tape Head Playback Preamplifier/NAB Equalization

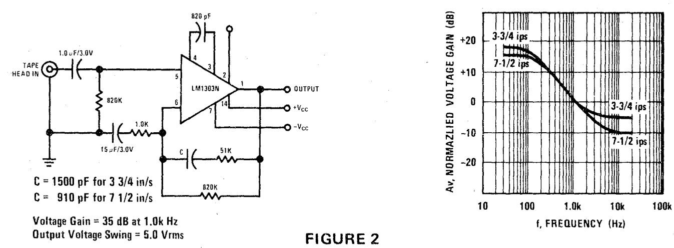
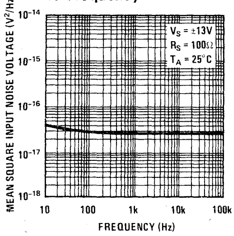


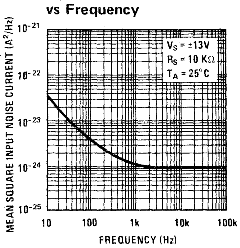
FIGURE 2

typical performance characteristics

Input Noise Voltage vs Frequency



Input Noise Current vs Frequency



Audio, Radio and TV Circuits

LM1304, LM1305, LM1307, LM1307E FM multiplex stereo demodulator

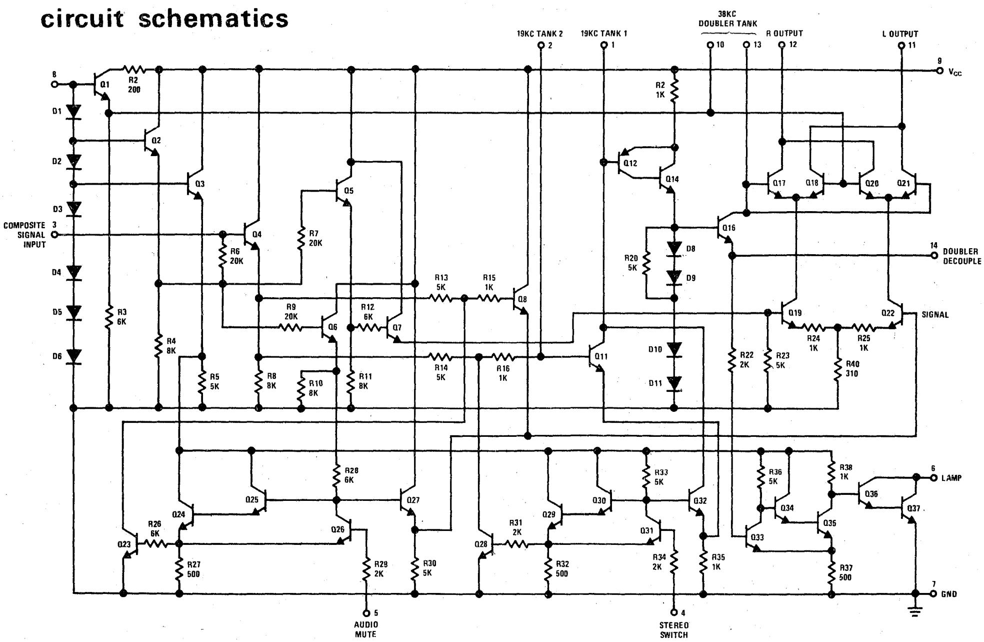
general description

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, LM1305N, LM1307N or LM1307EN
See Package 22

Order Number LM1304N-01, LM1305N-01, 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.

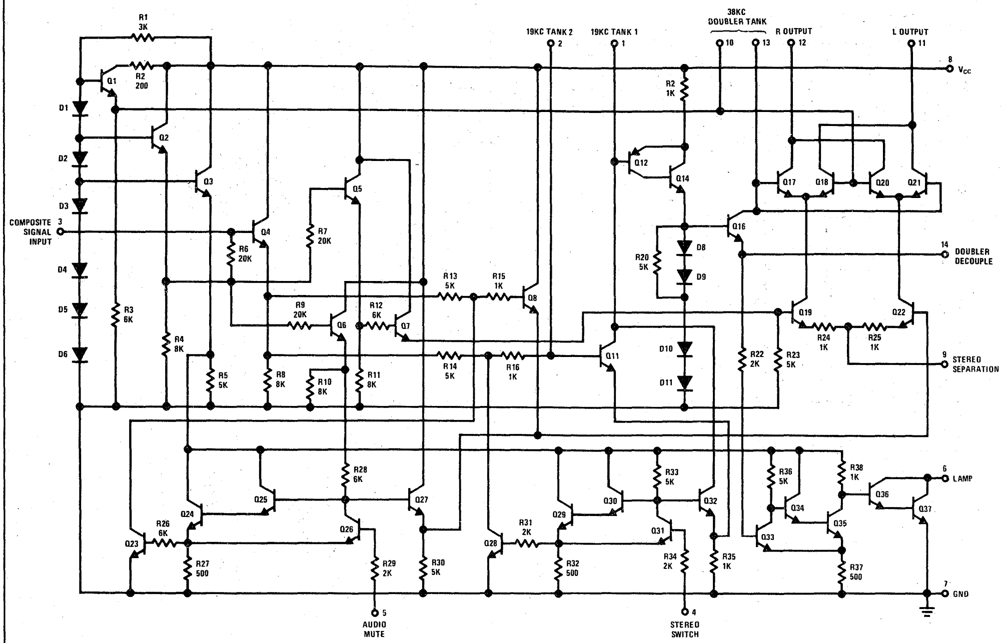
Note 2: Referenced to 1 kHz output signal with signal per Note 1.

Note 3: Stereo channel separation is adjusted for maximum separation in the LM1305 with a resistor from Pin 9 to GND.

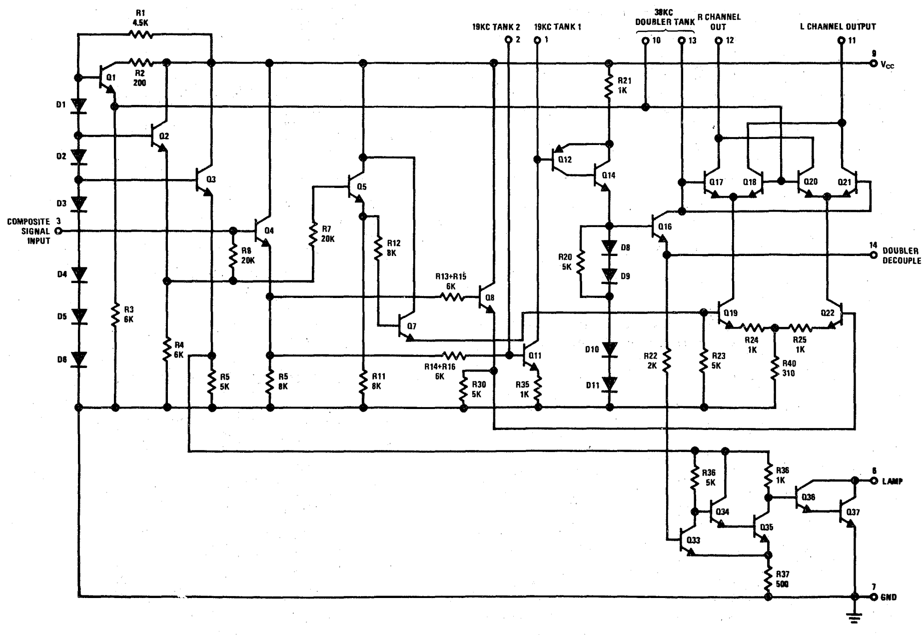
(R_A = 180Ω, All voltages measured with respect to GND)
(V_{CC} = 12V, 2.7 kΩ in series w/Pin 8)

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)



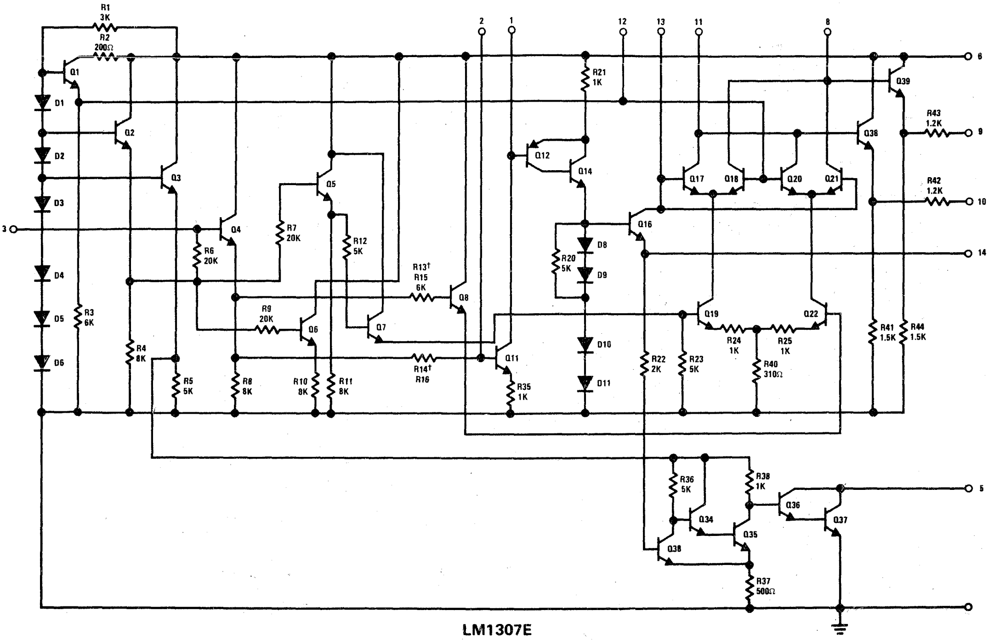
LM1305



LM1307

10

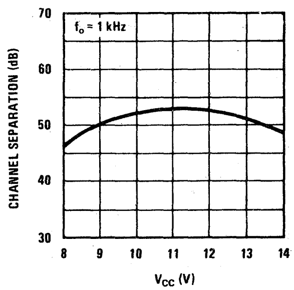
circuit schematics (con't)



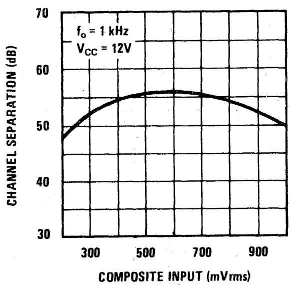
LM1307E

typical performance characteristics

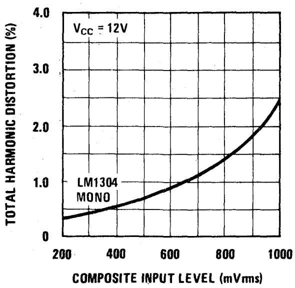
Channel Separation vs V_{CC}



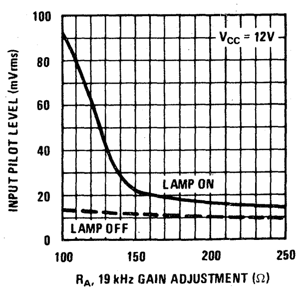
Channel Separation vs Composite Input Level



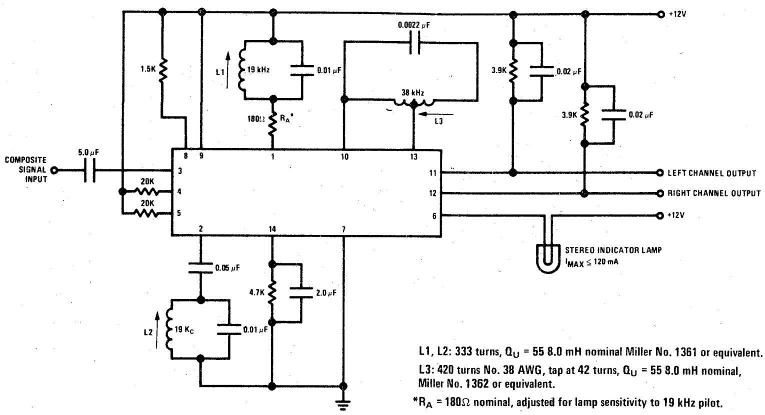
Total Harmonic Distortion vs Composite Input Level



Multiplex Sensitivity vs 19 kHz Gain Adjustment

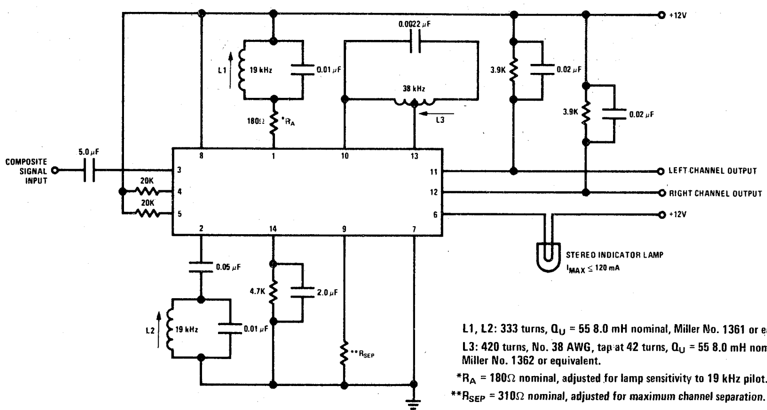


circuit configurations



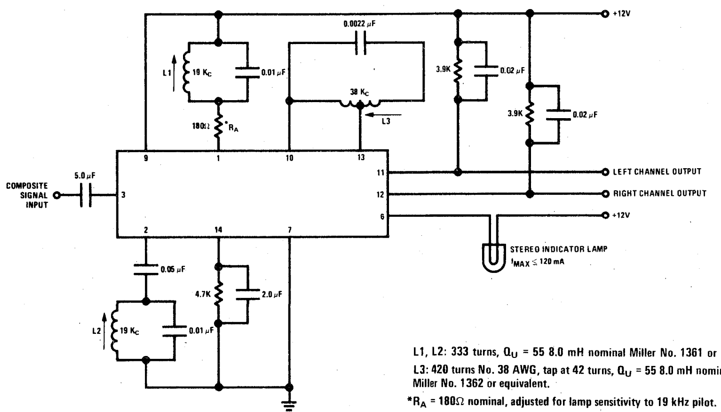
L1, L2: 333 turns, Q_U = 55 8.0 mH nominal Miller No. 1361 or equivalent.
L3: 420 turns No. 38 AWG, tap at 42 turns, Q_U = 55 8.0 mH nominal, Miller No. 1362 or equivalent.
*R_A = 180Ω nominal, adjusted for lamp sensitivity to 19 kHz pilot.

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.

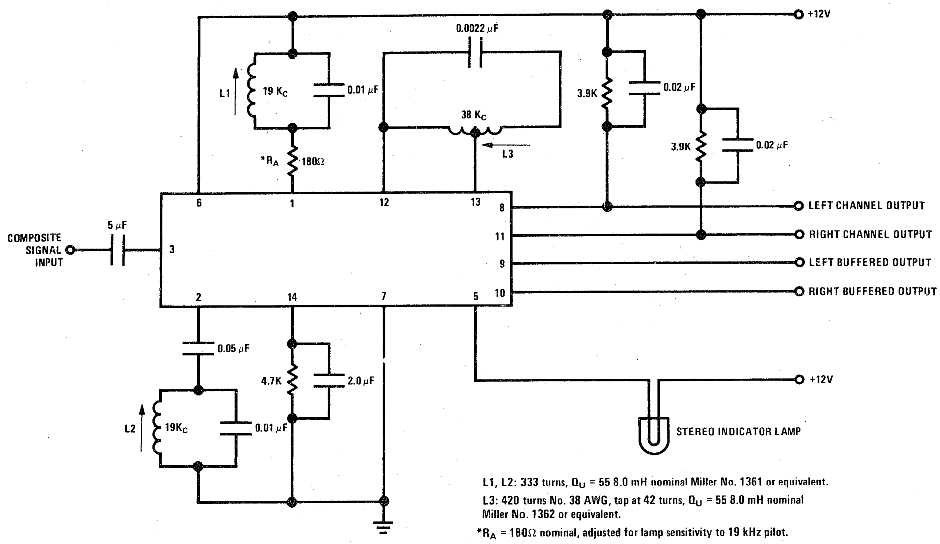
LM1305 Typical Circuit Configuration



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)



LM1307E Typical Circuit Configuration

Audio, Radio and TV Circuits

LM1310 phase locked loop FM stereo demodulator

general description

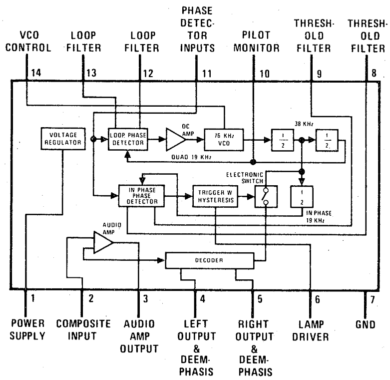
The LM1310 is an integrated FM stereo demodulator using phase locked loop techniques to regenerate the 38 kHz subcarrier. A second version also available is the LM1800 (see separate data sheet) which adds superb power supply rejection and buffered (emitter follower) outputs to the basic phase locked 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

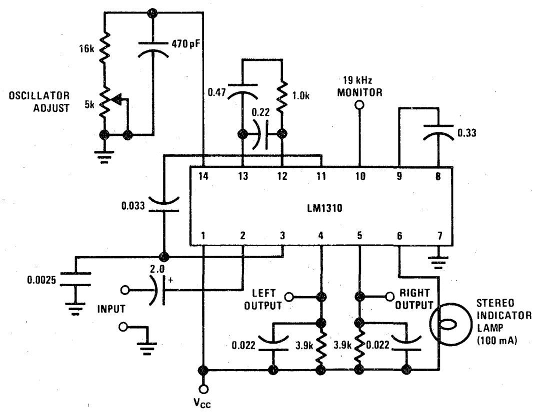
Dual-In-Line Package



TOP VIEW

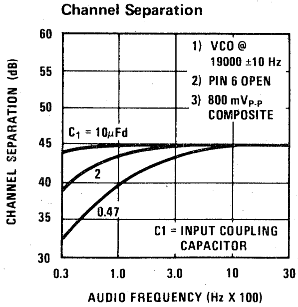
Order Number LM1310N
See Package 22

typical application

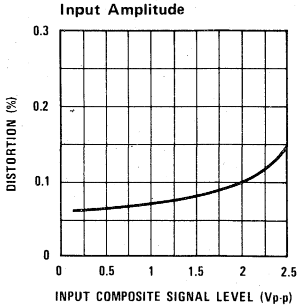


typical performance characteristics

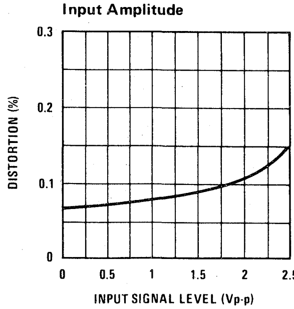
Channel Separation



Stereo Distortion vs Input Amplitude



Monaural Distortion vs Input Amplitude



absolute maximum ratings

Supply Voltage	18V	Operating Supply Voltage Range	10V to 18V
Power Dissipation (Note 2)	625 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		mA
Lamp Driver Saturation	100 mA Lamp Current		1.3		V
Lamp Driver Leakage			1.0		nA
Pilot Level for Lamp "ON"	Pin 11 Adjusted to 19.00 kHz		15	20	mVrms
Pilot Level for Lamp "OFF"	Pin 11 Adjusted to 19.00 kHz	3.0	7.0		mVrms
Composite Input	Maximum for THD < 0.5%	2.8			Vp-p
Monaural Input	Maximum for THD < 1.0%	2.8			Vp-p
Stereo Channel Separation		30	40		dB
	2.0Vp-p Composite with 10% Pilot		45		dB
Monaural Channel Unbalance	Pilot "OFF"		0.3	1.5	dB
Recovered Audio			485		mVrms
Total Harmonic Distortion			0.3		%
Total Harmonic Distortion	2.0 Vp-p Composite with 10% Pilot		0.15		%
Capture Range	50 mVrms of Pilot		±3.5		% of f_o
Ultrasonic Frequency Rejection	19 kHz		35		dB
	38 kHz		45		dB
Dynamic Input Resistance		20	50		kΩ
SCA Rejection	f = 67 kHz; Measure 9 kHz Beat Note with 1 kHz Modulation "OFF"		75		dB

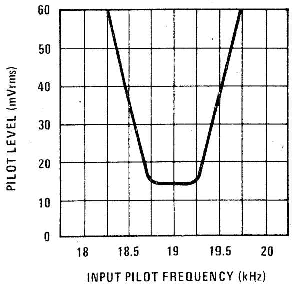
Note 1: Unless otherwise noted; V_{CC} = +12 V_{DC} and T_A = +25°C. The input signal is a 2.8 Vp-p standard multiplex composite signal using 10% Pilot and with L or R-channel only modulated at 1.0 kHz.

Note 2: The maximum junction temperature is +150°C and the package should be derated at 5.0 mW/°C above 25°C.

Note 3: The VCO can be defeated (sometimes desirable when using an AM-FM receiver in the AM mode) by returning pin 14 to ground through a 2.2k ohm resistor.

typical performance characteristics (con't)

Pilot Amplitude vs Capture Frequency



Audio, Radio and TV Circuits

LM1351 FM detector, limiter and audio amplifier

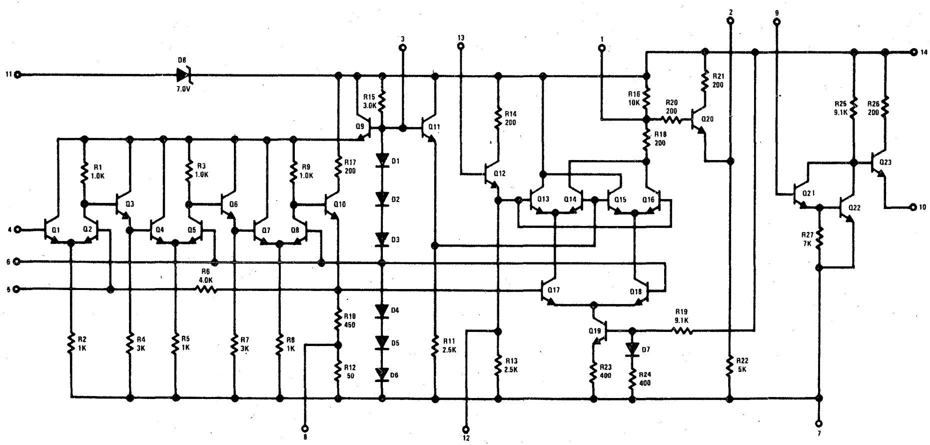
general description

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

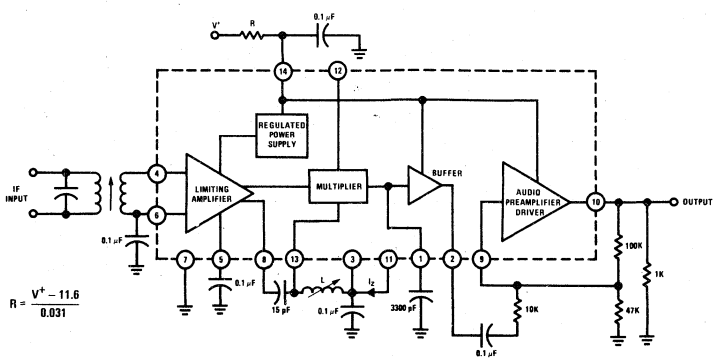
schematic diagram



Order Number LM1351N
See Package 22

Order Number LM1351N-01
See Package 24

logic diagram



$R = \frac{V^{+} - 11.6}{0.031}$

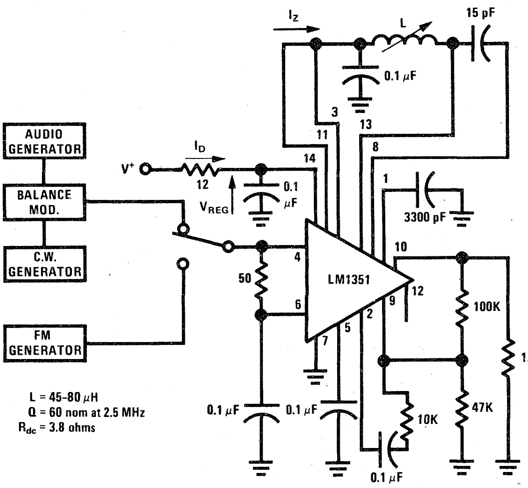
absolute maximum ratings

Supply Voltage	16V	Operating Temperature Range	0°C to 75°C
Input Signal Voltage (Pin 4)	0.7 Vrms	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, 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



LM1391, LM1394 phase-locked loop blocks

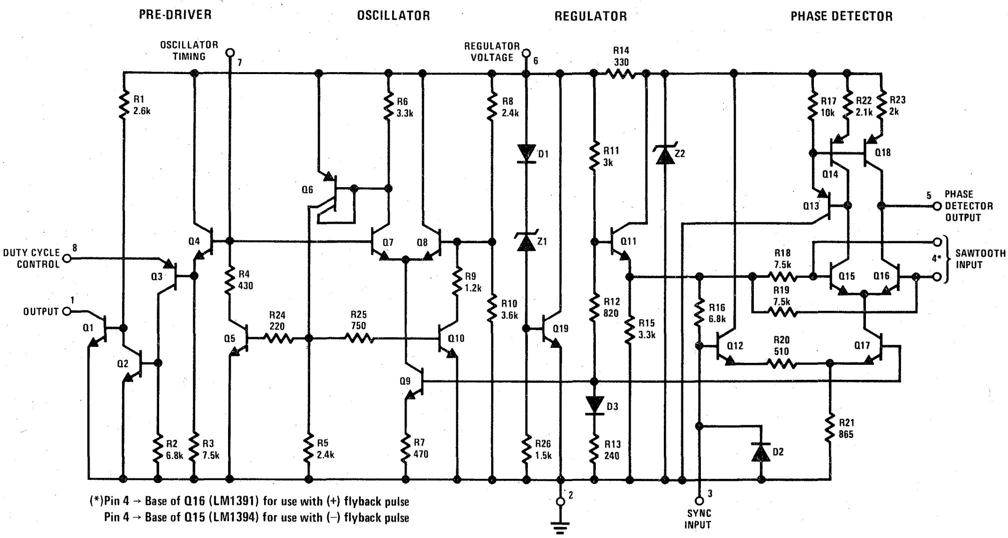
general description

The LM1391 and LM1394 integrated circuits have been designed primarily for use in the horizontal section of TV receivers, but may find use in other low frequency signal processing applications. They include a stable VCO, linear pulse phase detector, and variable duty cycle output driver. The only difference between the two devices is the polarity of the phase detector (see schematic and connection diagrams).

features

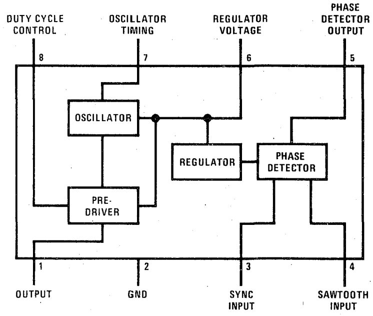
- Internal active regulator for improved supply rejection
- Uncommitted collector of output transistor
- Output transistor with low saturation and high voltage swing
- APC of the oscillator with a synchronizing signal
- DC controlled output duty cycle
- ±300 Hz typical pull-in
- Linear balanced phase detector
- Low thermal frequency drift
- Small static phase error
- Adjustable dc loop gain

schematic and connection diagrams



(*)Pin 4 → Base of Q16 (LM1391) for use with (+) flyback pulse
Pin 4 → Base of Q15 (LM1394) for use with (–) flyback pulse

Dual-In-Line Package



TOP VIEW

Order Number LM1391N or LM1394N
See Package 20

absolute maximum ratings

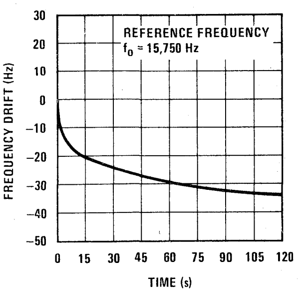
Supply Current	40 mA_{DC}	Power Dissipation (Package Limitation)	
Output Voltage	40 V_{DC}	Plastic Package	625 mW
Output Current	30 mA_{DC}	Derate above $T_A = +25^\circ C$	5.0 mW/°C
Sync Input Voltage (Pin 3)	5.0 Vp-p	Operating Temperature Range (Ambient)	0°C to +75°C
Flyback Input Voltage (Pin 4)	5.0 Vp-p	Storage Temperature Range	−65°C to +150°C

electrical characteristics $T_A = 25^\circ C$ (see test circuit, all switches in position 1)

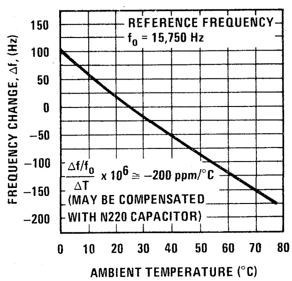
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Regulated Voltage (Pin 6)	$I_6 = 22\ mA_{DC}$	8.0	8.4	9.0	V_{DC}
Supply Current (Pin 6)			20		mA_{DC}
Collector-Emitter Saturation Voltage of Output Transistor (Pin 1)	$I_{C1} = 20\ mA$		0.30	0.40	V_{DC}
Pin 4 Voltage			2.0		V_{DC}
Oscillator Pull-in Range	Adjust R_H		±300		Hz
Oscillator Hold-in Range	Adjust R_H		±900		Hz
Static Phase Error	Δf = 300 Hz		0.5		μs
Free-running Frequency Supply Dependance	S1 in position 2		±3.0		Hz/V_{DC}
Phase Detector Leakage (Pin 5)	All switches in position 2			±1.0	μA
Sync Input Voltage (Pin 3)		2.0		5.0	Vp-p
Sawtooth Input Voltage (Pin 4)		1.0		3.0	Vp-p
Maximum Oscillator Frequency			500		kHz

typical performance characteristics

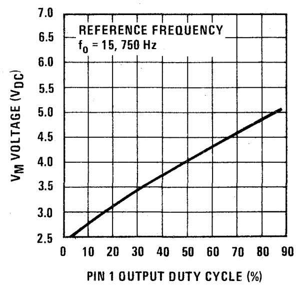
Frequency Drift vs Warm-Up Time



Frequency vs Temperature



Output Duty Cycle vs V_M Voltage



applications information

The following equations may be considered when using the LM1391 or LM1394 in a particular application.

$$R201 = R301 = \frac{V_{CC} - 8.6}{0.02}\ \Omega$$

$$f_o \cong \frac{1}{0.6\ R_o C_o}\ \text{Hz} \quad 1.5k \le R_o < 51k$$

$$R204 \cong 10\ R_o$$

$$C203 = C204 \cong \frac{1}{600\ f_o(\text{Hz})}\ \text{F}$$

DC Loop Gain $\mu\beta \cong 3.2 \times 10^{-5}\ R_o f_o$ Hz/rad

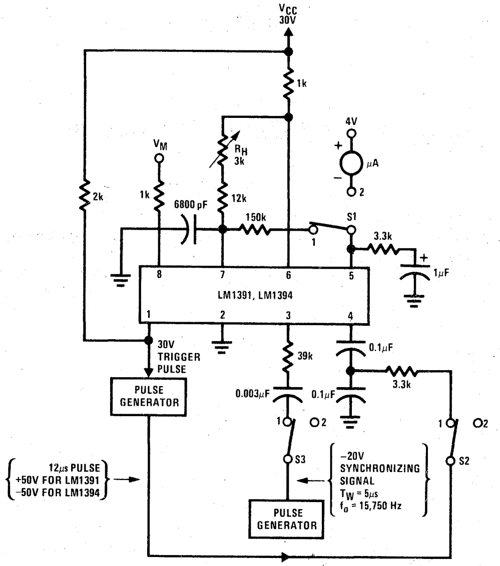
Noise Bandwidth

$$f_{nn} \cong \frac{1 + 2\pi \frac{R_X{}^2}{R_Y} C_c \mu\beta}{4 R_X C_c}\ \text{Hz}$$

Damping Factor

$$K \cong \frac{\pi}{2} \frac{R_X{}^2}{R_Y} C_c \mu\beta$$

test circuit



typical applications

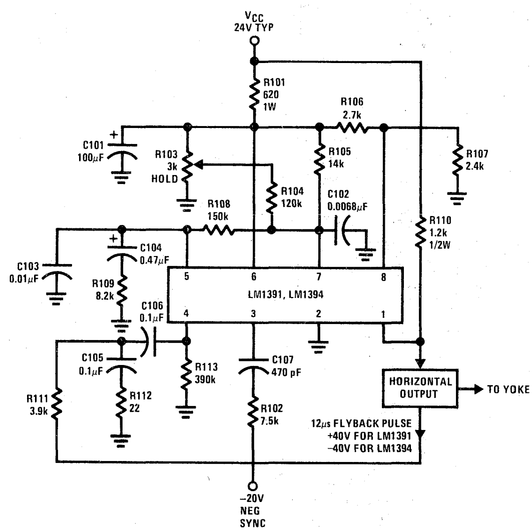


FIGURE 1. TV Horizontal Processor

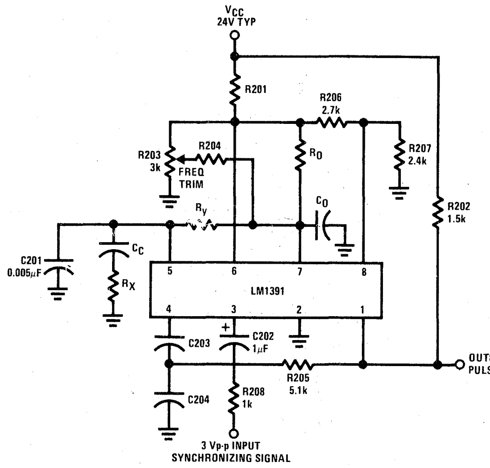


FIGURE 2. General Purpose Phase-Lock Loop
(See Applications Information)

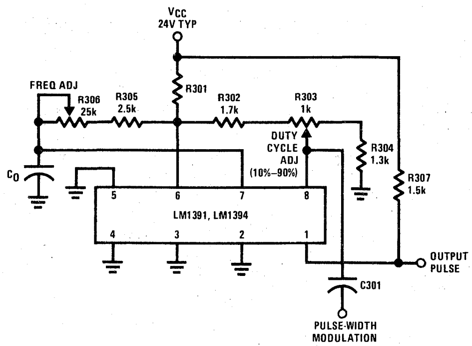


FIGURE 3. Variable Duty Cycle Oscillator
(See Applications Information)

Audio, Radio and TV Circuits

LM1596/LM1496 balanced modulator-demodulator

general description

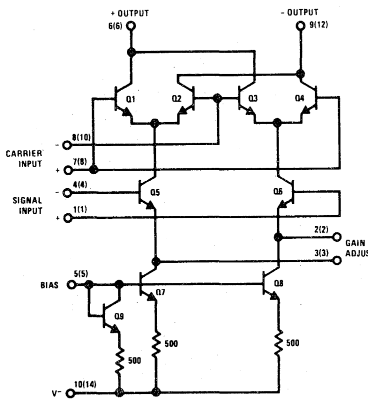
The LM1596/LM1496 are double balanced modulator-demodulators which produce an output voltage proportional to the product of an input (signal) voltage and a switching (carrier) signal. Typical applications include suppressed carrier modulation, amplitude modulation, synchronous detection, FM or PM detection, 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

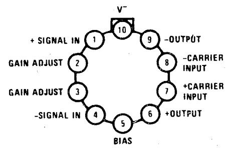
- Excellent carrier suppression
  - 65 dB typical at 0.5 MHz
  - 50 dB typical at 10 MHz
- Adjustable gain and signal handling
- Fully balanced inputs and outputs
- Low offset and drift
- Wide frequency response up to 100 MHz

schematic and connection diagrams



Numbers in parentheses show DIP connections.

Metal Can Package

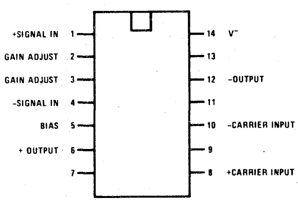


TOP VIEW

Note: Pin 10 is connected electrically to the case through the device substrate.

Order Number LM1496H or LM1596H
See Package 11

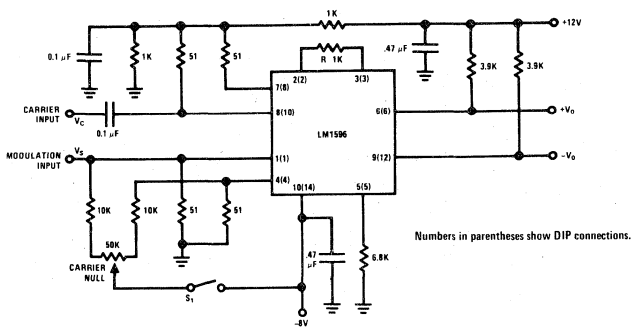
Dual-In-Line Package



TOP VIEW

Order Number LM1496J or LM1596J
See Package 16
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

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)

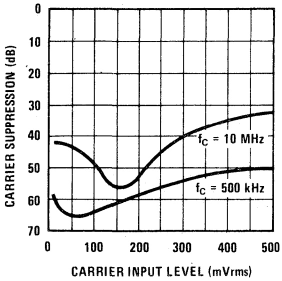
PARAMETER	CONDITIONS	LM1596			LM1496			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Carrier Feedthrough	V_C = 60 mVrms sine wave f_C = 1.0 kHz, offset adjusted		40			40		μVrms
	V_C = 60 mVrms sine wave f_C = 10 MHz, offset adjusted		140			140		μVrms
	V_C = 300 mV_{pp} square wave f_C = 1.0 kHz, offset adjusted		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	$(-55°C < T_A < +125°C)$ $(0°C < T_A < +70°C$		2.0			 2.0		nA/°C nA/°C
Output Offset Current	$(I_6 - I_9)$		14	50		14	60	μA
Average Temperature Coefficient of Output Offset Current	$(-55°C < T_A < +125°C)$ $(0°C < T_A < +70°C)$		90			 90		nA/°C 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.

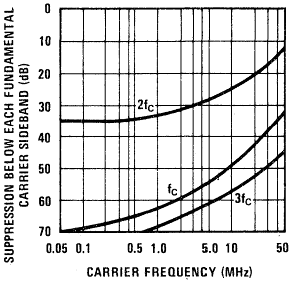
Note 2: Voltage applied between pins 6-7, 8-1, 9-7, 9-8, 7-4, 7-1, 8-4, 6-8, 2-5, 3-5.

typical performance characteristics

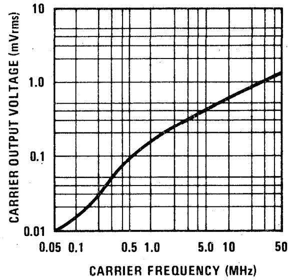
Carrier Suppression vs Carrier Input Level



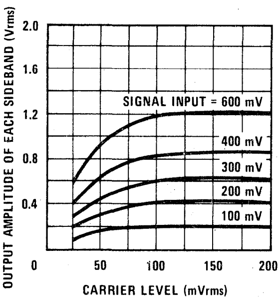
Carrier Suppression vs Frequency



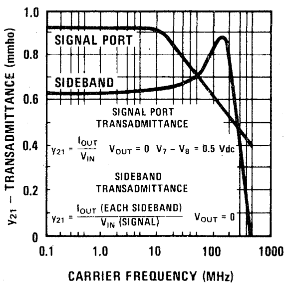
Carrier Feedthrough vs Frequency



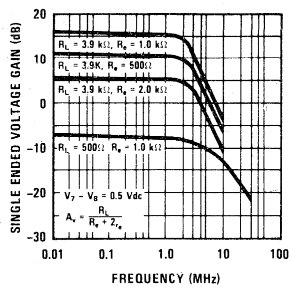
Sideband Output vs Carrier Levels



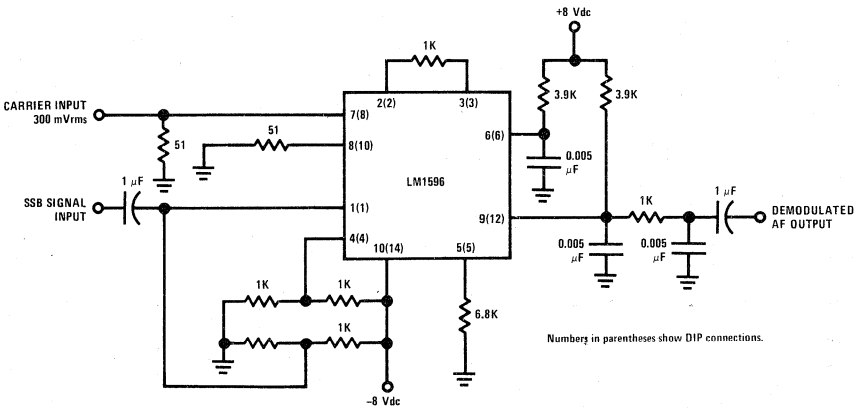
Sideband and Signal Port Transadmittances vs Frequency



Signal-Port Frequency Response



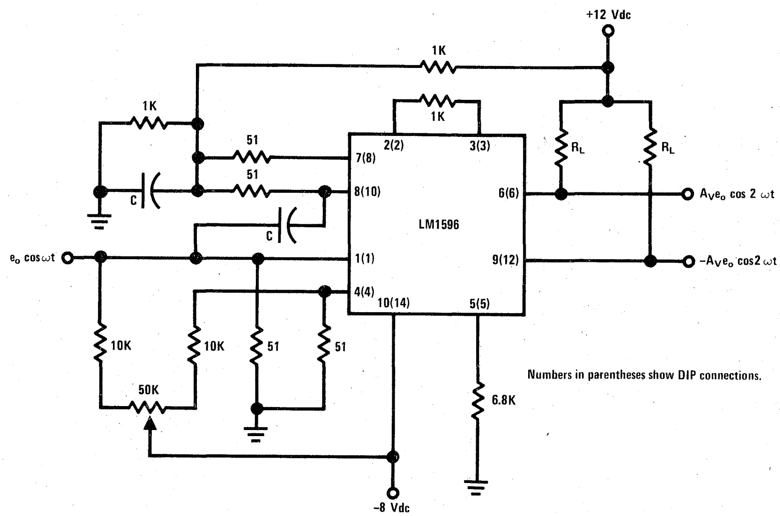
typical applications (con't)



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)



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.

Audio, Radio and TV Circuits

LM1800/LM1800A phase locked loop FM stereo demodulator

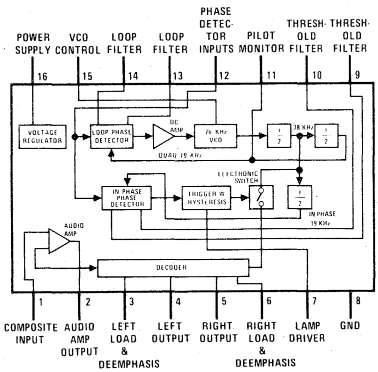
general description

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

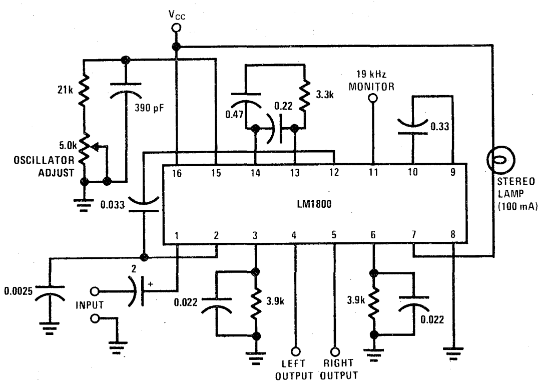
connection diagram



TOP VIEW

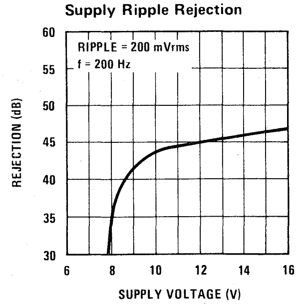
Order Number LM1800N
See Package 23

typical application

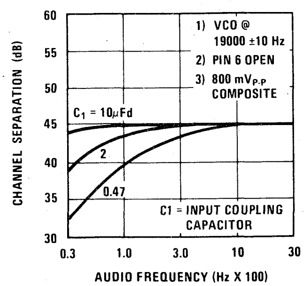


typical performance characteristics

Supply Ripple Rejection



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		15	20	mVrms
Pilot Level for Lamp "OFF"	Pin 11 Adjusted to 19.00 kHz	3.0	7.0		mVrms
Stereo Lamp Hysteresis		3.0	6.0		dB
Stereo Channel Separation	100 Hz (Note 2) 1000 Hz (Note 2) 10000 Hz (Note 2)	 30 	40 45 45		dB dB 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		0.4	1.0	%
Total Harmonic Distortion	500 mVrms, 1000 Hz Input, 1800A Only		0.1	0.3	%
Capture Range	25 mVrms of Pilot	±2.0		±6.0	% of f_o
Supply Ripple Rejection	200 mVrms of 200 Hz Ripple	35	45		dB
Dynamic Input Resistance		20	45		kΩ
Dynamic Output Resistance		900	1300	2000	Ω
SCA Rejection	(Note 4)		70		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.

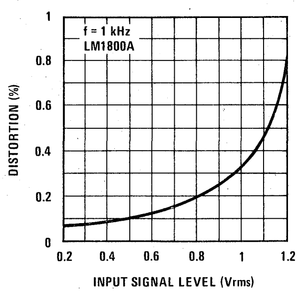
Note 3: The maximum junction temperature is +150°C and the package should be derated at +175°C/W junction to ambient.

Note 4: Measured with a stereo composite signal consistency of 80% stereo, 10% pilot and 10% SCA as defined in the FCC Rules on Broadcasting.

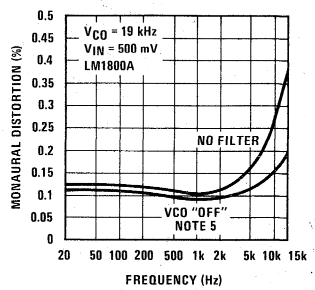
Note 5: VCO "OFF" curve represents the distortion attainable using good 19 kHz and 38 kHz filters.

typical performance characteristics (con't)

Monaural Distortion vs Input Amplitude



Monaural Distortion vs Frequency



10

Audio, Radio and TV Circuits

LM1807 TV phase lock video if and detector

general description

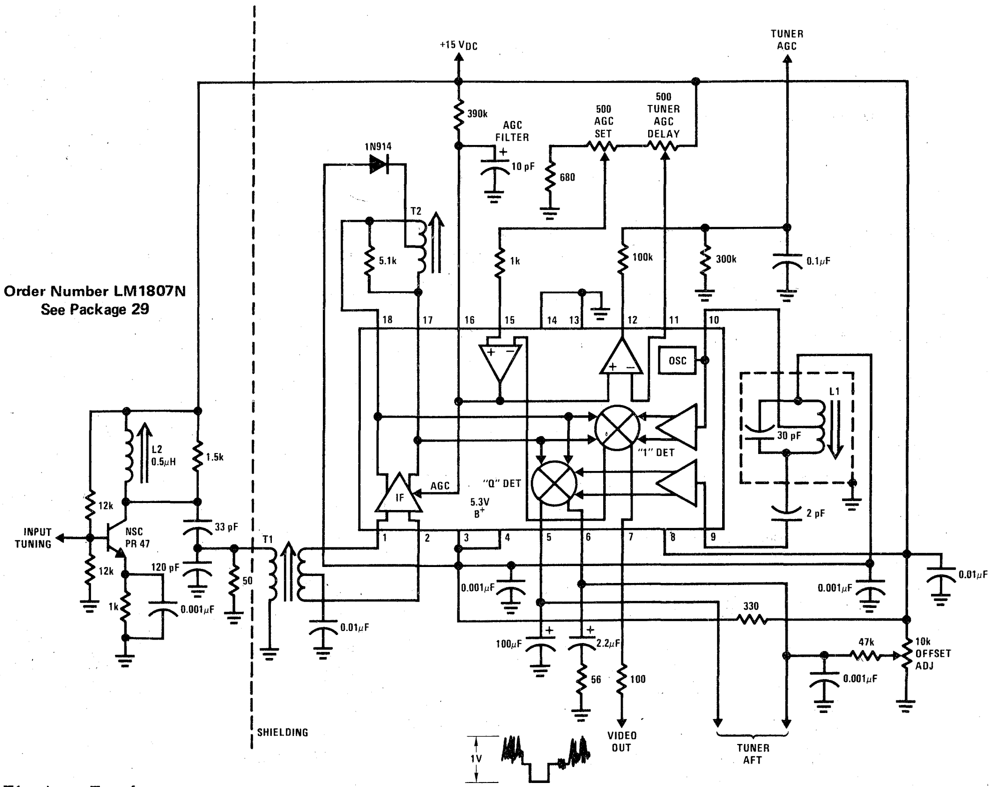
The LM1807 performs all of the video IF functions required in a television receiver. It includes a gain-controlled IF amplifier and a true synchronous detector with the reference supplied by a local oscillator on the chip. A phase-lock loop locks the tuner to the IF frequency, providing an AFT function. The AGC section gain reduces the IF amplifier and supplies a delayed control voltage to the tuner.

features

- Total conversion gain 72 dB
- Search oscillator for ±1 MHz capture range
- Intermodulation products below −55 dB
- 1.2 Vp-p negative video output
- White noise clipper
- IF AGC range > 70 dB
- Reverse tuner AGC output

block diagram and typical application

Order Number LM1807N
See Package 29



T1 – Input Transformer
2 turns of #32 enameled wire. Windings are tightly coupled and wound on a ferrite bead or toroid.
T2 – Interstage Transformer
7 turns of # 32 enameled wire. Windings are tightly coupled and wound on a 7/32" O.D. coil form with high freq. slug.
L1 – Oscillator Coil
7 turns of #20 bare wire wound 0.025" apart on an 11/32" O.D. coil form with high freq. slug. Tap at 2 1/4 turns from the ac ground end.

absolute maximum ratings

Supply Voltage, V8	18V	Power Dissipation	600 mW
Current, $I_3 + I_4$	50 mA	Operating Temperature Range	0°C to +70°C
Input Signal, V1 – V2	3.5V	Storage Temperature Range	–65°C to +150°C
Output Current, I_7	5 mA	Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics

	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
STATIC PARAMETERS (T_A = 25°C, V_{CC} = 15V, Test Circuit 1)						
I_8	Power Supply Current	V8 = 15V		40	55	mA
V3	Regulator Voltage		4.8	5.3	6.0	V
V1, V2	Input Bias Voltage			2.2		V
V7	Video Output Voltage		7.0	8.5	10.5	V
V12	RF AGC Output Voltage		6.0	10		V
V5, V6	AFC Output Voltage			7.5		V
V18–V17	IF Amplifier Balance	V1 = V2		0	±200	mV
DYNAMIC PARAMETERS (T_A = 25°C, V_{CC} = 15V, Test Circuit 2)						
	Input Impedance	f = 45 MHz				
R_{IN}	Resistance			220		Ω
C_{IN}	Capacitance			3		pF
R_{OUT}	Output Resistance			50		Ω
e_{OUT}	Video Output Level	Set R1		1		Vp-p
eg	Local Oscillator Level			300		mVp-p
A_V	Conversion Gain rms in to p-p out	V16 < 3V		72		dB
IM	Intermodulation Products	e_{IN} = 50 mVrms Sidebands –10 dB V_{OUT} = 1 Vp-p		–50		dB
S/N	Noise Quieting	e_{IN} = 100 mVrms		55		dB

circuit description

Input Amplifier

The input amplifier, Q1 - Q4, is a differential pair feeding cascode transistors Q5 and Q6. A load impedance between pins 17 and 18 converts the output current to a voltage which is buffered by Q16 - Q19. AGC action begins when diodes D5 and D6 cease conduction: A voltage divider action is formed with the 500Ω resistors and the low input impedance of Q5 and Q6. Further AGC action is provided by conduction of D3 and D4 which provide negative feedback further reducing the gain. Additional AGC action is provided by conduction of D1 and D2 providing further attenuation of the input signal.

