MOTOROLA
SEMICONDUCTORS
P.O. BOX 20912 • PHOENIX, ARIZONA 85036

OP-27

ULTRA-LOW NOISE PRECISION, HIGH SPEED OPERATIONAL AMPLIFIER

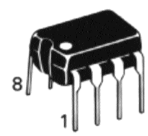
The OP-27 series of monolithic operational amplifiers combine low-noise, precision dc performance and high bandwidth in one device. Advanced Bipolar processing and innovative design techniques are used to produce this low noise precision operational amplifier. This device is trimmed for extremely low initial input offset voltage by utilizing a highly stable and reliable zener zap technique during factory testing which yields guaranteed V_{IO} limits as tight as 25 μV. A unique input bias current cancellation scheme maintains low I_{IB} and I_{IO} to typically ±20 nA and 15 nA respectively over the full military temperature range. Other sources of input errors are reduced in excess of −120 dB due to extremely high common-mode and power supply rejection ratios. The OP-27 has a gain bandwidth product of 8.0 MHz and slew rate of 2.8 V/μs.

The precision, low noise and high speed characteristics of this device makes it ideal for amplifying transducer signals, RIAA phono, NAB tape head and microphone preamplifiers, wide band instrumentation amplifiers and high speed signal conditioning for data acquisition systems.

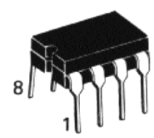
- Extremely Low-Noise — 3.0 nV/$\sqrt{Hz}$ at 1.0 kHz
  80 nVp-p, 0.1 Hz to 10 Hz
- Low Initial Input Offset Voltage — 10 μV
- Ultra Stable Input Offset Voltage — 0.2 μV/mo.
- High Gain Bandwidth Product and High Slew Rate — 8.0 MHz, 2.8 V/μs
- High Open-Loop Gain — 1.8 Million
- High Common-Mode Rejection — 126 dB

ULTRA-LOW NOISE PRECISION, HIGH SPEED OPERATIONAL AMPLIFIER

SILICON MONOLITHIC INTEGRATED CIRCUIT

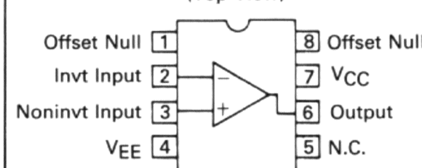


P SUFFIX
PLASTIC PACKAGE
CASE 626-05



Z SUFFIX
CERAMIC PACKAGE
CASE 693-02

(Top View)



ORDERING INFORMATION

Slew Rate	Device V_{IO} ≤ 25 μV	V_{IO} ≤ 60 μV	V_{IO} ≤ 100 μV	Temperature Range	Package
≥ 1.7 V/μs	OP-27AZ	OP-27BZ	OP-27CZ	−55 to +125°C	Ceramic DIP
	OP-27EZ	OP-27FZ	OP-27GZ	−25 to +85°C	Ceramic DIP
	OP-27EP	OP-27FP	OP-27GP	0 to +70°C	Plastic DIP

MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Supply Voltage	V_{CC} V_{EE}	+22 −22	V
Input Voltage Range (Note 1)	V_{IDR}	±22	V
Differential Input Voltage (Note 2)	V_{ID}	±0.7	V
Differential Input Current (Note 2)	I_{ID}	±25	mA
Output Short-Circuit Duration	t_s	Indefinite	
Power Dissipation and Thermal Characteristics Plastic Package (P Suffix) $T_A = +36°C$	P_D	500	mW
Derate above $T_A = +75°C$	$1/R_{\theta JA}$	6.7	mW/°C
Ceramic Package (Z Suffix) $T_A = +75°C$	P_D	500	mW
Derate above $T_A = +80°C$	$1/R_{\theta JA}$	7.1	mW/°C
Operating Ambient Temperature A,B and C Grades	