Detectors

Two double balanced demodulators are provided for demodulation of the IF signal.

Q26 - Q27 form a phase demodulator operating in quadrature with the IF signal. The output of this detector after filtering is used to drive the tuner AFC diode to maintain phase lock.

A low frequency "search oscillator" is formed by a low gain positive feedback loop consisting of Q37, Q38 and Q39. Working in conjunction with a large electrolytic capacitor, this oscillator serves to sweep the AFC control voltage at approximately 1-2 Hz so that the tuner local oscillator sweeps approximately 1.5 MHz—thereby increasing the lock range to this value.

AGC Generator

AGC voltage is developed at pin 16 by the action of Q15 which conducts on sync tips at a level set by a potentiometer in its emitter circuit (pin 15). As AGC progresses, increasing current into diodes D1 and D2 demand more current from Q8 which increases current flow in Q9. The voltage drop across R17 increases and Q10 turns off, causing the voltage at its collector to decrease providing reverse AGC for the tuner.

Local Oscillator

A 45.75 MHz local oscillator is included on the chip to provide the reference signal to drive the detectors. This oscillator is a differential pair Q43 - Q44 with positive feedback. Two buffers are provided Q41-Q42 and Q46–Q47 to drive the two detectors. A small capacitor coupled into pin 9 provides 90° phase shift to drive the phase detector in quadrature.

Power Supply Regulator

An on-chip 5.3V zener diode is connected between pins 3 and 13 to provide regulation of the low voltage power to the amplifier and local on-chip oscillator.

circuit application

Figure 1 shows a complete TV video IF system utilizing the LM1807. A conventional switched VHF tuner is used in conjunction with the 1807. The conventional AFC diode and circuitry is used to control the tuner local oscillator such that the IF frequency is phase locked to the on-chip local oscillator. A single transistor stage is used to provide a power gain of approximately 24 dB of gain between the input filter and the input of the LM1807. A single tuned circuit is used at both the input and the output of this stage for selectivity. Also included is an adjacent channel sound trap. The LM1807 is driven differentially by a 4:1 (impedance) step up transformer.

Approximately 40 dB of voltage gain is realized from the gain stage in the LM1807, when loaded with 5 kΩ. A center tapped coil is used to tune out interstage capacitance and act as a dc bias short to the power supply. Both the "I" and "Q" phase detectors are driven from this interstage.

A tapped-coil tuned circuit is used as the on-chip oscillator resonator, the voltage at the coil tap being used to drive the "I" detector, while a small capacitor (2 pF) is used to provide a 90° phase shifted drive signal to drive the Q detector.

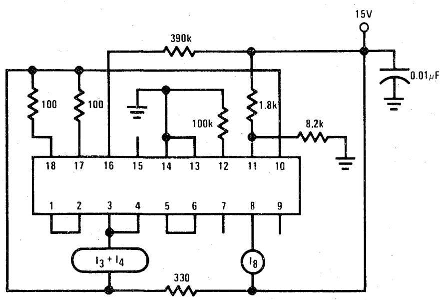
The level of detected video is adjusted with a 500Ω potentiometer which sets the threshold level of the AGC detector. A 10μF filter capacitor filters the pulse output of the AGC detector. A second on-chip comparator is adjusted to provide a negative going (8V to 0V) AGC voltage for the tuner. Another 500Ω potentiometer sets the point at which this circuit begins tuner AGC, and is adjusted for best compromise between good signal to noise and overload.

In addition, the dc output of the Q phase detector may be adjusted to zero with a 10k "offset adjust." A 100μF filter capacitor on pin 5 provides the necessary reactance to insure oscillation of the "search oscillator." The action of the search oscillator may be stopped by replacing this capacitor with a smaller one, approximately 0.1μF. The bandwidth, and hence response time of the phase lock loop is governed by the 2.2μF, 56Ω resistor on pin 6. It should be noted that no additional filter capacitance greater than 0.01μF should be used on this line or loop instability may result.

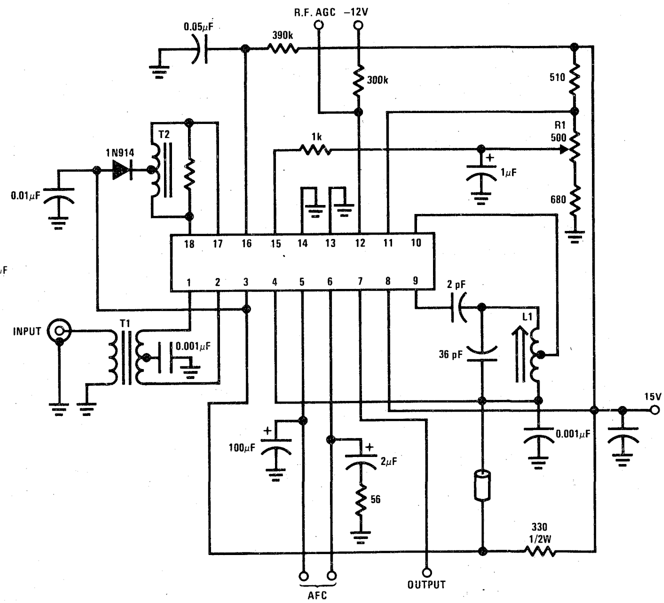
Some designers may note that phase shifts through the IF filter can contribute to loop instability; this is true. However, the bandwidth of this filter is considerably wider than that of the loop filter, hence the loop filter governs the stability.

Layout and parts placement of components around the LM1807 is critical, not so much from the danger of instability, but because of the danger that the on-chip local oscillator will radiate back to the IF input circuits, producing a phase shifted signal to the phase detectors, and hence an undesired output. This is particularly true in the Q channel where an input signal of 15μV can produce ±1 V_{DC} at the Q detector output—depending on filter tuning and AGC setting. Good shielding of L1 is important, as is bypassing the B+ supply near the oscillator coil. A balanced input transformer must be used.

test circuits

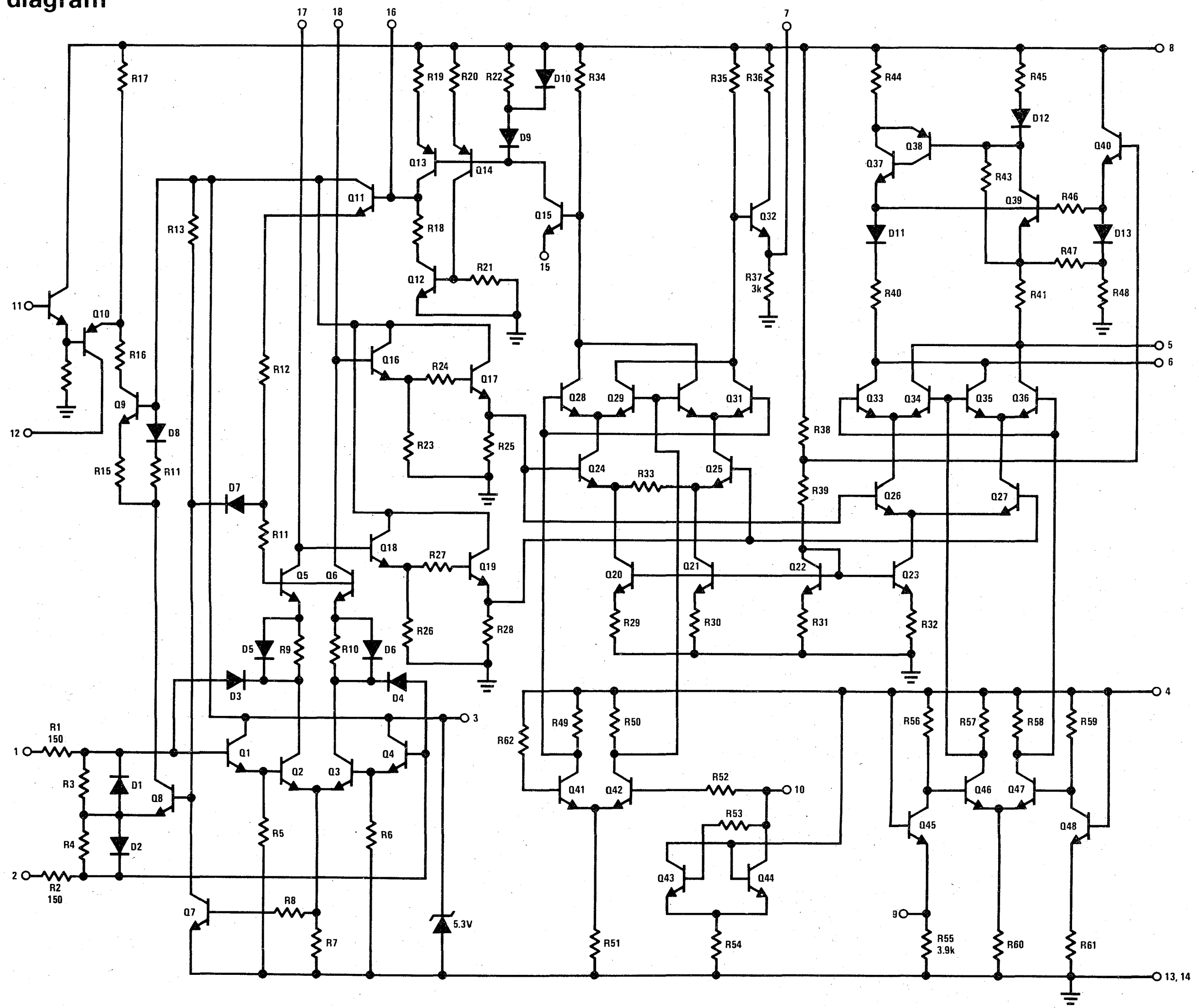


LM1807 Test Circuit 1 – DC Parameters



LM1807 Test Circuit 2 – AC Parameters

schematic diagram



Audio, Radio and TV Circuits

LM1808 monolithic TV sound system

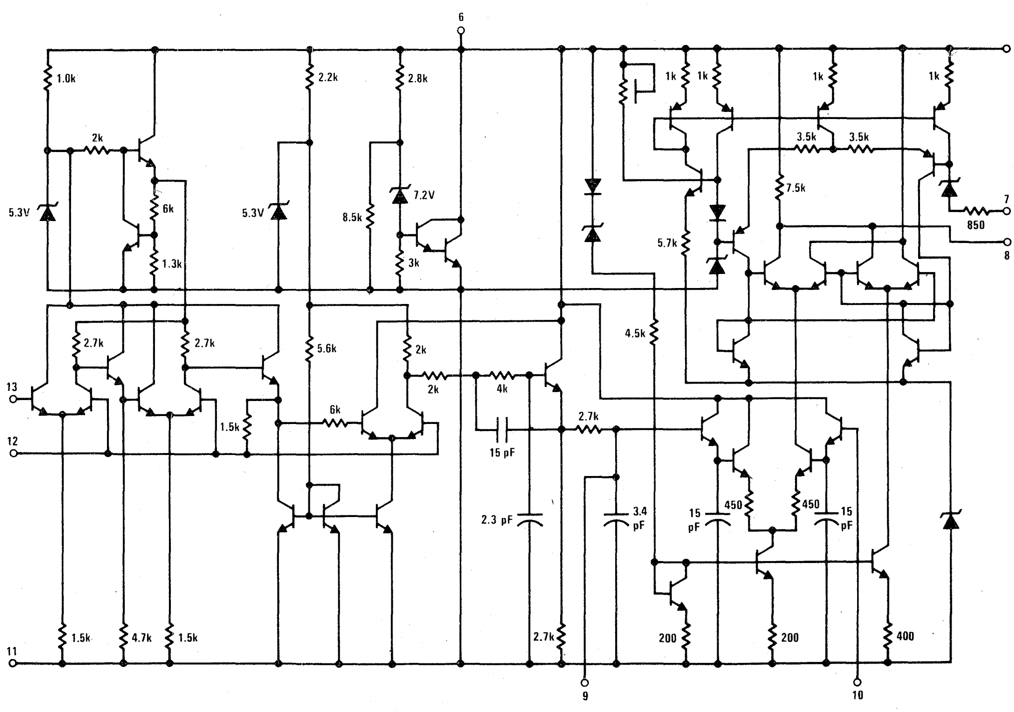
general description

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 diagrams (For power amplifier section of schematic see next page)



IF and Detector

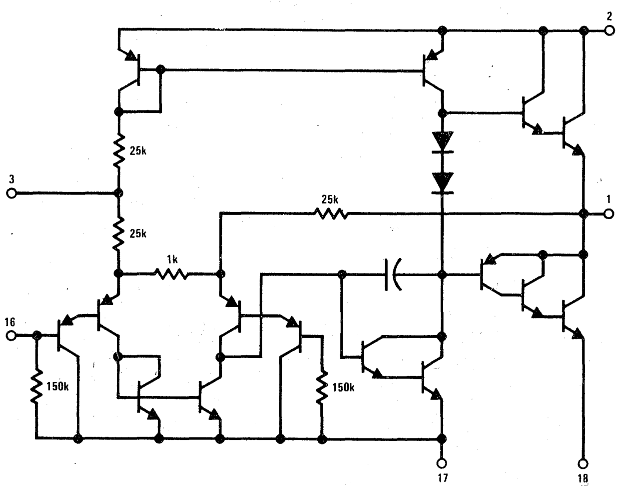
absolute maximum ratings

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)

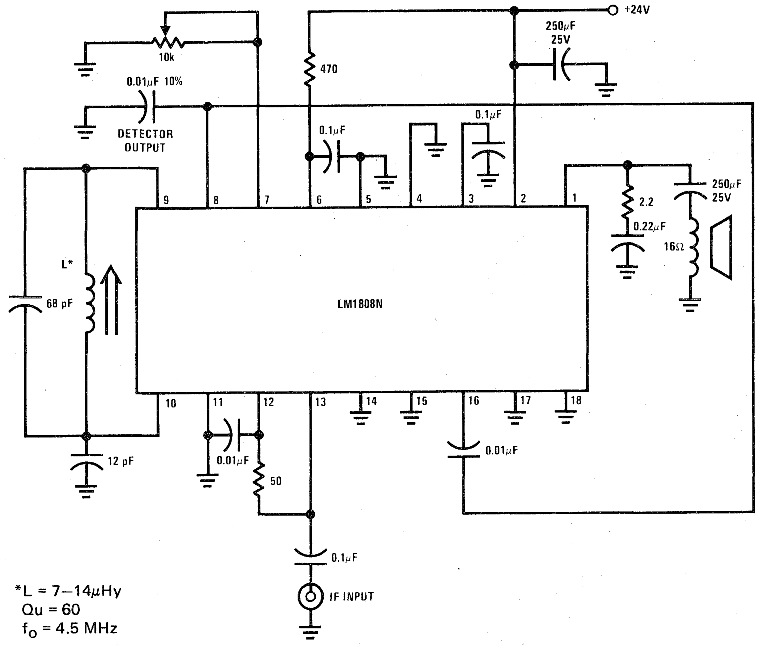
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Zener Regulating Voltage (Pin 6)		10.5	11.5	12.5	V
Output Swing (Pin 1)			16		Vp-p
Feedthrough Signal (Pin 1)	R Pin 7 = 0Ω			15	mVrms
Current into Pin 6	V Pin 6 = 10V	7	10.8	15	mA
AM Rejection	V_{IN} = 10 mVrms, Δf = 25 kHz, AM = 30%	40			dB
Recovered Audio (Pin 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 = 0Ω		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

schematic diagrams (con't)



Power Amplifier

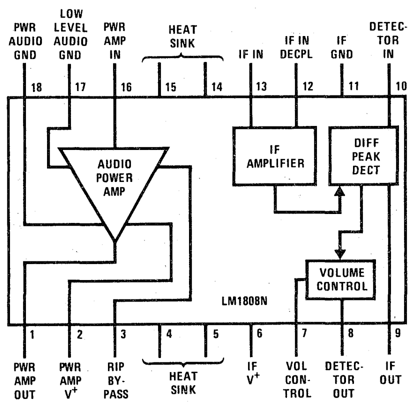
typical application and test circuit



Television Sound System

connection diagram

Dual-In-Line Package

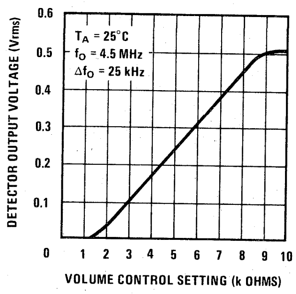


TOP VIEW

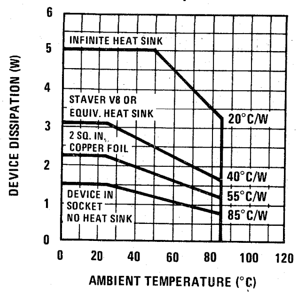
Order Number LM1808N
See Package 29

typical performance characteristics

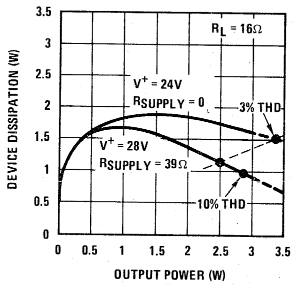
Volume Control Characteristic



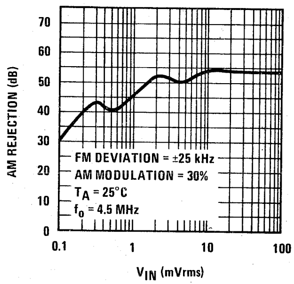
Allowable Device Dissipation vs Ambient Temperature



Device Dissipation vs Output Power



AM Rejection vs Input Signal Level



10

Audio, Radio and TV Circuits

LM1820 AM radio system

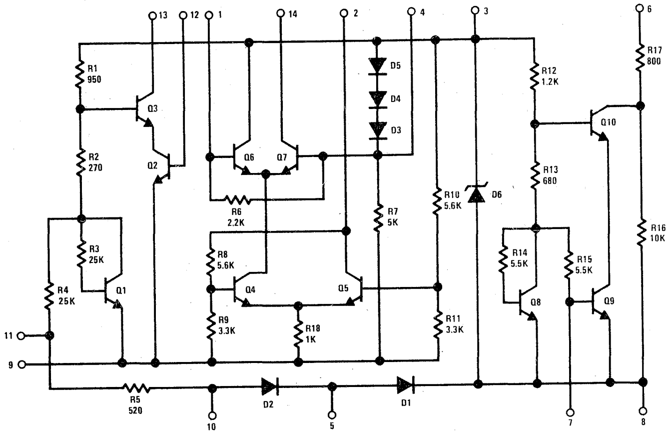
general description

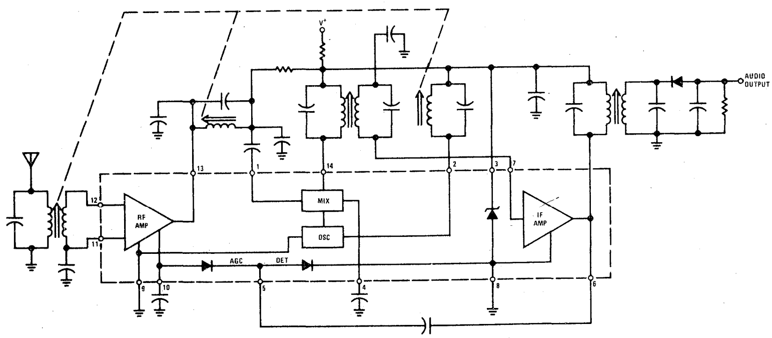
The LM1820 is a monolithic integrated circuit AM radio system. It includes two amplifiers a mixer-oscillator; an AGC detector and a zener regulator.

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 MIN	LIMITS TYP	LIMITS MAX	UNITS
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, $e_{12} = 100\mu V$, $e_5 = 0$ 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

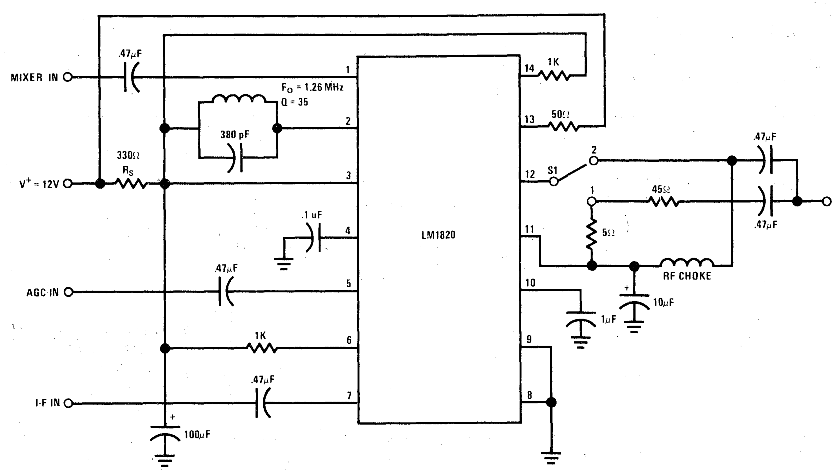


FIGURE 1.

Audio, Radio and TV Circuits

LM1828, LM1848 color television chroma demodulator

general description

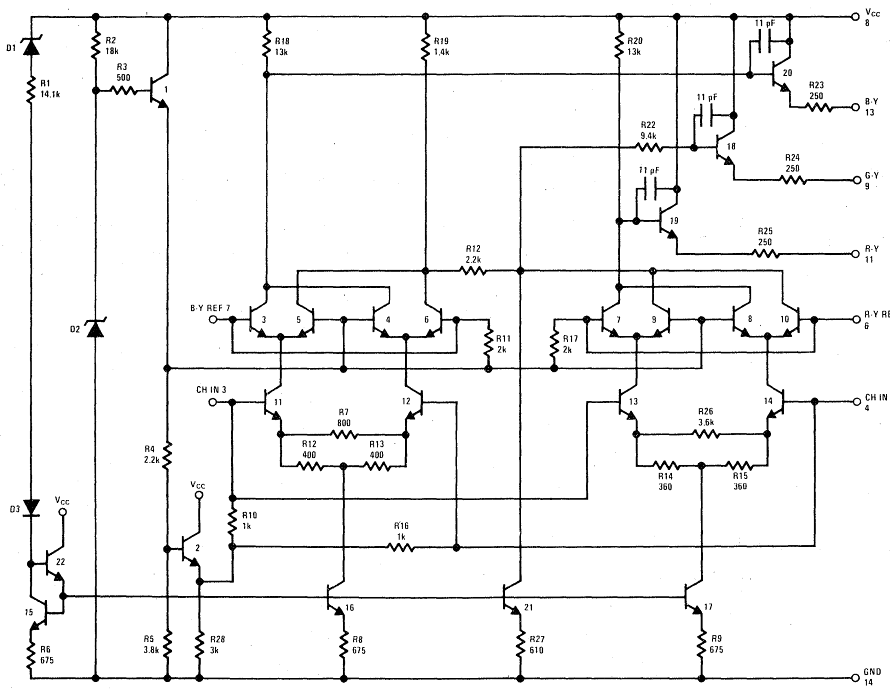
The LM1828, LM1848 are monolithic silicon integrated circuits which demodulate the chroma sub-carrier information contained in a color television video signal and provide color-difference signals at the outputs.

The low dc voltage drift of the outputs insures excellent performance in direct-coupled chrominance output circuitry.

features

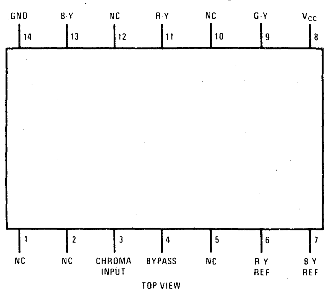
- Low output voltage drift with temperature
- Doubly balanced demodulation
- 10 Vp-p $E_B - E_Y$ output
- Built-in ripple filter capacitors
- Standard matrix in LM1828
- Revised matrix in LM1848
- Pin compatible with LM746, CA3072

schematic diagram



connection diagram

Dual-In-Line Package



Order Number LM1828N or LM1848N
See Package 22

absolute maximum ratings

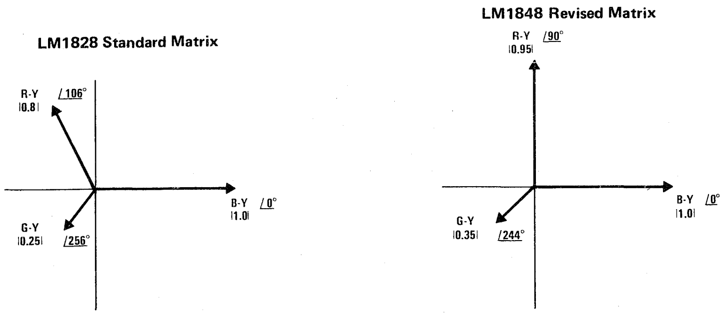
Power Dissipation	
T_A = 70°C or less	450 mW
T_A = 70°C or more	Derate 8.2 mW/°C
Operating Temperature Range	0°C to +70°C
Storage Temperature Range	−65°C to +150°C
Supply Voltage	30V
Reference Input	5 Vp-p
Chroma Input	5 Vp-p

electrical characteristics T_A = 25°C, V_{CC} = 24V, R_L = 3.3k

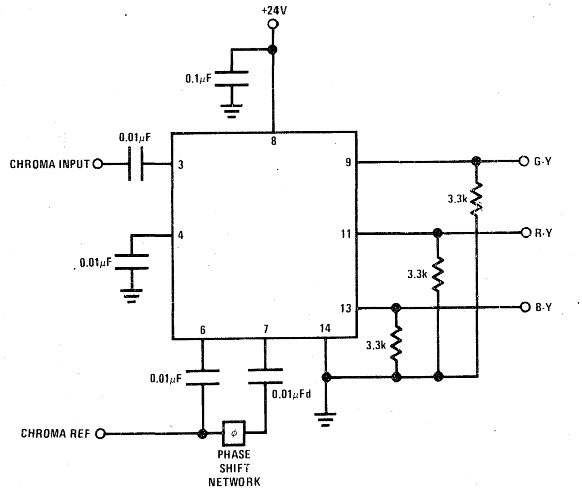
PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
STATIC						
I_S	Supply Current	e_c = 0, R_L = 1M	5.5	9.0	12.5	mA
		e_c = 0, R_L = 3.3k	16.5	22	25.5	mA
P_D	Power Dissipation	e_c = 0		340	430	mW
V9, V11, V13	dc Output Voltage	e_c = 0, R_L = 3.3k	13	14.5	16	V
$\lvert\Delta V_O\rvert$	Output Differential	e_c = 0, R_L = 3.3k		100	600	mV
	Output Tempco	e_c = 0		3		mV/°C
V6, V7	Reference Input dc			6.2		V
V3, V4	Chroma Input dc			3.4		V
DYNAMIC						
e_c	Chroma Input Sensitivity	B-Y = 5 Vp-p		0.4	0.7	Vp-p
V13	Max B-Y Output	e_c = 1.5 Vp-p	8	10		Vp-p
	ac Unbalance	e_c = 0		0.1	0.8	Vp-p
V9, V11, V13	Residual Carrier	B-Y = 5 Vp-p			1.5	Vp-p
	R-Y Output	B-Y = 5 Vp-p				
	LM1828		3.5	3.8	4.2	Vp-p
	LM1848		4.2	4.75	5.25	Vp-p
	G-Y Output					
	LM1828		0.75	1.0	1.25	Vp-p
	LM1848		1.3	1.75	2.2	Vp-p

Note : Values measured in test circuit.

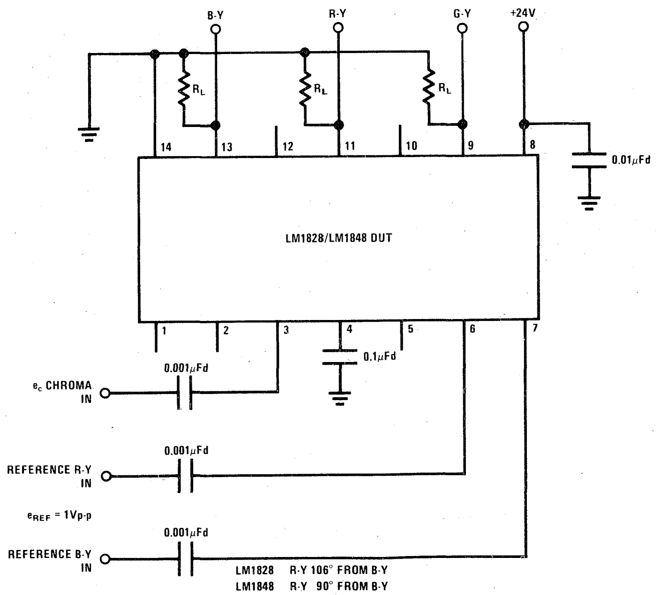
typical vector output diagrams



typical application



test circuit



Audio, Radio and TV Circuits

LM1841 FM detector and limiter

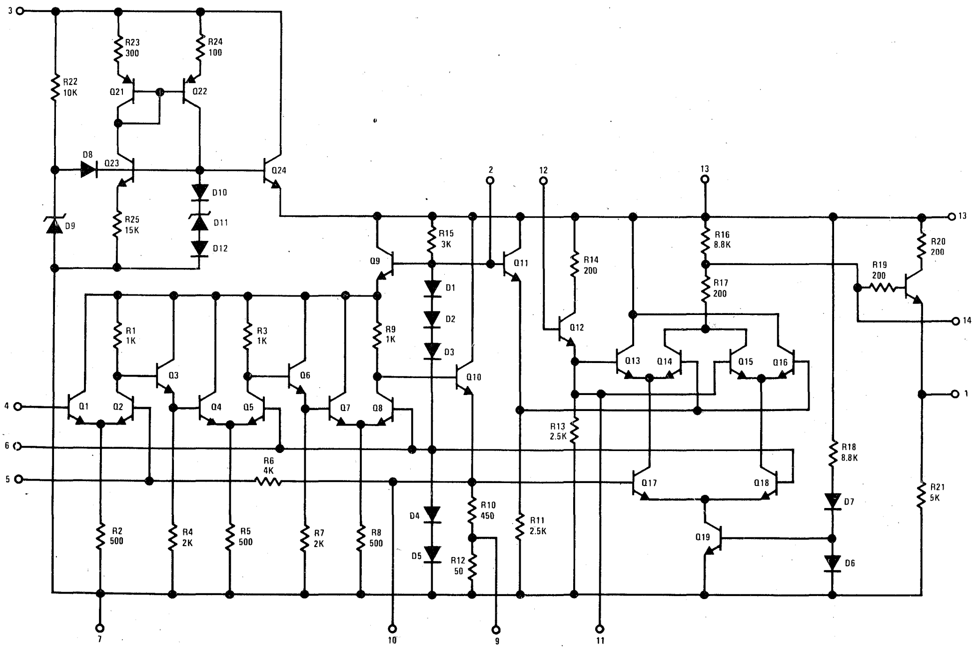
general description

The LM1841 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, a balanced product detector and a 7.8V regulator.

features

- A direct replacement for ULN2136A
- Simple detector alignment: one coil
- Sensitivity: 3 dB limiting voltage 300 μV typ.
- Low harmonic distortion
- High IF voltage gain
- Regulated 7.8V output

schematic diagram



Order Number LM1841N
See Package 22

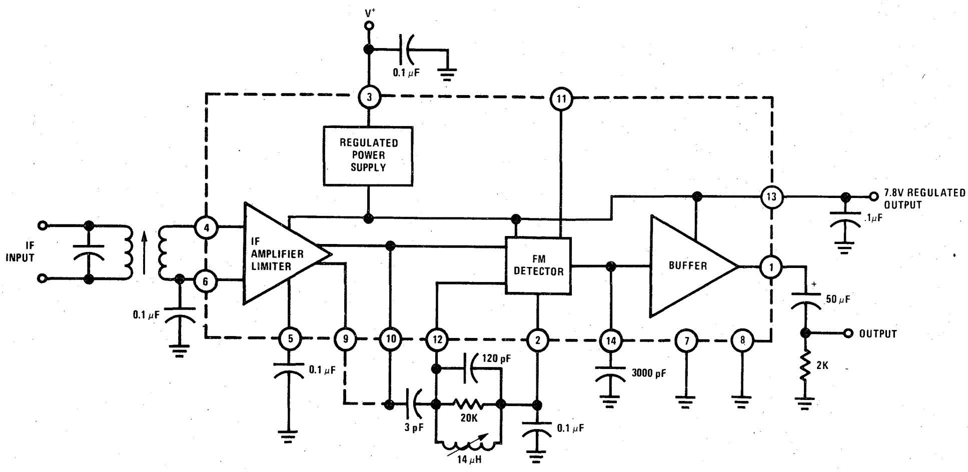
absolute maximum ratings

Supply Voltage	20V
Input Signal Voltage (Pin 4)	3.5V
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	−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 unless otherwise specified)

PARAMETER	CONDITIONS	LIMITS			UNITS
		MIN	TYP	MAX	
STATIC CHARACTERISTICS (amplifier and detector)					
Supply Current (I_3)	No Load at Pin 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		V
Detector Output Level (V_1)		3	3.8	4.6	V
Temperature Stability of Detector Output Level ($\Delta V_1/\Delta T$)			+1		mV/°C
De-emphasis Resistance (R_d)			8.8		kΩ
STATIC CHARACTERISTICS (regulator)					
Output Voltage (V_{13})	I_{LOAD} = 20 mA		7.8		V
Line Regulation (V_{13})			5	10	mV/V
Temperature Stability (V_{13})			+1.6		mV/°C
DYNAMIC CHARACTERISTICS f_o = 4.5 MH, Δf = ±25 kHz, Peak Separation = 150 kHz, Source Resistance = 50Ω					
Amplifier Voltage Gain (A_{IF})	$V_{IN} \leq$ 0.3 mVrms (Figure 1)		58		dB
Amplifier Output Voltage ($V_{10(IF)}$)	V_{IN} = 10 mV (Figure 1)		1.45		V_{P-P}
Input Limiting Threshold ($V_{IN(LIM)}$)	FM = 400 Hz (Figure 2)		300		μVrms
Recovered Audio Output ($V_{O(af)}$)	V_{IN} = 60 mV, FM = 400 Hz (Figure 2)		0.5		Vrms
Output Distortion (T_{HD})	100% FM Modulation (Figure 2)		1.5		%
AM Rejection (AMR)	AM: 1 kHz @ 30%, V_{IN} = 10 mV (Figure 2)		46		dB
DYNAMIC CHARACTERISTICS f_0 = 10.7 MHz, Δf = ±75 kHz, Peak Separation = 550 kHz, Source Resistance = 50Ω					
Amplifier Voltage Gain (A_{IF})	$V_{IN} \leq$ 0.3 mVrms (Figure 1)		53		dB
Amplifier Output Voltage ($V_{10(IF)}$)	V_{IN} = 10 mV (Figure 1)		1.45		V_{P-P}
Input Limiting Threshold ($V_{IN(LIM)}$)	FM = 400 Hz (Figure 2)		400		μV
Recovered Audio Output ($V_{O(af)}$)	V_{IN} = 60 mV, FM = 400 Hz (Figure 2)		0.3		Vrms
Output Distortion (T_{HD})	100% FM Modulation (Figure 2)		1		%
AM Rejection (AMR)	AM: 1 kHz = 30%, V_{IN} = 10 mV (Figure 2)		40		dB

block diagram



test circuits

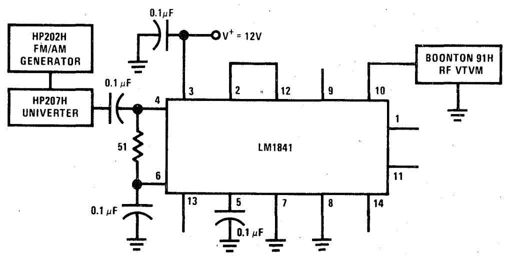


FIGURE 1.

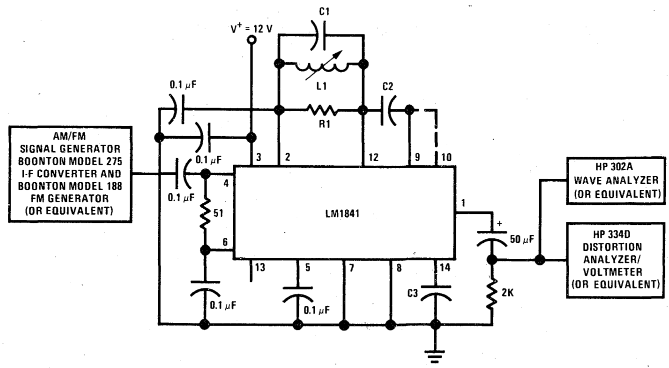


FIGURE 2.

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

Audio, Radio and TV Circuits

LM1845 signal processing system

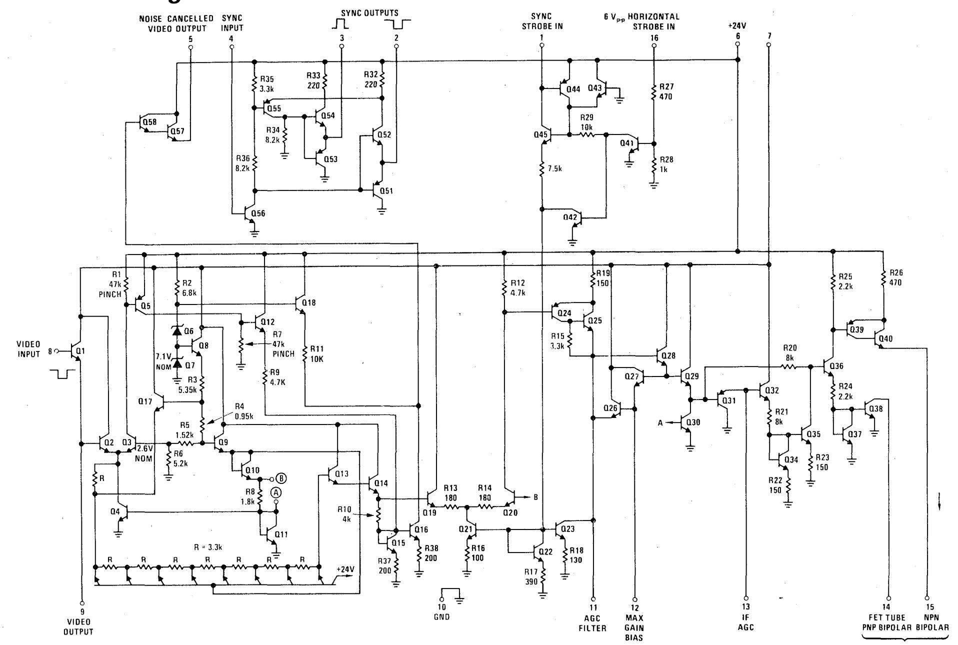
general description

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

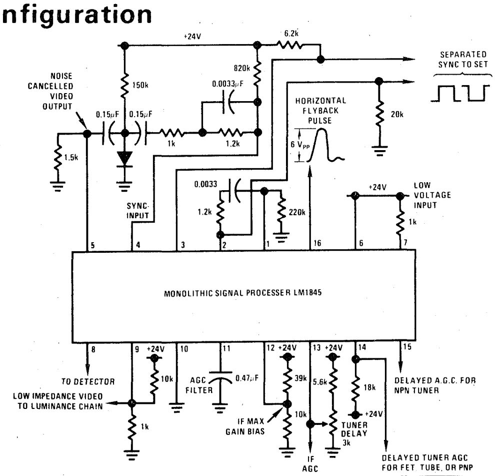
schematic diagram



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.

Audio, Radio and TV Circuits

LM1889 TV video modulator

general description

The LM1889 is designed to interface audio, color difference, and luminance signals to the antenna terminals of a TV receiver. It consists of a sound subcarrier oscillator, chroma subcarrier oscillator, quadrature chroma modulators, and R.F. oscillators and modulators for two low-VHF channels.

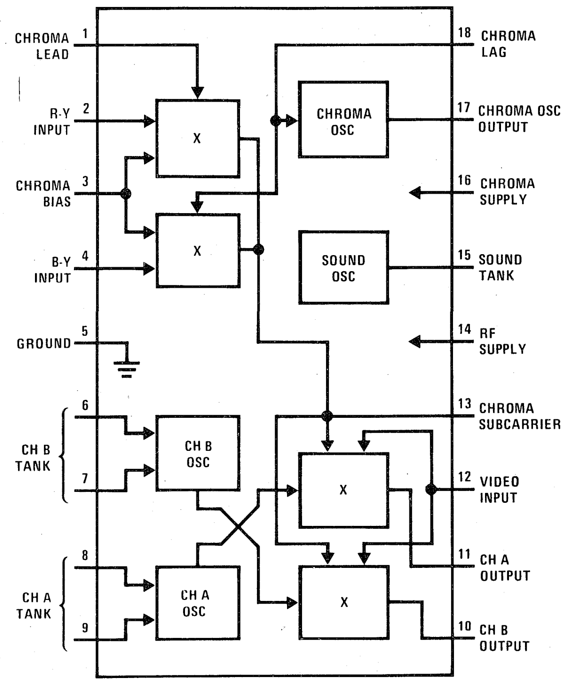
The LM1889 allows video information from VTR's, games, test equipment, or similar sources to be displayed on black and white or color TV receivers. When used with the MM57100 and MM53104, a complete TV game is formed.

features

- DC channel switching
- 12V to 18V supply operation
- Excellent oscillator stability
- Low intermodulation products
- 5 Vp-p chroma reference signal
- May be used to encode composite video

connection diagram

Dual-In-Line Package

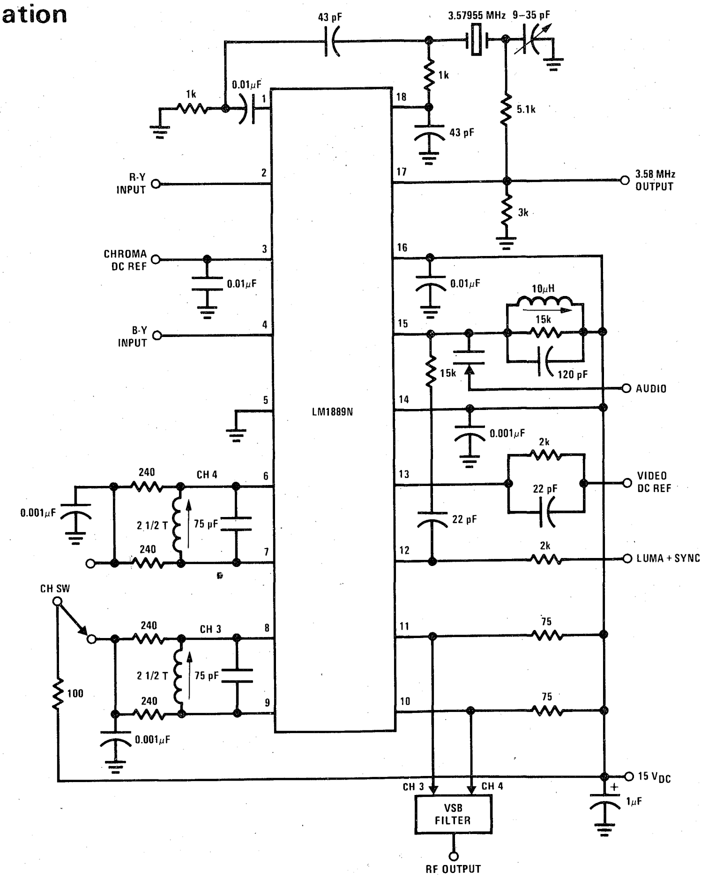


Order Number LM1889N
See Package 29

tentative electrical characteristics (Applications circuit, V = 15V)

	TYP
Supply Voltage Range V14, V16	12–18 V_{DC}
Total Supply Current $I_{14} + I_{16}$	35 mA_{DC}
Common-Mode Input Range	
Chroma Mod. V2, V3, V4	4–10.5 V_{DC}
RF Mod. V12, V13	3.5–11 V_{DC}
Oscillator Levels	
Sound Osc V15	3.5 Vp-p
Chroma Osc V17	5 Vp-p
RF Osc V6, V7 or V8, V9	300 mVp-p
Chroma Modulator Conversion Gain	
V13 Out/V4–V3	0.6 Vp-p/V_{DC}
V13 Out/V2 – V3	0.6 Vp-p/V_{DC}
Residual Chroma Output, V13 V2 = V3 = V4	50 mVp-p
RF Modulator Conversion Gain V10 or V11/V12-V13	10 mVrms/V_{DC}

typical application



Audio, Radio and TV Circuits

LM2111 FM detector and limiter

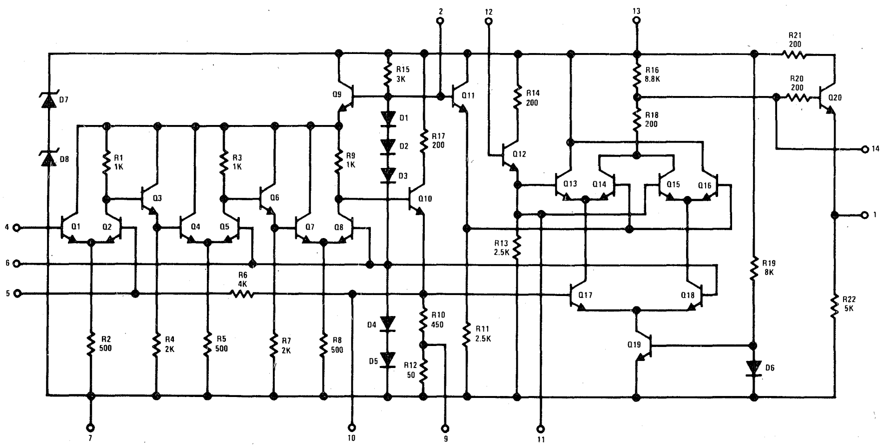
general description

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

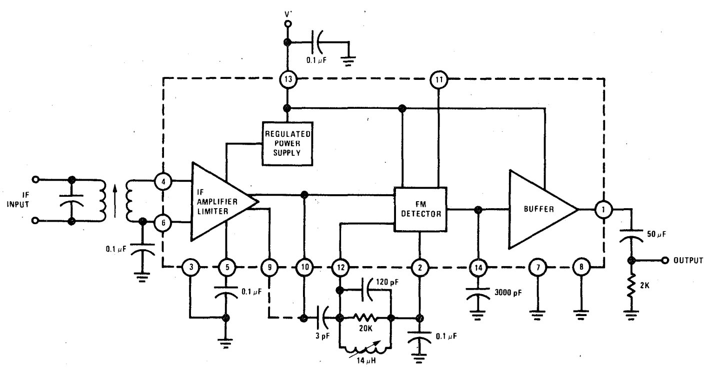
schematic diagram



Order Number LM2111N
See Package 22

Order Number LM2111N-01
See Package 24

block diagram



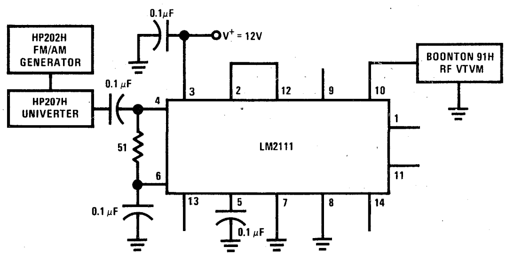
absolute maximum ratings

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		

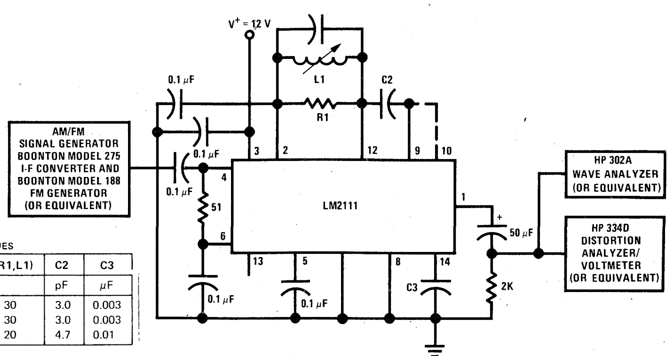
electrical characteristics (T_A = 25°C, V_{CC} = 12V)

PARAMETER	SYMBOL	TEST CIRCUIT	CONDITIONS	LIMITS MIN	LIMITS TYP	LIMITS MAX	UNITS
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	$V_{0(af)}$	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	$V_{0(af)}$	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 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

Audio, Radio and TV Circuits

LM3011 wide band amplifier

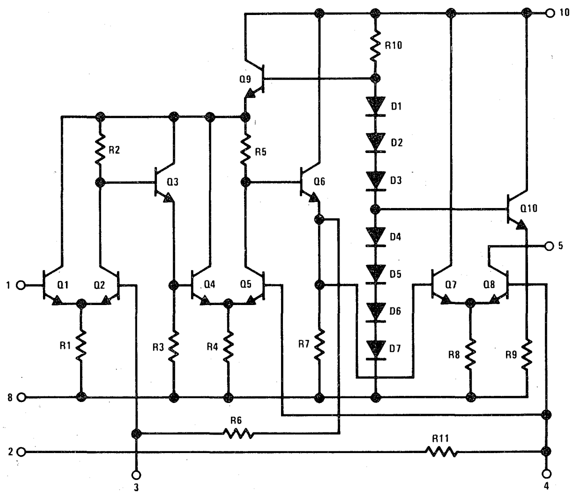
general description

The LM3011 is a monolithic wide band amplifier circuit that requires a minimum of external components for operation. It includes three stages of limiting.

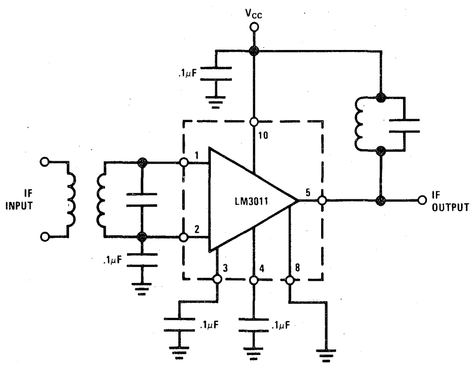
features

- A direct replacement for CA3011
- High amplifier gain
- Excellent limiting characteristics
- Wide frequency capability

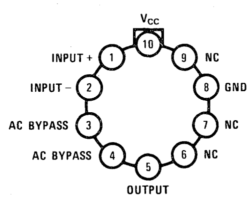
schematic diagram



block diagram



connection diagram



Order Number LM3011H
See Package 12

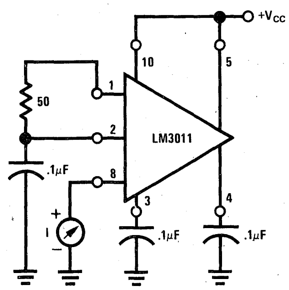
absolute maximum ratings

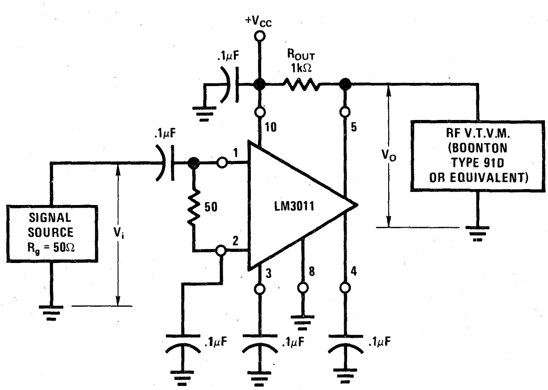
Supply Voltage	15V	Operating Temperature Range	−55°C to +125°C
Input Signal (Pin 1)	±3V	Storage Temperature Range	−65°C to +150°C
Power Dissipation	300 mW	Lead Temperature (Soldering, 10 sec)	300°C

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





Audio, Radio and TV 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

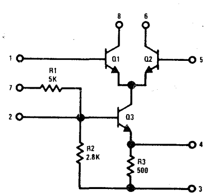
- Controlled for input offset voltage, input offset current, and input bias current*
- Balanced differential amplifier configuration with controlled constant-current source to provide unexcelled versatility
- Single- and dual-ended operation
- Operation from DC to 120 MHz*
- Balanced-AGC capability*
- Wide operating-current range.

*Does not apply to the LM3053.

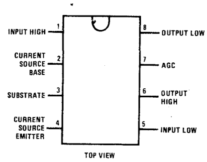
applications

- 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

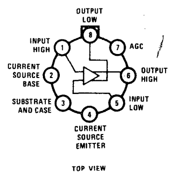


Dual-In-Line Package



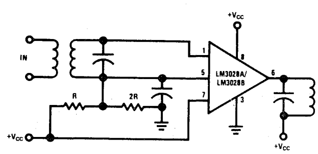
Order Number LM3053N
See Package 20

Metal Can Package

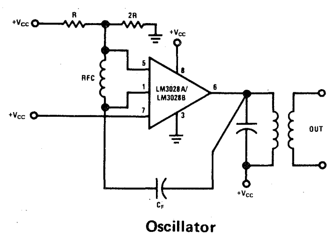


Order Number LM3028AH, LM3028BH or LM3053H
See Package 11

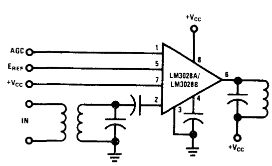
typical applications



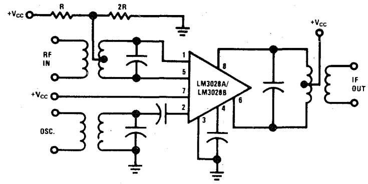
A Balanced Differential Amplifier with a Controlled Constant-Current-Source Drive and AGC Capability



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	
H—Metal Can Package	−55°C to 125°C
N—Package	0°C to 70°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)	

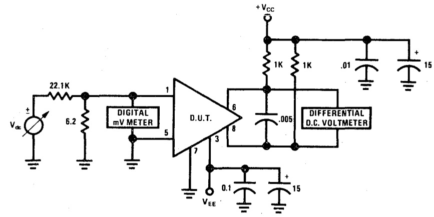
dc electrical characteristics ($T_A = 25°C$)

	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

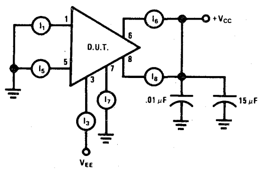
ac electrical characteristics ($T_A = 25°C$)

	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

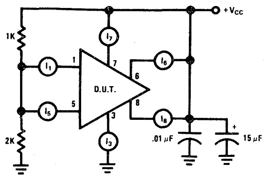
test circuits



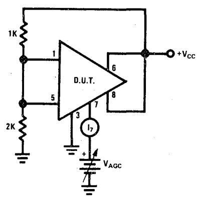
Test Circuit A: VOS LM3028A & LM3028B



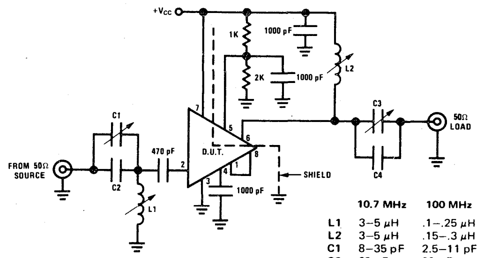
Test Circuit B: I_{OS}, I_{BIAS}, P_D, I_Q & I_7 for LM3028A & LM3028B



Test Circuit C: I_{BIAS}, P_D, I_Q for LM3053

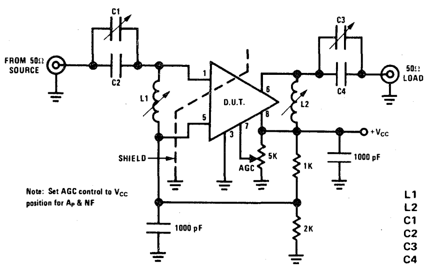


Test Circuit D: I_{AGC} vs V_{AGC} and I_7 for LM3028A & LM3028B



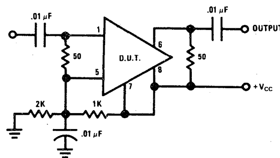
	10.7 MHz	100 MHz
L1	3–5 μH	.1–.25 μH
L2	3–5 μH	.15–.3 μH
C1	8–35 pF	2.5–11 pF
C2	39 pF	20 pF
C3	8–35 pF	2.5–11 pF
C4	36 pF	

Test Circuit E: Cascode Ap & NF 10.7 MHz & 100 MHz

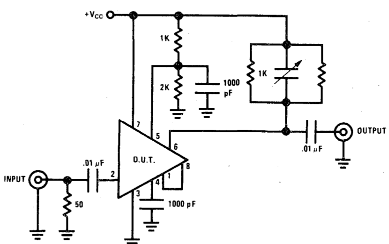


	10.7 MHz	100 MHz
L1	3–6 μH	.2–.5 μH
L2	3–6 μH	.2–.5 μH
C1	8–35 pF	2.5–11 pF
C2	39 pF	–
C3	8–35 pF	2.5–11 pF
C4	36 pF	–

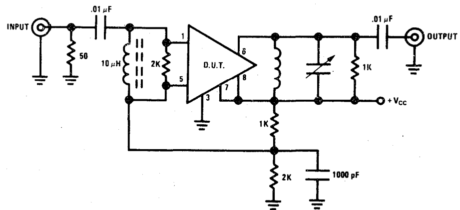
Test Circuit F: Differential Ap, NF and AGC Range, 10.7 MHz & 100 MHz



Test Circuit G: P_o (Untuned) for LM3028A & LM3028B

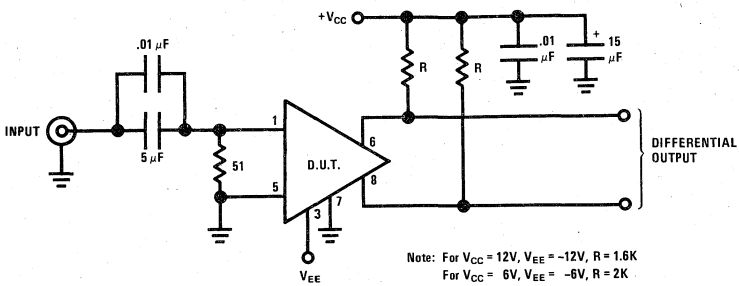


Test Circuit H: Cascode A_V and Transfer Function, 10.7 MHz

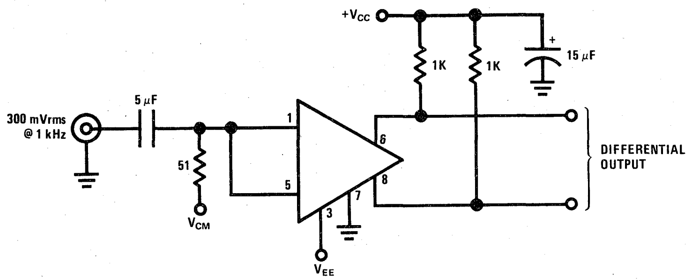


Test Circuit I: Differential Mode A_V and Transfer Function, 10.7 MHz

test circuits (con't)



Test Circuit J: A_V, V_{OUT}, MAX, p/p B.W. for LM3028B



Test Circuit K: CMRR and V_{CM} Range for LM3028B

Audio, Radio and TV Circuits

LM3064 television automatic fine tuning

general description

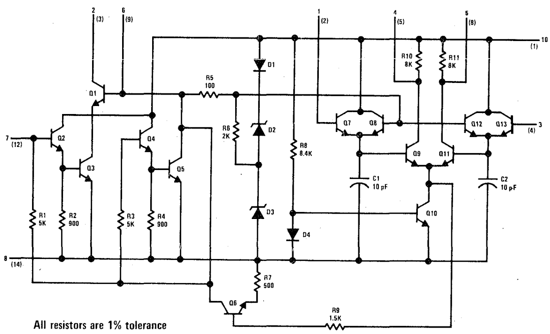
The LM3064 is a monolithic integrated circuit designed primarily for AFT (automatic fine tuning) applications. It includes a zener regulated power supply, IF amp, differential peak detector, and an AGC circuit.

The LM3064 is supplied in both the formed and straight lead TO-5 and 14 lead dual-in-line package.

features

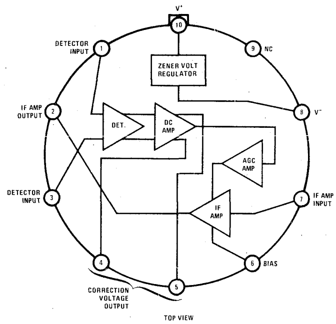
- Primarily intended for AFT applications
- High gain input amp (18 mV for rated output)
- Differential output correction voltage
- Wide operating temperature −40°C to +85°C
- Formed leads available for easy PC board design

schematic and connection diagrams



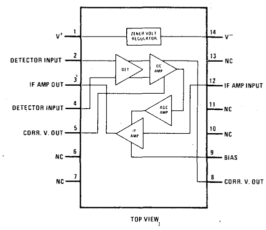
All resistors are 1% tolerance and are in ohms.

Metal Can Package



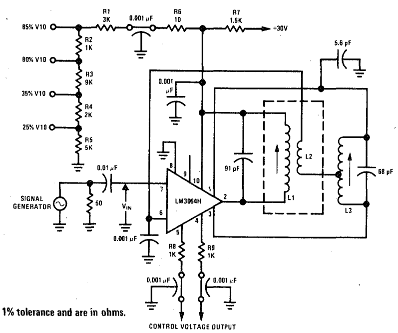
Order Number LM3064H
See Package 14

Dual-In-Line Package



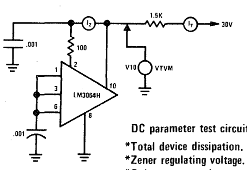
Order Number LM3064N, N-01
See Package 22 & 24

test circuits



All resistors are 1% tolerance and are in ohms.

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

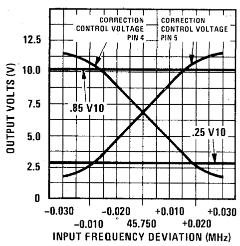
Power Dissipation
- T_A = 25°C or Less — 700 mW
- T_A = 25°C or More — Derate Linearly 5.6 mW/°C for TO-5; Derate Linearly 10 mW/°C for DIP

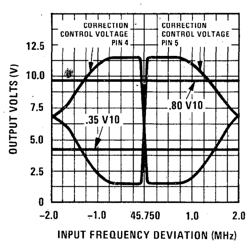
Operating Temperature Range — -40°C to +85°C
Storage Temperature Range — -65°C to +150°C
Power Supply Current — 50 mA

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.

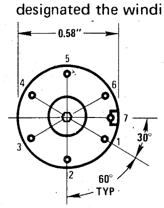
Start winding at Terminal No. 2; finish at Terminal No. 5, connect center tap to Terminal No. 7. See Notes.

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.

Audio, Radio and TV Circuits

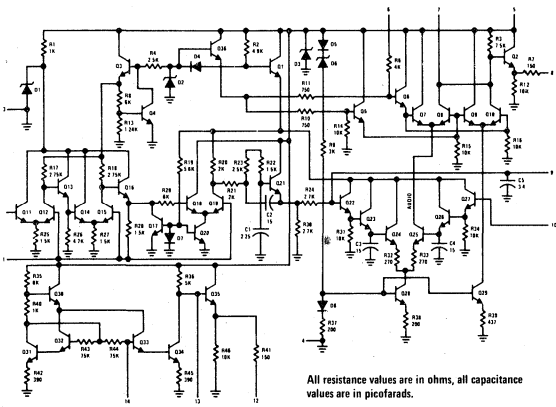
LM3065 television sound system

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:

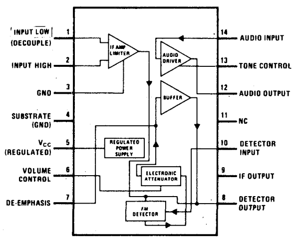
- Electronic attenuator: replaces conventional ac volume control
- Volume reduction range: >60 dB
- Sensitivity: 3 dB limiting voltage—200 μV typically
- High stability
- Low harmonic distortion
- Audio drive capability: 6 mA p-p
- Undistorted audio output voltage: 7V p-p
- Differential peak detector
- 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

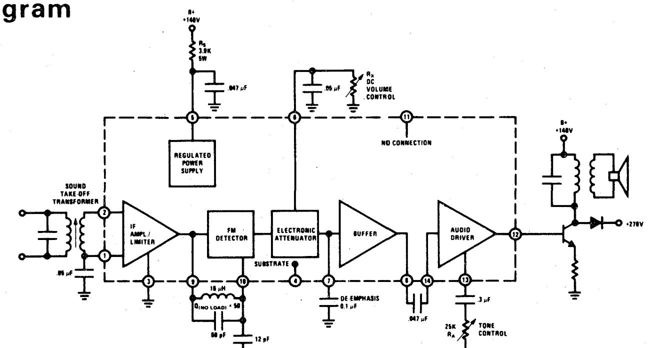


TOP VIEW

Order Number LM3065N
See Package 22

Order Number LM3065N-01
See Package 24

block diagram



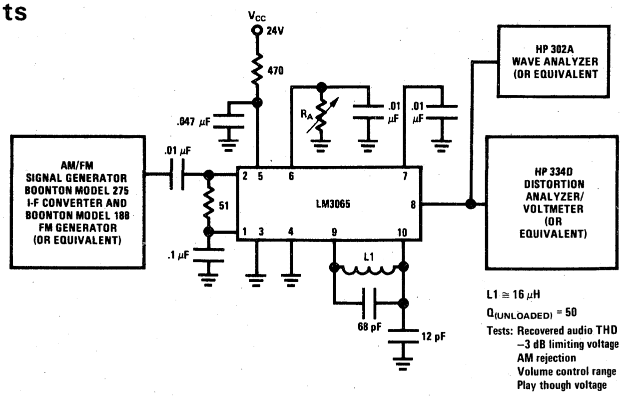
absolute maximum ratings

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

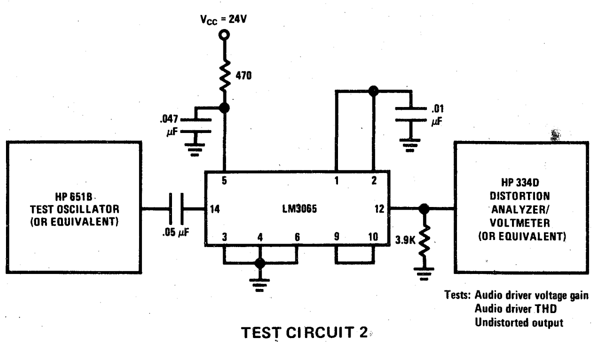
electrical characteristics

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
Ouiescent 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



TEST CIRCUIT 1



TEST CIRCUIT 2

Audio, Radio and TV Circuits

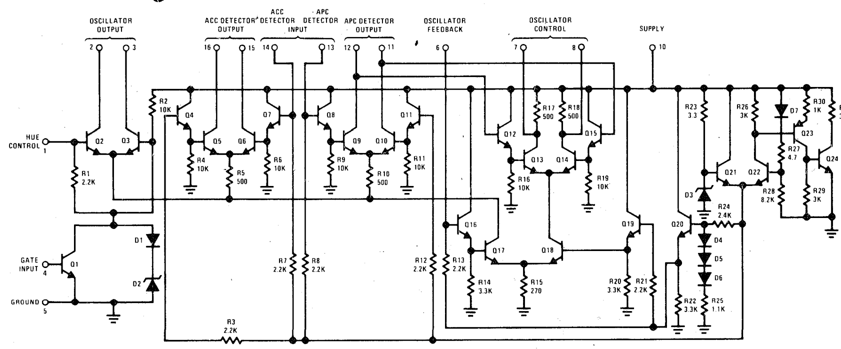
LM3070 chroma subcarrier regenerator

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.

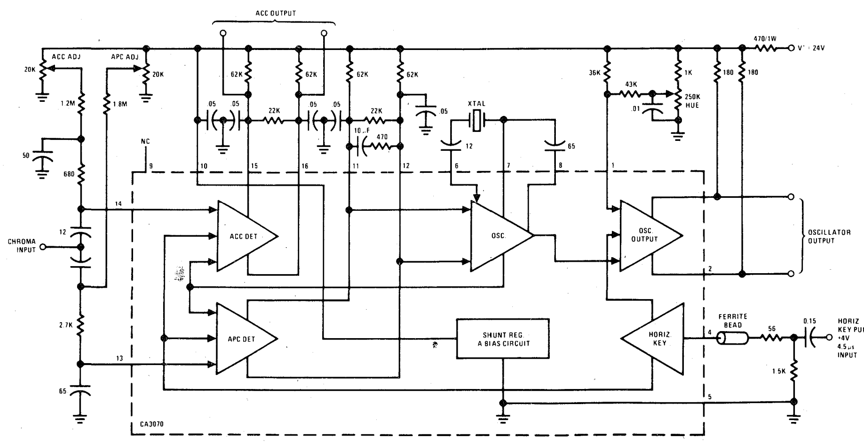
schematic diagram



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.

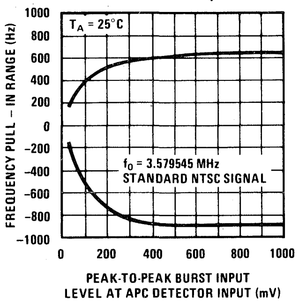
absolute maximum ratings

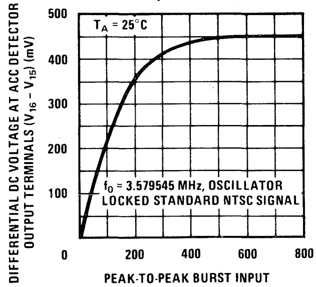
Supply Current	40 mA
Internal Power Dissipation up to 70°C	550 mW
Above 70°C Derate at 7 mW/°C	
Operating Temperature	−40°C to +85°C
Storage Temperature	−65°C to +150°C

electrical characteristics $T_A = 25°C$ $V^+ = 24V$

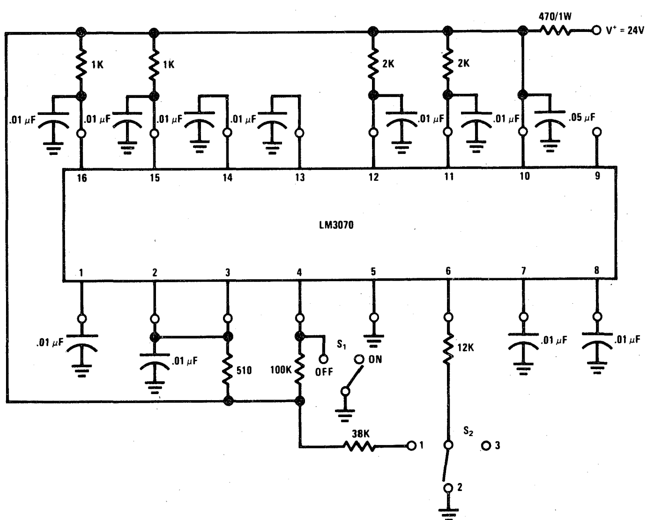
PARAMETER	SYMBOL	CONDITIONS	LIMITS			UNITS
			MIN	TYP	MAX	
STATIC (Refer to Test Circuit 1)						
Supply Current	I_S			25.5		mA
Voltage at Supply Terminal	V_{10}		11.3	12	12.8	V
Supply Regulation	ΔV_{10}	$V^+ = 21V$ to $V^+ = 27V$		30		mV
Total Current into Oscillator Output Terminals	$I_2 + I_3$	S_1 "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



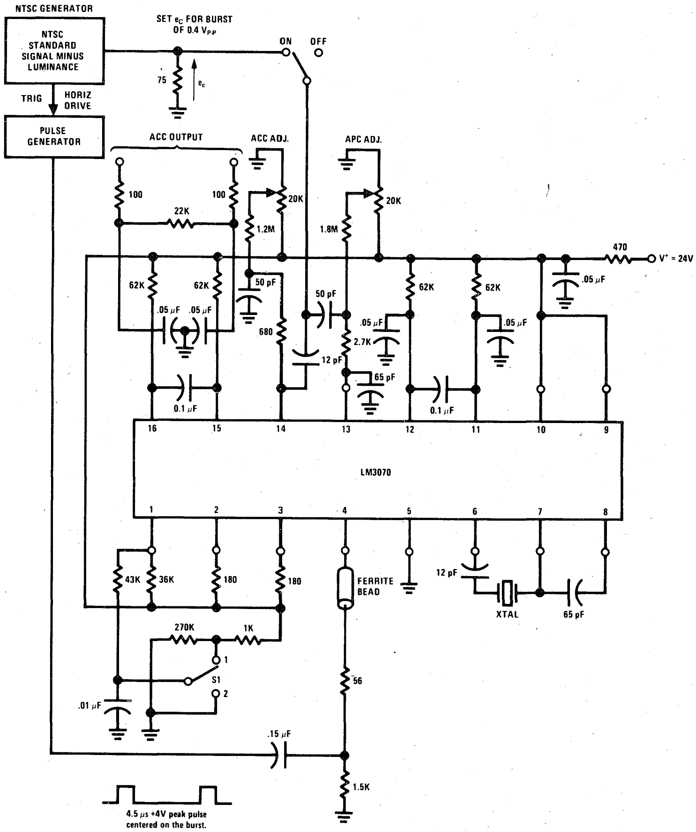


dc test circuit



TEST CIRCUIT 1

ac test circuit



TEST CIRCUIT 2

Audio, Radio and TV Circuits

LM3071 television chroma IF amplifier

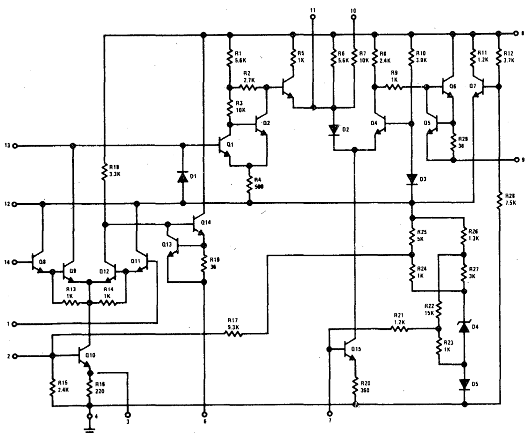
general description

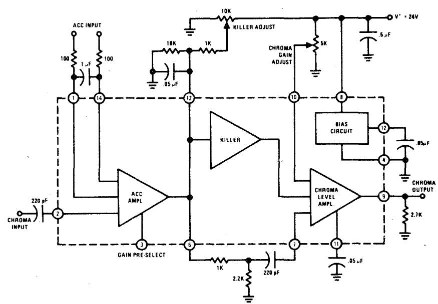
The LM3071 is a two stage chroma IF amplifier on a single silicon chip encapsulated in a 14 lead molded-Dual-In-Line Package. The first stage is an automatic gain controlled amplifier, and its output from Pin 6 is used to drive the ACC detector of the LM3070 or an equivalent circuit. The output from 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

schematic and functional diagrams

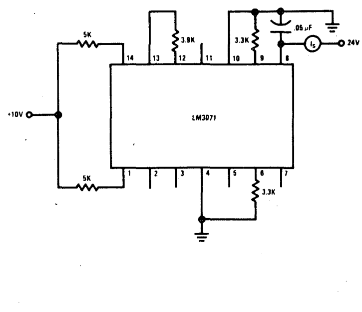




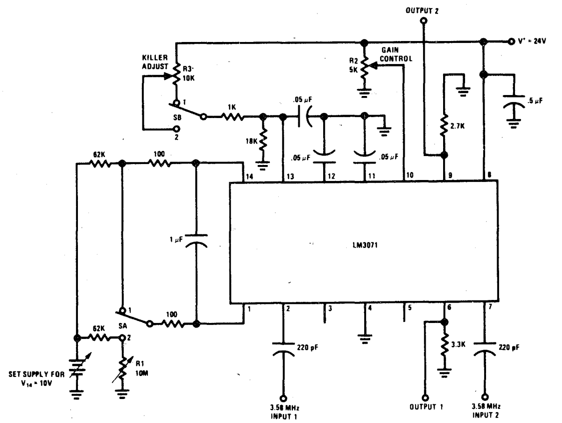
Order Number LM3071N
See Package 22

Order Number LM3071N-01
See Package 24

test circuits



TEST CIRCUIT 1



TEST CIRCUIT 2

absolute maximum ratings

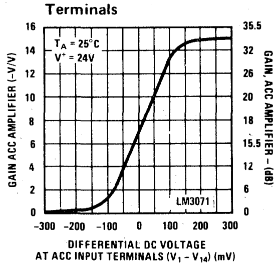
Supply Voltage	$V^+ = 30V$
Internal Power Dissipation at 70°C	550 mW
Above 70°C derate at 7 mW/°C	
Operating Temperature	−40°C to +85°C
Storage Temperature	−65°C to +150°C

electrical characteristics $T_A = 25°C$ $V^+ = 24V$

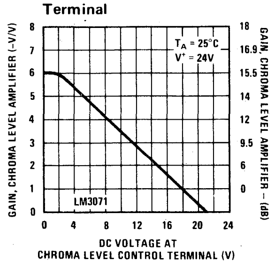
PARAMETER	SYMBOL	CONDITIONS	LIMITS MIN	TYP	MAX	UNIT
STATIC (Refer to Test Circuit 1)						
Supply Current	I_S		17	24	31	mA
Bias Voltage at Pin 12	V_{12}		14	15.3	16.5	V
Voltage at Input 1	V_2			1.7		V
Voltage at Input 2	V_7			1.4		V
Voltage at Output 1	V_6	$V_{ACC} = V_1 - V_{14} = 0V$	15.5	17.5	20	V
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



Audio, Radio and TV Circuits

LM3075 FM detector/limiter and audio preamplifier

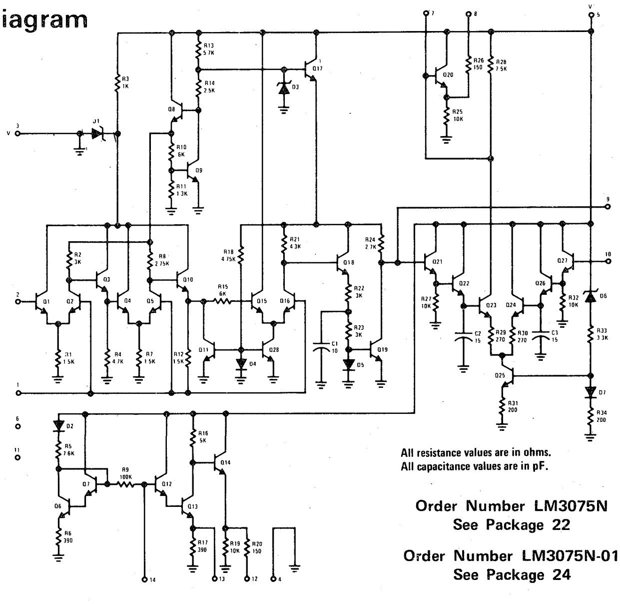
general description

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

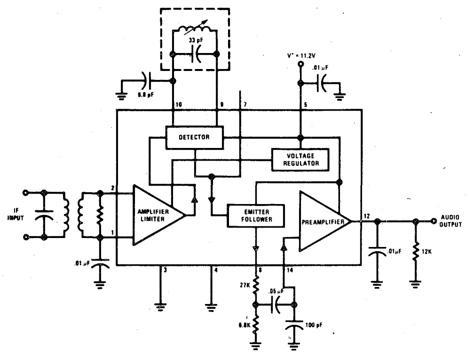


All resistance values are in ohms.
All capacitance values are in pF.

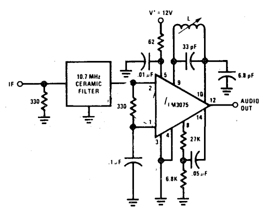
Order Number LM3075N
See Package 22

Order Number LM3075N-01
See Package 24

block diagram



typical application



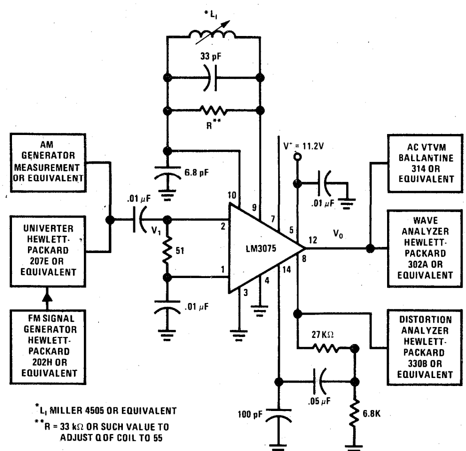
absolute maximum ratings

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

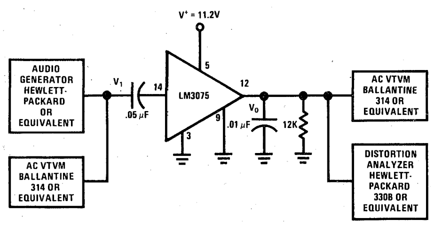
electrical characteristics T_A = 25°C

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



TEST CIRCUIT 1



TEST CIRCUIT 2

10

Audio, Radio and TV Circuits

LM3089 FM receiver IF system

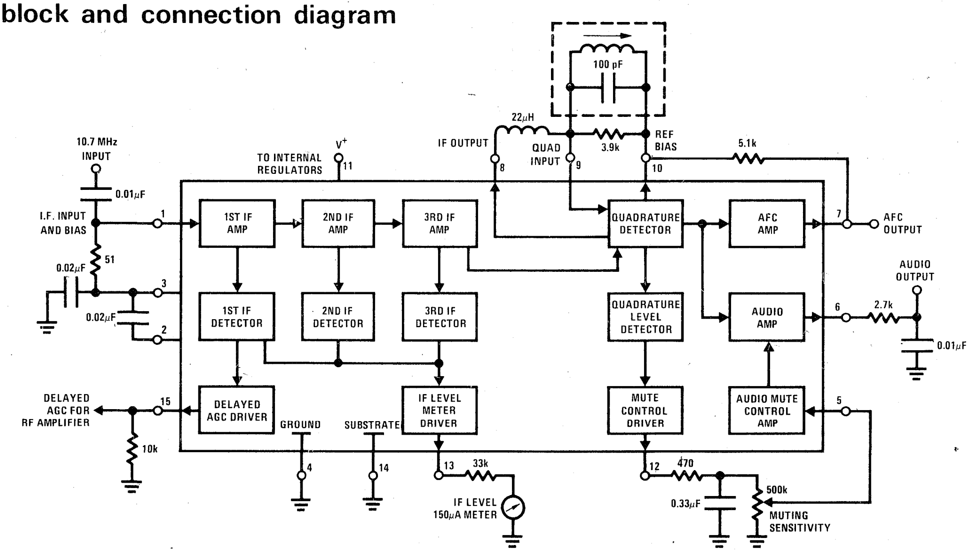
general description

The LM3089 has been designed to provide all the major functions required for modern FM IF designs of automotive, high-fidelity and communications receivers.

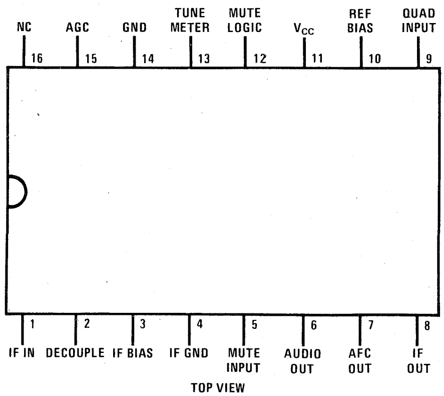
features

- 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 with distortion as low as 0.1% with proper external coil designs
- Four internal carrier level detectors provide delayed AGC signal to tuner, IF level meter drive current and interchannel mute control
- AFC amplifier provides AFC current for tuner and/or center tuning meters
- Improved operating and temperature performance, especially when using high Q quadrature coils in narrow band FM communications receivers
- No mute circuit latchup problems
- A direct replacement for CA3089E

block and connection diagram



Dual-In-Line Package



Order Number LM3089N
See Package 23

absolute maximum ratings

Supply Voltage Between Pin 11 and Pins 4, 14	+16V	Operating Temperature Range	−40°C to +85°C
DC Current Out of Pin 12	5 mA	Storage Temperature Range	−65°C to +150°C
DC Current Out of Pin 13	5 mA	Lead Temperature (Soldering, 10 seconds)	300°C
DC Current Out of Pin 15	2 mA		
Power Dissipation			
Up to T_A = 60°C	600 mW		
Above T_A = 60°C	Derate Linearly 6.7 mW/°C		

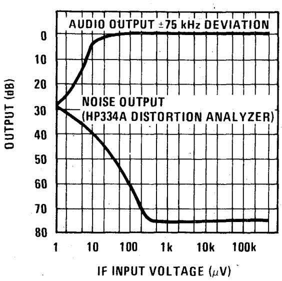
electrical characteristics (T_A = 25°C, V_{CC} = +12V, see Test Circuit)

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
DC CHARACTERISTICS (V_{IN} = 0, NOT MUTED)						
I_{11}	Supply Current		16	23	30	mA
V1, 2, 3	IF Input and Bias		1.2	1.9	2.4	V
V6	Audio Output		5.0	5.6	6.0	V
V7	AFC Output		5.0	5.6	6.0	V
V10	Reference Bias		5.0	5.6	6.0	V
V12	Mute Control		5.0	5.4	6.0	V
V13	IF Level			0	0.5	V
V15	Delayed AGC		4.2	4.7	5.3	V
DYNAMIC CHARACTERISTICS f_o = 10.7 MHz, Δf = ±75 kHz @ 400 Hz						
V_{IN}(LIM)	Input Limiting −3 dB			12	25	µV
AMR	AM Rejection	V_{IN} = 100 mV, AM: 30%	45	55		−dB
V_O (AF)	Recovered Audio	V_{IN} = 10 mV	300	400	500	mVrms
THD	Total Harmonic Distortion					
	Single Tuned (Note 1)	V_{IN} = 100 mV		0.5	1.0	%
	Double Tuned (Note 1)	V_{IN} = 100 mV		0.1	0.3	%
S+N/N	Signal to Noise Ratio	V_{IN} = 100 mV	60	70		dB
V12	Mute Control	V_{IN} = 100 mV		0	0.5	V
V13	IF Level	V_{IN} = 100 mV	4.0	5.0	6.0	V
V13	IF Level	V_{IN} = 500µV	1.0	1.5	2.0	V
V15	Delayed AGC	V_{IN} = 100 mV		0.1	0.5	V
V15	Delayed AGC	V_{IN} = 30 mV		2.5		V
V_O (AF)	Audio Muted	V_{IN} = 100 mV, V5 = +2.5V		60		−dB

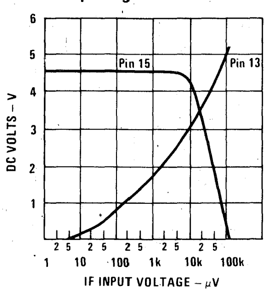
Note 1: Distortion is a function of quadrature coil used.

typical performance characteristics

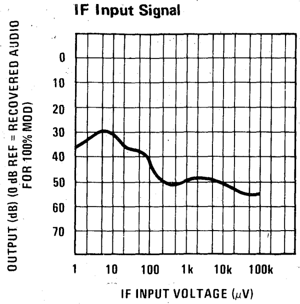
Typical S + N/N and IF Limiting Sensitivity vs IF Input Signal



Typical AGC (Pin 15) and Meter Output (Pin 13) vs IF Input Signal

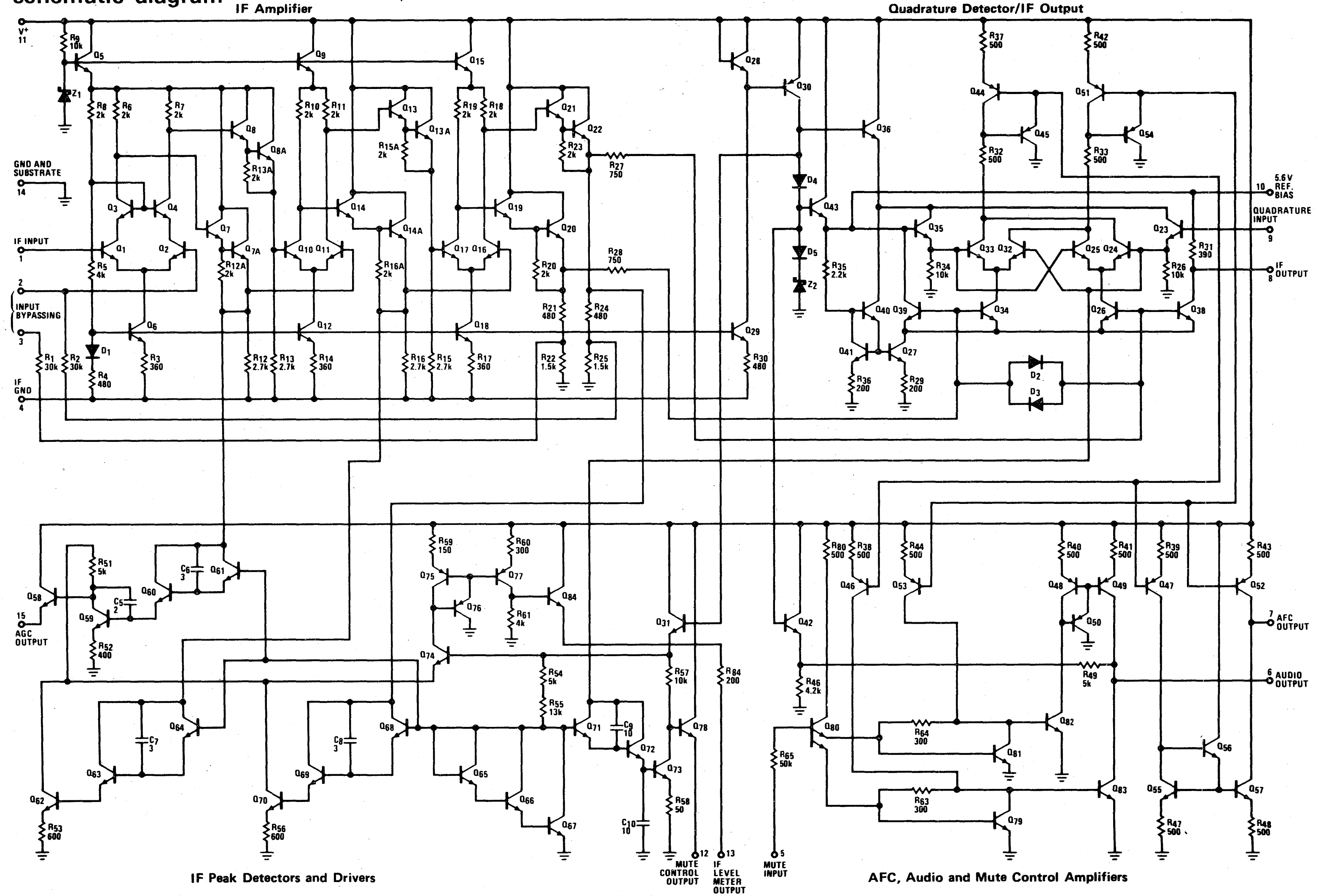


AM Rejection (30% Mod) vs IF Input Signal



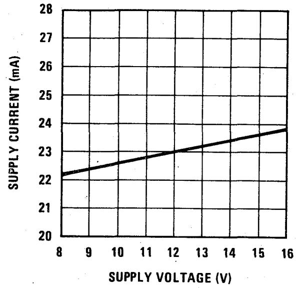
10

schematic diagram

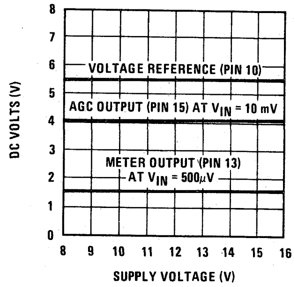


typical performance characteristics (con't)

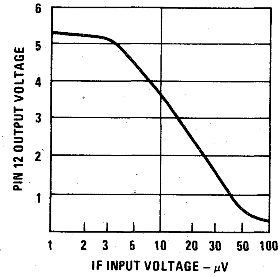
Supply Current (I_{11}) vs Supply Voltage (V11)



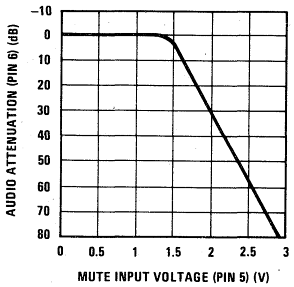
Reference Voltage, AGC and Meter Output vs Supply Voltage



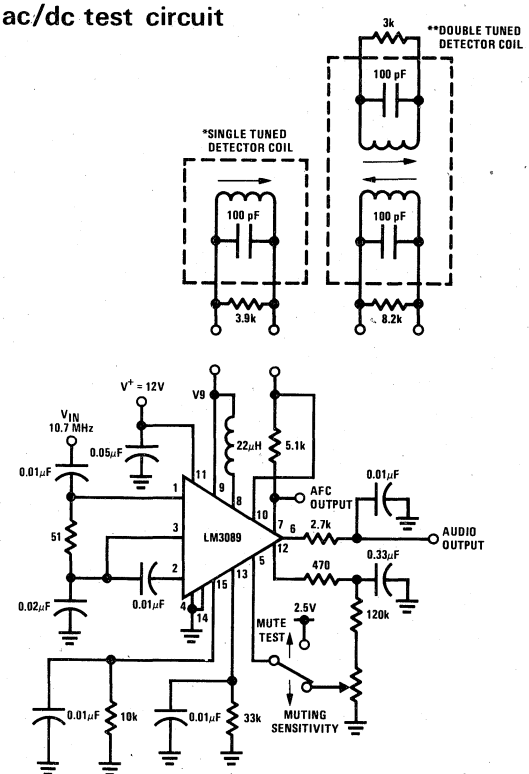
Mute Control Output (Pin 12) vs IF Input Signal



Typical Audio Attenuation (Pin 6) vs Mute Input Voltage (Pin 5)



ac/dc test circuit



*For single tuned detector coil:
L_O tunes with 100 pF at 10.7 MHz
Q_{UL} (unloaded) ≅ 75
Q_L (loaded) ≅ 13 for V9 ≅ 150 mVrms

**For double tuned detector coil:
$Q_{ULPRI} = Q_{ULSEC}$ ≅ 75
kQ ≅ 0.7 for V9 ≅ 150 mVrms

Note:
The recovered audio output voltage will be approximately 0.5 dB less when using the double tuned detector coil.

For proper operation of the mute circuit, the RF voltage at pin 9 should be 150 mVrms ±30 mV.

Audio, Radio and TV Circuits

LM3126 TV chroma processor

general description

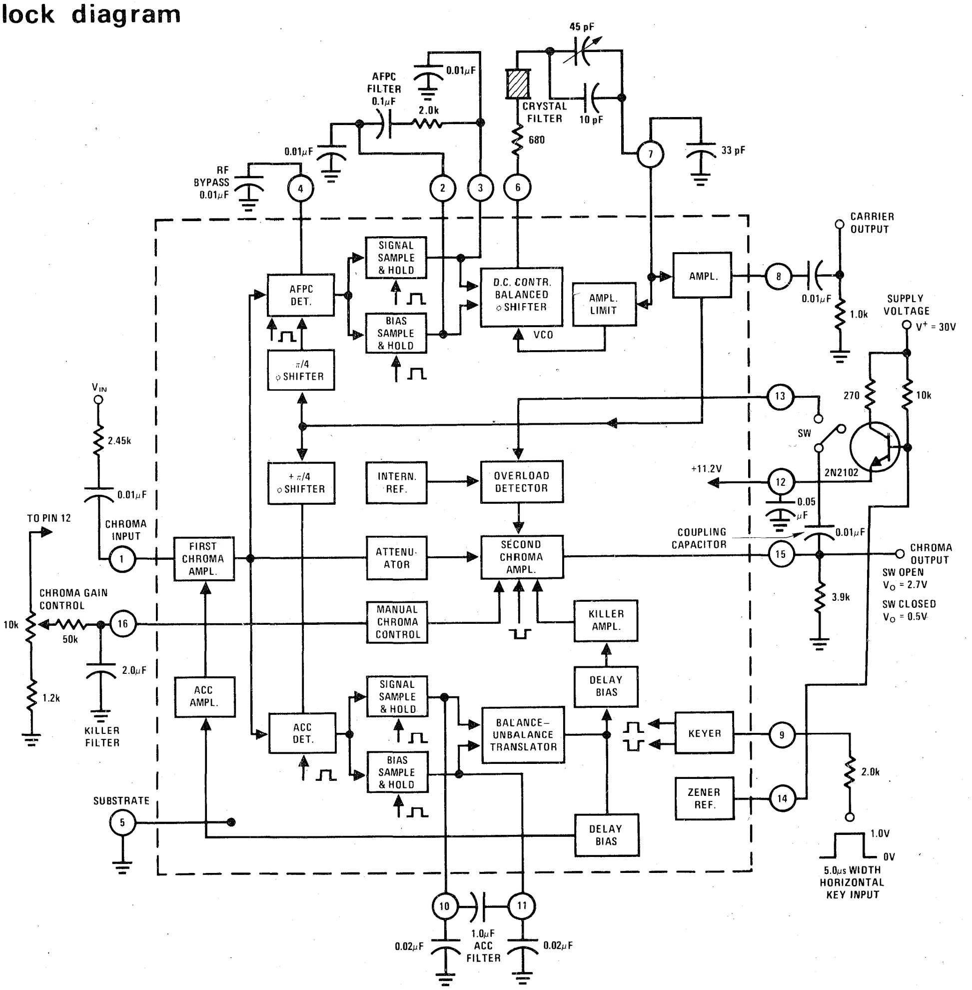
The LM3126 is a monolithic integrated circuit which provides complete color TV chroma signal processing except for tint control and chroma demodulation. Subcarrier regeneration is performed by a phase locked loop utilizing sample-and-hold techniques. A crystal controlled voltage controlled oscillator (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.

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

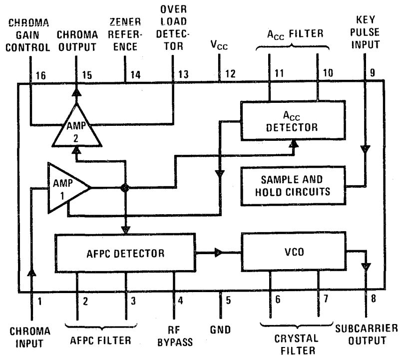
ac electrical characteristics

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

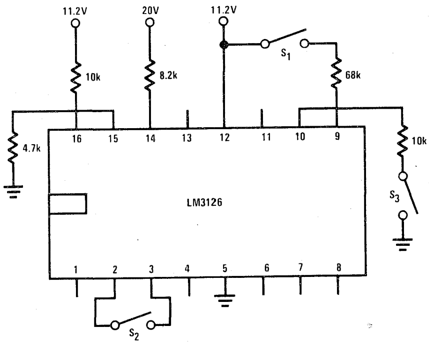
Dual-In-Line Package



TOP VIEW

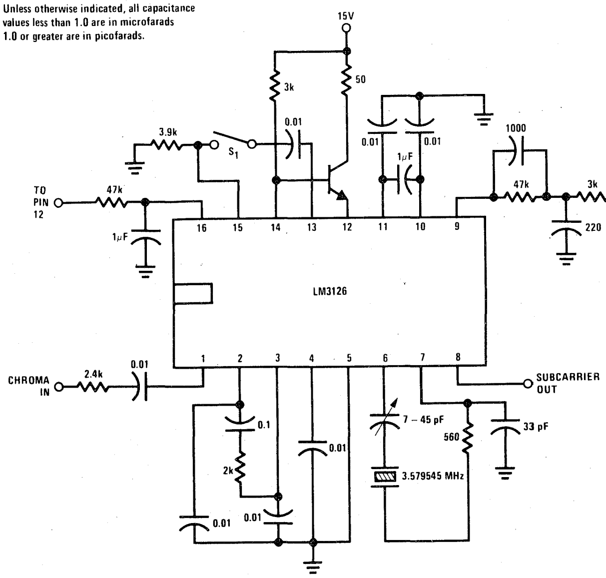
Order Number LM3126N
See Package 23

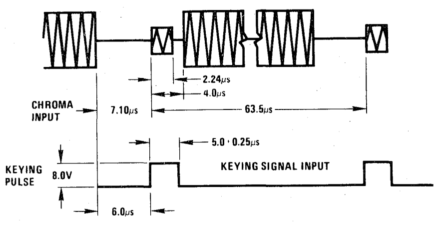
ac test circuits



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.





TEST CIRCUIT 2

Audio, Radio and TV Circuits

TBA120S IF amplifier and detector

general description

The TBA120S is a monolithic integrated circuit specifically designed for audio detection in TV and FM radio receivers. It incorporates an 8-stage limiting IF amplifier and balanced detector plus a dc operated volume control.

features

- Electronic attenuator: replaces conventional ac volume control
- Volume reduction range 85 dB typ
- Sensitivity: 3 dB limiting voltage 30μV typ
- Excellent AM rejection 68 dB typ at 10 mV
- Audio output voltage 1V typ
- Wide supply voltage range (6-18V)
- Internal zener diode regulator
- Very low external component requirement
- Simple detector alignment: one coil

The TBA120S is supplied in four groups depending on the resistance required between pin 5 and ground to attenuate the audio output by 30 dB. The group number as defined below is marked on the package.

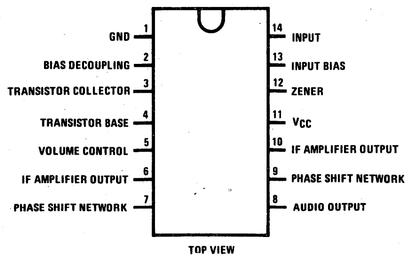
GROUP	II	III	IV	V	
R5-Gnd	1.9-2.2	2.1-2.5	2.4-2.9	2.8-3.3	kΩ

Pins 3 and 4 are connected to the collector and base of a transistor which may be used as an AF-preamplifier or as a switch.

At pin 12 a zener-diode is accessible which can be used to stabilize the supply voltage of this integrated circuit or the voltage of other circuit elements in the set.

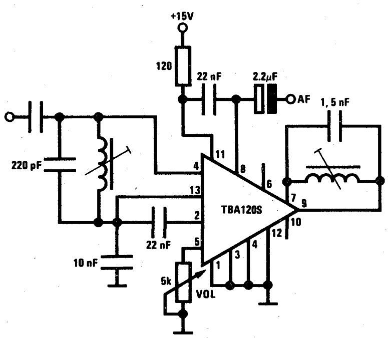
connection diagram

Dual-In-Line Package

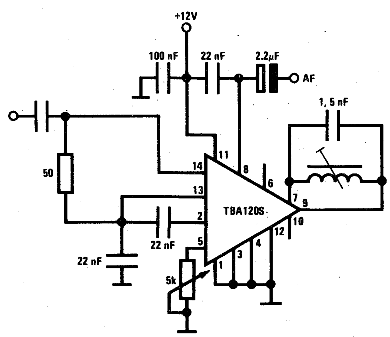


Dual-In-Line Package TBA 120 S
Quad-in-line Package TBA 120 S Q

typical application (5.5 MHz)



test circuit (5.5 MHz)



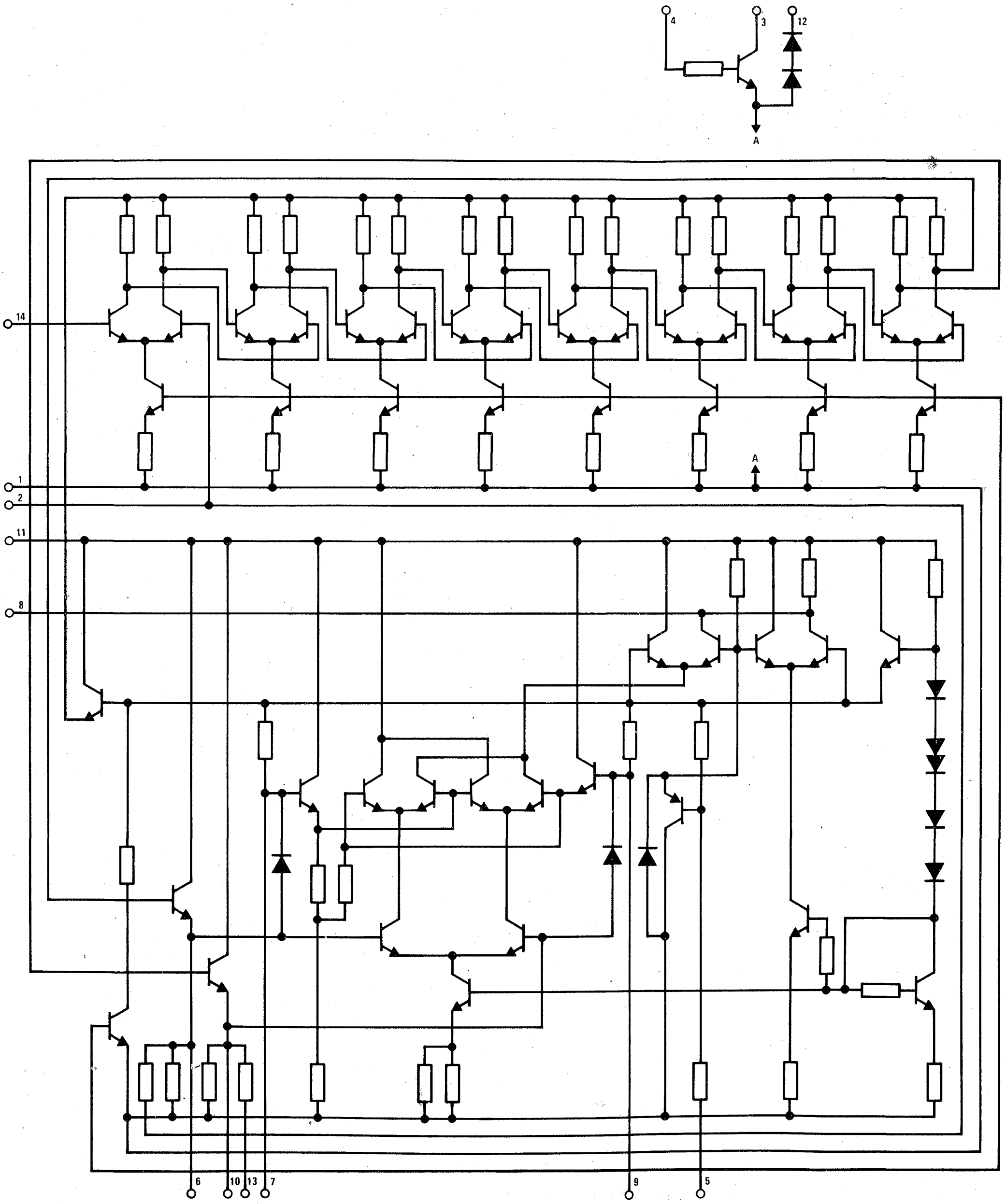
absolute maximum ratings

Supply Voltage, V11	18V	Transistor Base Current, I_4	2 mA
Volume Control Voltage, V5	4V	Bias Resistance (Max), R13-14	1 kΩ
Zener Current, I_{12}	20 mA	Operating Temperature Range	−15°C to +70°C
Transistor Collector Current, I_3	5 mA	Storage Temperature Range	−65°C to +150°C

electrical characteristics (V_{CC} = 12V, T_A = 25°C)

	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
I_{CC}	Supply Current	R5 = ∞	10	14	18	mA
		R5 = 0	11		20	mA
G_V	IF Voltage Gain	f = 5.5 MHz		68		dB
V_O	IF Output Voltage, Each Output, at Limiting		170	250		mVp-p
Vaf	AF Output Voltage	f = 5.5 MHz, Δf = ±50 kHz, f_{MOD} = 1 kHz, V_I = 10 mV, Q = 45	0.7	1.0		V
	Distortion (5.5 MHz)	f = 5.5 MHz, Δf = 25 kHz, f_{MOD} = 1 kHz, V_I = 10 mV, Q = 45		1.5		%
	Distortion (10.7 MHz)	f = 10.7 MHz, Δf = ±50 kHz, f_{MOD} = 1 kHz, V_I = 10 mV, Q = 20		0.2		%
V_{LIM}	Input Voltage Before Limiting	f = 5.5 MHz, Δf = ±50 kHz, f_{MOD} = 1 kHz, Q = 45		30	60	μV
Z_I	Input Impedance	f = 5.5 MHz	15/6	40/4.5		kΩ/pF
R_O	Output Resistance		1.9	2.6	3.3	kΩ
$\frac{Vaf\ max}{Vaf\ min}$	Volume Control Range		70	85		dB
V8	DC Component of the Output Signal	V_I = 0	6.2	7.3	8.4	V
a_{AM}	AM Rejection	f = 5.5 MHz, Δf = ±50 kHz, f_{MOD} = 1 kHz, V_I = 500μV, m = 30%	50	60		dB
a_{AM}	AM Rejection	f = 5.5 MHz, Δf = ±50 kHz, f_{MOD} = 1 kHz, V_I = 10 mV, m = 30%		68		dB
R5	Potentiometer Resistance	1 dB Attenuation		3.7	4.7	kΩ
V5	Voltage	1 dB Attenuation		2.2	2.5	V
R5	Potentiometer Resistance	70 dB Attenuation	1.0	1.4		kΩ
V5	Voltage	70 dB Attenuation		1.2		V
	Noise Voltage at Output	V_I = 10 mV		30		μV
V12	Zener Voltage	I_{12} = 5 mA	11.2	12	13.4	V
R_Z	Zener Slope Resistance			30	50	Ω
V_{cbo}	Breakdown Voltage		45	65		V
V_{ceo}	Breakdown Voltage	I_3 = 500μA	18	24		V
h_{fe}	Current Gain	I_3 = 1 mA	50	100	500	

schematic diagram



Audio, Radio and TV Circuits

TBA 120 U/T IF amplifier and detector

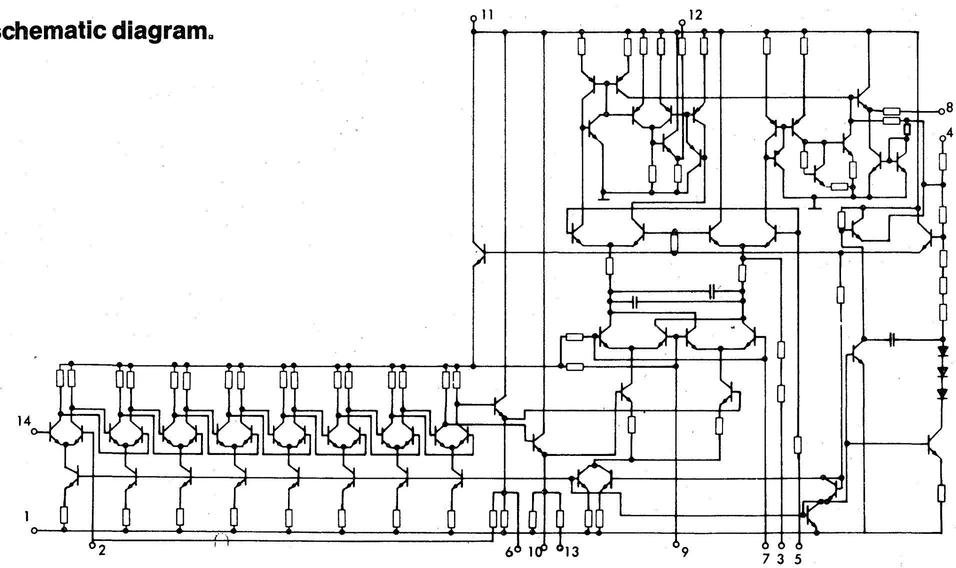
general description

The TBA 120 U/T is a monolithic integrated circuit specifically designed for audio detection in T.V. and FM radio receivers. It incorporates an 8 stage limiting IF amplifier and balanced detector plus a d.c. operated volume control. The circuit also provides connection facilities for a video tape recorder. The TBA 120 T is designed primarily for use with ceramic filters while the TBA 120 U is optimised for inductive tuning.

features

- Electronic attenuator: replaces conventional ac volume control
- Volume reduction range: 85 dB typ
- Sensitivity: 3 dB limiting voltage 30 μV typ
- Excellent AM rejection 68 dB typ. 500 μV
- Wide supply voltage range (6 to 18 V)
- Easy video recorder connection
- Very low external component requirement.
- Simple detector alignment: one coil

schematic diagram.



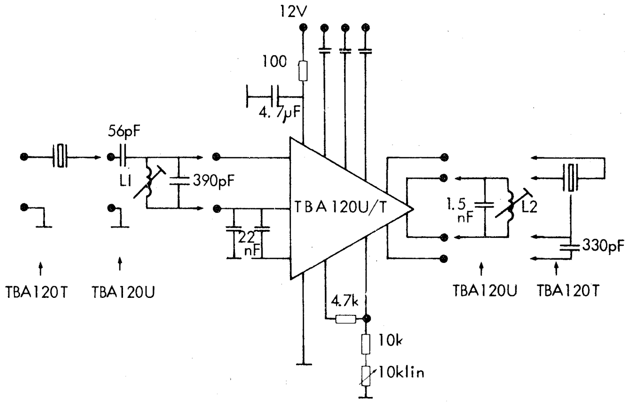
absolute maximum ratings

Supply Voltage	V_{11}	18	V
Operating Temperature Range	T_u	−15 to +70	°C
Storage Temperature Range	T_s	−40 to +125	°C
Voltage Pin 5	V_5	6	V
Current Pin 4	I_4	5	mA
Operating Frequency Range	f	0 to 12	MHz
Power Dissipation	P_{tot}	400	mW
Resistor Parallel to Pins 13 and 14		1	kohm

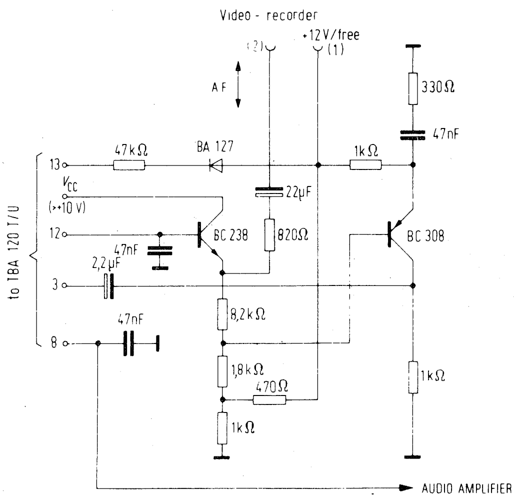
electrical characteristics (Vcc = 12 v Ta = 25° C)

Parameter	Symbol	Conditions	Limits Min.	Typ.	Max.	Units.
Supply Current.	Icc		9.5	13.5	17.5	mA
I.F. Voltage Gain	Gv	f = 5.5 MHz		68		dB
I.F. Output Voltage (Each Output Limiting)	Vo			250		mV pK-pK
Output Impedance	R8			1.1		kohm
Output Impedance	R12			1.1		kohm
Input Impedance	R3			2		kohm
Regulator Impedance	R4			12		ohms
D.C. Output Level	V8	Vi = 0		4		V
D.C. Output Level	V12	Vi = 0		5.6		V
Regulator Voltage	V4		4.2	4.8	5.3	V
Volume Control	Vafmax / Vafmin		70	85		dB
Video Recorder Output Ratio	Vaf8 / Vaf3			7.5		
Sensitivity	Vlim	Vaf −3 dB, f = 5.5 MHz		30	60	μV
Supply Rejection	V8 / V11			35		dB
	V12 / V11			30		dB
Impedance	R4-5		1		10	kohm
Output Ratio	Vafmax / Vaf8	R4-5 = 5 kohm R5-1 = 13 kohm	20	28	36	dB
TBA 120 T only						
Input Impedance	Zi	f = 5.5 MHz		800/5		ohm/pF
A.M. Rejection	aA.M.	f = 5.5 MHz m = 30% $\triangle$ f = ±50 kHz Vi = 500 μV f_{MOD} = 1 kHz	50	60		dB
A.F. Output Voltage	Vaf8	f = 5.5 MHz f_{MOD} = 1 kHz		900		mV
A.F. Output Voltage	Vaf12	$\triangle$ f = ±50 kHz		650		mV
TBA 120 U only						
Input Impedance	Zi	f = 5.5 MHz	15/6	40/4.5		kohm/pF
A.M. Rejection	aA.M.	f = 5.5 MHz Vi = 500 μV f_{MOD} = 1 kHz $\triangle$ f = ±50 kHz m = 30%	50	60		dB
A.F. Output Voltage	Vaf8	f = 5.5 MHz f_{MOD} = 1 kHz $\triangle$ f = ±50 kHz Vi = 10 mV Q_B = 45		1.3		V
A.F. Output Voltage	Vaf12			1.0		V
Distortion	k	f = 5.5 MHz $\triangle$ f = ±50 kHz f_{MOD} = 1 kHz Q_B = 45 Vi = 10 mV		1		%

typical application (5.5 MHz)

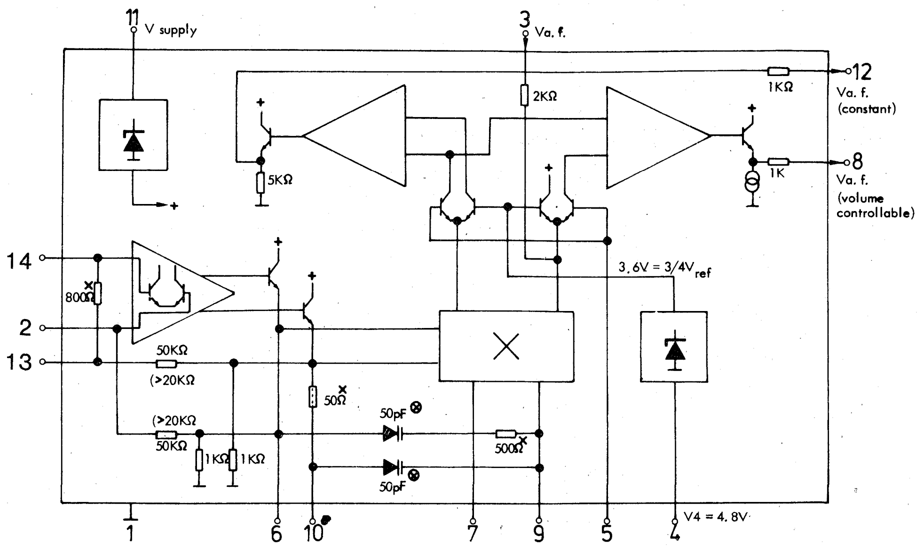


circuit for direct connection to video recorders



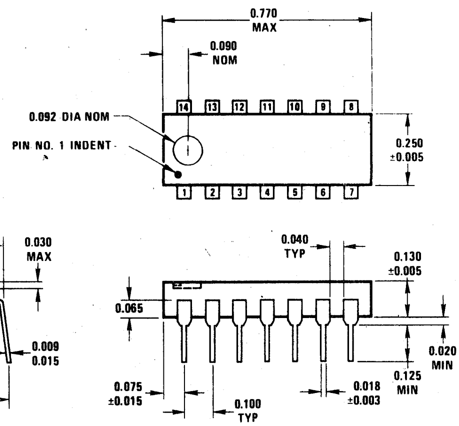
Socket (1): Switching voltage: on playback +12 V
on record open circuit.
Socket (2): Video recorder input/output

block circuit diagram



× only TBA 120 T
⊗ only TBA 120 U

physical dimensions



14-PIN Molded Dual-In-Line Package
Order Number TBA 120 U/T

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TBA 440 C Video IF amplifier and detector

general description

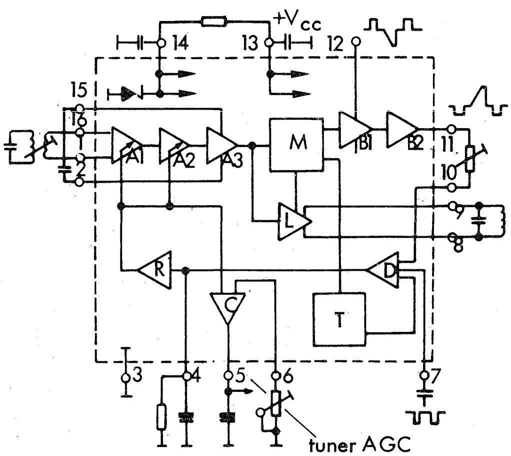
The TBA 440 C is a monolithic Video IF amplifier for colour and monochrome television receivers.

The circuit includes three IF amplifier stages, a balanced video detector and a gated AGC section for the IF amplifier and PNP tuner.

features

- High gain – high stability
- Minimal noise increase with AGC
- Minimum RF breakthrough to video outputs
- Fast AGC action – gating largely independent of pulse shape and amplitude
- Very low intermodulation products
- Positive and negative video signals available from low impedance outputs
- Integrated temperature compensating circuit

block diagram



A 1	Gain controlled I. F. Amplifier
A 2	Gain controlled I. F. Amplifier
A 3	Fixed I. F. Amplifier
M	Mixer-Detector
B 1	Low impedance video output
B 2	Inverting video Amplifier
L	Tuned limiting Amplifier
R	A. G. C. Amplifier
C	Comparator for delayed tuner A. G. C.
T	Temperature compensation
D	Gated Detector

absolute maximum ratings

Supply voltage	15 v	Operating Temperature Range	−25 °C to 70 °C
Current into Pin 14	50 mA	Storage Temperature Range	−65 °C to 150 °C
Power Dissipation ($T_{amb} \leqq 55$ °C)	700 mW	Lead Temperature (Soldering 10 sec)	300° C
Maximum resistanc between pins 8 & 9	20 ohm	Voltage on Pin 5	20 v
		Voltage on Pin 4	5 v

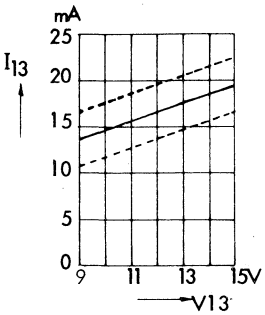
electrical characteristics ($T_{amb} = 25$ °C $V_{cc} = 13$ v $I_{14} = 40$ mA)

Parameter	Symbol	Conditions	Limits Min.	Typ.	Max.	Units
Current Consumption	I_{13}	$V_{13} = 15$ v	14.5	17.5	20.5	mA
Internal supply voltage	V_{14}	$I_{14} = 40$ mA	5.5	6.0	6.8	V
D.C. Output voltage	V_{11}	$V_{in} = 0$	5.5	7	8	V
D.C. Output voltage	V_{12}	$V_{in} = 0$	1.7	3	4.3	V
Tuner A.G.C. current	I_5	$V_5 \geqq 2$ v, 10 dB after beginning of A.G.C.	3	–	–	mA
Gain control voltage						
a. max. gain	V_4	G max	0	–	.5	V
b. min. gain	V_4	G min	2.5	–	–	V
A.G.C. gating voltage	V_7		−2	⊥	−5	V
A.G.C. loop control	R_{10-11}	$V_{11} = 3$v pk−pk	3	4	10	Kohm
Video output current capability						
a. current source	I_{11}, I_{12}		–	–	5	mA
b. current sink			–	–	−1	mA
Input impedance	Z_{1-16}	Large signal	–	1.8/2	–	Kohm/pF
Input impedance	Z_{1-16}	Small Signal	–	1.9/0	–	Kohm/pF
Input voltage	V_{1-16}	$V_{11} = 2$ V pk−pk	–	100	–	μV
(Note 1)	V_{1-16}	$V_{11} = 3$ v pk−pk	–	150	–	μV
Video bandwidth	f 3db		–	9	–	mHz
A.G.C. range	Gv		50	55	–	dB
Sound/Chroma Intermodulation (Note 2)			–	–	−40	dB

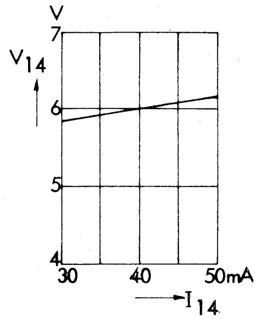
Note 1. RMS of synctip voltage, see test circuit.
Note 2. Sound subcarrier −24 dB, colour Subcarrier −2 dB.

typical performance characteristics

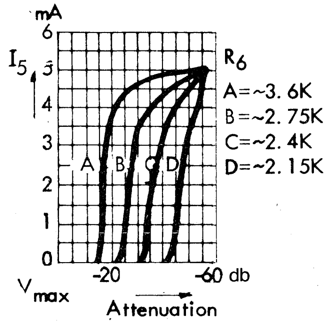
Supply Requirements



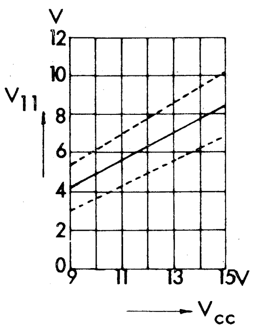
Regulator Characteristic



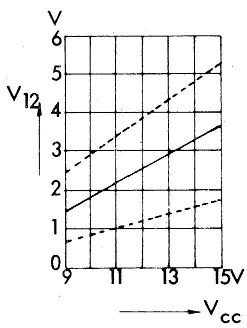
Tuner A. G. C. Current



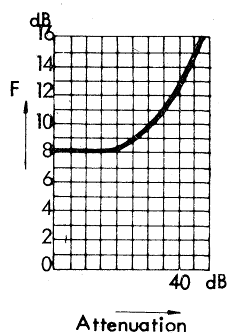
D. C. Output vs. Supply



D. C. Output vs. Supply



Noise Figure vs. Gain Control

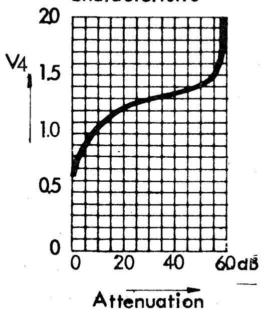


$V_5 = 3V$, $V_{13} = 15V$

f = 36MHz, Δf = 3MHz

R_s = 500 Ohm

Gain Control Characteristic



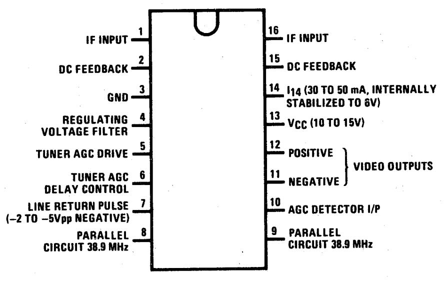
$V_5 = 3V$, $V_{13} = 15V$

f = 36 MHz

R_s = 500 Ohm

connection diagram

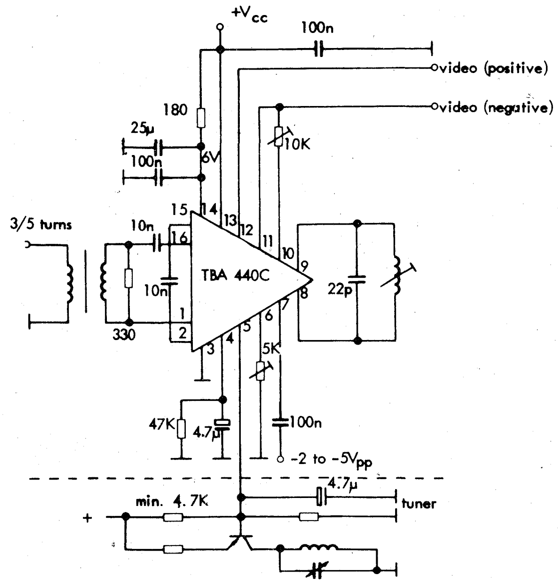
Dual-In-Line Package



TOP VIEW

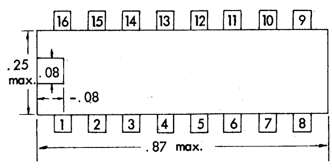
Dual-in-Line package TBA 440 C
Quad-in-Line package TBA 440 C Q

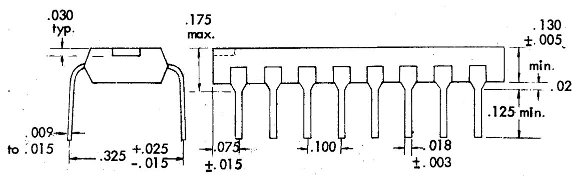
Test circuit



1, 16	IF input
2, 15	DC feedback
3	Ground
4	AGC time constant
5	Tuner AGC Drive
6	Tuner AGC Delay Control
7	AGC Gating Pulse (−2 to −5V)
8, 9	Carrier Tank Coil
10	AGC Detector I/P
11, 12	Video output {Negative, Positive}
13	V_{cc} (10 to 15V)
14	I_{14} (30 to 50mA, Internally stabilized to 6V)

physical dimensions



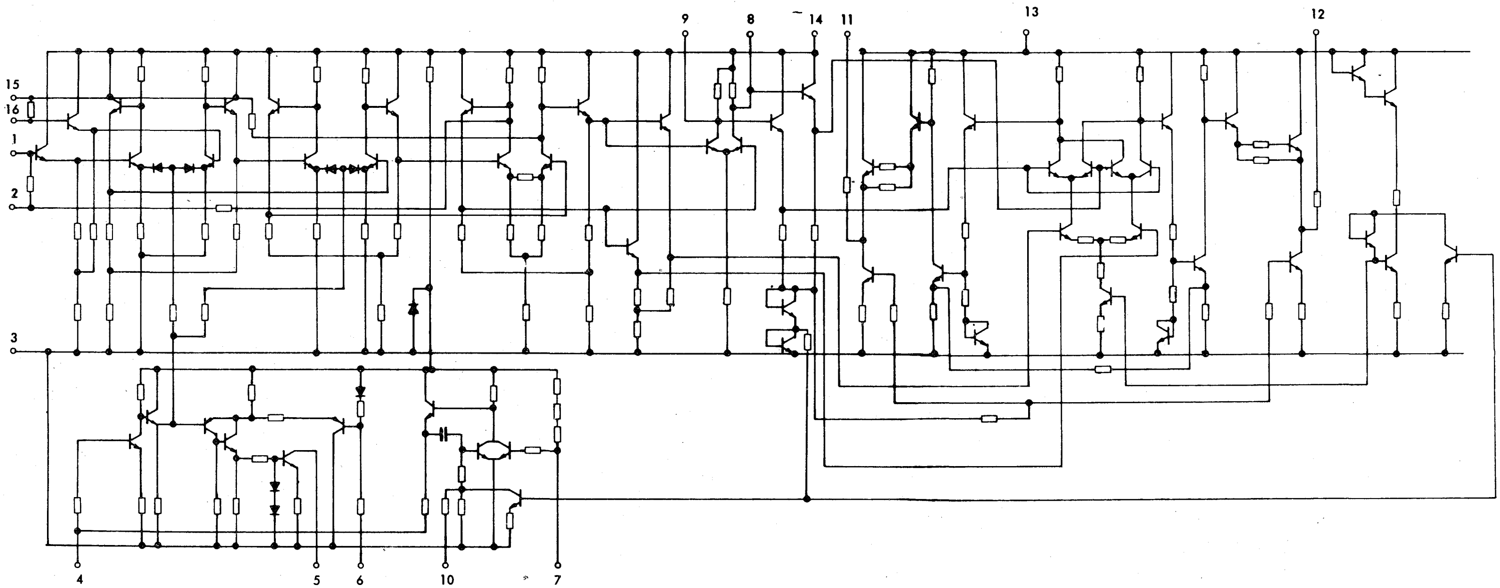


Moulded Dual-In-Line Package (N)

Order Number TBA 440 C

10

schematic diagram



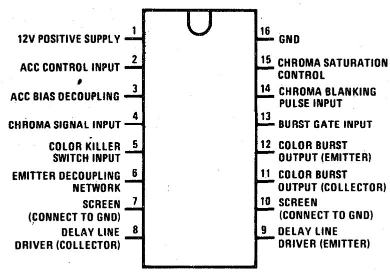
TBA510 chrominance combination

general description

The TBA510 is an integrated chrominance amplifier circuit for color TV receivers incorporating a variable gain ACC circuit, a dc control for chroma saturation which can be ganged to the receiver contrast control, chroma blanking and burst gating functions, a burst output stage, a color killer and a PAL delay line driver.

connection diagram

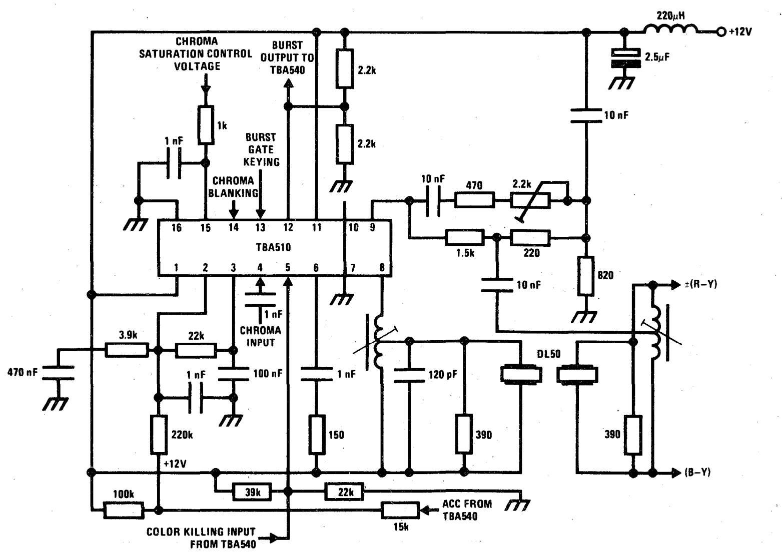
Dual-In-Line Package



TOP VIEW

Dual-In-Line Package, TBA510
Quad-In-Line Package, TBA510Q

typical application



Note: The A.C.C. loop gain can be defined by inserting a suitable resistor between pins 2 & 3. (Example 22 kΩ).

absolute maximum ratings

Power Dissipation, (T_A = 60°C)	550 mW
V1-16	13.2V
V13-16	−5V
V14-16	−5V
V8-16	+20V
V11-16	+20V
$I_8 = -I_9$	20 mA
$I_{11} = -I_{12}$	20 mA
Operating Temperature Range	−20°C to +60°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (V1-16 = 12V, T_A = 25°C)

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
CHROMINANCE SIGNAL (FED IN VIA 1 nF)						
V4-16	Input Voltage Range		15		300	mVp-p
|Z4-16|	Input Impedance		2	3		kΩ
BURST SIGNAL OUTPUT						
V12-16	DC Voltage			7.7		V
V12-16	Output Signal			1		Vp-p
I_{11}	Collector Current of Output Transistor			4		mA
CHROMINANCE SIGNAL OUTPUT (BURST BLANKED INTERNALLY)						
V9-16	DC Voltage			6.8		V
V9-16	Output Signal (Color Bars) at Nominal Saturation and Maximum Contrast			1		Vp-p
	Range of Contrast and Saturation Control		−30		+6	dB
I_8	Collector Current of Output Transistor			5		mA
ACC INPUT						
V2-16	ACC Threshold Voltage			2.5		V
|Z2-16|	Input Impedance		50			kΩ
CHROMA-SATURATION CONTROL						
V15-16	Control Voltage Range		1.5		4.5	V
|Z15-16|	Input Impedance		50			kΩ
CHROMA BLANKING PULSE						
V14-16	Switching Level			−1		V
|Z14-16|	Input Impedance			2		kΩ

electrical characteristics (con't) ($V_{1\text{-}16}$ = 12V, T_A = 25°C)

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
BURST GATE PULSE						
V13-16	Switching Level			−2.2		V
|Z13-16|	Input Impedance			4		kΩ
COLOR KILLER						
V5-16	Input Voltage For:					
	Color "ON"		2.3			V
	Color "OFF"				1.9	V
	Signal Suppression at Color "OFF"			50		dB
|Z5-16|	Input Impedance		50			kΩ

Note 1: The phase difference between the chroma and burst outputs at nominal saturation is less than 5°.
Note 2: Phase shift of chroma output signal over saturation control range +6 to −10 dB is less than 5°.

pin function description

1. Positive 12V supply.

2. ACC control potential input. The potential required at pin 2 for maximum gain is about 2.5V; gain reduction occurs when this potential is reduced, $Z_{IN} > 50$ kΩ.

3. ACC gain adjustment point. The internal ACC circuit consists of a long-tailed pair system. The "cold" side of the pair is internally established at a dc potential of 2.5V and is brought out on pin 3. This enables a decoupling capacitor to be connected. A very high loop gain in the ACC system is possible but as this is not necessarily desirable, because of stability and ripple considerations, a resistor of a suitable value can be connected between pins 2 and 3 to reduce the control sensitivity to any desired level.

4. Chroma input signal. The input voltage range is 15 to 300 mVp-p (26 dB) with a color bar signal.

5. Color killer switching input. The input impedance is greater than 50 kΩ. Color "ON" 2.3V; color "OFF" 1.9V. The chroma signal suppression when killed is greater than 50 dB.

6. Emitter decoupling network. The series network decouples an emitter of an amplifier stage. The value of resistance influences the gain of both the chroma channel and the burst channel.

7. Screen. This pin must be connected to pin 10 and taken via a direct path to earth. The function of this is to minimize crosstalk between burst and chroma channels.

8. Delay line driver (collector). Supplies the chroma signal drive to the delay line driver transformer, the cold end of which is connected to +12V. The maximum permitted voltage excursion at this pin is to 20V peak. Maximum ac signal current swing, 12 mAp-p.

9. Delay line driver (emitter). Supplies the chroma to the network which provides the non-delayed signal to the delay line output transformer. The emitter is established internally at a potential of 6.8 ±1V and the external network, which must incorporate a resistive dc path to earth, must not demand more than 20 mA peak current.

10. Screen. Connect to pin 7 and then to earth.

11. Color burst output (collector). If a low impedance color burst is required (from the emitter of the color burst output, pin 12) pin 11 will be connected to the +12V supply. The maximum voltage and current excursions permitted on pin 11 are 20V peak and 20 mA peak.

12. Color burst output (emitter). An external load resistor of 2 kΩ is required, connected to earth, and a dc potential of 7.7V is established on pin 11 due to the internal circuitry. The burst output voltage is 1 Vp-p ±1 dB over the chroma input signal range of amplitudes.

13. Burst gate gating pulse. A pulse derived from the horizontal flyback pulse can be used as a source of gating waveform. A negative-going pulse of not greater than 5V amplitude is necessary, the input impedance is 4 kΩ and the switching is about −2.2V.

14. Chroma blanking pulse input. A negative-going horizontal flyback pulse can be used here. Its amplitude should not exceed 5V. The input impedance at this pin is 2 kΩ and the switching level is about −1.0V. This pulse is used to blank the burst output from the chroma channel.

15. Chroma saturation control. The dc control voltage range required is from 1.5-4.5V (highest gain at −4.5V). The input impedance is greater than 50k and a control range of from +6 to −30 dB is given.

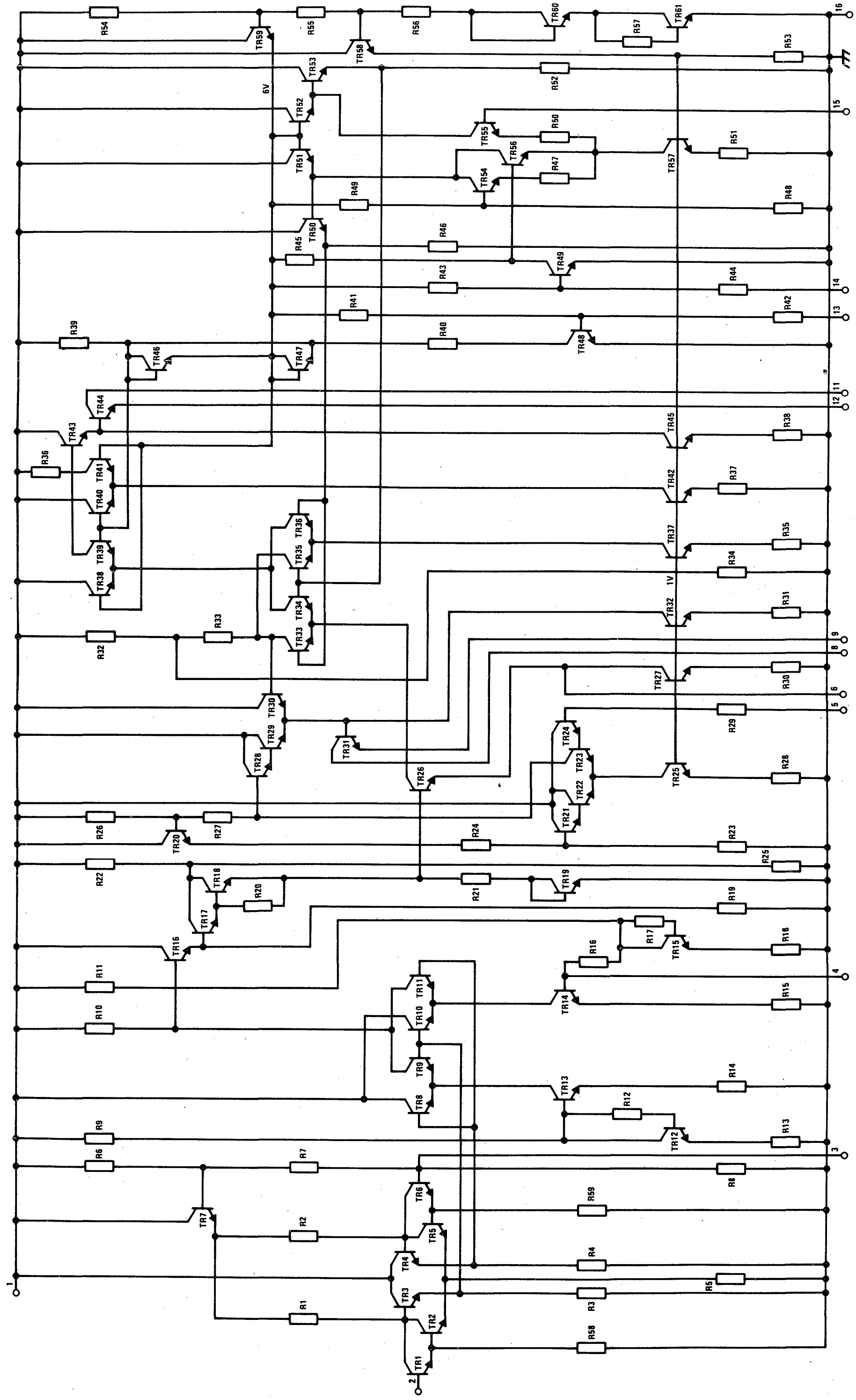
16. Negative supply or earth.

PERFORMANCE COMMENTS

(a) The phase difference between the chroma and burst outputs at nominal saturation is less than 5°.

(b) Phase shift of chroma output signal over saturation control range +6 to −10 dB is less than 5°.

schematic diagram



TBA530 RGB matrix preamplifier

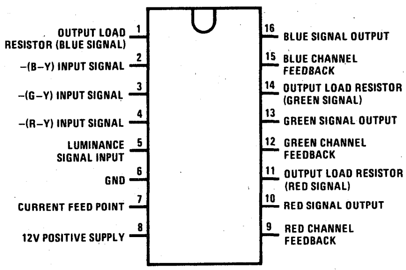
general description

The TBA530 is an integrated circuit for color TV receivers incorporating a matrix preamplifier for R-G-B cathode or grid drive of the picture tube without clamping circuits.

It has been designed to be driven from the TBA990 or TBA520 synchronous demodulator circuits and exhibits excellent channel matching and stability.

connection diagram

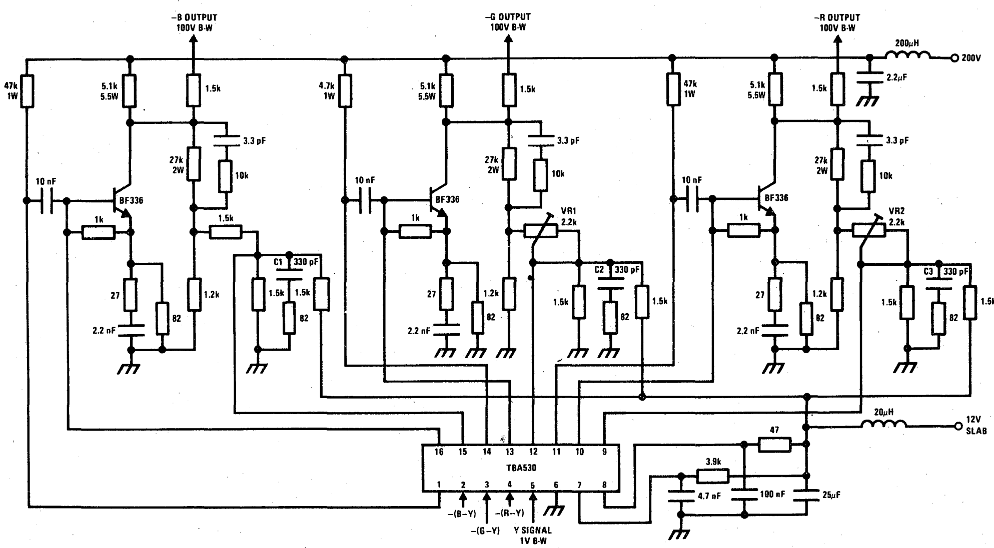
Dual-In-Line Package



TOP VIEW

Dual-In-Line Package, TBA530
Quad-In-Line Package, TBA530Q

typical application



Note 1: DC output voltages R, G and B are typically 140V in this circuit.

Note 2: The voltage gain between pins 2, 3, 4 and collectors (BF336) is typically 100.

Note 3: The normal bias voltage on pins 1, 11, 14 is 8V.

Note 4: Pin 7 requires a 4.7 nF decoupling capacitor.

Note 5: DC bias level shift, provided by internal zeners between pins 1-16, 14-13 and 11-10, requires 10 nF bypass capacitors for H.F.

absolute maximum ratings

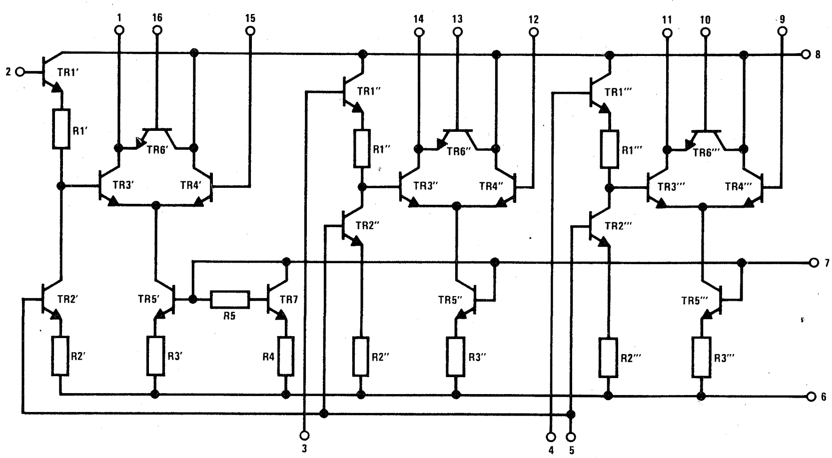
V8-6	13.2V
I_1, I_{11}, I_{14}	10 mA
I_{10}, I_{13}, I_{16}	50 mA
Power Dissipation (T_A = 60°C)	400 mW
Operating Temperature Range	−20°C to +60°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics

Measuring Conditions: Black Level: $V_{R\text{-}Y} = V_{G\text{-}Y} = V_{B\text{-}Y} = 7.5V$, $V_Y = 1.5V$, V8–6 = 12V, $T_A = 25°C$

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
	Ratio of Gain of Luminance Amplifier to Color Amplifiers	As Measured in Application Circuit	0.9		1.1	
R2-6 R3-6 R4-6	Input Resistance of Color Difference Amplifiers	1 kHz		60 60 60		kΩ kΩ kΩ
C2-6 C3-6 C4-6	Input Capacitance of Color Difference Amplifiers	1 MHz		3 3 3		pF pF pF
R5-6	Input Resistance of Luminance Amplifier	1 kHz		20		kΩ
C5-6	Input Capacitance of Luminance Amplifier	1 MHz		10		pF
B	Bandwidth of all Channels	3 dB		6		MHz
I_8	Total Current Drain			30		mA
I_7	Bias Current			2.5		mA

schematic diagram



pin function description

The function is quoted against the corresponding pin number.

1. Output load resistor, blue signal. (Also pins 11 and 14 for red and green signals respectively.) Resistors (47 kΩ, 1W) connected to +200V provide the high value loads for the internal amplifying stages. The nominal operating potential on these pins is defined by the IC and dc feedback and is approximately +8V. The maximum current which can be allowed at each of these pins is 10 mA.

2. −(B-Y) input signal. This signal is fed via a low-pass filter from the TBA520 demodulator IC (pin 7) having a dc level of about +7.5V. The input resistance for this pin is typically 60 kΩ with an input capacitance of less than 5 pF (similarly for pins 3 and 4).

3. −(G-Y) input signal. The dc black level of this signal is about +7.5V. (See pin 2.)

4. −(R-Y) input signal. The dc black level of this signal is about +7.5V. (See pin 2.)

5. Luminance signal input. The dc level on this pin for picture black is +1.6V. The required signal amplitude is 1V black-to-white with negative-going syncs (or blanking) for cathode drive as shown. The input resistance at this pin is 20 kΩ approximately with a capacitance of less than 15 pF.

6. Negative supply (earth).

7. Current feed point. A current of approximately 2.5 mA is required at this pin, fed via a 3.9 kΩ resistor from +12V, to bias the internal differential amplifiers. A decoupling capacitor of 4.7 nF is necessary.

8. Positive 12V supply. Maximum supply voltage permitted, 13.2V. Current consumption approximately 30 mA.

9. Red channel feedback (green channel, pin 12; blue channel, pin 15). The dc working points and gains of both the output stages and the IC amplifier stages are stabilized by the feedback circuits. The black level potentials at the collectors of the output stages (tube cut-off) are adjusted by setting correctly the dc levels of the color difference signals produced by the TBA520 demodulator IC. The gains of the R-G-B output stages are adjusted to give the correct white points setting on the picture tube by adjusting the potentiometers in the feedback paths (VR1, VR2). (See notes on setting up decoder.)

10. Red signal output (green and blue signal outputs on 13 and 16). These pins are internally connected with pins 11, 14 and 1 respectively via zener type junctions to give a dc level shift appropriate for driving the output transistor bases directly. To bypass the zener junctions at h.f. three 10 nF capacitors are required.

11. Output load resistor, red channel (see pin 1).

12. Green channel feedback (see pin 9).

13. Green signal output (see pin 10).

14. Output load resistors, green channel (see pin 1).

15. Blue channel feedback (see pin 9).

16. Blue signal output (see pin 10).

Note 1: Careful attention to earth paths should be given, avoiding common impedances between the input (decoder) side and the output stages. Also, to enable matched performance to be achieved, a symmetrical board and component layout should be adopted for the three output stages. To compensate for the effect upon h.f. response of inevitable differences the compensating capacitors C1 and C2 and C3 may be appropriately selected for any given board layout.

Note 2: The signal black level at the collectors of the R-G-B output stages depends upon the +12V supply, the dc level of the color difference signals from the TBA520 demodulator IC and the black level potential of the luminance signal applied to the TBA530 matrix IC. The dc levels of the signals produced and handled by the IC's are designed to have approximately proportional tracking with the 12V supply potential,

$$\text{i.e., } \frac{\Delta V_{(\text{dc level, signal})}}{\Delta V_{12V}} \triangleq \frac{V_{\text{nom (dc level, signal)}}}{12}$$

To ensure that changes in picture black level due to variations on the 12V supply to the IC's occur in a predictable way, all the IC's should be operated from a common supply line. This is specially important for the TBA520 and TBA530. Furthermore, to limit the changes in picture black level during receiver operation, the 12V supply should have a stability of not worse than ±3% due to operational variations.

Note 3: To reduce the possibility of patterning on the picture due to radiation of the harmonics of the products of the demodulation process, the leads carrying the drive signals to the picture tube should be as short as the receiver layout will allow. Resistors (typically 1k 5Ω) connected in series with the leads and mounted close to the collectors of the output transistors provide useful additional filtering of harmonics.

Audio, Radio and TV Circuits

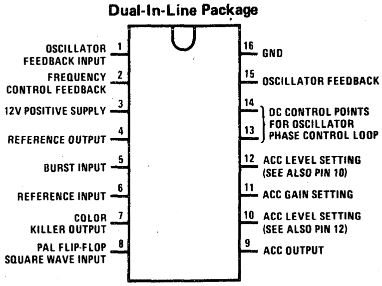
TBA540 reference combination

general description

The TBA540 is an integrated 'color reference' oscillator circuit for PAL TV receivers. The oscillator employs a quartz crystal and incorporates automatic phase and amplitude control. A synchronous demodulator is used to compare the phase and amplitude of the swinging burst ripple with the PAL flip-flop waveform and generates appropriate ACC color killer and identification signals. A high standard of noise immunity has been obtained by using synchronous demodulation.

connection diagram

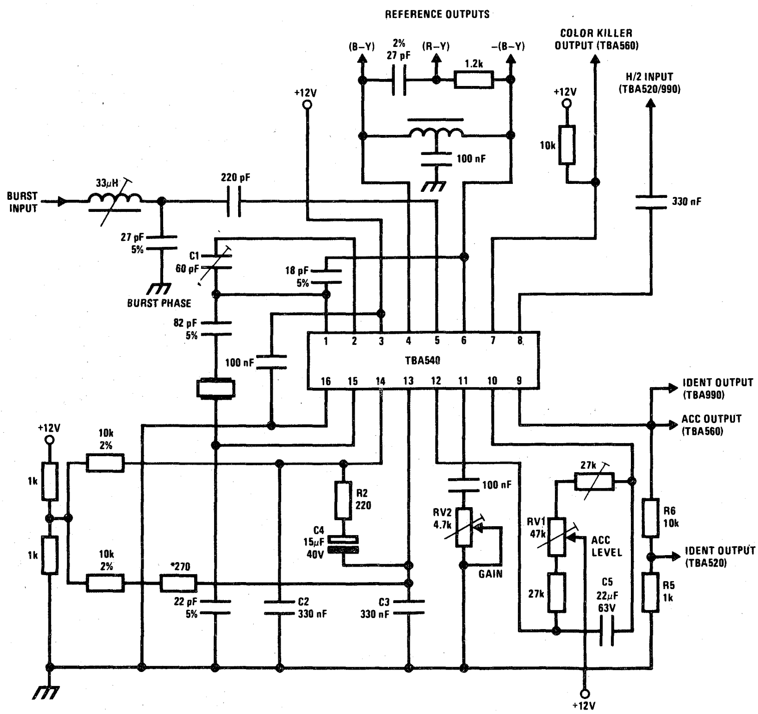
Dual-In-Line Package



TOP VIEW

Dual-In-Line Package, TBA540
Quad-In-Line Package, TBA540Q

typical application



absolute maximum ratings

V3-16	13.2V	Storage Temperature Range	−65°C to +150°C
Power Dissipation (T_A = 60°C)	780 mW	Lead Temperature (Soldering, 10 seconds)	300°C
Operating Temperature Range	−20°C to +60°C		

electrical characteristics (V3-16 = 12V, T_A = 25°C as measured in typical application circuit)

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
	Output Signals					
V4-16	B-Y Reference Signal Output		1	1.4	2	Vp-p
V7-16	Color Killer Output					
	Color "ON"			12		V
	Color "OFF"			100	250	mV
V9-16	ACC Output Signal Range					
	At Correct Phase of PAL Switch			4 to 0.2		V
	At Incorrect Phase of PAL Switch			4 to 11		V
	Oscillator Section (Amplifier)					
R15-16	Input Resistance			3.5		kΩ
C15-16	Input Capacitance			5		pF
G15-1	Voltage Gain			4.7		
	Reactance Control Section					
G15-2	Voltage Gain With Pins 13 and 14 Shorted			1.3		
$\frac{\Delta G15\text{-}2}{\Delta\phi 5\text{-}4}$	Rate of Change of Gain G15-2 With Phase Difference Between Burst and Reference Signal			5		rad^{-1}
	Burst Input					
R5-16	Input Resistance			1		kΩ
	Burst Input Level		0.7	1.5		Vp-p
	Flip-Flop Input					
V8-16	Voltage			2.5		Vp-p
R8-16	Resistance			3.3		kΩ
	Phase Lock Loop					
	Oscillator Phase Error for a Burst Signal	Crystal Frequency I_{400} Hz			±10	DEG
	Holding Range			±600		Hz
	Pull-in Range			±300		Hz
	Temperature Coefficient of Oscillator				2	Hz/°C

application notes

A dc connection between pins 4 and 6 is necessary via the bifilar coupling inductor. The function of this inductor is to produce, on pin 6, a signal of equal amplitude and opposite phase (B-Y) to that on pin 4. A center tap on the inductor, connected to earth via a dc blocking capacitor, is therefore necessary.

DC Control Points in Reference Control Loop

Pins 13 and 14 are connected to opposite sides of a differential amplifier circuit and are brought out for the purpose of dc balancing of the reactance stage and the connection of the bandwidth—determining filter network. Two 2% tolerance 10k resistors with the addition of a 270Ω resistor at pin 13 are used in place of the previous balancing network. The 270Ω resistor may be modified according to the nature of the noise that appears at pin 5.

Initial Adjustment

(a) Remove burst signal.

(b) Short-circuit pins 13-14. Adjust oscillator to correct frequency by C1.

(c) Set the ACC level adjustment RV1, to give +4V on pin 9. Remove short circuit.

(d) Apply burst signal.

(e) Adjust ACC gain, RV2, to give a burst amplitude of 1.5Vp-p on pin 5.

pin function description

1. Oscillator feedback output. The crystal receives its energy from this pin. The output impedance is approximately 2 kΩ in parallel with 5 pF.

2. Reactance control stage feedback. This pin is fed internally with a sinewave derived from the reference output (pin 4) and controlled in amplitude by the internal reactance control circuit. The phase of the feedback from pin 2 to the crystal via C1 is such that the value of C1 is effectively increased. Pin 2 is held internally at a very low impedance, therefore the tuning of the crystal is controlled automatically by the amplitude of the feedback waveform and its influence on the effective value of C1.

3. Positive 12V supply. The maximum voltage must not exceed 13.2V.

4. Reference waveform output. This pin is driven internally by the regenerated subcarrier waveform in B-Y phase. (The output is in B-Y rather than R-Y phase as the burst phase network produces a lag of 90° of the burst applied to pin 5). An output amplitude of nominally 1.4Vp-p is produced at low impedance. No dc load to earth is required. A dc connection between pins 4 and 6 is, however, necessary via the bifilar coupling inductor. The function of this inductor is to produce, on pin 6, a signal of equal amplitude and opposite phase (−(B-Y)) to that on pin 4. A center tap on the inductor, connected to earth via a dc blocking capacitor, is therefore necessary.

5. Burst waveform input. A burst waveform amplitude of 1.5Vp-p is required to be ac-coupled to this pin. The amplitude of the burst will normally be controlled by the adjustment and operation of the ACC circuit. The input impedance at this pin is approximately 1 kΩ and a threshold level of 0.7V must be exceeded before the burst signal becomes effective. A dc bias of 400 mV is internally derived for pin 5.

The absolute level of the tip of the burst at pin 5 will normally reach 1.5V (1.5Vp-p burst amplitude).

6. Reference waveform input. This pin requires a reference waveform in the −(B-Y) phase, derived from pin 4 via a bifilar transformer (see pin 4), to drive the internal balanced reactance control stage. A dc connection between pins 4 and 6 must be made via the transformer.

7. Color killer output. This pin is driven from the collector of an internal switching transistor and requires an external load resistor (typically 10 kΩ) connected to +12V. The unkilled and killed voltages on this pin are then +12V and $<$ 250 mV respectively. (The voltage range on pin 9 over which switching of the color killed output on pin 7 occurs is nominally +2.5V.)

8. PAL flip-flop square wave input. A 2.5Vp-p square wave derived from the PAL flip-flop (in the TBA520 or TBA990 demodulator IC) is required at this pin, ac-coupled via a capacitor. The input impedance is about 3.3 kΩ.

9. ACC output. An emitter follower provides a low impedance output potential which is negative-going with a rising burst input amplitude. With zero burst input signal the dc potential produced at pin 9 is set to be +4V (RV1). The appearance of a burst signal on pin 5 will cause the potential on pin 9 to go in a negative direction in the event that the PAL flip-flop is identified to be in the correct phase. The range of potential over which full ACC control is exercised at pin 9 is determined by the control characteristic of the ACC amplifier, i.e., for the TBA560 from 0.8 to 1V. The potential on pin 9 will fall to a value within this range as the burst input signal is stabilized to an amplitude of 1.5Vp-p. The latter condition is achieved by correct adjustment of RV2. If, however, the PAL flip-flop phase is wrong the potential on pin 9 will move positively. The potential divider R5, R6 will then operate a PAL switch cut-off function in the TBA520 demodulator IC.

10. ACC level setting. The network connected between pins 10 and 12 balances the ACC circuit and RV1 is adjusted to give +4V on pin 9 with no burst input signal to pin 5. C5 provides filtering.

11. ACC gain control. RV2 is adjusted to give the correct amplitude of burst signal on pin 5 (1.5 Vp-p) under ACC control.

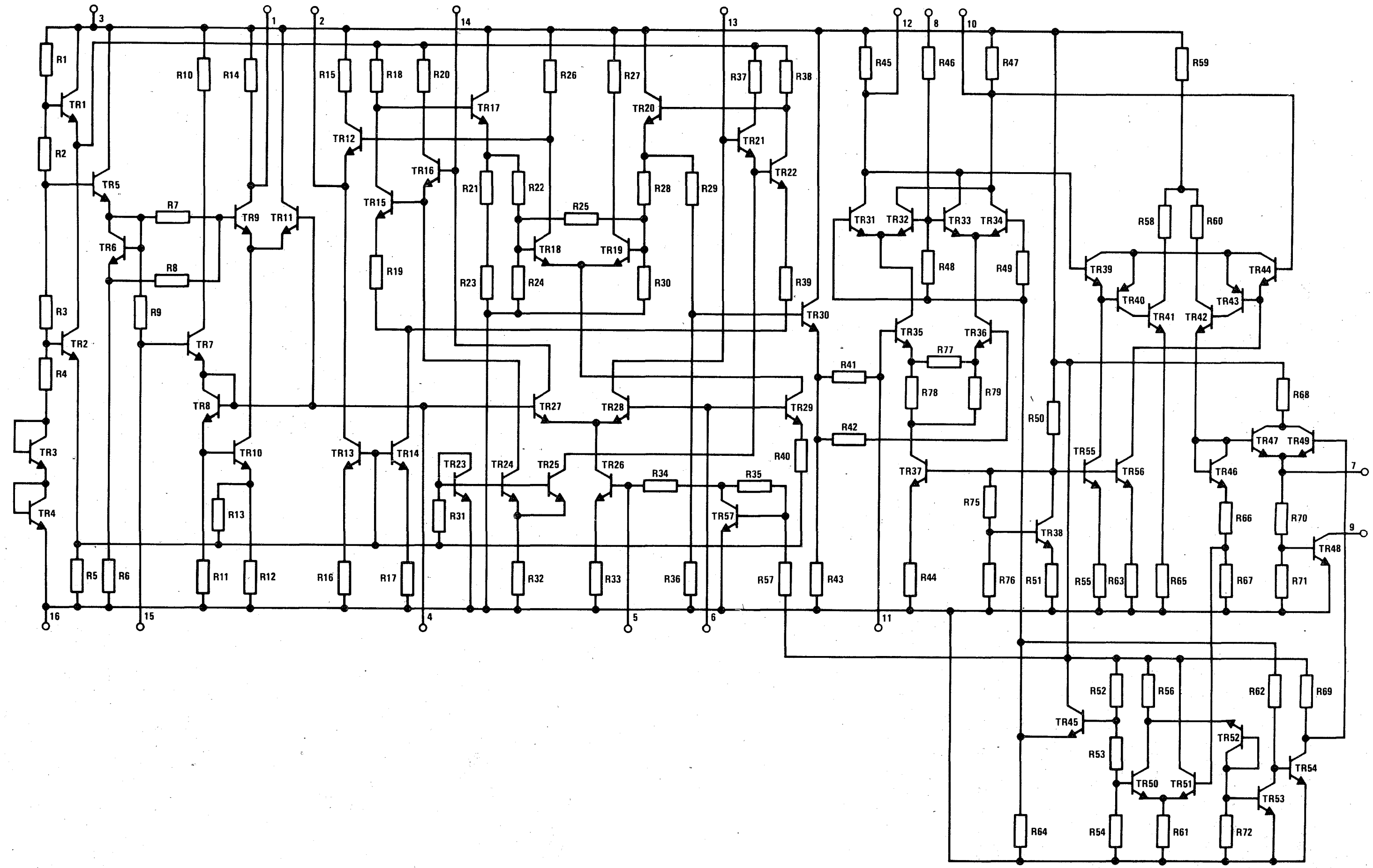
12. See pin 10.

13. See pin 14.

14. DC control points in reference control loop. Pins 13 and 14 are connected to opposite sides of a differential amplifier circuit and are brought out for the purpose of dc balancing of the reactance stage and the connection of the bandwidth-determining filter network. Two 2% tolerance 10k resistors with the addition of a 270Ω resistor at pin 13 are used in place of the previous balancing network. The 270Ω resistor may be modified according to the nature of the noise that appears at pin 5.

The filter network consists of R2, C2, C3 and C4. The dc potentials on these pins are nominally +6V.

schematic diagram



Audio, Radio and TV Circuits

TBA560C luminance and chrominance control combination

general description

The TBA560C is an integrated circuit for processing and controlling luminance and chrominance signals in PAL TV receivers.

The luminance amplifier comprises:

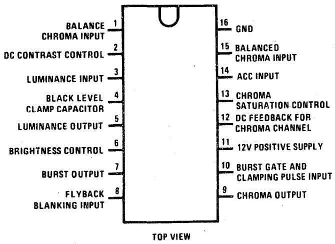
- DC contrast control
- Brightness control
- Black level clamping
- Blanking of flyback
- Input matched to the luminance delay line

The chrominance amplifier comprises:

- Gain-controlled amplifier
- DC chroma gain control tracked with contrast control
- Separate dc saturation control
- PAL delay line driver
- Burst gate
- Color killer
- Chroma signal flyback blanking

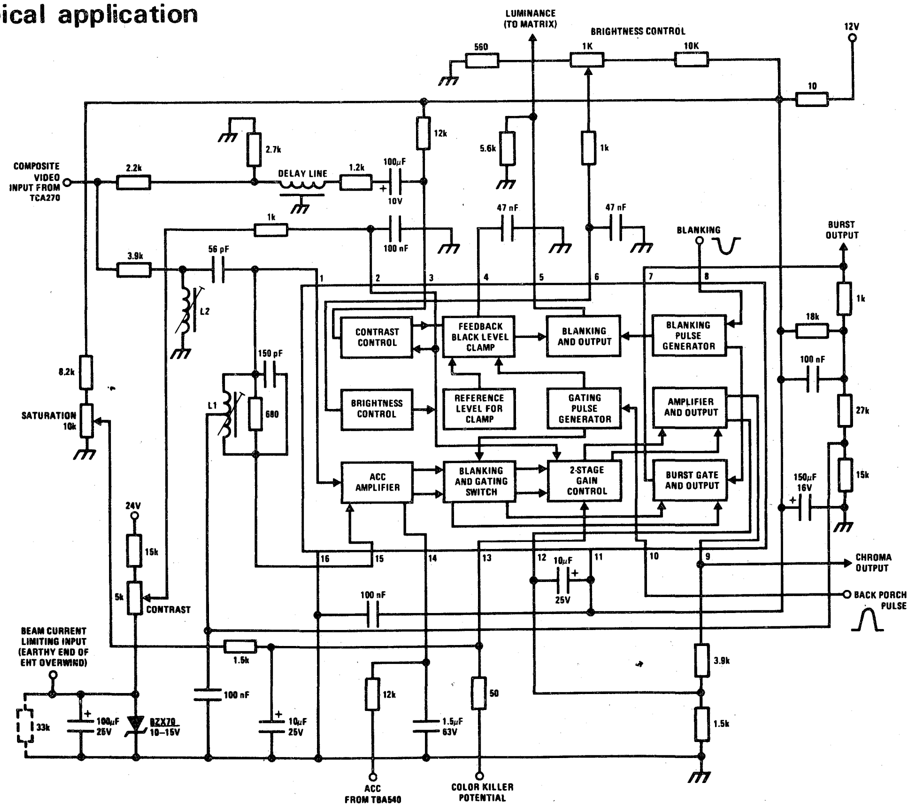
connection diagram

Dual-In-Line Package



Dual-In-Line Package, TBA560C
Quad-In-Line Package, TBA560CQ

typical application



absolute maximum ratings (Note 1)

V11-16	13.2V
V8-16 Min.	−5V
V10-16 Min.	−5V
V12-16	−5V to +6V
V13-16	−3V to +6.5V
V14-16 Min.	−5V
I_Q	−10 mA
Continuous Total Power Dissipation	550 mW
Operating Free Air Temperature Range	−20°C to +60°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics with V11-16 = 12V, T_A = 25°C (as measured in typical application circuit)

	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V1-15	Chrominance Input Signal Range (Value of Color Bars With 75% Saturation)		4		80	mVp-p
I_3	Luminance Input Current Black to White			0.5	1.5	mAp-p
V2-16	Contrast Control Characteristic	Full Gain		5.6		V
		6 dB Attenuation		3.7		V
		20 dB Attenuation (Note 2)		2.0		V
V6-16	Brightness Control Voltage for Black Level of 1.5V at Pin 5	(Note 3)		1.3		V
V8-16	Flyback Blanking Pulses					
V8-16	For 0V Blanking Level at Pin 5		0	−0.5	−1	Vp-p
	For 1.5V Blanking Level at Pin 5		−2	−2.5	−3	Vp-p
V13-16	Saturation Control Characteristic	Full Gain		6.2		V
		6 dB Attenuation		4.4		V
		20 dB Attenuation (Note 2)		2.7		V
I_{10}	Burst Gating Pulse		0.05		1	mAp-p
V13-16	Color Killer		0.5		1	V
	Automatic Chrominance Control					
V14-16	Voltage for Maximum Gain			1.2		V
	Voltage for Minimum Gain			0.5		V
	Gain Reduction			26		dB
	Input Resistance		50			kΩ
V5-16	Luminance Output Voltage (Black-White) at Nominal Contrast and Input Current as above	(Note 2)		1	3	Vp-p
	Black Level Shift Due to Changes of Contrast and Video Content at Constant Brightness Setting				100	mV
V7-16	Burst Output			1		Vp-p
V9-16	Chrominance Output at Nominal Contrast and Saturation	(Note 2)		1		Vp-p
	3 dB Bandwidth of Chrominance and Luminance Amplifier			5		MHz
	Matching of Luminance to Chrominance Ratio at 10 dB Contrast Control				2	dB

Note 1: V2-16 and V13-16 must always be lower than V11-16.
Note 2: Typical or nominal contrast or saturation = maximum value −6 dB. Thus the control is +6 to −14 dB on the nominal.
Note 3: When V6-16 is increased above 1.7V the black level of the output signal remains at 2.7V.

pin function description

1. Balanced chroma signal input (in conjunction with pin 15). This is derived from the chroma signal bandpass filter, designed to provide a push-pull input. An input signal amplitude of at least 4 mVp-p is required between pins 1 and 15. Both pins require a dc potential of approximately +3.0V. This is derived as a common mode signal from a network connected to pin 7 (burst output). In this way dc feedback is provided over the burst channel to stabilize its operation. All figures for the chrominance signal are based on a color bar signal with 75% saturation; i.e., burst-to-chroma ratio of input signal is 1:2.

2. DC contrast control. With +3.7V on this pin, the gain in the luminance channel is such that a 0.5 mA black-to-white input signal to pin 3 gives a luminance output signal amplitude on pin 5 of 1V black-to-white. A variation of voltage on pin 2 between +5.6V and +2V gives a corresponding gain variation of +6 to > -14 dB. A similar variation in gain in the chroma channel occurs in order to provide the correct tracking between the two signals. Beam current limiting can be applied via the contrast control network as shown in the peripheral circuit, when a separate overwind is available on the line output transformer.

3. Luminance signal input. This terminal has a very low input impedance and acts as a current sink. The luminance signal from the delay line is fed via a series terminating resistor and a dc blocking capacitor and requires to be about 0.5 mAp-p amplitude. A dc bias current is required via a 12 kΩ resistor to the +12V line.

4. Charge storage capacitor for black level clamp.

5. Luminance signal output. An emitter follower provides a low impedance output signal of 1V black-to-white amplitude at nominal contrast setting having a nominal black level in the range 0 to +2.7V. An external emitter load resistor is required, not less than 1 kΩ. If a greater luminance output is required than 1V, with normal control settings, the input current swing at pin 3 should be increased in proportion.

6. Brightness control. Over the range of potential +0.9 to +1.7V the black level of the luminance output signal (pin 5) is increased from 0 to +2.7V. The output signal black level remains at +2.7V when the potential on pin 6 is increased above +1.7V.

7. Burst output. A 1 Vp-p burst (controlled by the ACC system) is produced here. Also, to achieve good dc stability by negative feedback in the burst channel the dc potential at this pin is fed back to pins 1 and 15 via the chroma input transformer.

8. Flyback blanking input waveform. Negative-going horizontal and vertical blanking pulses may be applied here. If rectangular blanking pulses of not greater than −1V negative excursion, or dc coupled pulses of similar amplitude whose negative excursion is at zero volts dc are applied, the signal level at the luminance output (pin 5) during blanking will be 0V. However, if the blanking pulses applied to pin 8 have an amplitude of −2 to −3V the signal level at the luminance output during blanking will be +1.5V. The negative pulse amplitude should not exceed −5V.

9. Chroma signal output. With a 1 Vp-p burst output signal (pin 7) and at nominal contrast and saturation setting (pins 2 and 13) the chroma signal output amplitude is 1 Vp-p. An external network is required which provides dc negative feedback in the chroma channel via pin 12.

10. Burst gating and clamping pulse input. A positive pulse of not less than 50μA is required on this pin to provide gating in the burst channel and luminance channel black-level clamp circuit. The timing and width of this current pulse should be such that no appreciable encroachment occurs into the sync pulse or picture line periods during normal operation of the receiver.

11. +12V LT supply. Correct operation occurs within the range 10.8 to 13.2V. All signal and control levels have a linear dependency on supply voltage but, in any given receiver design this range may be restricted due to considerations of tracking between the power supply variations and picture contrast and chroma levels. The power dissipation must not exceed 550 mW at 60°C ambient temperature.

12. DC feedback for chroma channel (see pin 9).

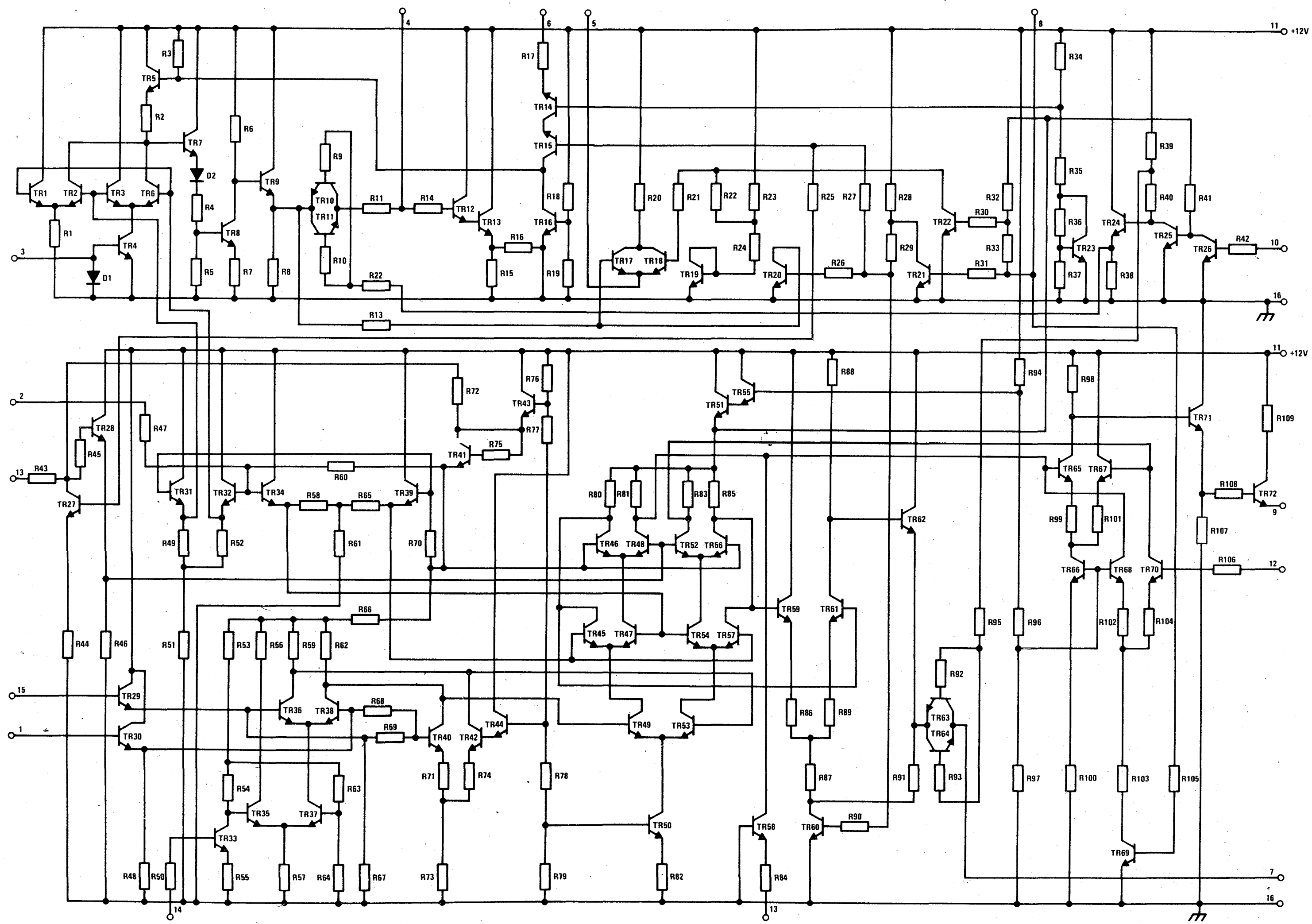
13. Chroma saturation control. A control range of +6 to > -14 dB is provided over a range of dc potential on pin 13 from 6.2 to 2.7V. Color killing is also achieved at this terminal by reducing the dc potential to less than +1V, e.g., from the TBA540 color killer output terminal. The minimum "kill factor" is 40 dB.

14. ACC input. A negative-going potential gives an ACC range of about 26 dB starting at +1.2V. From 1V to 800 mV the steepest part of the characteristic occurs, but a small amount of gain reduction also occurs from 800 mV to 500 mV. The input resistance is at least 50 kΩ.

15. Chroma signal input (see pin 1).

16. Negative supply, 0V (Earth).

schematic diagram



Audio, Radio and TV Circuits

TBA920 line oscillator combination

general description

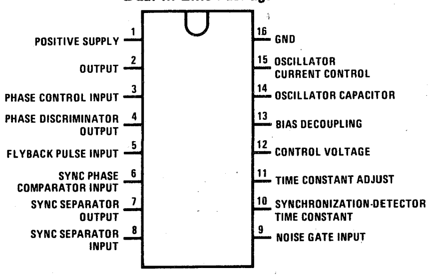
The TBA920 is a monolithic integrated circuit intended for TV receivers with transistor-thyristor- or valve equipped output stages.

It combines the following functions:

- Noise gated sync separator
- Phase comparison between sync pulse and oscillator
- Line oscillator
- Loop gain and time constant switching (also for video recorder applications)
- Phase comparison between line-flyback pulse and oscillator
- Output stage for driving a variety of line output stages

connection diagram

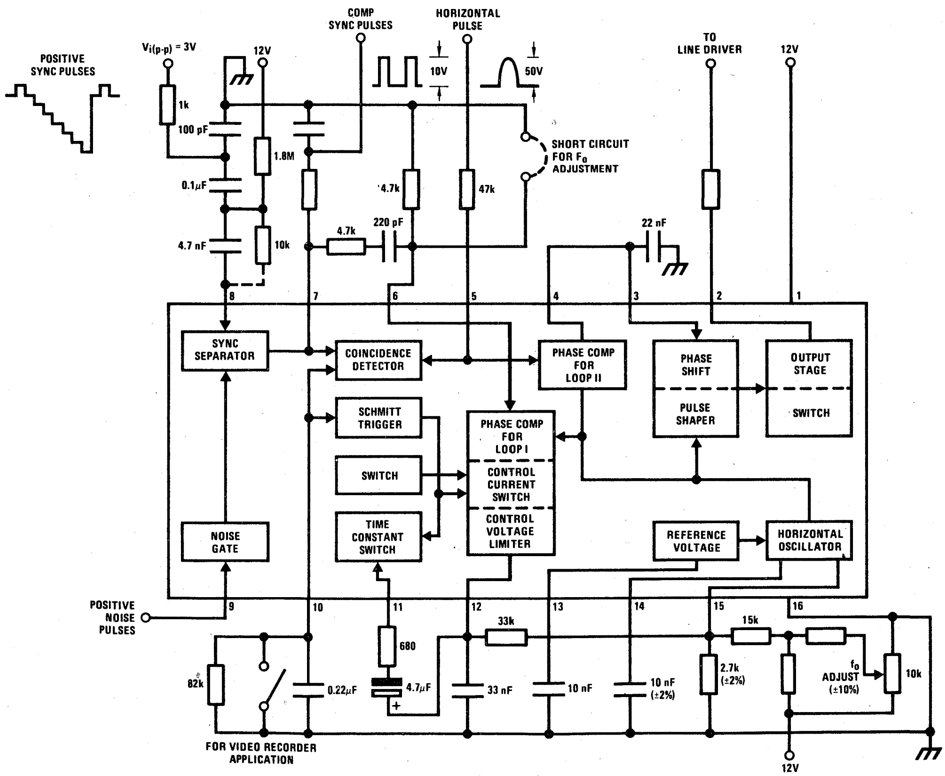
Dual-In-Line Package



TOP VIEW

Dual-In-Line Package, TBA920
Quad-In-Line Package, TBA920Q

typical application



absolute maximum ratings

V1-16	13.2V	Operating Temperature Range	−20°C to +60°C
I_2 (Mean)	20 mA	Storage Temperature Range	−65°C to +150°C
I_2 (Peak)	200 mA	Lead Temperature (Soldering, 10 seconds)	300°C
I_5, I_7, I_9	10 mA	Power Dissipation (T_A = 60°C)	600 mW

electrical characteristics at V1-16 = 12V, T_A = 25°C as measured in application circuit

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
	Current Consumption					
I_1		I_2 = 0		36		mA
	Video Signal					
V1	Input Voltage Range		1		7	Vp-p
I_Q	Input Current During Sync Pulse			100		μA
	Noise Gating (Pin 9)					
V9-16	Input Voltage (Peak Value)		0.7			V
I_9	Input Current (Peak Value)		0.03		10	mA
	Flyback Pulse (Pin 5)					
V5-16	Input Voltage (Peak Value)			±1		V
I_5	Input Current (Peak Value)		0.05	1		mA
R5-16	Input Resistance			400		Ω
t_5	Pulse Duration at 15,625 Hz		10			μs
	Composite Sync Pulses (Positive: Pin 7)					
V7-16	Output Voltage			10		Vp-p
	Output Resistance					
R7-16	At Leading Edge of Pulse (Emitter Follower)			50		Ω
R7-16	At Trailing Edge			2.2		kΩ
R7-16 (ext)	Additional External Load Resistance		2			kΩ
	Driver Pulse (Pin 2)					
V2-16	Output Voltage			10		Vp-p
I_2	Average Output Current				20	mA
I_2	Peak Output Current				200	mA
t_2	Output Pulse Duration When Synchronized		12		32	μs
$t_{o\ tot}$	Permissible Delay Between Leading Edge of Output Pulse and Flyback Pulse at t_5 = 12μs		0		15	μs
V1-16	Supply Voltage at Which Output Pulses are Obtained		4			V
	Oscillator					
f_o	Frequency; Free Running	R15-16 = 3.3 kΩ, (Note 1)		15,625		Hz
$\frac{\Delta f_o}{f_o}$	Spread of Frequency at Nominal Values of Peripheral Components				±5	%
$\left\lvert\frac{\Delta f_o}{f_o}\right\rvert$	Frequency Change When Decreasing the Supply Down to Minimun 4V				10	%
$\frac{\delta f_o}{f_o} / \frac{\delta V_P}{V_{Pnom}}$	Influence of Supply Voltage on Frequency at Vp = 12V				5	%
$\delta f_o/\delta I_{15}$	Frequency Control Sensitivity			16.5		Hz/μA
	Control Loop I (Between Sync Pulse and Oscillator)					
V12-16	Control Voltage Range		0.8		5.5	V
	Control Current (Peak Values)					
I_{12M}		V10-16 > 4.5V, V6-16 > 1.5V		±2		mA
I_{12M}		V10-16 < 2V, V6-16 > 1.5V		±6		mA

electrical characteristics (con't)

	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
	Loop Gain of APC System					
$\frac{\Delta f}{\Delta t}$	Time Coincidence Between Sync Pulse and Flyback Pulse or V10-16 > 4.5V			1		kHz/μs
$\frac{\Delta f}{\Delta t}$	No Time Coincidence or V10-16 < 2V			3		kHz/μs
Δf	Catching and Holding Range	(Note 2)		±1		kHz
t	Pull-in Time	$\Delta f/f_o$ = ±3% (Δf = 470 Hz)		20		ms
t	Switch-over From Large Control Sensitivity to Small Control Sensitivity After Catching			20		ms
	Control Loop II (Between Flyback Pulse and Oscillator)					
$t_{d\ tot}$	Permissible Delay Between Leading Edge of Output Pulse (Pin 2) and Leading Edge of Flyback Pulse		0		15	μs
$\frac{\Delta t}{\Delta t_d}$	Static Control Error	(Note 3)			0.5	%
	Overall Phase Relation					
t	Phase Relation Between Leading Edge of Sync Pulse and Middle of Flyback Pulse	(Note 4)		4.9		μs
|Δt|	Tolerance of Phase Relation	(Note 5)			1	μs
V3-16	Voltage	t_2 = 12μs		6		V
V3-16		t_1 = 32μs		8		V
I_3	Input Current				2	μA
	Time Constant Switch Voltage on Pin 10					
V10-16		For Internal R11 = 150Ω	4.5			V
V10-16		For Internal R11 = 2 kΩ			2	V

Note 1: The oscillator frequency can be changed for other TV standards by an appropriate value of C14-16.

Note 2: Adjustable with R12-15.

Note 3: The control error is the remaining error in reference to the nominal phase position between leading edge of the sync pulse and the middle of the flyback pulse caused by a variation in delay of the line output stage.

Note 4: This phase relation assumes a luminance delay line with a delay of 500 ns between the input of the sync separator and the drive to the picture tube. If the sync separator is inserted after the luminance delay line or if there is no delay line at all (black-and-white sets), then the phase relation is achieved by C5-16 = 560 pF.

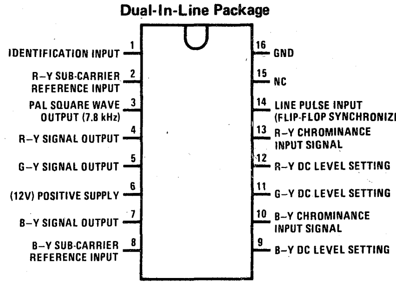
Note 5: The adjustment of the overall phase relation and consequently the leading edge of the output pulse at pin 2 occurs automatically by the control loop II or by applying a dc voltage to pin 3.

TBA990 color demodulator

general description

The TBA990 is an integrated color demodulator circuit for color television receivers incorporating two active synchronous demodulators for the R-Y and B-Y chrominance signals, a matrix (producing the G-Y color difference signal), PAL phase switch and flip-flop. It is suitable for dc coupled drive to the picture tube when associated with the matrix integrated circuit (TBA530) and R-G-B output stages. Special attention has been given in the design to minimizing dc level drift with temperature.

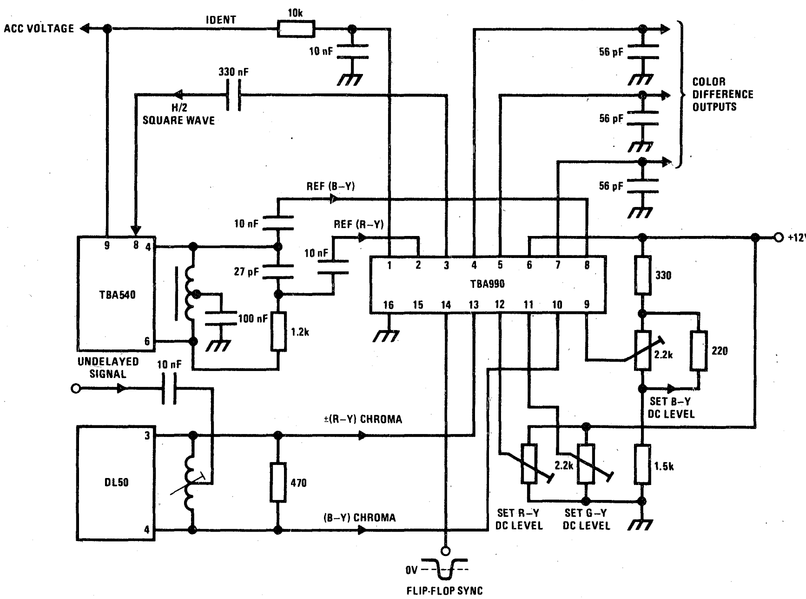
connection diagram



TOP VIEW

Dual-In-Line Package, TBA990
Quad-In-Line Package, TBA990Q

typical application



absolute maximum ratings

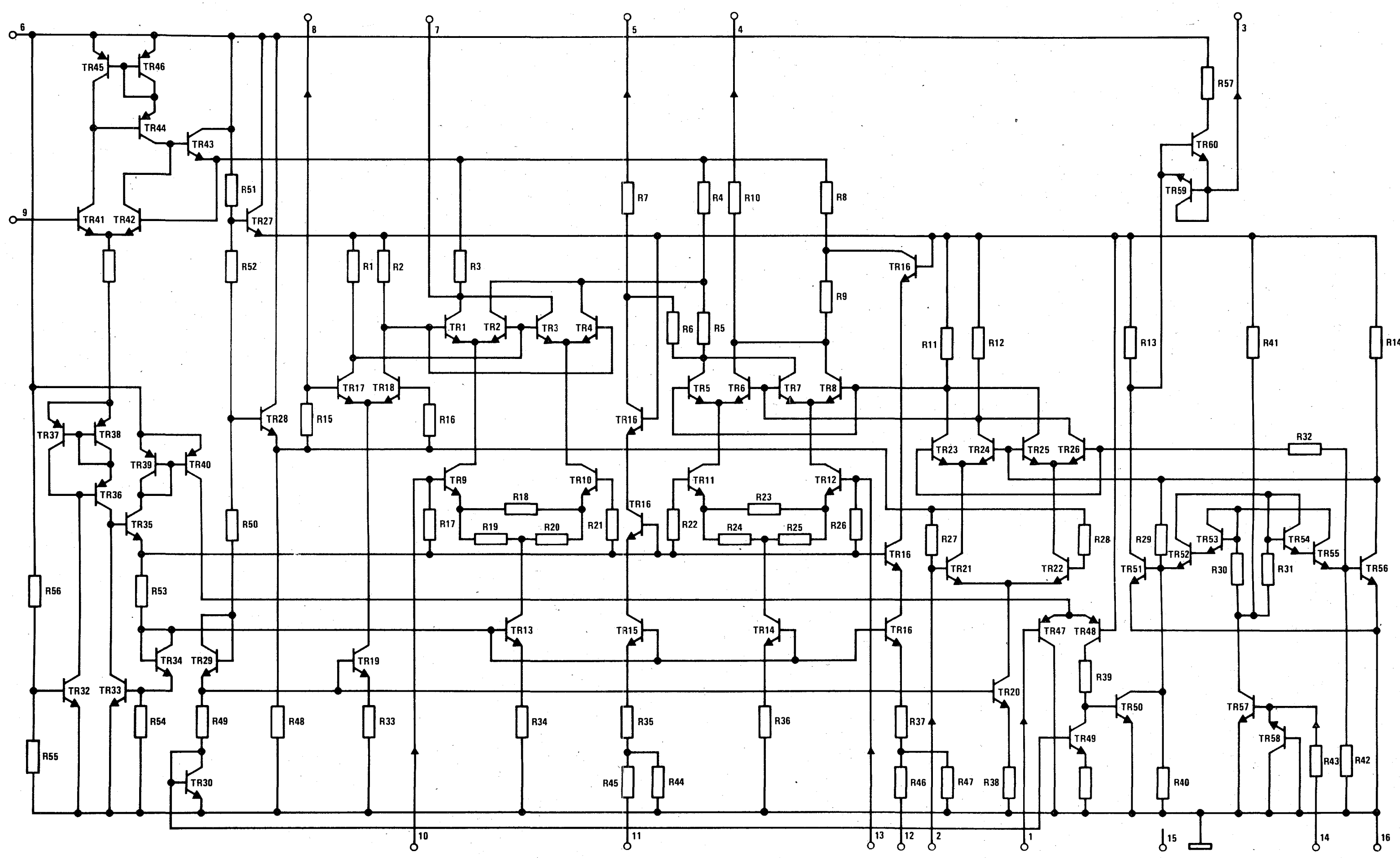
Supply Voltage, V6-16	13.2V
Continuous Total Power Dissipation (T_A = 60°C)	300 mV
Operating Free-Air Temperature Range	−20°C to +60°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics (V6-16 = 12V, T_A = 25°C)

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
$I_{6\text{-}16}$	Supply Current Consumption			17		mA
G13-4	Gain of Chrominance (R-Y) Signal Channel V_{IN} = 50 mV, f = 4.4 MHz (Peak to Peak Ratio)			3.8		
	Ratio of Demodulator Gains					
$G_{B\text{-}Y}/G_{R\text{-}Y}$			1.60	1.78	1.96	
$G_{G\text{-}Y}/G_{R\text{-}Y}$		(Note 1a)	0.765	0.85	0.935	
$G_{G\text{-}Y}/G_{R\text{-}Y}$		(Note 1b)	0.135	0.17	0.20	
V4-16, V5-16, V7-16	Color-Difference dc Output Voltages			7.5		V
V4-16, V5-16, V7-16	Drift of dc Output Voltages	ΔT_A = 40°C			50	mV
V4-16, V5-16, V7-16	Relative Change of dc Output Voltages Between Channels	ΔT_A = 40°C			20	mV
	Color Difference Output Signals Peak to Peak Values					
V4-16	R-Y		1.6			Vp-p
V7-16	B-Y		2.0			Vp-p
V5-16	G-Y		0.9			Vp-p
	Impedance of Chrominance Inputs					
R10-16		$V_{IN(rms)}$ = 20 mV	0.8	1		kΩ
R13-16		(Sinusoidal),	0.8	1		kΩ
C10-16		f = 4.4 MHz			10	pF
C13-16					10	pF
R2-16	Impedance of Reference			5		kΩ
R8-16	Signal Inputs			5		kΩ
R4-16	Impedance of Color-			3		kΩ
R7-16	Difference Signal Outputs			3		kΩ
R5-16				3		kΩ
V3-16	PAL Flip-Flop Output Voltage	f = 7.8 kHz	2.5	3.5		Vp-p
Input Voltages						
V2-16	Color Reference Signal at Reference R-Y		0.5	1	2	Vp-p
V8-16	Reference B-Y		0.5	1	2	Vp-p
V14-16	Identification Circuit Line Pulse Input		2		5	Vp-p
$I_{14\text{-}16}$	Input Current During Positive Part of Pulse		0.1		5	mA
$I_{1\text{-}16}$	Current for "Ident Off"				0.1	mA

Note 1: Condition (a) refers to the (B-Y) + (R-Y) addition in the G-Y matrix.
Condition (b) refers to the phase reversal (R-Y) input signal where (G-Y) is obtained by subtraction.

schematic diagram



pin function description

1. Identification bias. The PAL flip-flop is stopped, for identification purposes, when the voltage on pin 1 increases above 6V. This threshold is internally generated and has a porportional behavior with the 12V supply voltage. The threshold level of 6V is chosen to match the output characteristic of the TBA540 and has a sufficiently high safety margin above the zero chroma signal level of 4V to eliminate spurious identifying.

2. R-Y subcarrier reference input. A 1Vp-p signal is required via a dc blocking capacitor. Under no circumstances should this signal be less than 0.5 Vp-p. The input resistance at this pin is typically 5 kΩ.

3. PAL square wave output. The amplitude is 3Vp-p from an emitter follower. No external load resistor is required.

4. R-Y signal output (G-Y at pin 5 and B-Y at pin 7). These outputs require no external dc loads except that direct connection must be made via the low pass filters to the appropriate pins on the R-G-B matrix TBA530. In a complete circuit using the TBA530 and video output stages the dc levels of these outputs will be adjusted to give the correct setting of the picture tube drive black levels. The changes in dc level with supply voltage are proportional and track together.

The unwanted products of demodulation occurring in the color difference outputs are chiefly 8.86 MHz and harmonics together with a small amount of 4.43 MHz due to possible unbalance in the demodulators. To avoid possible troubles in the receiver because of radiation of these demodulation products from the R-G-B drive circuits, low-pass filters must be employed in each of the color difference outputs. The filters shown have a −3 dB bandwidth of 1 MHz, adequate attenuation of the 8.8 MHz component, and sufficient attenuation of the 4.4 MHz component to give less than 4 Vp-p amplitude at the picture tube cathodes.

5. G-Y signal output (see pin 4).

6. Positive supply. The maximum allowable voltage on this pin is 13.2V.

7. B-Y signal output (see pin 4).

8. B-Y subcarrier reference input. The requirements here are identical with those for pin 2.

9. DC level setting for B-Y output signal. This is a "common adjustment" which controls all three output dc levels together.

10. Chrominance B-Y input signal. An input signal of approximately 360 mVp-p (color bars) is required at this pin. The input resistance is greater than 800Ω and the input capacitance is less than 10 pF. The spread in gain of the internal circuitry in the chrominance channel is ±10% maximum.

11. DC level setting for G-Y output signal. This adjusts the G-Y output dc level relative to the B-Y dc level.

12. DC level setting for R-Y output signal. This adjusts the R-Y output dc level relative to the B-Y dc level.

13. Chrominance R-Y input signal. An input signal of approximately 500 mVp-p (color bars) is required at this pin. The input impedance and spread in gain is the same as for pin 9.

14. Line pulse input (flip-flop synchronizing). A waveform derived from the line timebase can be used for synchronizing providing that its amplitude lies between 2V and 5Vp-p. The trigger point occurs where the negative-going edge crosses approximately +0.6V. Prior to this sufficient current must be supplied to pin 14 to turn the input transistor fully on.

15. N.C. This pin should not be used for external connections.

16. Negative supply (earth).

TDA 440 Video IF amplifier and detector

general description

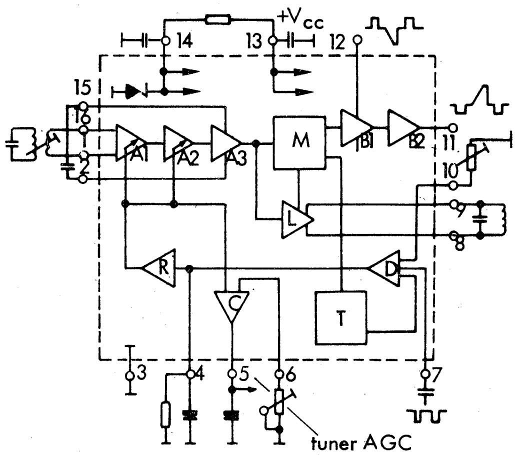
The TDA 440 is a monolithic Video IF amplifier for colour and monochrome televison receivers.

The circuit includes three IF amplifier stages, a balanced video detector and a gated AGC section for the IF amplifier and PNP tuner.

features

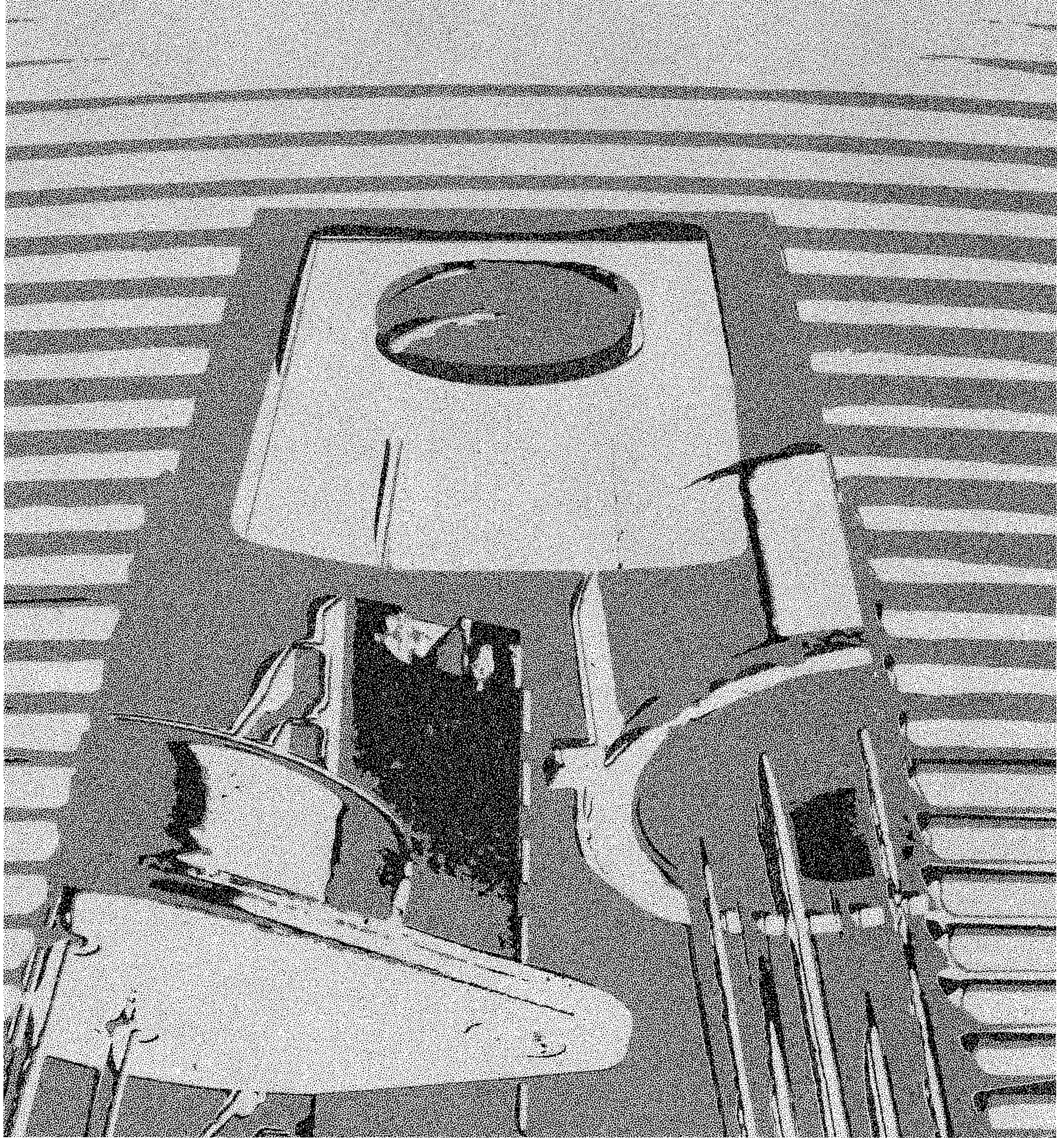
- High gain – high stability
- Minimal noise increase with AGC
- Minimum RF breakthrough to video outputs
- Fast AGC action – gating largely independent of pulse shape and amplitude
- Very low intermodulation products
- Positive and negative video signals available from low impedance outputs
- Integrated temperature compensating circuit
- Adjustable white Level
- Constant input impedance independent of AGC
- Negative video output independent of supply

block diagram



A 1	Gain controlled I. F. Amplifier
A 2	Gain controlled I. F. Amplifier
A 3	Fixed I. F. Amplifier
M	Mixer-Detector
B 1	Low impedance video output
B 2	Inverting video Amplifier
L	Tuned limiting Amplifier
R	A. G. C. Amplifier
C	Comparator for delayed tuner A. G. C.
T	Temperature compensation
D	Gated Detector

National Semiconductor
TRANSISTOR/DIODE ARRAYS
Section 11



Transistor/Diode Arrays

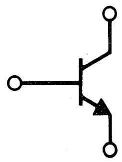
Section Contents

Note: Also see display drivers in National Semiconductor's Interface Catalog.

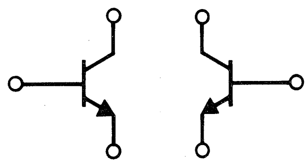
11

Transistor/Diode Arrays

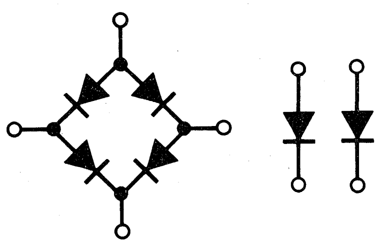
Selection Guide



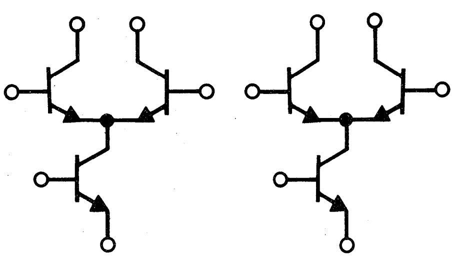
LM195/LM295/LM395
(Current Limit, Thermal Limit,
Safe Area Protection)



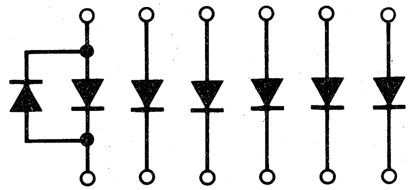
LM114/LM114A
LM115/LM115A
LM194/LM394



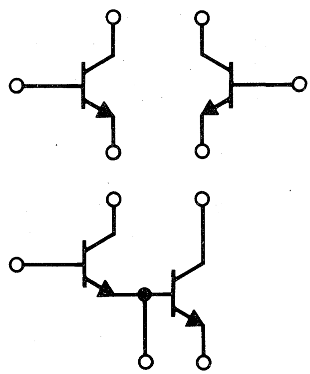
LM3019



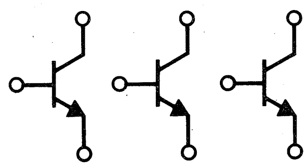
LM3026
LM3054



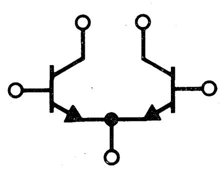
LM3039



LM3018/LM3018A
LM3118/LM3118A



LM3045
LM3046
LM3086



LM3145/LM3145A
LM3146/LM3146A

Transistor/Diode Arrays

LM114/LM114A, LM115/LM115A
high gain matched dual monolithic transistors

general description

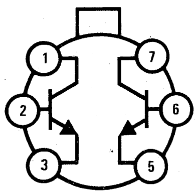
These devices contain a pair of junction-isolated NPN transistors fabricated on a single silicon substrate. This monolithic structure makes possible extremely-tight parameter matching at low cost. Further, advanced processing techniques yield exceptionally high current gains at low collector currents, virtual elimination of "popcorn noise," low leakages and improved long-term stability.

features

- 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.
- CMRR > 100 dB

Although designed primarily for high breakdown voltage and exceptional dc characteristics, these transistors have surprisingly good high-frequency performance. The gain-bandwidth product is 300 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 pF at 5V.

connection diagram



TOP VIEW

Order Number LM114H, 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)	0.8W	
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.

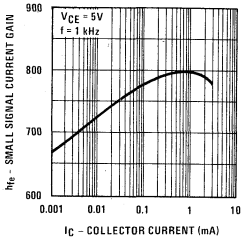
electrical characteristics (Note 2)

PARAMETER	CONDITIONS	MAXIMUM LIMITS				UNITS
		LM114A	LM114	LM115A	LM115	
Offset Voltage	$1\ \mu A \leq I_C \leq 100\ \mu A$	0.5	2.0	0.5	2.0	mV
Offset Current	$I_C = 10\ \mu A$ $I_C = 1\ \mu A$	2.0 0.5	10	2.0 0.5	10	nA nA
Bias Current	$I_C = 10\ \mu A$ $I_C = 1\ \mu A$	20 3.0	40	40 6.0	40	nA nA
Offset Voltage Change	$0V \leq V_{CB} \leq V_{max}$ $I_C = 10\ \mu A$	0.2	1.5	0.3	2.0	mV
Offset Current Change	$0V \leq V_{CB} \leq V_{max}$ $I_C = 10\ \mu A$	1.0	4.0	1.0	4.0	nA
Offset Voltage Drift	$-55°C \leq T_A \leq 125°C$ $I_C = 10\ \mu A$	2.0	10	2.0	10	µV/°C
Offset Current	$-55°C \leq T_A \leq 125°C$ $I_C = 10\ \mu A$	12	50	20	50	nA
Bias Current	$-55°C \leq T_A \leq 125°C$ $I_C = 10\ \mu A$	60	150	150	150	nA
Collector-Base Leakage Current	$V_{CB} = V_{max}$ $T_A = 25°C$ $T_A = 125°C$	10 10	50 50	10 10	50 50	pA nA
Collector-Emitter Leakage Current	$V_{CE} = V_{max}$, $V_{EB} = 0$ $T_A = 25°C$ $T_A = 125°C$	50 50	200 200	50 50	200 200	pA nA
Collector-Collector Leakage Current	$V_{CC} = V_{max}$ $T_A = 25°C$ $T_A = 125°C$	100 100	300 300	100 100	300 300	pA nA

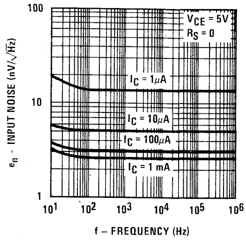
Note 2: These specifications apply for $T_A = 25°C$ and $0V \leq V_{CB} \leq V_{max}$, unless otherwise specified. For the LM114 and LM114A, $V_{max} = 30V$. For the LM115 and LM115A, $V_{max} = 45V$.

typical performance characteristics

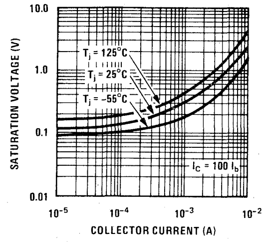
Small Signal Current Gain



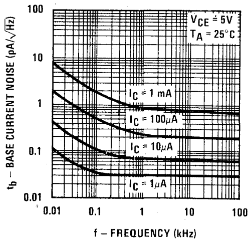
Input Voltage Noise



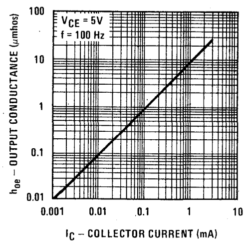
Saturation Voltage



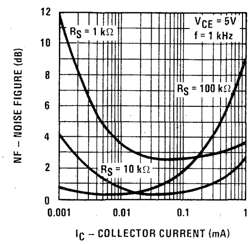
Current Noise



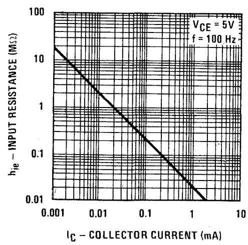
Small Signal Output Conductance



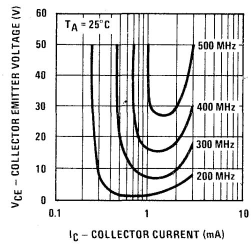
Noise Figure



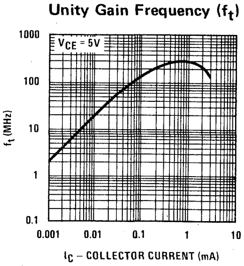
Small Signal Input Resistance



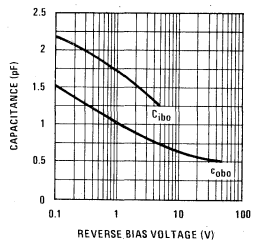
Contours of Constant Gain Bandwidth Product



Unity Gain Frequency (f_t)



Input and Output Capacitance



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.

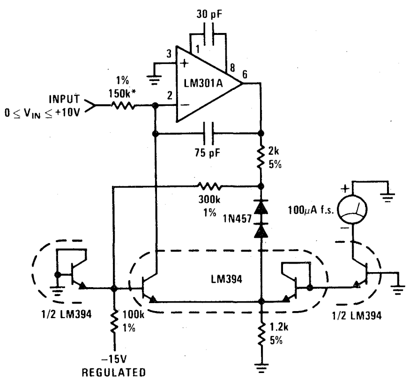
The LM194 and LM394/LM394B are available in an isolated header 6-lead TO-5 metal can package. The LM194 is identical to the LM394 except for tighter electrical specifications and wider temperature range.

features

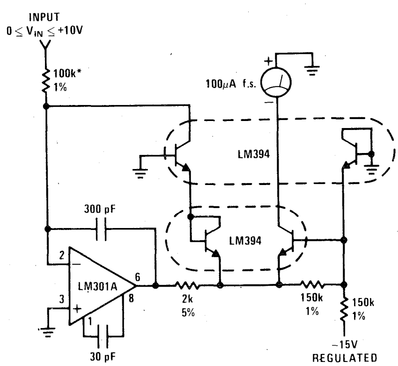
- Emitter-base voltage matched to 50μV
- Offset voltage drift less than 0.1μV/°C
- Current gain (h_{FE}) matched to 2%
- Common-mode rejection ratio greater than 120 dB
- Parameters guaranteed over 1μA to 1 mA collector current
- Extremely low noise
- Superior logging characteristics compared to conventional pairs
- Plug-in replacement for presently available devices

typical applications

Low Cost Accurate Square Root Circuit
$I_{OUT} = 10^{-5} \cdot \sqrt{10\, V_{IN}}$



Low Cost Accurate Squaring Circuit
$I_{OUT} = 10^{-6}\,(V_{IN})^2$



*Trim for full scale accuracy

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 +125°C
LM394, LM394B	−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			LM394B			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
Current Gain (h_{FE})	V_{CB} = 0V to 40V (Note 1)										
	I_C = 1 mA	500	700		300	700		225	500		
	I_C = 100μA	400	550		250	550		200	400		
	I_C = 10μA	300	450		200	450		150	300		
	I_C = 1μA	200	300		150	300		100	200		
Current Gain Match (h_{FE} Match)	V_{CB} = 0V to 40V										
$= \frac{[\Delta I_B][h_{FE}(min)]}{100 I_C}$	I_C = 10μA to 1 mA		0.5	2		0.5	4		1.0	5	%
	I_C = 1μA		1.0			1.0			2.0		%
Emitter-Base Offset Voltage	V_{CB} = 0, I_C = 1μA to 1 mA		25	50		25	150		50	200	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		10	100	μV
Change in Emitter-Base Offset Voltage vs Collector Current	V_{CB} = 0V, I_C = 1μV to 0.3 mA		5	25		5	50		5	50	μV
Emitter-Base Offset Voltage Temperature Drift	I_C = 10μA to 1 mA (Note 2)										
	$I_{C1} = I_{C2}$		0.08	0.3		0.08	1.0		0.2	1.5	μV/°C
	V_{OS} Trimmed to 0 at 25°C		0.03	0.1		0.03	0.3		0.03	0.5	μV/°C
Logging Conformity	I_C = 3 nA to 300μA, V_{CB}=0, (Note 3)		150			150			150		μV
Collector-Base Leakage	V_{CB} = 40V		0.05	0.25		0.05	0.5		0.05	0.5	nA
Collector-Collector Leakage	V_{CC} = 40V		0.1	2.0		0.1	5.0		0.1	5.0	nA
Input Voltage Noise	I_C = 100μA, V_{CB} = 0V, f = 100 Hz to 100 kHz		1.8			1.8			1.8		nV/√Hz
Collector to Emitter Saturation Voltage	I_C = 1 mA, I_B = 10μA		0.2			0.2			0.2		V
	I_C = 1 mA, I_B = 100μA		0.1			0.1			0.1		V

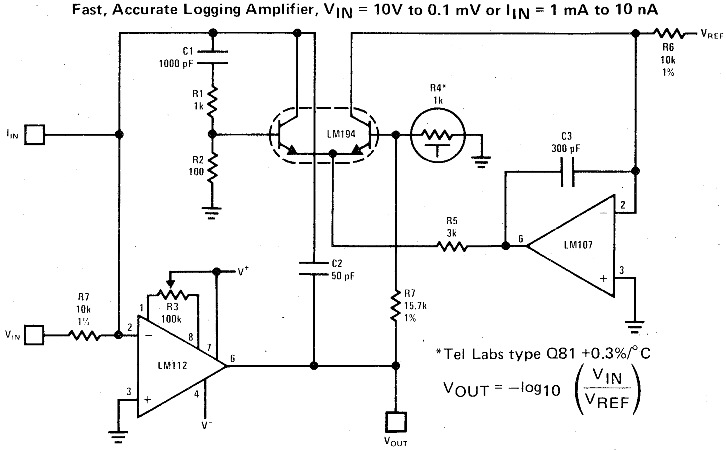
Note 1: Collector base voltage is swept from 0 to 40V at a collector current of 1μA, 10μA, 100μA, and 1 mA.

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 (con't)

Fast, Accurate Logging Amplifier, V_{IN} = 10V to 0.1 mV or I_{IN} = 1 mA to 10 nA



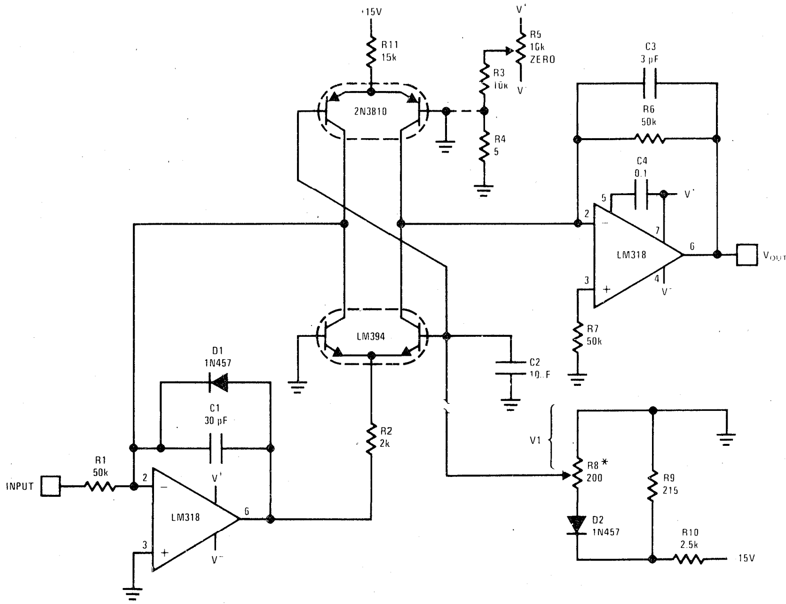
*Tel Labs type Q81 +0.3%/°C

$$V_{OUT} = -\log_{10}\left(\frac{V_{IN}}{V_{REF}}\right)$$

11

typical applications (con't)

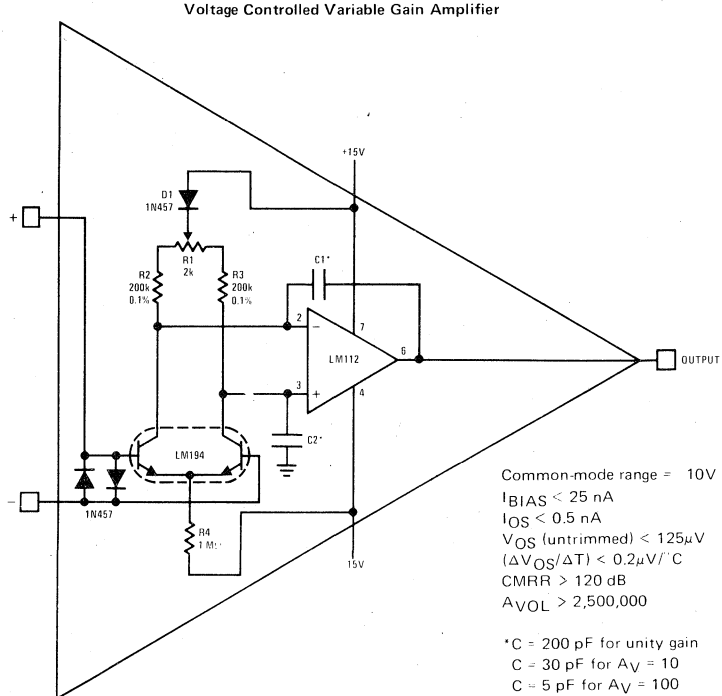
Precision Low Drift Operational Amplifier



*R8 – R10 and D2 povide a temperature independent gain control.
G = −336 V1 (dB)

Distortion < 0.1%
Bandwidth ≃ 1 MHz
100 dB gain range

Voltage Controlled Variable Gain Amplifier

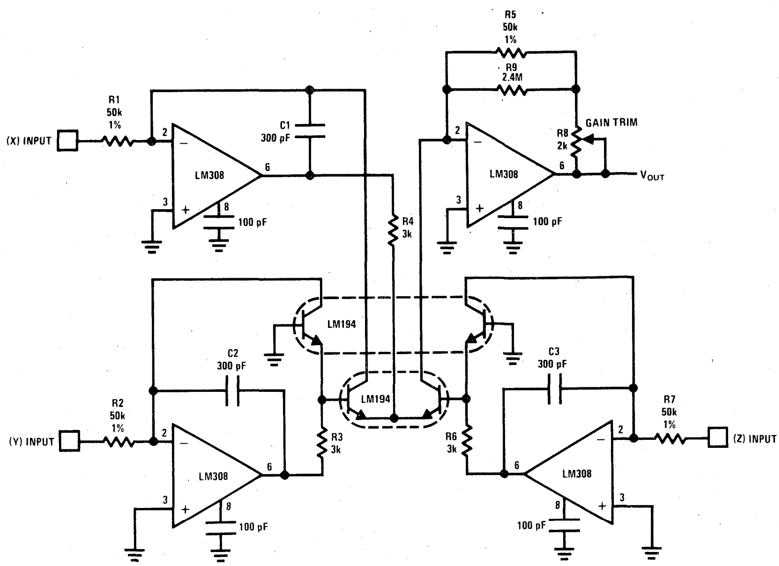


Common-mode range = 10V
$I_{BIAS} < 25$ nA
$I_{OS} < 0.5$ nA
V_{OS} (untrimmed) < 125μV
$(\Delta V_{OS}/\Delta T) < 0.2\mu V/°C$
CMRR > 120 dB
$A_{VOL} > 2,500,000$

*C = 200 pF for unity gain
C = 30 pF for $A_V = 10$
C = 5 pF for $A_V = 100$
C = 0 for $A_V \geq 1000$

typical applications (con't)

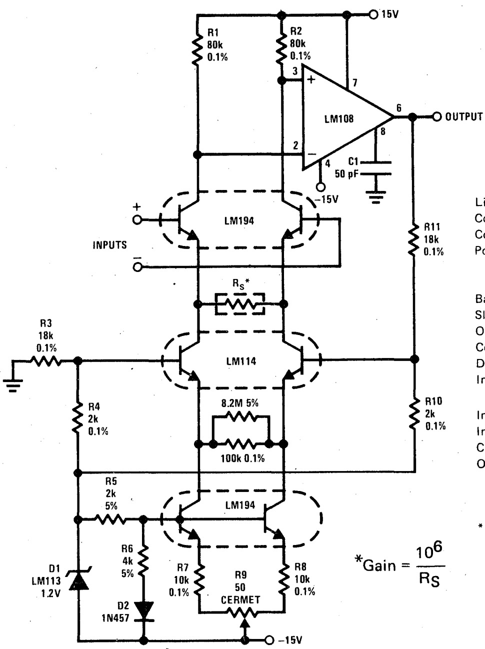
High Accuracy One Quadrant Multiplier/Divider



$$V_{OUT} = \frac{(X)\,(Y)}{(Z)} \text{ ; positive inputs only.}$$

*Typical linearity 0.1%

High Performance Instrumentation Amplifier



$$^{*}\text{Gain} = \frac{10^6}{R_S}$$

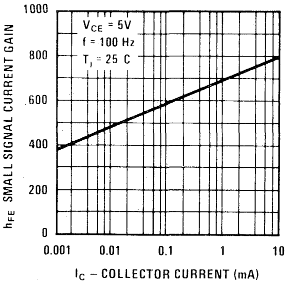
Performance Characteristics

	G = 10,000	G = 1,000	G = 100	G = 10	
Linearity of Gain (±10V Output)	≤ 0.01	≤ 0.01	≤ 0.02	≤ 0.05	%
Common-Mode Rejection Ratio (60 Hz)	≥ 120	≥ 120	≥ 110	≥ 90	dB
Common-Mode Rejection Ratio (1 kHz)	≥ 110	≥ 110	≥ 90	≥ 70	dB
Power Supply Rejection Ratio					
+ Supply	> 110	> 110	> 110	> 110	dB
− Supply	> 110	> 110	> 90	> 70	dB
Bandwidth (−3 dB)	50	50	50	50	kHz
Slew Rate	0.3	0.3	0.3	0.3	V/μs
Offset Voltage Drift**	≤ 0.25	≤ 0.4	≤ 2	≤ 10	μV/°C
Common-Mode Input Resistance	> 10^9	> 10^9	> 10^9	> 10^9	Ω
Differential Input Resistance	> 3×10^8	> 3×10^8	> 3×10^8	> 3×10^8	Ω
Input Referred Noise (100 Hz ≤ f ≤ 10 kHz)	5	6	12	70	$nV/\sqrt{Hz}$
Input Bias Current	75	75	75	75	nA
Input Offset Current	1.5	1.5	1.5	1.5	nA
Common-Mode Range	±11	±11	±11	±10	V
Output Swing (R_L = 10 kΩ)	±13	±13	±13	±13	V

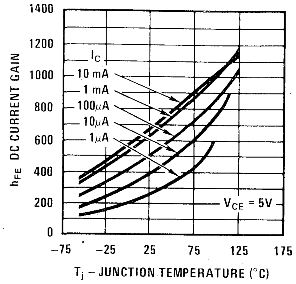
**Assumes ≤ 5 ppm/°C tracking of resistors

typical performance characteristics

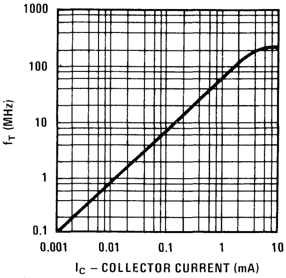
Small Signal Current Gain vs Collector Current



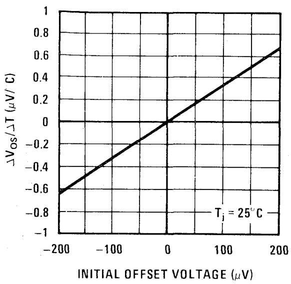
DC Current Gain vs Temperature



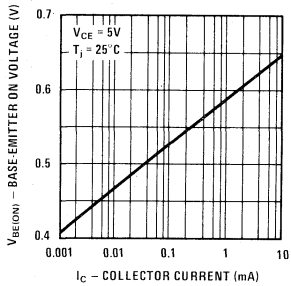
Unity Gain Frequency (ft) vs Collector Current



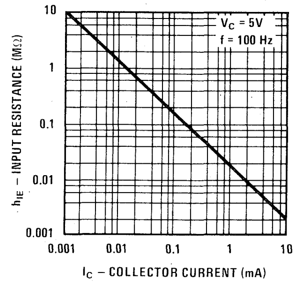
Offset Voltage Drift vs Initial Offset Voltage



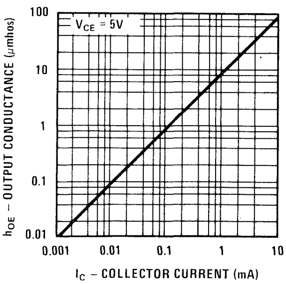
Base-Emitter On Voltage vs Collector Current



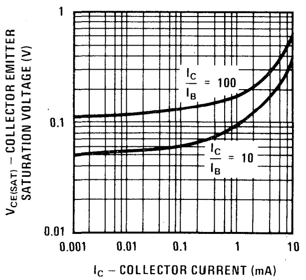
Small Signal Input Resistance (h_{ie}) vs Collector Current



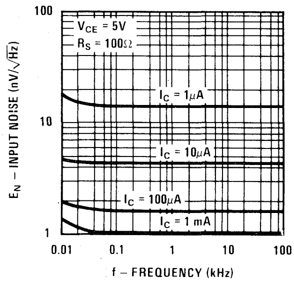
Small Signal Output Conductance vs Collector Current



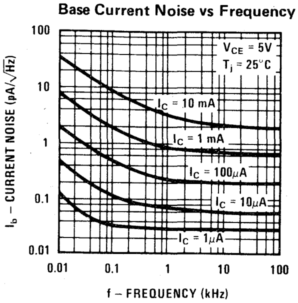
Collector-Emitter Saturation Voltage vs Collector Current



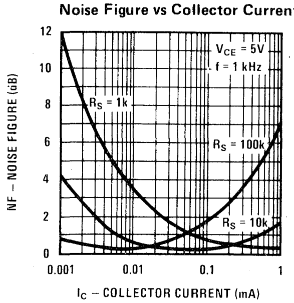
Input Voltage Noise vs Frequency



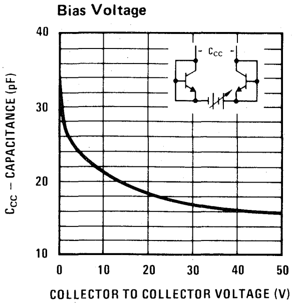
Base Current Noise vs Frequency



Noise Figure vs Collector Current

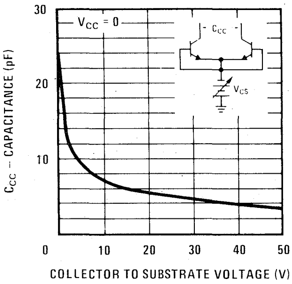


Collector to Collector Capacitance vs Reverse Bias Voltage

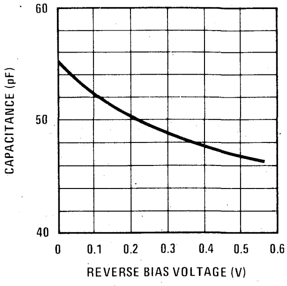


typical performance characteristics (con't)

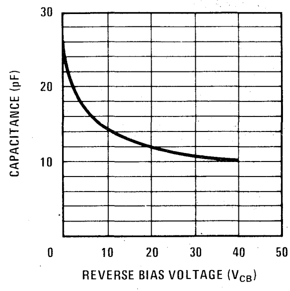
Collector to Collector Capacitance vs Collector-Substrate Voltage



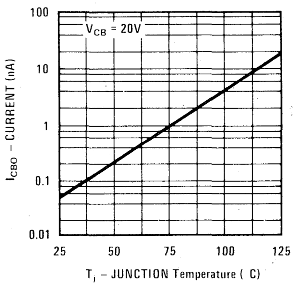
Emitter-Base Capacitance vs Reverse Bias Voltage



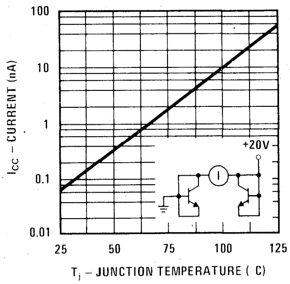
Collector-Base Capacitance vs Reverse Bias Voltage



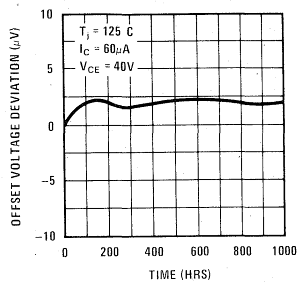
Collector-Base Leakage vs Temperature



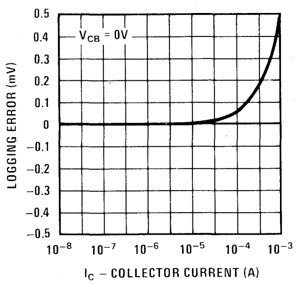
Collector to Collector Leakage vs Temperature



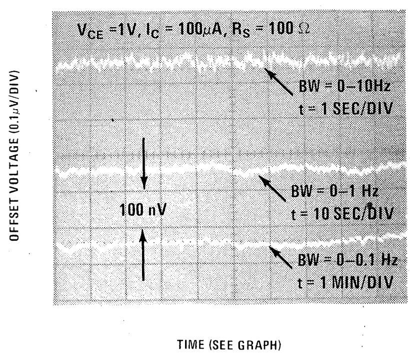
Offset Voltage Long Term Stability at High Temperature



Emitter-Base Log Conformity



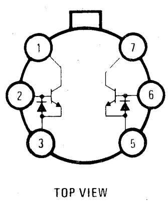
Low Frequency Noise of Differential Pair*



*Unit must be in still air environment so that differential lead temperature is held to less than 0.0003°C.

connection diagram

Metal Can Package



TOP VIEW

Order Number LM194H, LM394H
or LM394BH
See Package 10

Transistor/Diode Arrays

LM195/LM295/LM395 ultra reliable 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.

features

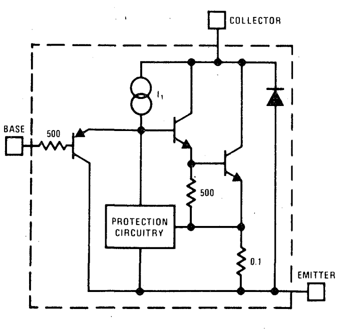
- Internal thermal limiting
- Greater than 1.0A output current
- 3.0μA typical base current
- 500 ns switching time
- 2.0V saturation
- Base can be driven up to 40V without damage
- Directly interfaces with CMOS or TTL

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.

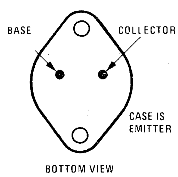
The LM195/LM295/LM395 are available in standard TO-3 power packages and solid Kovar TO-5. The LM195 is rated for operation from −55°C to +150°C, the LM295 from −25°C to +150°C and the LM395 from 0°C to +125°C.

simplified circuit and connection diagrams



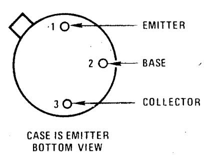
Simplified Circuit of the LM195

TO-3 Metal Can Package



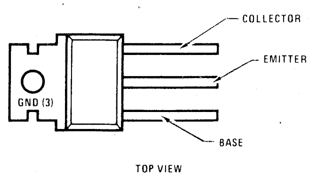
Order Number LM195K, LM295K or LM395K
See Package 18

TO-5 Metal Can Package



Order Number LM195H, LM295H or LM395H
See Package 9

TO-220 Power Package



Order Number LM395T
See Package 26

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)

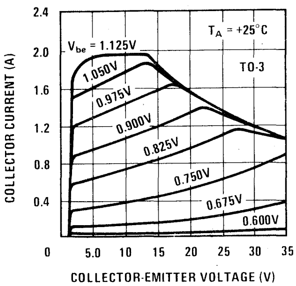
PARAMETER	CONDITIONS	LM195, LM295			LM395			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Collector-Emitter Operating Voltage	$I_Q \leq I_C \leq I_{MAX}$			42			36	V
Base to Emitter Breakdown Voltage	$0 < V_{CE} \leq V_{CEMAX}$	42			36	60		V
Collector Current								
TO-3	$V_{CE} \leq 15V$	1.2	2.0		1.0	2.0		A
TO-5	$V_{CE} \leq 7.0V$	1.2	2.0		1.0	2.0		A
TO-220	$V_{CE} \leq 15V$				1.0	2.0		A
Saturation Voltage	$I_C \leq 1.0A$		1.8	2.0		1.8	2.2	V
Base Current	$0 < I_C < I_{MAX}$ $0 \leq V_{CE} < V_{CEMAX}$		3.0	5.0		3.0	10	μA
Quiescent Current	$V_{be} = 0$ $0 \leq V_{CE} < V_{CEMAX}$		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		2.3	3.0		2.3	3.0	°C/W
	TO-5 Package		12	15		12	15	°C/W

Note 1: Unless otherwise specified, these specifications apply for $-55°C \leq T_j \leq +150°C$ for the LM195, $-25°C \leq T_j \leq +150°C$ for the LM295 and $0°C \leq +125°C$ for the LM395.

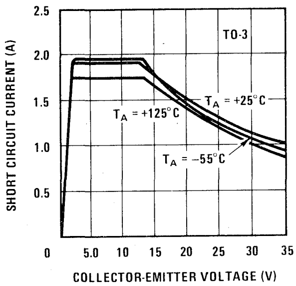
Note 2: Without a heat sink, the thermal resistance of the TO-5 package is about +150°C/W, while that of the TO-3 package is +35°C/W.

typical performance characteristics

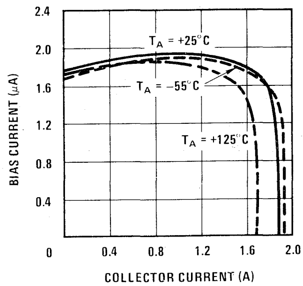
Collector Characteristics



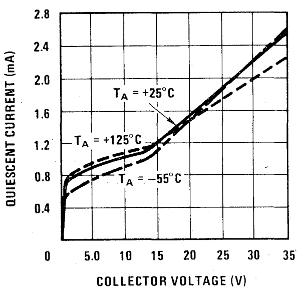
Short Circuit Current



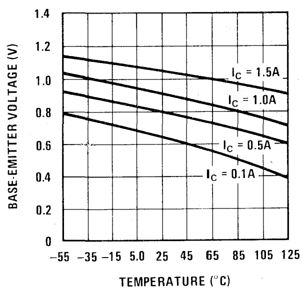
Bias Current



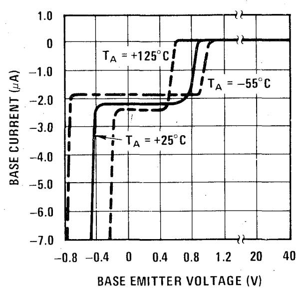
Quiescent Current



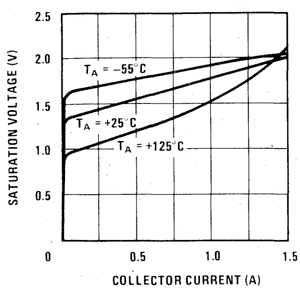
Base Emitter Voltage



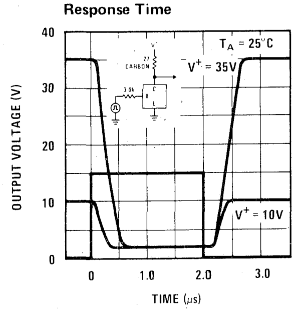
Base Current



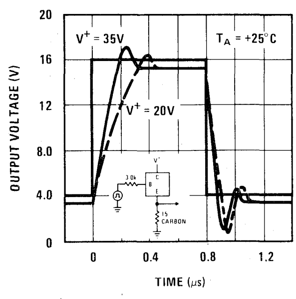
Saturation Voltage



Response Time

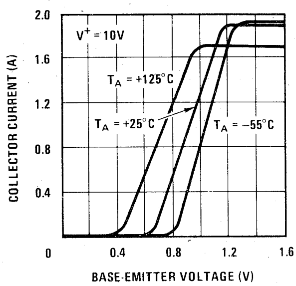


Response Time

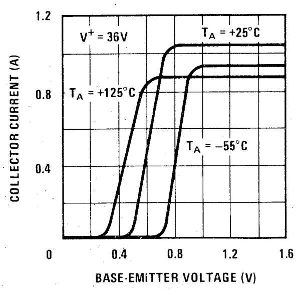


typical performance characteristics (con't)

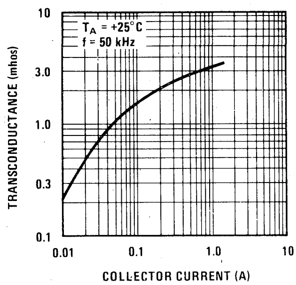
10V Transfer Function



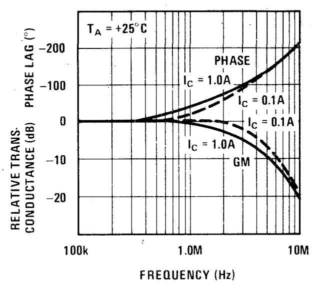
36V Transfer Function



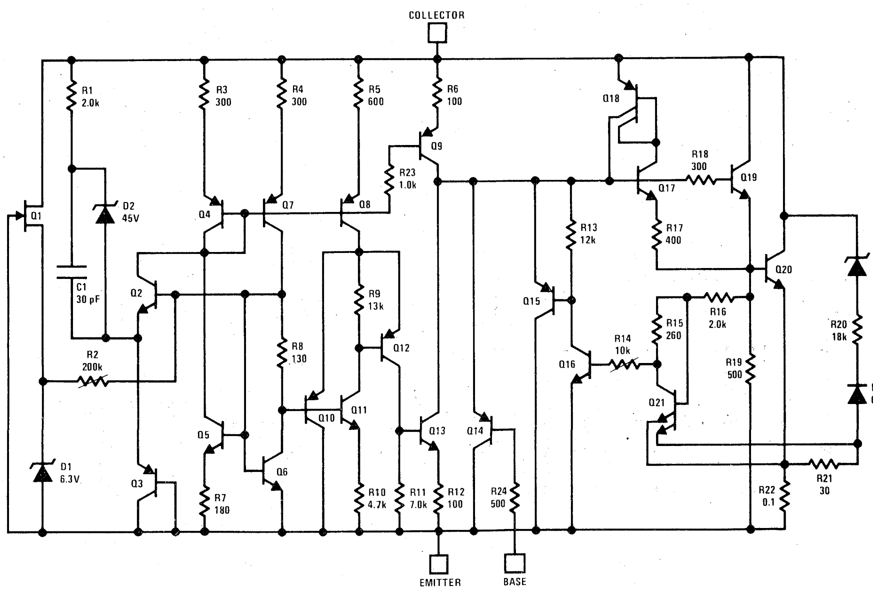
Transconductance



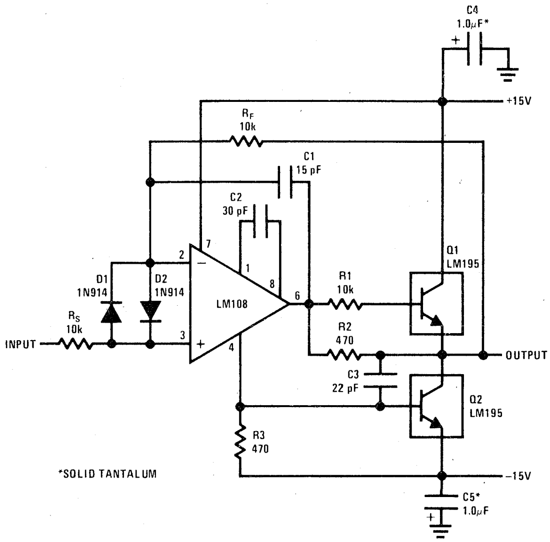
Small Signal Frequency Response



schematic diagram

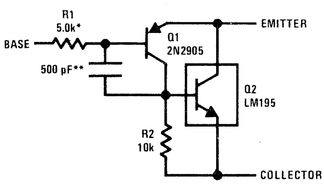


typical applications



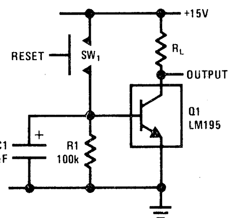
*SOLID TANTALUM

1.0 Amp Voltage Follower

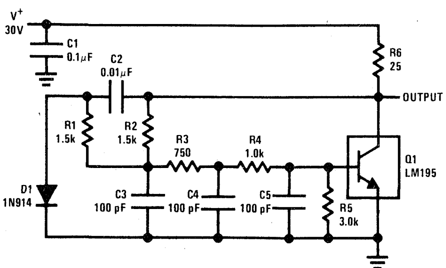


*PROTECTS AGAINST EXCESSIVE BASE DRIVE
**NEEDED FOR STABILITY

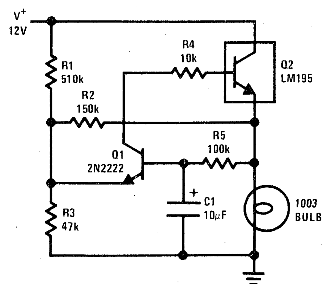
Power PNP



Time Delay

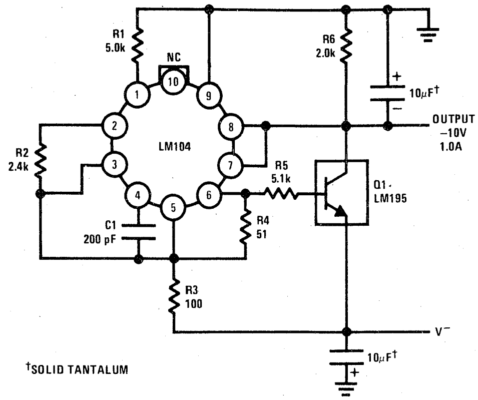


1.0 MHz Oscillator



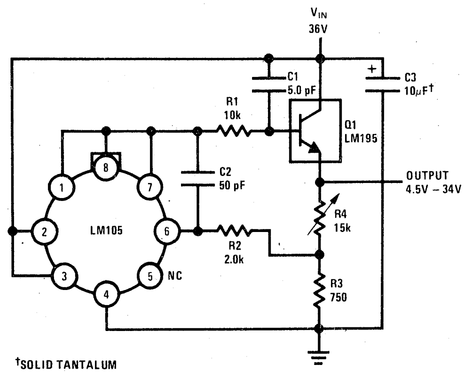
1.0 Amp Lamp Flasher

typical applications (con't)



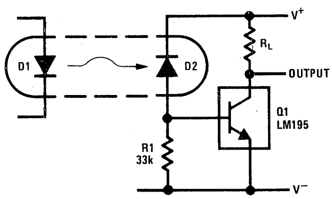
†SOLID TANTALUM

1.0 Amp Negative Regulator

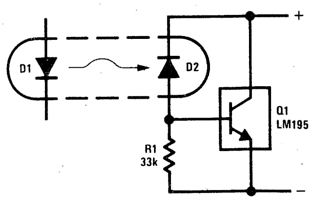


†SOLID TANTALUM

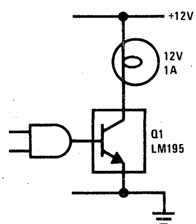
1.0 Amp Positive Voltage Regulator



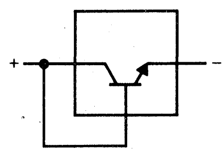
Fast Optically Isolated Switch



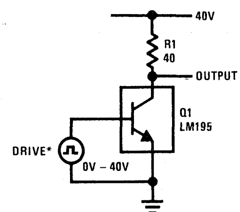
Optically Isolated Power Transistor



CMOS or TTL Lamp Interface



Two Terminal Current Limiter

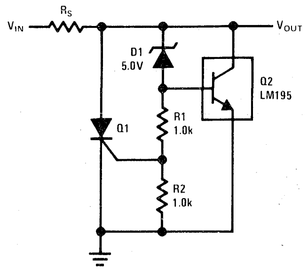


*DRIVE VOLTAGE 0V TO ≥ 1.0V ≤ 42V

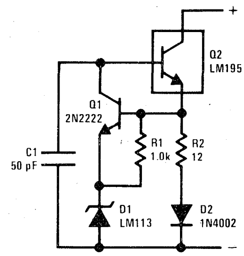
40V Switch

11

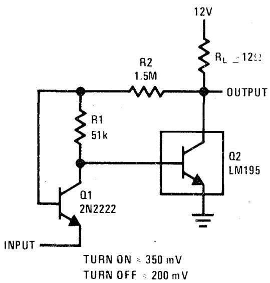
typical applications (con't)



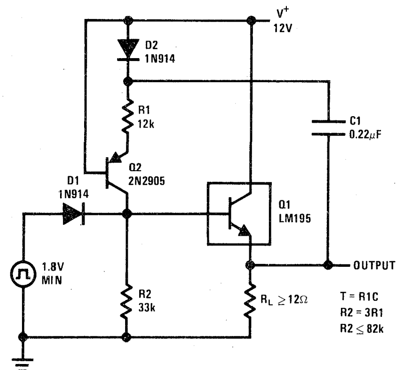
6.0V Shunt Regulator with Crowbar



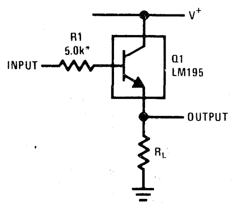
Two Terminal 100 mA Current Regulator



Low Level Power Switch

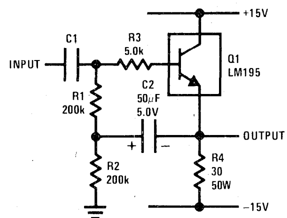


Power One-Shot

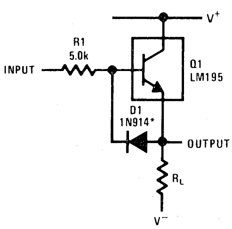


*NEED FOR STABILITY

Emitter Follower



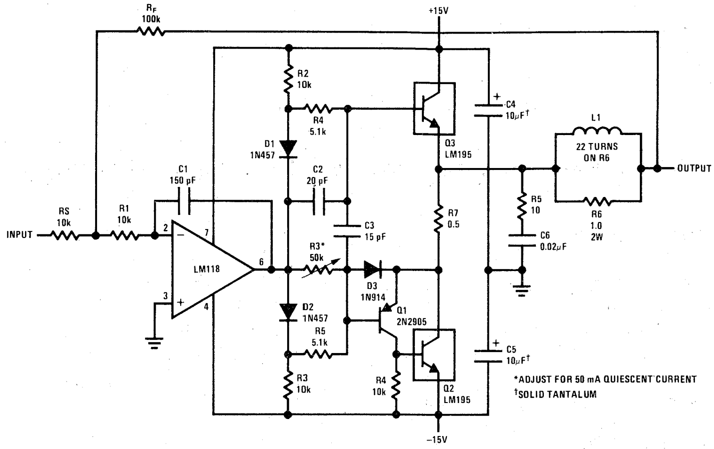
High Input Impedance AC Emitter Follower



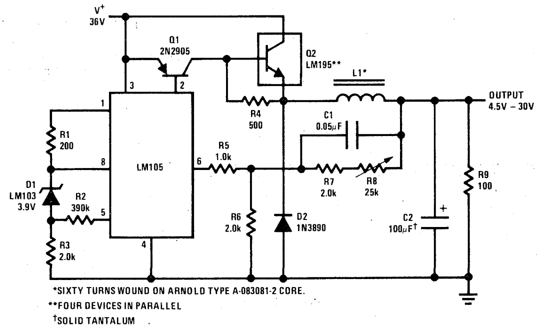
*PREVENTS STORAGE WITH FAST FALL TIME SQUARE WAVE DRIVE

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

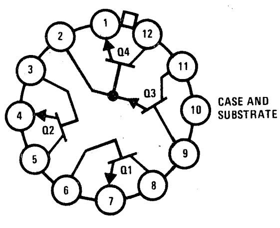
- Matched monolithic general purpose transistors
- H_{FE} matched ±10%
- V_{BE} matched
  - LM3018 ±5 mV
  - LM3018A ±2 mV
- Operation from DC to 120 MHz
- Wide operating current range
- LM3018A performance controlled from 10μA to 10 mA
- Low noise figure 3.2 dB typical at 1 kHz
- Full military temperature 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 ($V_{(BR)CBO}$)	$I_C = 10\mu A, I_E = 0$	20	60		30	60		V
Emitter to Base Breakdown Voltage ($V_{(BR)EBO}$)	$I_E = 10\mu A, I_C = 0$	5	7		5	7		V
Collector to Substrate Breakdown Voltage ($V_{(BR)CIO}$)	$I_C = 10\mu A, I_{CI} = 0$	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 $I_C = 10\mu A$	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 $I_C = 100\mu A$	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} ($V_{9\text{-}1}$))	$V_{CE} = 3V$, $I_E = 10$ 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 $T_A = 25°C$

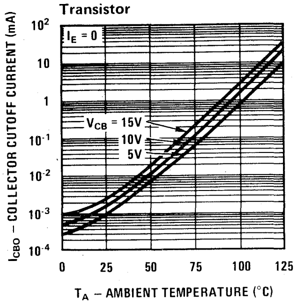
PARAMETER	CONDITIONS	LM3018 MIN	LM3018 TYP	LM3018 MAX	LM3018A MIN	LM3018A TYP	LM3018A MAX	UNITS
DYNAMIC CHARACTERISTICS								
Low Frequency Noise Figure (NF)	f = 1 kHz, $V_{CE} = 3V$, $I_C = 100\mu A$, Source Resistance = 1 kΩ		3.25			3.25		dB
Low Frequency, Small-Signal Equivalent Circuit Characteristics:								
Forward Current Transfer Ratio (h_{fe})	f = 1 kHz, $V_{CE} = 3V$, $I_C = 1$ mA		110			110		
Short Circuit Input Impedance (h_{ie})	f = 1 kHz, $V_{CE} = 3V$, $I_C = 1$ mA		3.5			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 −j1.5			31 −j1.5		mmho
Input Admittance (Y_{ie})	f = 1 MHz, $V_{CE} = 3V$, $I_C = 1$ mA		.3 +j0.04			.3 +j0.04		mmho
Output Admittance (Y_{oe})	f = 1 MHz, $V_{CE} = 3V$, $I_C = 1$ mA		.001 +j0.03			.001 +j0.03		mmho
Reverse Transfer Admittance (Y_{re})	f = 1 MHz, $V_{CE} = 3V$, $I_C = 1$ mA		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 $T_A > 85°C$

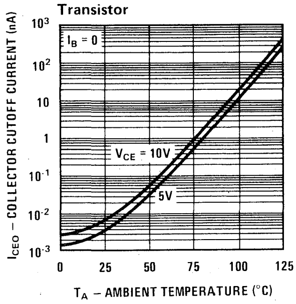
Note 2: The collector of each transistor of the LM3018 and LM3018A is isolated from the substrate by an integral diode. The substrate (terminal 10) must be connected to the most negative point in the external circuit to maintain isolation between transistors and to provide for normal transistor action.

typical performance characteristics

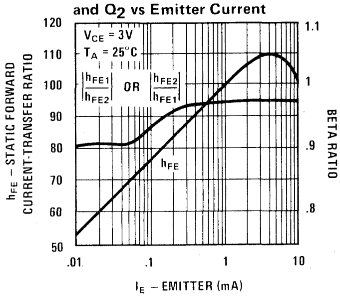
Typical Collector-To-Base Cutoff Current vs Ambient Temperature for Each Transistor



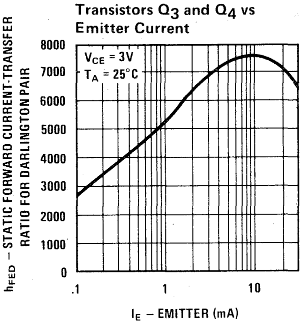
Typical Collector-To-Emitter Cutoff Current vs Ambient Temperature for Each Transistor



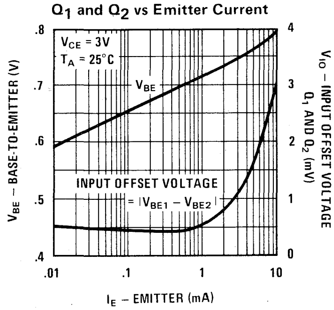
Typical Static Forward Current-Transfer Ratio and Beta Ratio for Transistors Q_1 and Q_2 vs Emitter Current



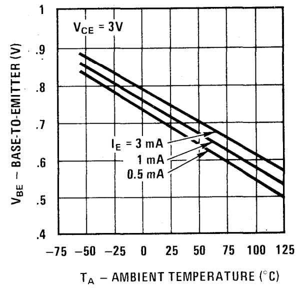
Typical Static Forward Current-Transfer Ratio for Darlington-connected Transistors Q_3 and Q_4 vs Emitter Current



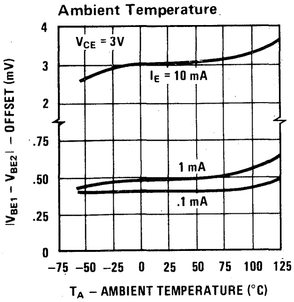
Typical Static Base-To-Emitter Voltage Characteristic and Input Offset Voltage for Q_1 and Q_2 vs Emitter Current



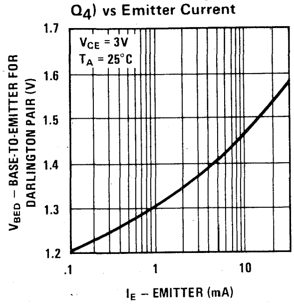
Typical Base-To-Emitter Voltage Characteristic for Each Transistor vs Ambient Temperature



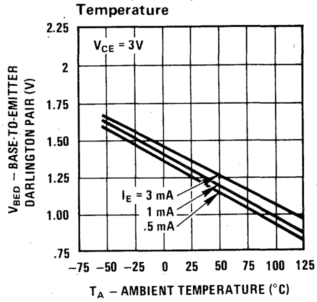
Typical Offset Voltage Characteristic vs Ambient Temperature



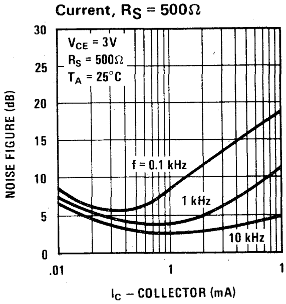
Typical Static Input Voltage Characteristic for Darlington Pair (Q_3 and Q_4) vs Emitter Current



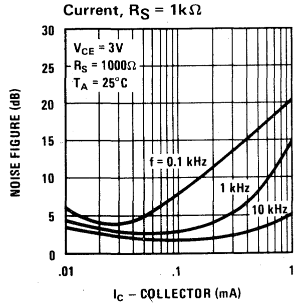
Typical Static Input Voltage Characteristic for Darlington Pair (Q_3 and Q_4) vs Ambient Temperature



Noise Figure vs Collector Current, $R_S = 500\Omega$

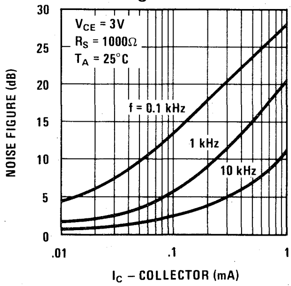


Noise Figure vs Collector Current, $R_S = 1k\Omega$

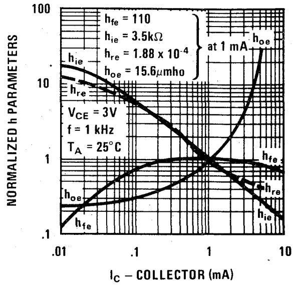


typical performance characteristics (con't)

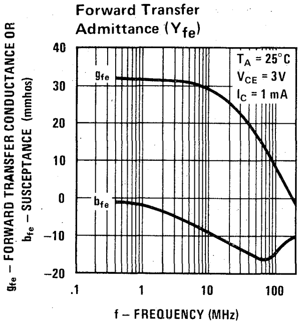
Noise Figure vs Collector Current, $R_S = 10k\Omega$



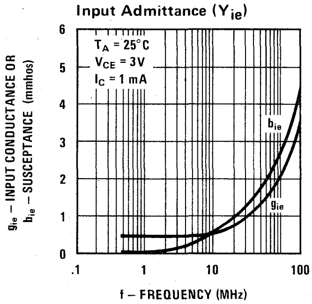
Forward Current-Transfer Ratio (h_{fe}), Short-Circuit Input Impedance (h_{ie}), Open-Circuit Output Impedance (h_{oe}), and Open-Circuit Reverse Voltage-Transfer Ratio (h_{re}) vs Collector Current



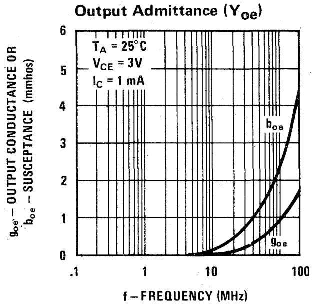
Forward Transfer Admittance (Y_{fe})



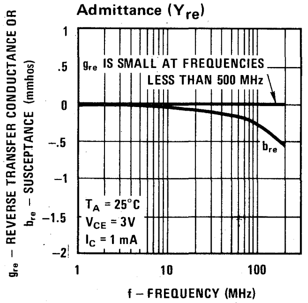
Input Admittance (Y_{ie})



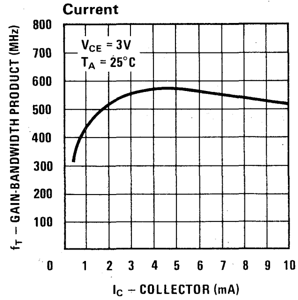
Output Admittance (Y_{oe})



Reverse Transfer Admittance (Y_{re})



Typical Gain-Bandwidth Product (f_T) vs Collector Current



11

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

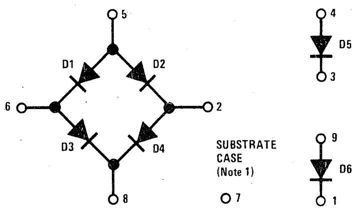
features

- Excellent diode match
- Low leakage current
- Low pedestal voltage when gating
- Built-in temperature stability for operation from −55°C to +125°C

applications

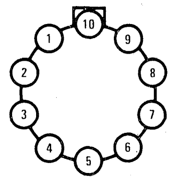
- Modulator
- Mixer
- Balanced modulator
- Analog switch
- Diode gate for chopper-modulator applications

schematic and connection diagrams



NOTE 1: CONNECT TO MOST NEGATIVE CIRCUIT POTENTIAL.

Metal Can Package



Order Number LM3019H
See Package 12

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

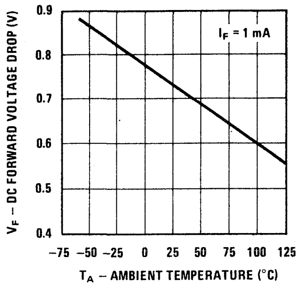
Power Dissipation	
Any One Diode Unit	20 mW
Total For Device	120 mW
Storage Temperature Range	−65°C to +200°C
Operating Temperature Range	−55°C to +125°C
Lead Temperature (Soldering, 10 seconds)	300°C

electrical characteristics for each diode unit, unless otherwise specified, T_A = 25°C.

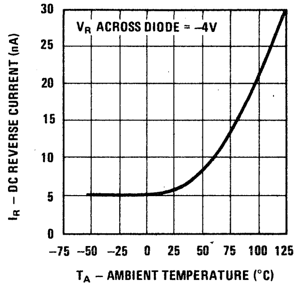
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
DC Forward Voltage Drop (V_F)	DC Forward Current I_F = 1 mA		.73	.78	V
DC Reverse Breakdown Voltage ($V_{(BR)R}$)	DC Reverse Current I_R = −10μA	4	6		V
DC Reverse Breakdown Voltage Between Any Diode Unit and Substrate ($V_{(BR)R}$)	DC Reverse Current I_R = −10μA	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 ($C_{DQ\text{-}1}$)	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

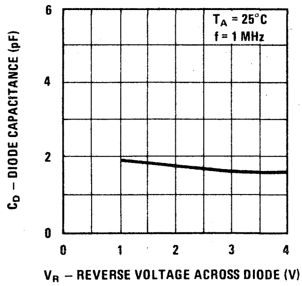
DC Forward Voltage Drop (Any Diode) vs Temperature



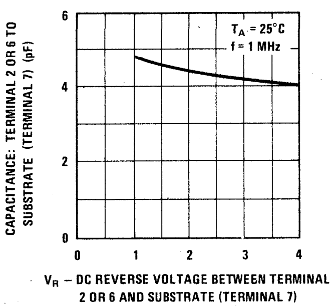
Reverse (Leakage) Current (Any Diode) vs Temperature



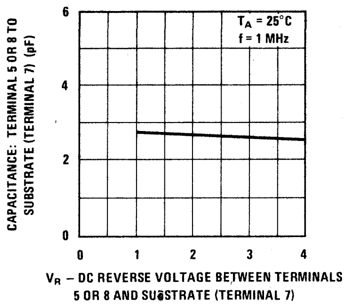
Diode Capacitance (Any Diode) vs Reverse Voltage



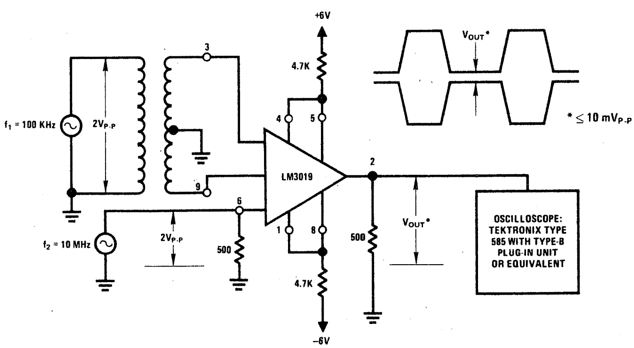
Diode Quad-To-Substrate Capacitance vs Reverse Voltage



Diode Quad-To-Substrate Capacitance vs Reverse Voltage



series gate switching test setup



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

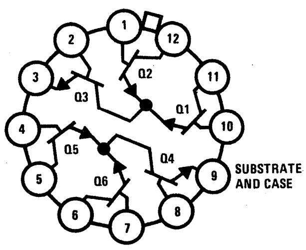
- Two differential amplifiers on a common substrate
- Independently accessible inputs and outputs
- Maximum input offset voltage ±5 mV
- Full military temperature range capability −55°C to +125°C
- Limited temperature range, LM3054 −40°C to +85°C

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

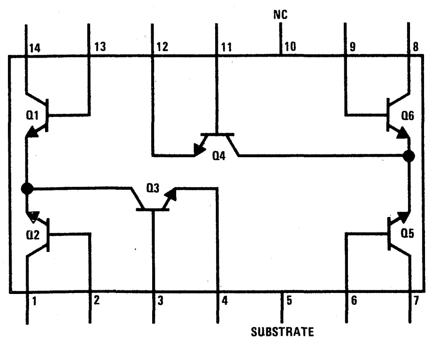
Metal Can Package



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})			.45	5	mV
Input Offset Current (I_{IO})			.3	2	μA
Input Bias Current (I_I)	V_{CB} = 3V		10	24	μA
Quiescent Operating Current Ratio $\left(\frac{I_{C(Q1)}}{I_{C(Q2)}} \text{ or } \frac{I_{C(Q5)}}{I_{C(Q6)}}\right)$	$I_{E(Q3)} = I_{E(Q4)}$ = 2 mA		.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 μA		.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 = 10μA, I_E = 0	20	60		V
Collector to Substrate Breakdown Voltage ($V_{(BR)CIO}$)	I_C = 10μA, I_{CI} = 0	20	60		V
Emitter to Base Breakdown Voltage ($V_{(BR)EBO}$)	I_E = 10μA, 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)			100		dB
AGC Range, One Stage (AGC)	V_{CC} = 12V, V_{EE} = −6V, V_x = −3.3V, f = 1 kHz		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)					

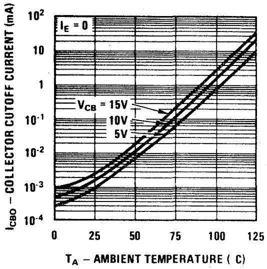
Note: The collector of each transistor of the LM3026 and LM3054 is isolated from the substrate by an integral diode. The substrate must be connected to a voltage which is more negative than any collector voltage in order to maintain isolation between transistors and provide for normal transistor action. 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)

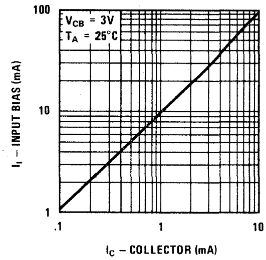
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Forward Transfer Admittance (y_{21})	V_{CB} = 3V Each Collector $I_C \approx$ 1.25 mA f = 1 MHz		−20 + j0		mmho
Input Admittance (y_{11})			.22 + j0.1		mmho
Output Admittance (y_{22})			.01 + j0		mmho
Reverse Transfer Admittance (y_{12})			−0.003 + j0		mmho
Admittance Characteristics; Cascode Circuit Configuration: (For Each Amplifier)					
Forward Transfer Admittance (y_{21})	V_{CB} = 3V Total Stage $I_C \approx$ 2.5 mA f = 1 MHz		68 − j0		mmho
Input Admittance (y_{11})			.55 + j0		mmho
Output Admittance (y_{22})			0 + j0.02		mmho
Reverse Transfer Admittance (y_{12})			.004 − j.005		μmho
Noise Figure (NF)	f = 100 MHz		8		dB

typical performance characteristics

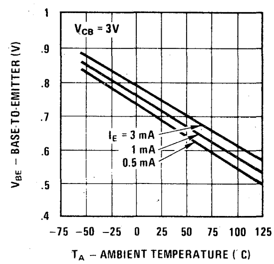
Collector-To-Base Cutoff Current vs Ambient Temperature for Each Transistor



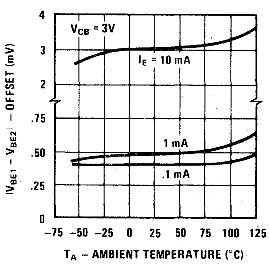
Input Bias Current Characteristic vs Collector Current for Each Transistor



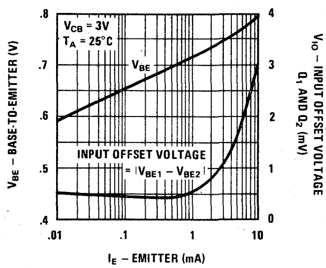
Base-To-Emitter Voltage Characteristic for Each Transistor vs Ambient Temperature



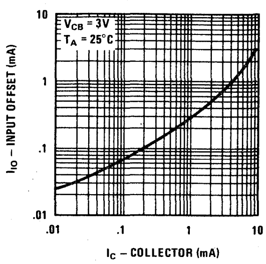
Offset Voltage Characteristic vs Ambient Temperature for Differential Pairs



Static Base-To-Emitter Voltage Characteristic and Input Offset Voltage for Differential Pairs vs Emitter Current

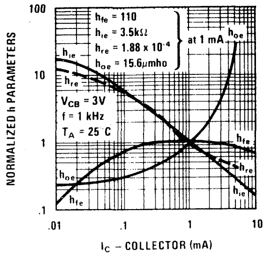


Input Offset Current for Matched Differential Pairs vs Collector Current

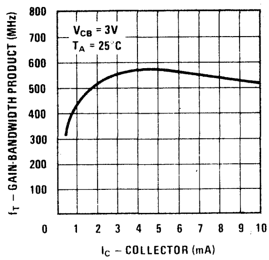


typical performance characteristics (con't)

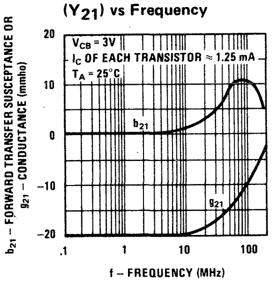
Forward Current-Transfer Ratio (h_{fe}), Short-Circuit Input Impedance (h_{ie}), Open-Circuit Output Impedance (h_{oe}), and Open-Circuit Reverse Voltage-Transfer Ratio (h_{re}) vs Collector Current for Each Transistor



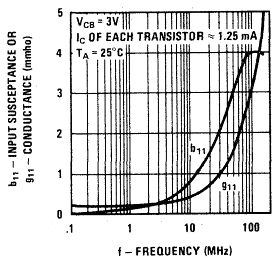
Gain-Bandwidth Product (f_T) vs Collector Current



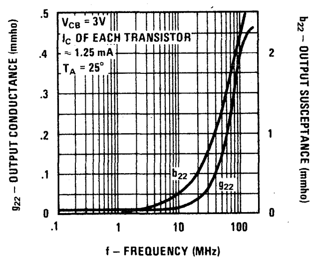
Forward Transfer Admittance (Y_{21}) vs Frequency



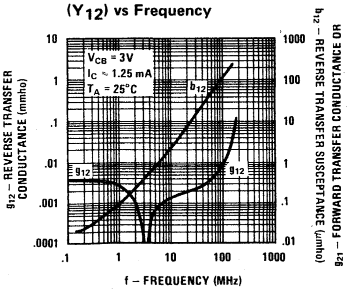
Input Admittance (Y_{11})



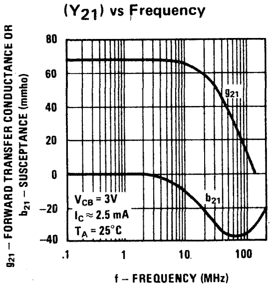
Output Admittance (Y_{22}) vs Frequency



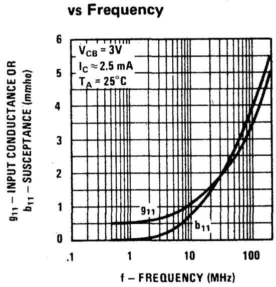
Reverse Transfer Admittance (Y_{12}) vs Frequency



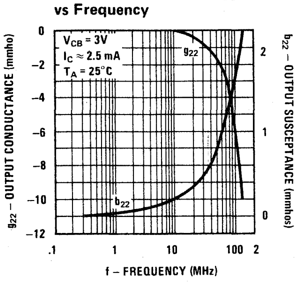
Forward Transfer Admittance (Y_{21}) vs Frequency



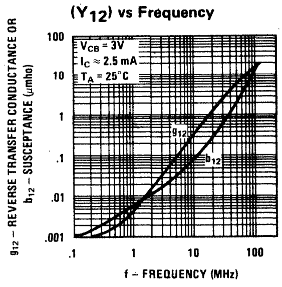
Input Admittance (Y_{11}) vs Frequency



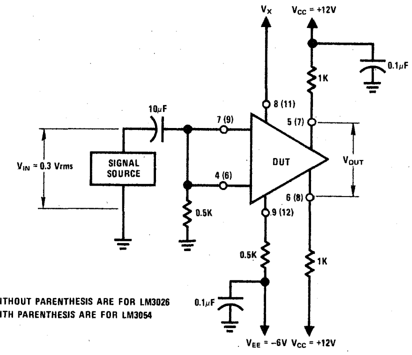
Output Admittance (Y_{22}) vs Frequency



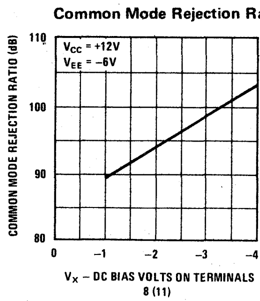
Reverse Transfer Admittance (Y_{12}) vs Frequency

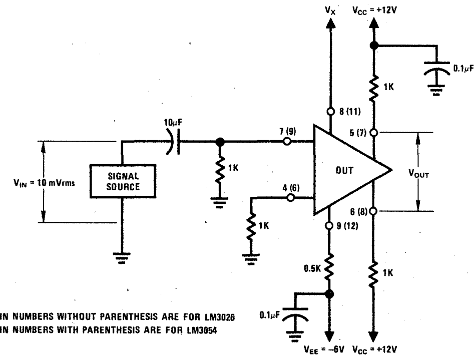


typical performance characteristics (con't)

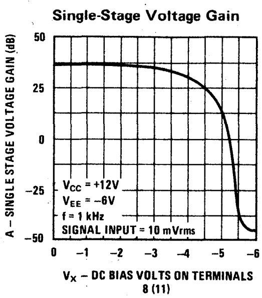


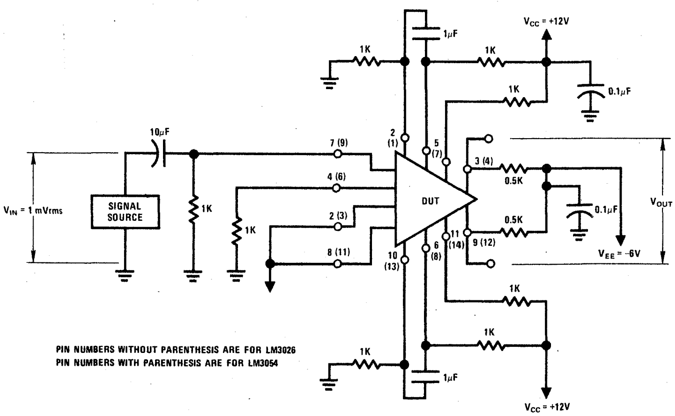
PIN NUMBERS WITHOUT PARENTHESIS ARE FOR LM3026
PIN NUMBERS WITH PARENTHESIS ARE FOR LM3054



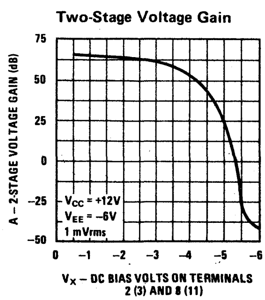


PIN NUMBERS WITHOUT PARENTHESIS ARE FOR LM3026
PIN NUMBERS WITH PARENTHESIS ARE FOR LM3054





PIN NUMBERS WITHOUT PARENTHESIS ARE FOR LM3026
PIN NUMBERS WITH PARENTHESIS ARE FOR LM3054



maximum pin voltages

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

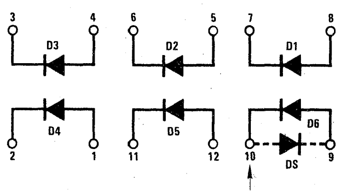
- Excellent reverse recovery time — 1 ns typ
- Matched monolithic construction — V_F matched within 5 mV
- Low diode capacitance — C_D = .65 pF typ at V_R = −2V

applications

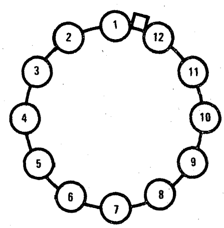
- Balanced modulators or demodulators
- Ring modulators
- High speed diode gates
- Analog switches

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

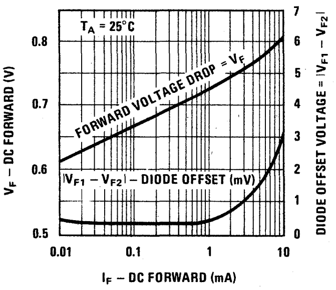
electrical characteristics

(T_A = 25°C) Characteristics apply for each diode unit, unless otherwise specified.

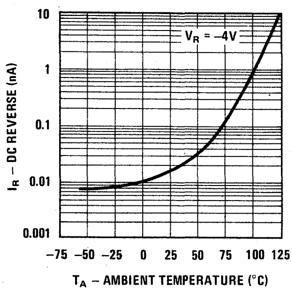
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
DC Forward Voltage Drop (V_F)	$I_F = 50\mu A$		.65	.69	V
	1 mA		.73	.78	V
	3 mA		.76	.80	V
	10 mA		.81	.90	V
DC Reverse Breakdown Voltage ($V_{(BR)R}$)	$I_R = -10\mu A$	5	7		V
DC Reverse Breakdown Voltage Between Any Diode Unit and Substrate ($V_{(BR)R}$)	$I_R = -10\mu A$	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) ($\lvert V_{F_1} - V_{F_2}\rvert$)	I_F = 1 mA		.5	5	mV
Temperature Coefficient of $\lvert V_{F_1} - V_{F_2}\rvert$ $\left(\frac{\Delta\lvert V_{F_1} - V_{F_2}\rvert}{\Delta T}\right)$	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

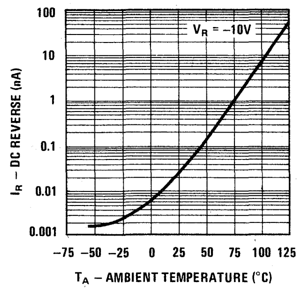
DC Forward Voltage Drop (Any Diode) and Diode Offset Voltage vs DC Forward Current



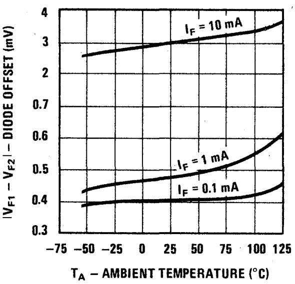
DC Reverse (Leakage) Current (Diodes 1, 2, 3, 4, 5) vs Temperature



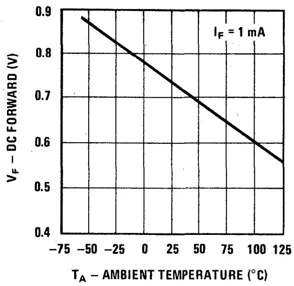
DC Reverse (Leakage) Current Between Diodes (1, 2, 3, 4, 5) and Substrate vs Temperature



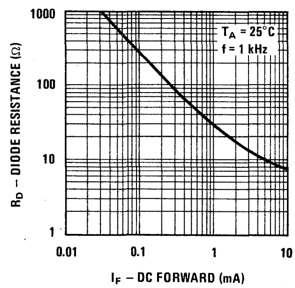
Diode Offset Voltage (Any Diode) vs Temperature



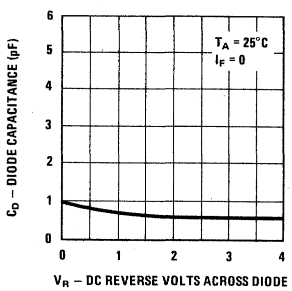
DC Forward Voltage Drop (Any Diode) vs Temperature



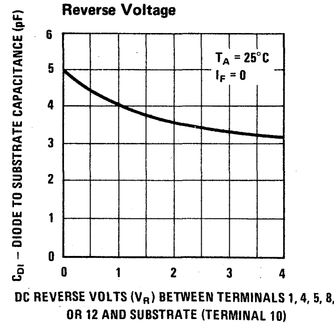
Diode Resistance (Any Diode) vs DC Forward Current



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

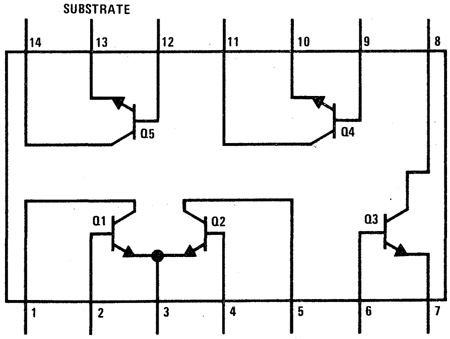
- Two matched pairs of transistors
  - V_{BE} matched ±5 mV
  - Input offset current 2μA max at I_C = 1 mA
- Five general purpose monolithic transistors
- Operation from DC to 120 MHz
- Wide operating current range
- Low noise figure 3.2 dB typ at 1 kHz
- Full military temperature range (LM3045) −55°C 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

Order Number LM3045J
See Package 16

Order Number LM3046N
or LM3086N
See Package 22

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		−40°C to +85°C		
Storage Temperature Range	−65°C to +150°C		−65°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 = 10μA, 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 = 10μA, I_{CI} = 0	20	60		20	60		V
Emitter to Base Breakdown Voltage ($V_{(BR)EBO}$)	I_E = 10μA, 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 μA	40	100 100 54		40	100 100 54		
Input Offset Current for Matched Pair Q_1 and Q_2 $\|I_{O1} - I_{IO2}\|$	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 $\left(\frac{\Delta V_{10}}{\Delta T}\right)$	V_{CE} = 3V, I_C = 1 mA		1.1					μV/°C

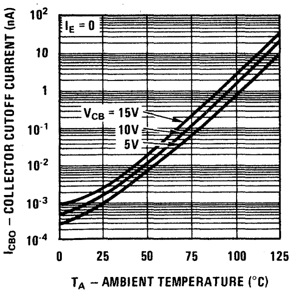
Note 1: The collector of each transistor of the LM3045, LM3046, and LM3086 is isolated from the substrate by an integral diode. The substrate (terminal 13) must be connected to the most negative point in the external circuit to maintain isolation between transistors and to provide for normal transistor action.

electrical characteristics (con't)

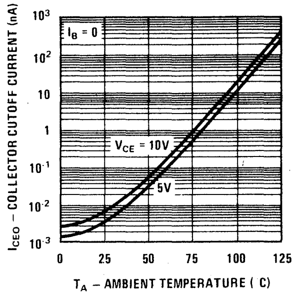
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Low Frequency Noise Figure (NF)	f = 1 kHz, V_{CE} = 3V, I_C = 100μA R_S = 1 kΩ		3.25		dB
Low Frequency, Small Signal Equivalent Circuit Characteristics:					
Forward Current Transfer Ratio (h_{fe})	f = 1 kHz, V_{CE} = 3V, I_C = 1 mA		110 (LM3045, LM3046) (LM3086)		
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})			1.8×10^{-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

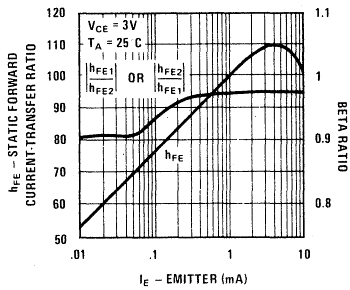
Typical Collector To Base Cutoff Current vs Ambient Temperature for Each Transistor



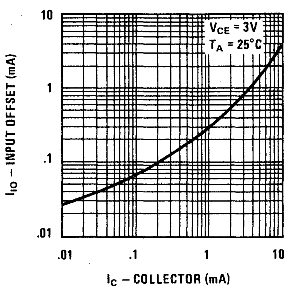
Typical Collector To Emitter Curoff Current vs Ambient Temperature for Each Transistor



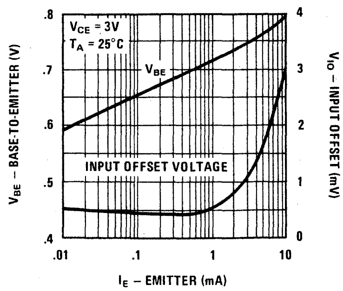
Typical Static Forward Current-Transfer Ratio and Beta Ratio for Transistors Q_1 and Q_2 vs Emitter Current



Typical Input Offset Current for Matched Transistor Pair Q_1 Q_2 vs Collector Current

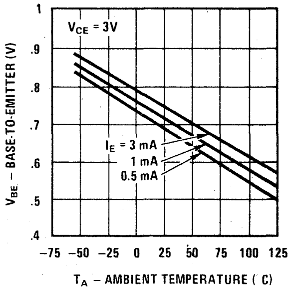


Typical Static Base To Emitter Voltage Characteristic and Input Offset Voltage for Differential Pair and Paired Isolated Transistors vs Emitter Current

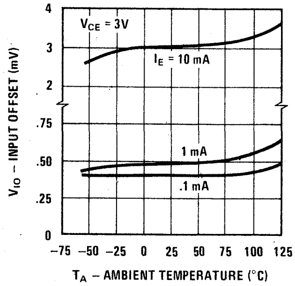


typical performance characteristics (con't)

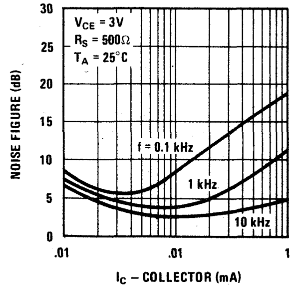
Typical Base To Emitter Voltage Characteristic for Each Transistor vs Ambient Temperature



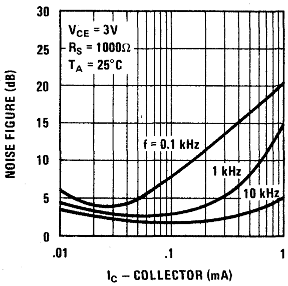
Typical Input Offset Voltage Characteristics for Differential Pair and Paired Isolated Transistors vs Ambient Temperature



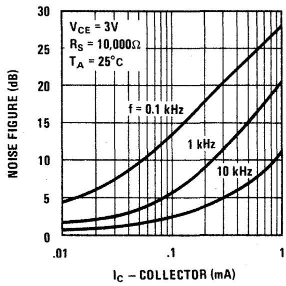
Typical Noise Figure vs Collector Current



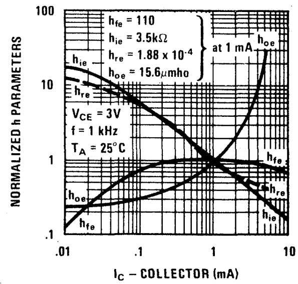
Typical Noise Figure vs Collector Current



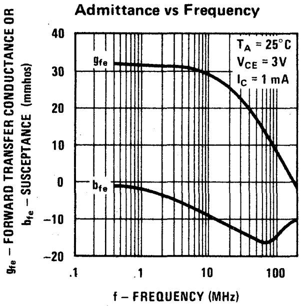
Typical Noise Figure vs Collector Current



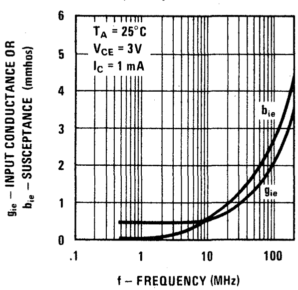
Typical Normalized Forward Current Transfer Ratio, Short Circuit Input Impedance, Open Circuit Output Impedance, and Open Circuit Reverse Voltage Transfer Ratio vs Collector Current



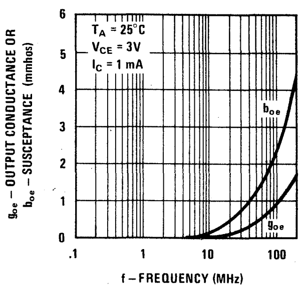
Typical Forward Transfer Admittance vs Frequency



Typical Input Admittance vs Frequency

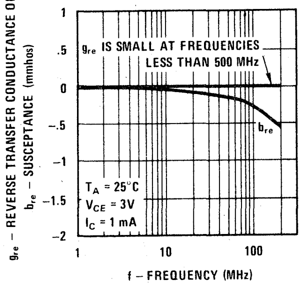


Typical Output Admittance vs Frequency

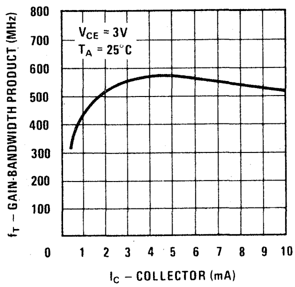


typical performance characteristics (con't)

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

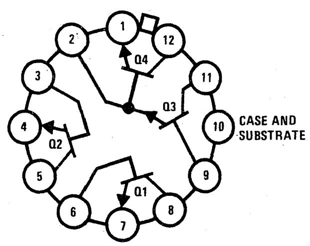
- High voltage matched monolithic general purpose transistors
- h_{FE} matched ±10%
- V_{BE} matched ±5 mV
- Operation from dc to 120 MHz
- Wide operating current range
- Low noise figure 3.2 dB typ at 1 kHz
- Full military temperature range capability −55°C to +125°C

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 ($V_{(BR)CBO}$)	$I_C = 10\mu A$, $I_E = 0$	50	72		40	72		V
Emitter to Base Breakdown Voltage ($V_{(BR)EBO}$) (Note 3)	$I_E = 10\mu A$, $I_C = 0$	5	7		5	7		V
Collector to Substrate Breakdown Voltage ($V_{(BR)CIO}$)	$I_{CI} = 10\mu A$, $I_B = 0$, $I_E = 0$	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 $V_{CE} = 5V$, $I_C = 10\mu A$	 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						UNITS
		LM3118A			LM3118			
		MIN	TYP	MAX	MIN	TYP	MAX	
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 $T_A > +85°C$.

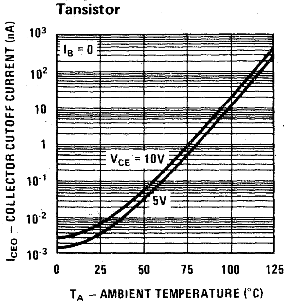
Note 2: The collector of each transistor is isolated from the substrate by an integral diode. The substrate must be connected to a voltage which is more negative than any collector voltage in order to maintain isolation between transistors and provide normal transistor action. To avoid undesired coupling 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.

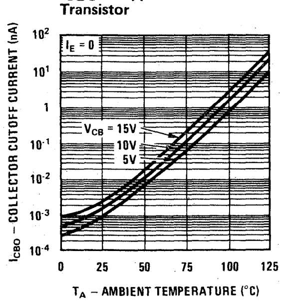
Note 4: See curve.

typical performance characteristics

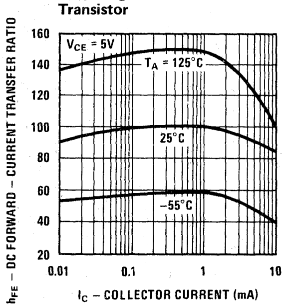
I_{CEO} vs T_A for Any Tansistor



I_{CBO} vs T_A for Any Transistor



h_{FE} vs I_C for Any Transistor



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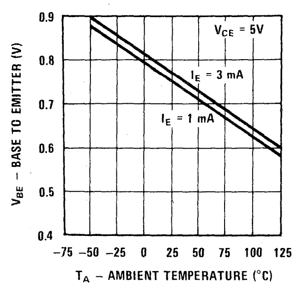
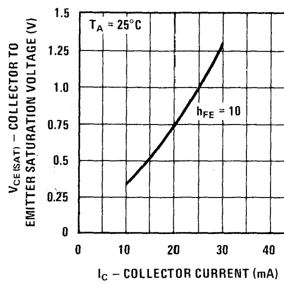
typical performance characteristics (con't)

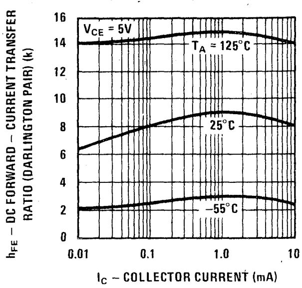
V_{BE} vs T_A for Any Transistor



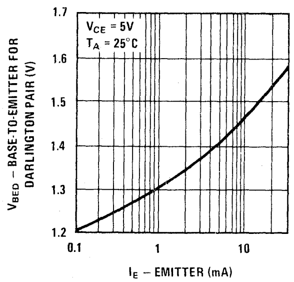
$V_{CE(SAT)}$ vs I_C for Any Transistor



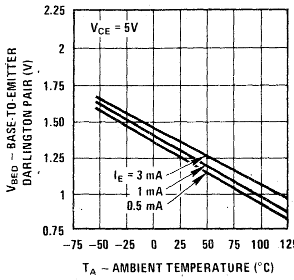
h_{FE} vs I_C for Darlington Pair (Q3 and Q4)



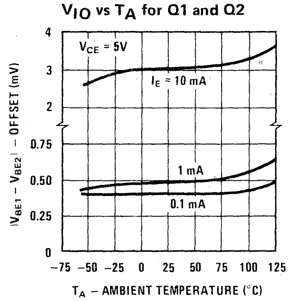
V_{BE} vs I_E for Darlington Pair (Q3 and Q4)



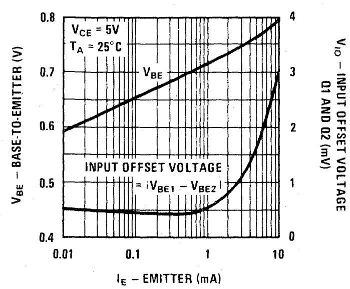
V_{BE} vs T_A for Darlington Pair (Q3 and Q4)



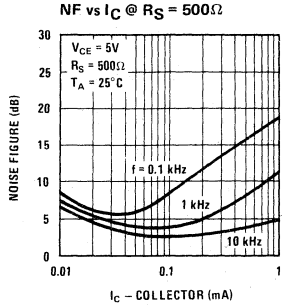
V_{IO} vs T_A for Q1 and Q2



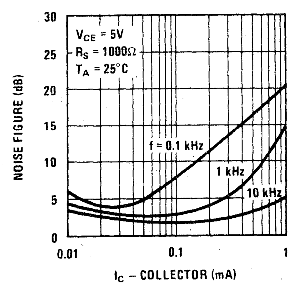
V_{BE} and V_{IO} vs I_E for Q1 and Q2



NF vs I_C @ $R_S = 500\Omega$

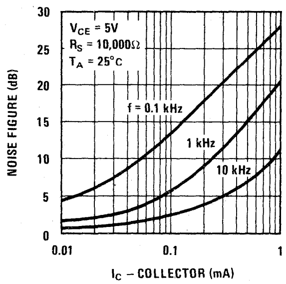


NF vs I_C @ $R_S = 1\ k\Omega$

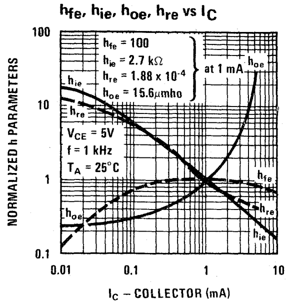


typical performance characteristics (con't)

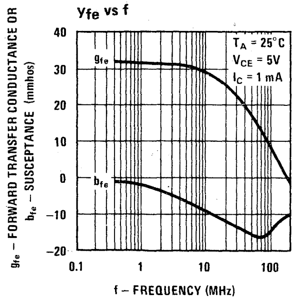
NF vs I_C @ R_S = 10 kΩ



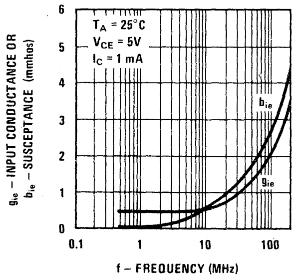
h_{fe}, h_{ie}, h_{oe}, h_{re} vs I_C



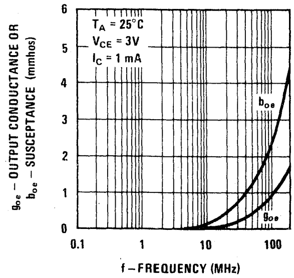
y_{fe} vs f



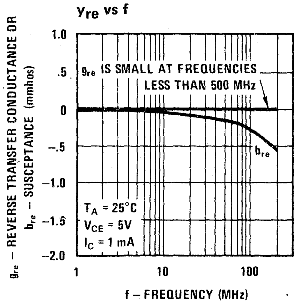
y_{ie} vs f



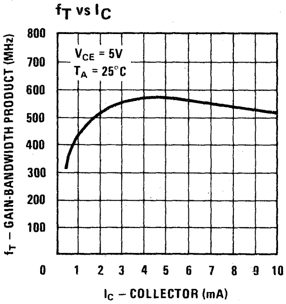
y_{oe} vs f



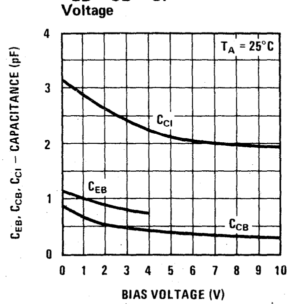
y_{re} vs f



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

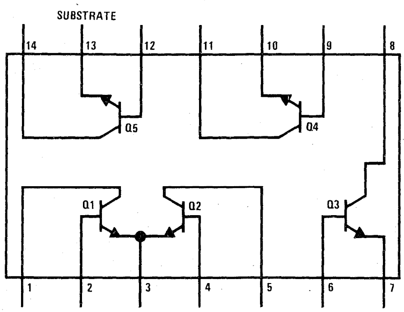
- High voltage matched pairs of transistors, V_{BE} matched ±5 mV, input offset current 2μA max at I_C = 1 mA
- Five general purpose monolithic transistors
- Operation from dc to 120 MHz
- Wide operating current range
- Low noise figure 3.2 dB typ at 1 kHz
- Full military temperature range (LM3145) −55°C 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 LM3145J or LM3145AJ
See Package 16

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

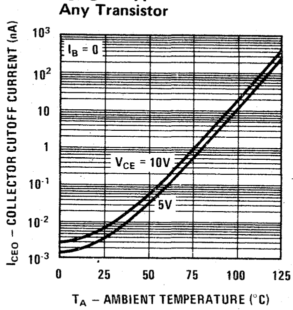
Note 1: The collector of each transistor is isolated from the substrate by an integral diode. The substrate must be connected to a voltage which is more negative than any collector voltage in order to maintain isolation between transitors and provide normal transistor action. To avoid undesired coupling 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.

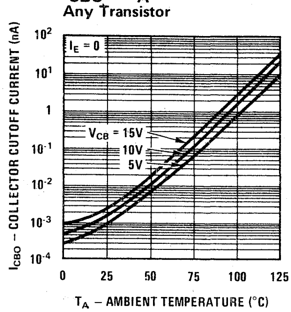
Note 3: See curve.

typical performance characteristics

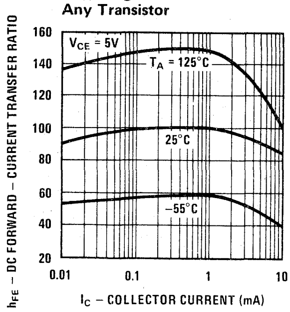
I_{CEO} vs T_A for Any Transistor



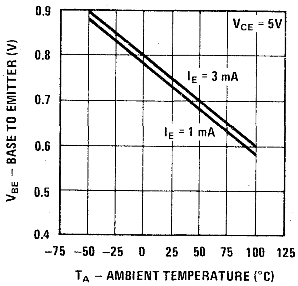
I_{CBO} vs T_A for Any Transistor



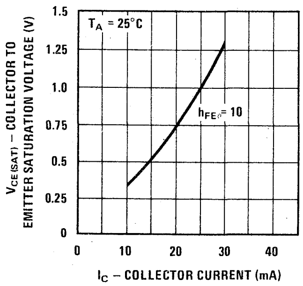
h_{FE} vs I_C for Any Transistor



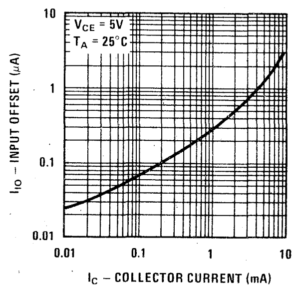
V_{BE} vs T_A for Any Transistor



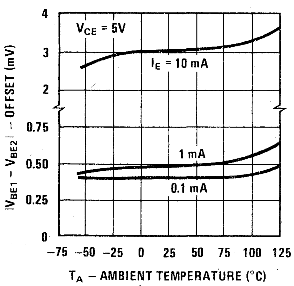
$V_{CE(SAT)}$ vs I_C for Any Transistor



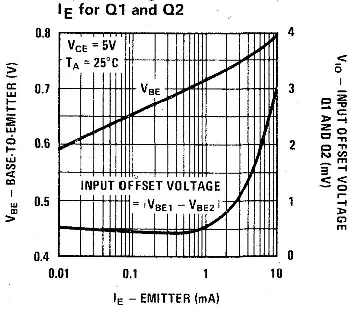
I_{IO} vs I_C (Q1 and Q2)



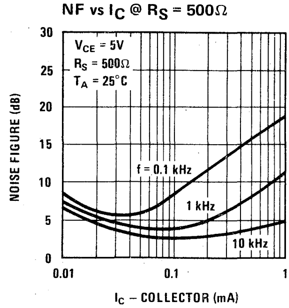
V_{IO} vs T_A for Q1 and Q2



V_{BE} and V_{IO} vs I_E for Q1 and Q2

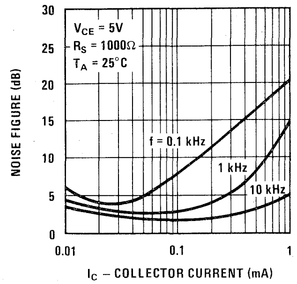


NF vs I_C @ R_S = 500Ω

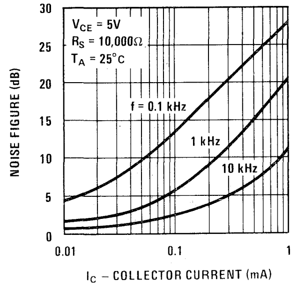


typical performance characteristics (con't)

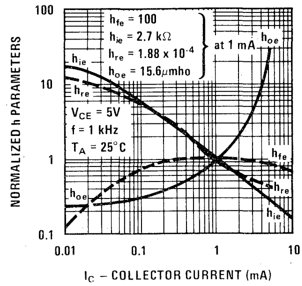
NF vs I_C @ R_S = 1 kΩ



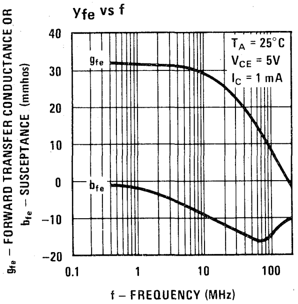
NF vs I_C = R_S = 10 kΩ



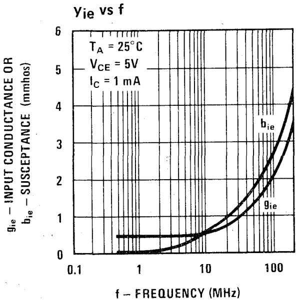
h_{fe}, h_{ie}, h_{oe}, h_{re} vs I_C



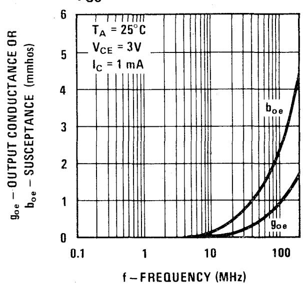
y_{fe} vs f



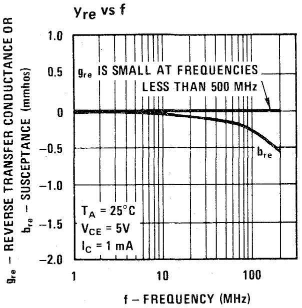
y_{ie} vs f



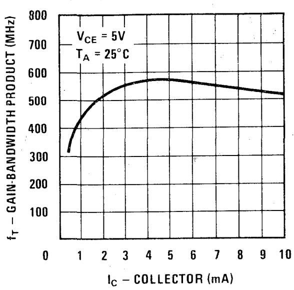
y_{oe} vs f



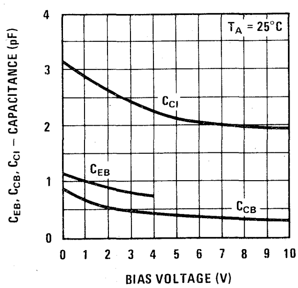
y_{re} vs f



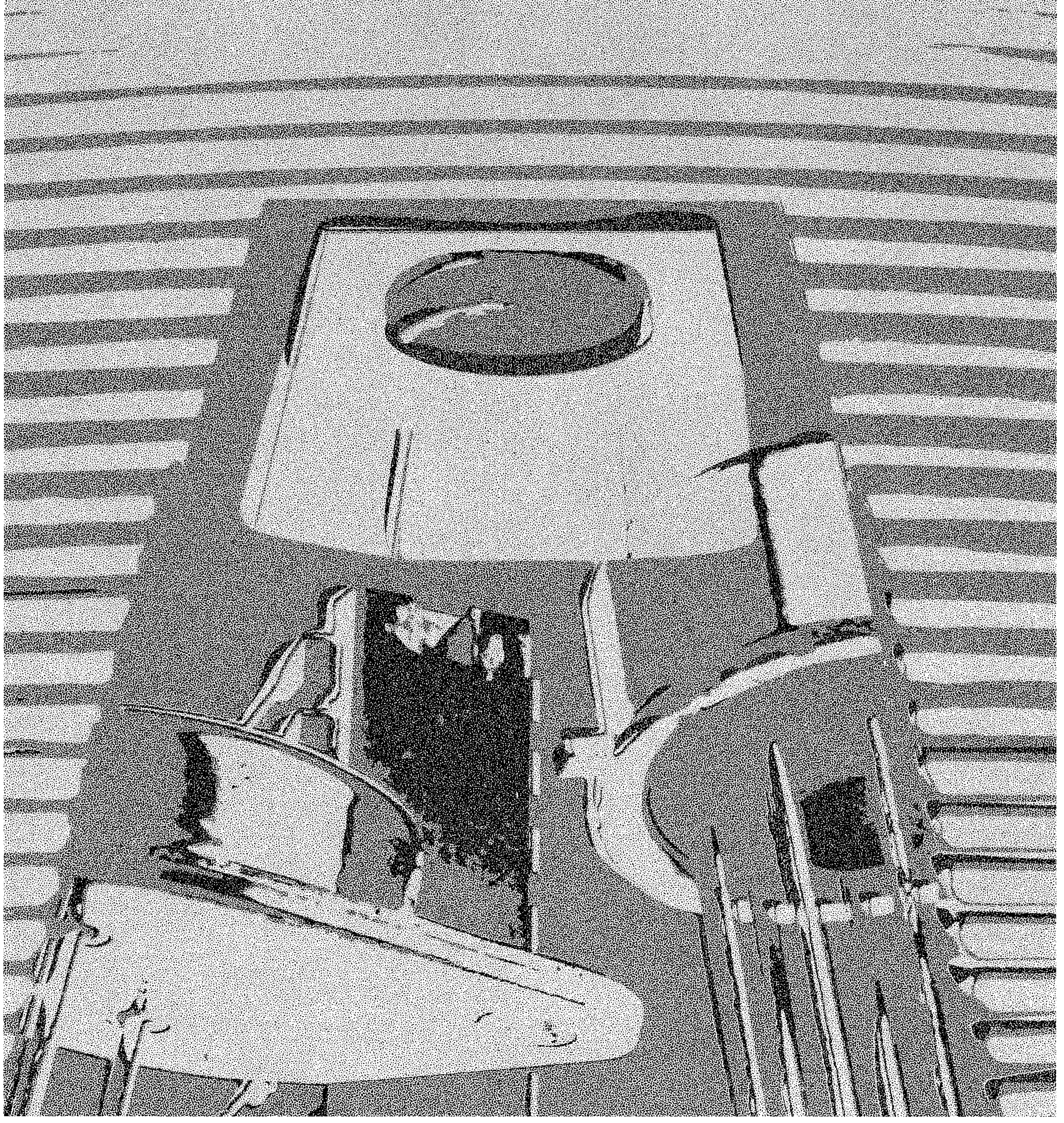
f_T vs I_C



C_{EB}, C_{CB}, C_{CI} vs Bias Voltage



National Semiconductor
APPENDICES/ PHYSICAL DIMENSIONS
Section 12



The B+ Program from National

B+ Program: a comprehensive program that assures high quality and high reliability of molded, integrated circuits.

The B+ program improves both the quality and the reliability of National's linear integrated circuits in Epoxy B packages. It is intended for the manufacturing user who cannot perform incoming inspection of discrete components, or does not wish to do so, yet needs significantly-better-than usual incoming quality and reliability levels for his parts.

Integrated circuit users who specify B+ processed parts will find that the program

- Eliminates incoming electrical inspection
- Eliminates the need for, and thus the cost of, independent testing laboratories
- Reduces the cost of reworking assembled boards
- Reduces field failures
- Reduces equipment downtime

Reliability Saves You Money

With the increased component density in modern electronic products has come an increased concern with component failures in such products.

And rightly so, for at least two major reasons.

First of all, the effect of component reliability on product reliability can be quite dramatic. For example, suppose that you, as a product manufacturer, were to choose an IC component that is 99 percent reliable. You would find that if your product used only 70 such components, the overall reliability of the product's IC component portion would be only 50 percent. In other words, only one product in two would operate. The result? Products very costly to build and probably very difficult to sell.

Secondly, you cannot afford to be hounded by the spectre of unnecessary maintenance costs. Not only because labor, repair and rework costs have risen—and promise to continue to rise—but also because field replacement may be prohibitively expensive.

If you ship a product that contains a marginally-performing component, a component that later fails in the field, the cost of replacement may be—literally—hundreds of times more than the cost of the failed component itself.

Reliability vis-a-vis Quality

The words "reliability" and "quality" are often used interchangeably, as though they connoted identical facets of a product's merit. But reliability and quality are different, and discrete component users must understand the essential difference between the two concepts in order to evaluate properly the various vendors' programs for product improvement that are generally available, and National's B+ program in particular.

The concept of quality gives us information about the population of faulty components among good components, and generally relates to the number of faulty components that arrive at a user's plant. But looked at in another way, quality can instead relate to the number of faulty components that escape detection at the component vendor's plant.

It is the function of a vendor's Quality Control arm to monitor the degree of success of that vendor in reducing the number of faulty components that escape detection. QC does this by testing the outgoing parts on a sampled basis. The Acceptable Quality Level (AQL) in turn determines the stringency of the sampling. As the AQL decreases it becomes more difficult for bad parts to escape detection, thus the quality of the shipped parts increases.

The concept of reliability, on the other hand, refers to how well a part that is initially good will withstand its environment. Reliability is measured by the percentage of parts that fail in a given period of time.

Thus, the difference between quality and reliability means that discrete components of high quality may, in fact, be of low reliability, while those of low quality may be of high reliability.

Improving the Reliability of Shipped Parts

The most important factor that affects a component's reliability is its construction: the materials used and the method by which they are assembled.

Now, it's true that reliability cannot be tested into a part. Still, there are tests and procedures that a component vendor can implement, which will subject the component to stresses in excess of those that it will endure in actual use, and which will eliminate most marginal, short-life parts.

In any test for reliability the weaker parts will normally fail first. Further, stress tests will accelerate, or shorten, the time to failure of the weak parts. Because the stress tests cause weak parts to fail prior to shipment to the user, the population of shipped parts will in fact demonstrate a higher reliability in use.

Quality Improvement

When a discrete component vendor specifies 100 percent final testing of his parts then, in theory, every shipped part should be a good part. However, in any population of mass-produced items there does exist some small percentage of defective parts.

One of the best ways to reduce the number of such faulty parts is simply to retest the parts prior to shipment. Thus, if there is a one-percent chance that a bad part will escape detection initially, retesting the parts reduces that probability to only 0.01 percent. (A comparable tightening of the QC group's sampled test plan ensures the maintenance of the improved quality level.)

National's B+ Program Gets It All Together

We've stated that the B+ program improves both the quality and reliability of National's epoxy-packaged discrete transistors, and pointed out the difference between the two concepts. Now, how do we bring them together? The answer is in B+ program processing, which is a continuum of stress and double testing. With the exception of the final QC inspection, which is sampled, all steps of the B+ process are performed on 100 percent of the program parts. The following flow chart shows how we do it, step by step.

Epoxy B Processing for All Molded Parts—At National, all molded semiconductors have been built by this process for some time now. All processing steps, inspections and QC monitoring are designed to provide highly reliable products. (A reliability report is available that gives, in detail, the background of Epoxy B, the reason for its selection at National and reliability data that proves its success.)

Six Hour, 150°C Bake—This stress places the die bond and all wire bonds into a combined tensile and shear stress mode, and helps eliminate marginal bonds and electrical connections.

Five Thermal Shock Cycles (0°C to 100°C)—Exercising the transistors over a 100°C temperature range further stresses the bonds and generally eliminates any marginal bonds missed during the bake.

High Temperature (100°C) Functional Electrical Test—A high-temperature test such as this with voltages applied places the die under the most severe stress possible. The test is actually performed at 100°C; that's 30°C higher than the commercial ambient limit. All devices are thoroughly exercised at the 100°C ambient. (Even though Epoxy B processing has virtually eliminated thermal intermittents, we perform this test to ensure against even the remote possibility of such a problem. Remember, the emphasis in the B+ program is on the elimination of those marginally performing devices that would otherwise lower field reliability of the parts.)

DC Functional and Parametric Tests—These room-temperature functional and parametric tests are the normal, final tests through which all National products pass.

Tighter-Than-Normal QC Inspection Plans—Most vendors sample inspect outgoing parts to a 0.65% AQL. Some use even a looser 1% AQL. When you specify the B+ program, however, not only do we sample your parts to a 0.28% AQL for all data-sheet dc parameters, but they receive a 0.14% AQL for functionality as well. Now, functional failures—not parameter shifts beyond spec—cause most product failures. Thus the five-times to seven-times tightening of the sampling procedure (from 0.65-1% to 0.14% AQL) gives a substantially higher quality to your B+ parts—you can relay on the integrity of your received transistors without incoming tests at your facility.

Ship Parts

Here are the QC sampling plans used in our B+ test program.

TEST	TEMPERATURE	AQL
Electrical Functionality	25°C	0.14%
Parametric, dc	25°C	0.28%
Parametric, dc	(100°C)	1%
Parametric, ac	25°C	1%
Major Mechanical	—	0.25%
Minor Mechanical	—	1%

Okay—Want More Information?

Simple. Just contact your local National Field Sales office. They'll be happy to help you. As always.

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.

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 qualify 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

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	LM710N	
SN52710S		LM710H
SN52710L		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

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

MOTOROLA DEVICE NUMBER	NATIONAL PIN-FOR-PIN EQUIVALENT	NATIONAL FUNCTIONAL EQUIVALENT
MC1458CP1	LM1458N	
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
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
MC1569R		LM105H

MOTOROLA DEVICE NUMBER	NATIONAL PIN-FOR-PIN EQUIVALENT	NATIONAL FUNCTIONAL EQUIVALENT
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	

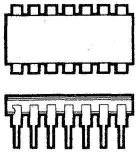
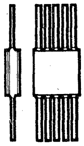
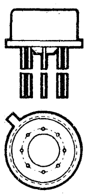
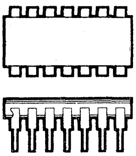
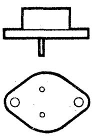
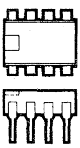
SIGNETICS DEVICE NUMBER	NATIONAL PIN-FOR-PIN EQUIVALENT	NATIONAL FUNCTIONAL EQUIVALENT
N5201A		LM301AD
N5307T	LM307H	
N5308T	LM308H	
N53A1T	LM301AH	
N53A1V	LM301AN	
N53A8T	LM308AH	
N5556V		LM307N
N5558F	LM1458N	
N5558T	LM1458H	
N5596K	LM1496H	
N5596K		LM1496N
N5709A	LM709CN	
N5709T	LM709CH	
N5709V		LM709CN
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
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	
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

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	

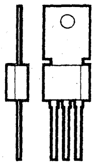
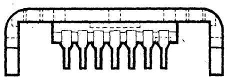
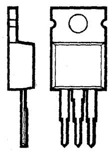
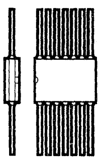
FAIRCHILD DEVICE NUMBER	NATIONAL PIN-FOR-PIN EQUIVALENT	NATIONAL FUNCTIONAL EQUIVALENT
786		LM3067
796HC	LM1496H	
MC1458G	LM1458H	
MC1458P1	LM1458N	
MC1558G	LM1558H	
CA3018	LM3018H	
CA3018A	LM3018AH	
CA3019	LM3019H	
CA3026	LM3026H	
CA3039	LM3039H	
CA3045	LM3045D	
CA3046	LM3046N	
CA3054	LM3054N	
CA3064T	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

Industry Package Cross-Reference Guide

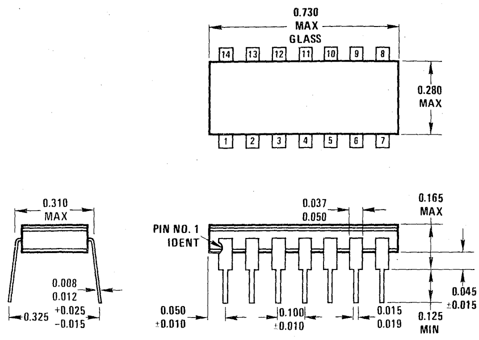
Package	NSC	Signetics	Fairchild	Motorola	TI	RCA	Silicon General	AMD	Raytheon
 14/16 Lead Glass/Metal DIP	D	I	D	L		D	D	D	D, M
 Glass/Metal Flat-Pack	F	Q	F	F	F, S	K	F	F	J, F, Q
 TO-99, TO-100, TO-5	H	T, K, L, DB	H	G	L	S*, V1**	T	H	T, H
 8, 14 and 16-Lead Low-Temperature Ceramic DIP	J	F	R, D	L	J				DC, DD
 TO-3 (Steel)	K						K		K
TO-3 (Aluminum)	KC	DA	K	K	K		K		LK, TK
 8, 14 and 16-Lead Plastic DIP	N	V, A, B	T, P	P	P, N	E	M, N	PC	N, DN, DP, MP

*With dual-in-line formed leads.

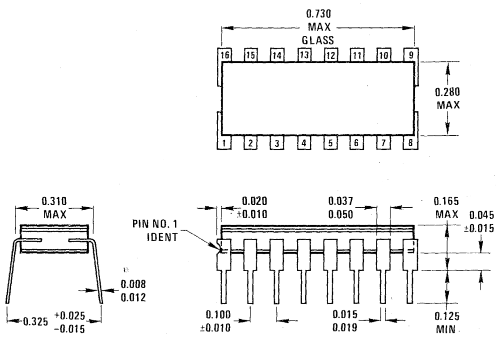
**With radially formed leads.

Package	NSC	Signetics	Fairchild	Motorola	TI	RCA	Silicon General	AMD	Raytheon
 TO-202 (D-40, Durawatt) (Package 37)	P								
 "SGS" Type Power DIP (Package 39)	S		BP						
 TO-220 (Package 26)	T	U	U		KC				
 Low Temperature Glass Hermetic Flat Pack	W		F	F	W			FM	
 TO-92 (Plastic) (Package 38)	Z	S	W	P	LP				

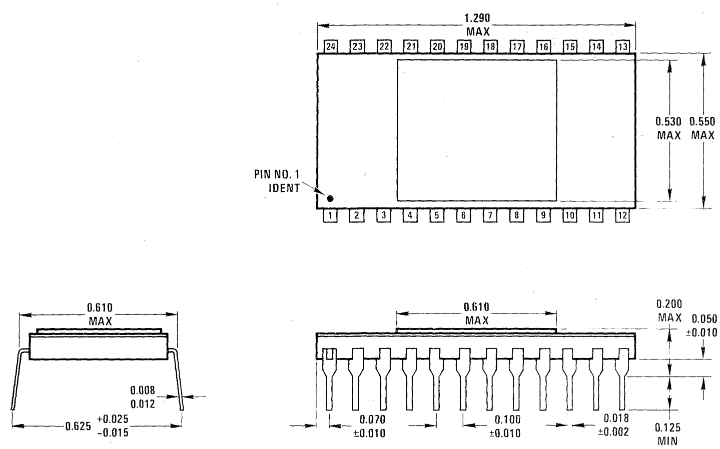
Physical Dimensions



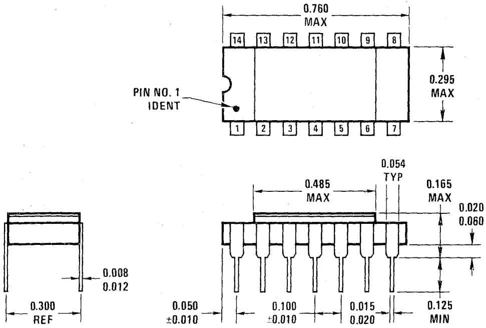
Package 1
14 Lead Cavity DIP (D)



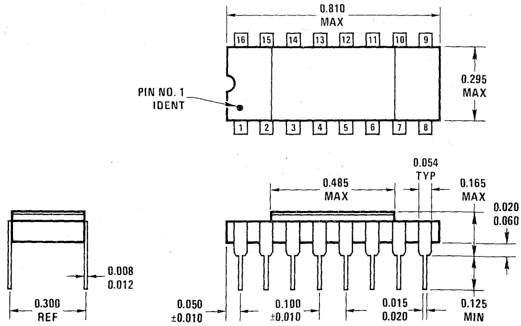
Package 2
16 Lead Cavity DIP (D)



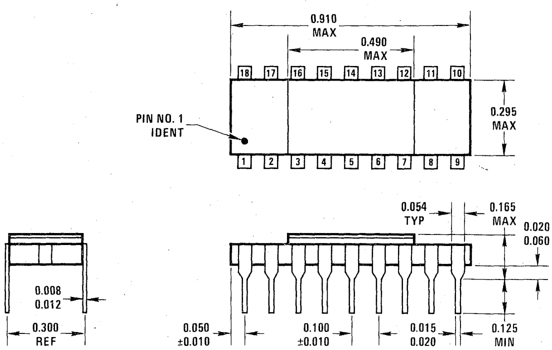
Package 2A
24 Lead Cavity DIP (D)



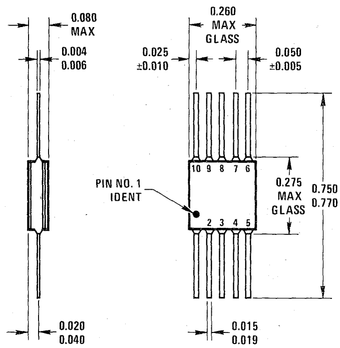
Package 2B
14 Lead Side-Brazed Cavity DIP (D)



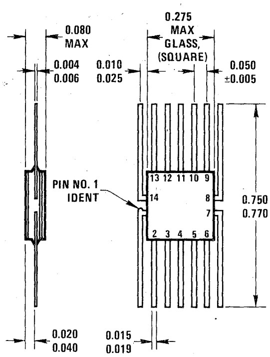
Package 2C
16 Lead Side-Brazed Cavity DIP (D)



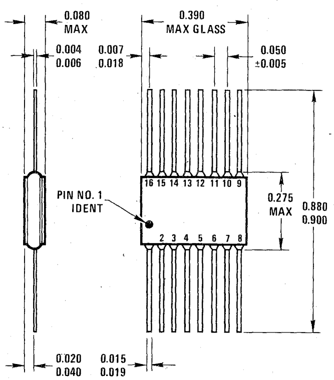
Package 2D
18 Lead Side-Brazed Cavity DIP (D)



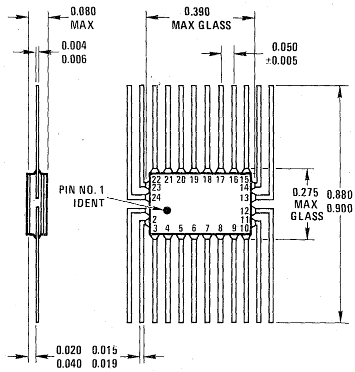
Package 3
10 Lead Flat Package (F)



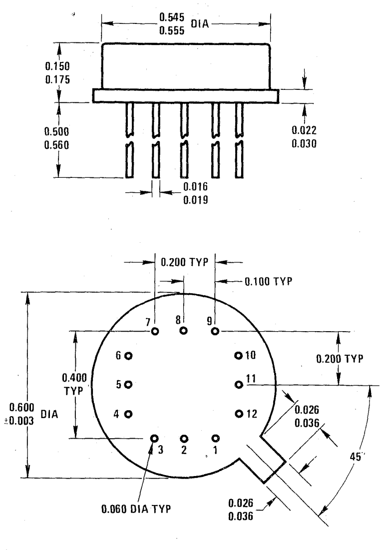
Package 4
14 Lead Flat Package (F)



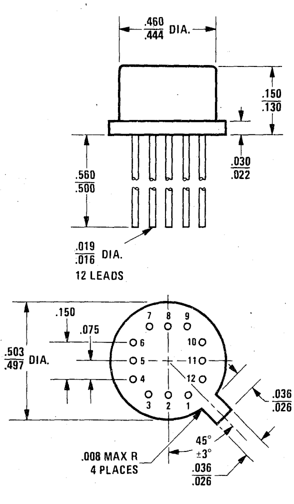
Package 5
16 Lead Flat Package (F)



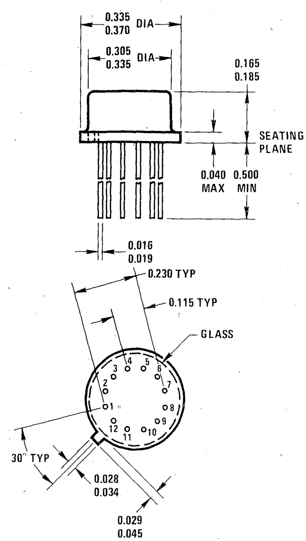
Package 5A
24 Lead Flat Package (F)



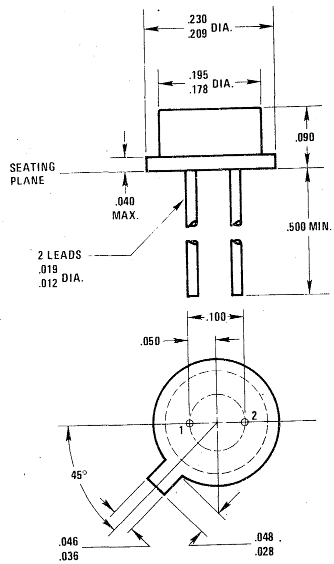
Package 6
12 Lead TO-8 Metal Can (G)



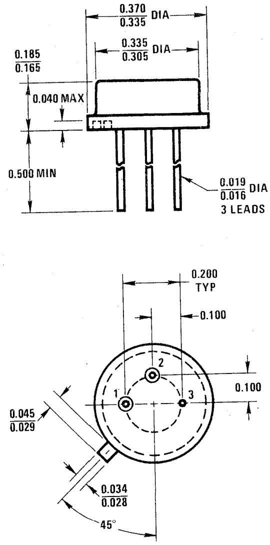
Package 6A
12 Lead TO-8 Metal Can (G)
(AH2114/AH2114C only)



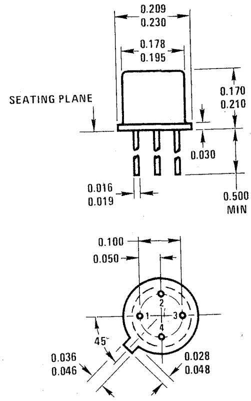
Package 7
12 Lead TO-8 Metal Can (H)



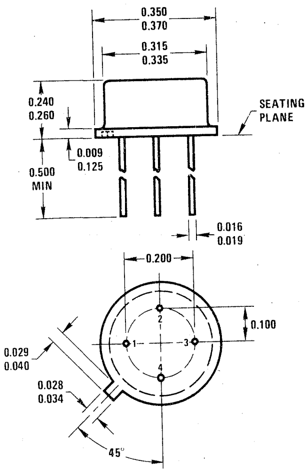
Package 8
2 Lead TO-46 Metal Can (H)



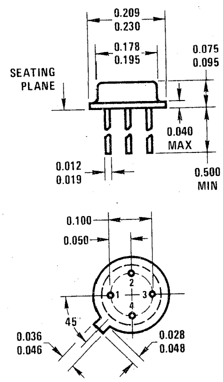
Package 9
3 Lead TO-39 Metal Can (H)



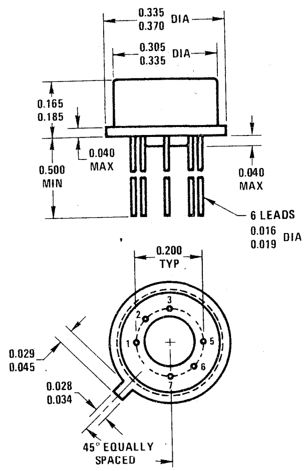
Package 9A
4 Lead TO-72 Metal Can (H)



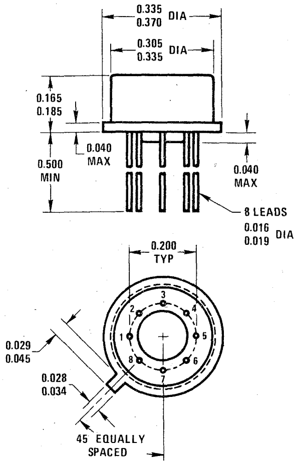
Package 9B
4 Lead TO-5 Metal Can (H)



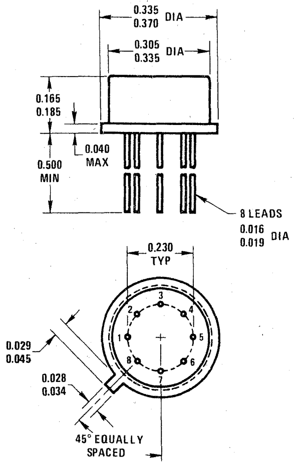
Package 9C
4 Lead TO-46 Metal Can (H)



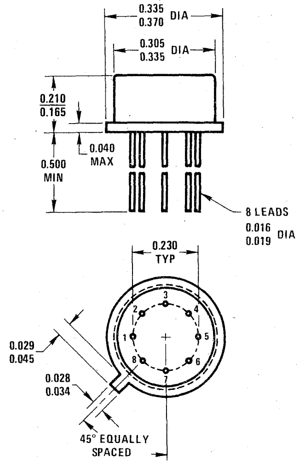
Package 10
6 Lead TO-5 Metal Can (H)



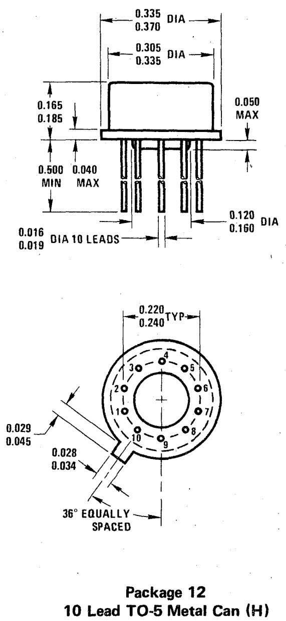
Package 11
8 Lead TO-5 Metal Can (H)



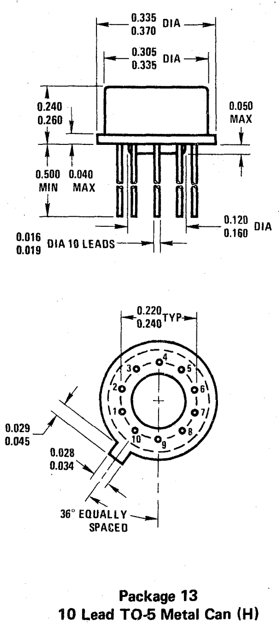
Package 11A
8 Lead TO-5 Metal Can (H)



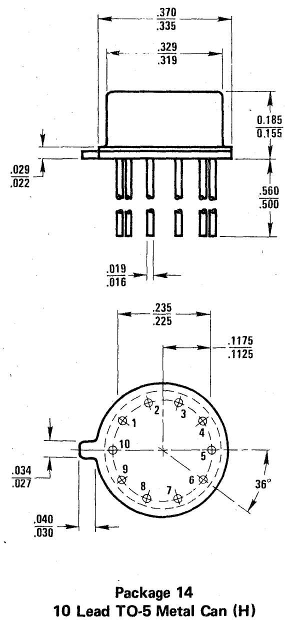
Package 11B
8 Lead TO-5 Metal Can (H)



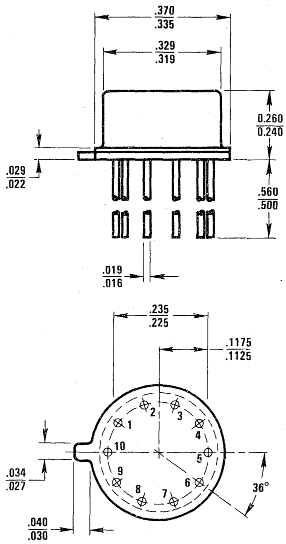
Package 12
10 Lead TO-5 Metal Can (H)
(Low Profile)



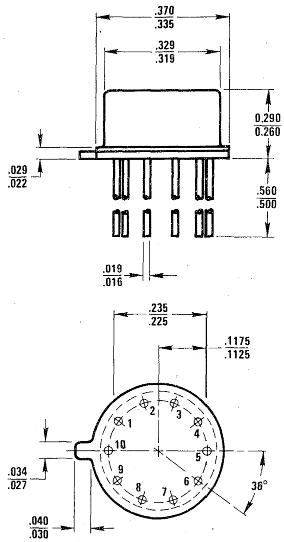
Package 13
10 Lead TO-5 Metal Can (H)
(High Profile)



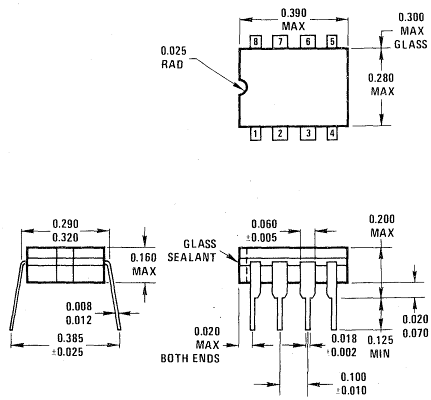
Package 14
10 Lead TO-5 Metal Can (H)



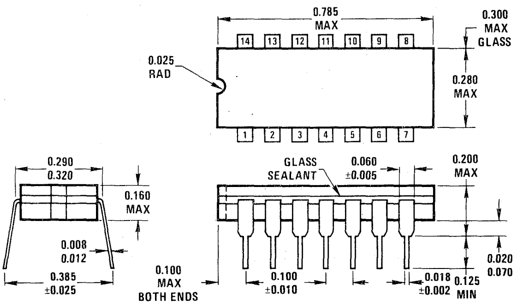
Package 14A
10 Lead TO-5 Metal Can (H)



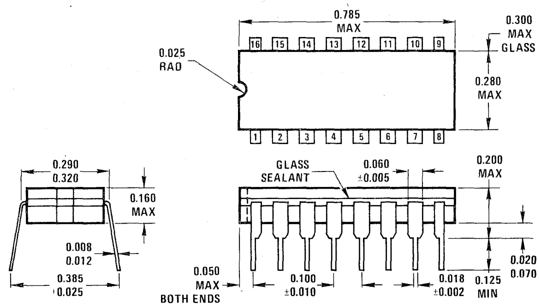
Package 14B
10 Lead TO-5 Metal Can (H)



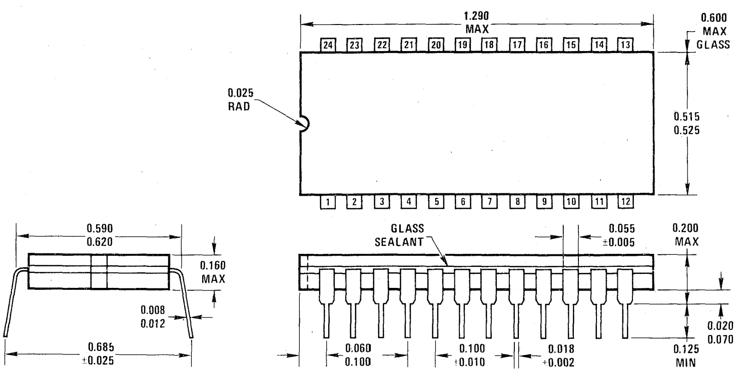
Package 15
8 Lead Cavity DIP (J)



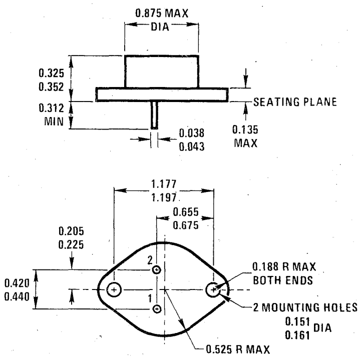
Package 16
14 Lead Cavity DIP (J)



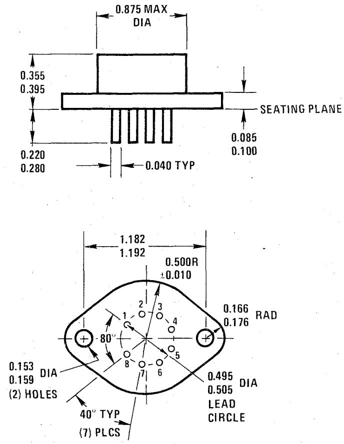
Package 17
16 Lead Cavity DIP (J)



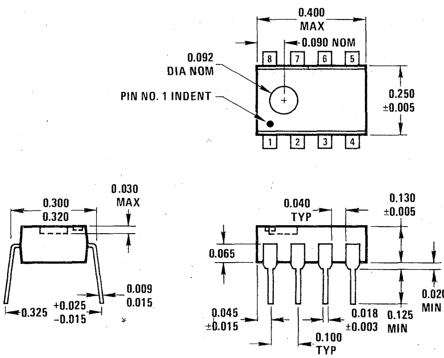
Package 17A
24 Lead Cavity DIP (J)



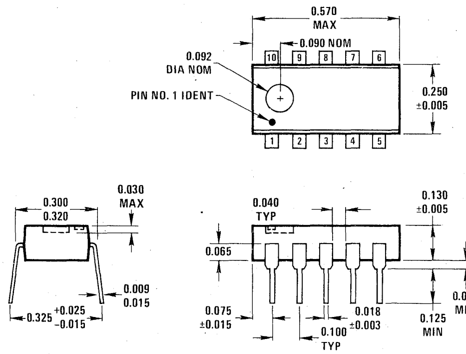
Package 18
2 Lead TO-3 Metal Can (K)



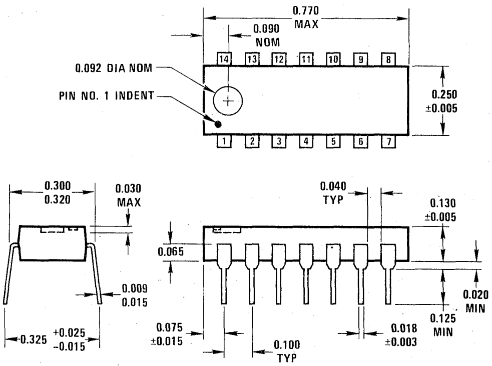
Package 19
8 Lead TO-3 Metal Can (K)



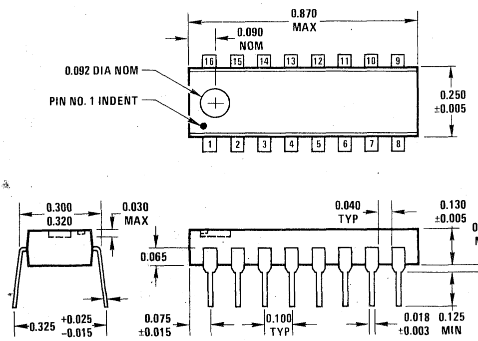
Package 20
8 Lead Molded Mini DIP (N)



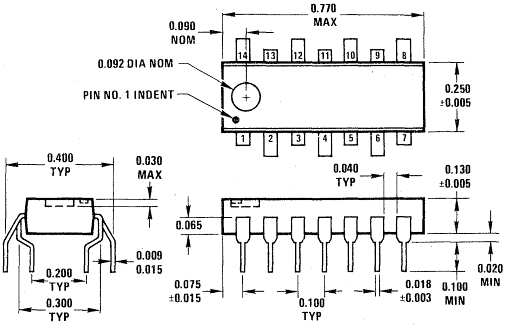
Package 21
10 Lead Molded DIP (N)



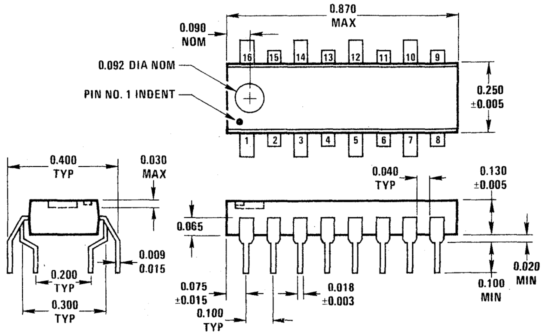
Package 22
14 Lead Molded DIP (N)



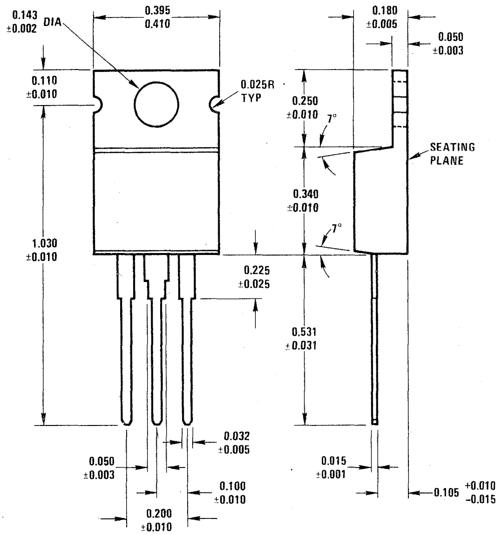
Package 23
16 Lead Molded DIP (N)



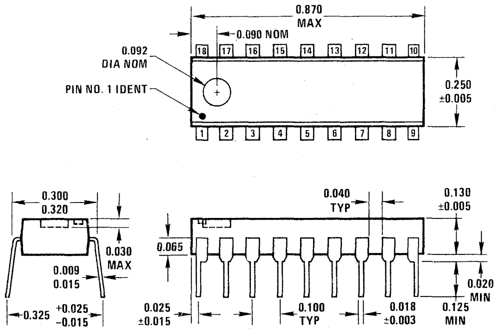
Package 24
14 Lead Molded DIP (N-01)
(Staggered Leads)



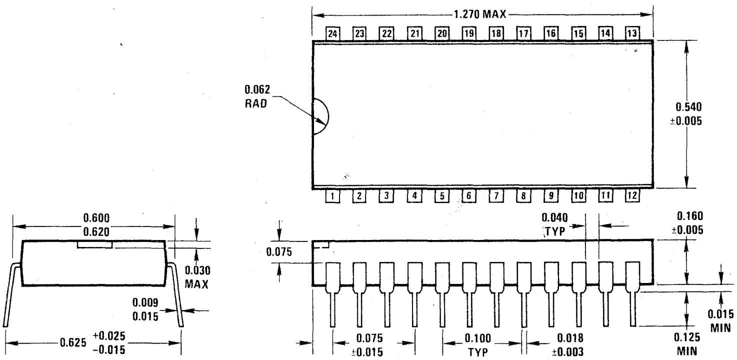
Package 25
16 Lead Molded DIP (N-01)
(Staggered Leads)



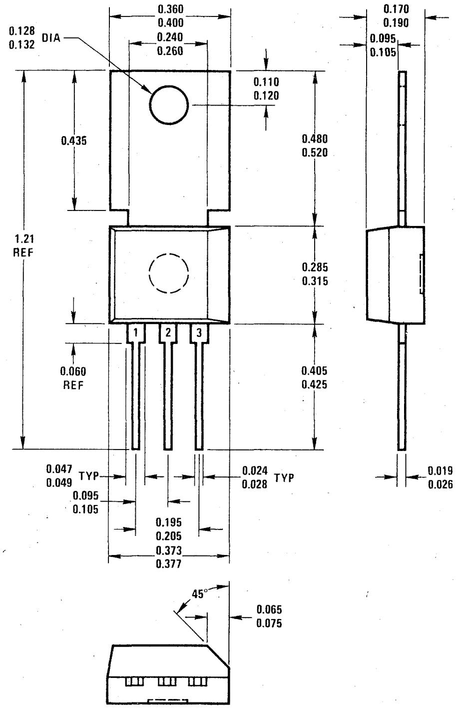
Package 26
3 Lead TO-220 Power Package (T)



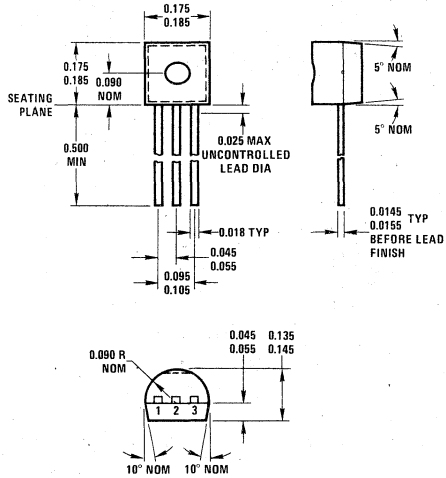
Package 29
18 Lead Molded DIP (N)



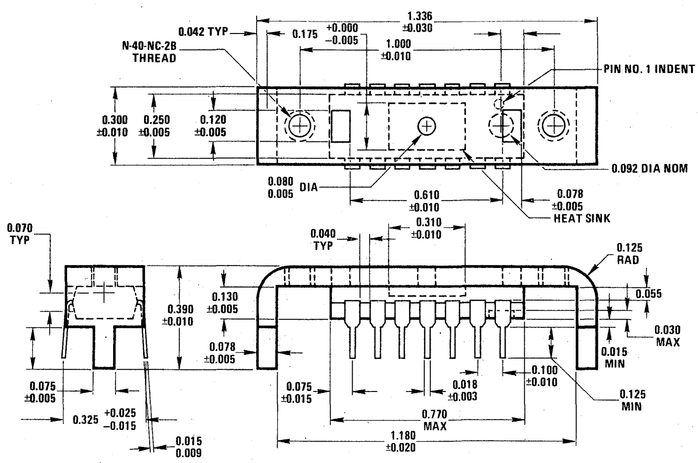
Package 29A
24 Lead Molded DIP (N)



Package 37
3 Lead TO-202 (P)

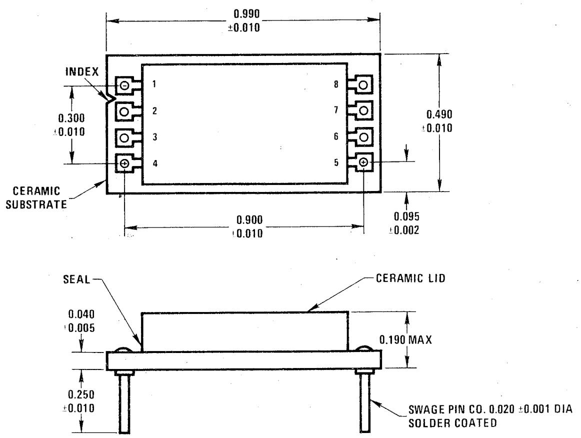


Package 38
3 Lead TO-92 Plastic Package (Z)

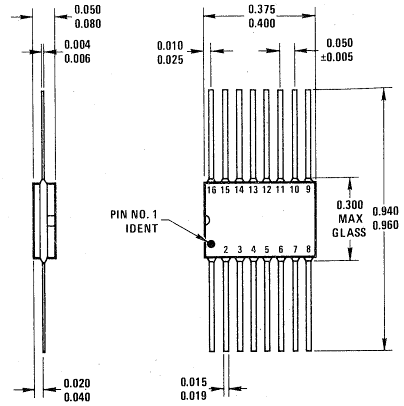


Package 39
14 Lead "SGS" Type Power DIP (S)

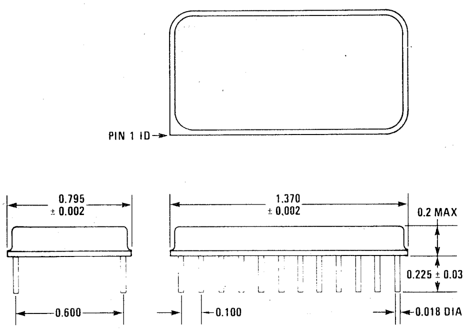
12



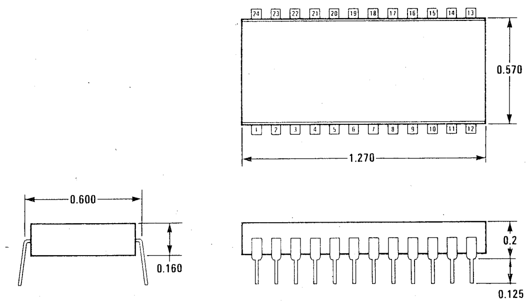
Package 40
8 Lead Cavity Package (J)



Package 41
16 Lead Flat Package (W)



Package 42
22 Lead Metal DIP (D)



Package 43
24 Lead Cavity Plastic DIP (N)

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

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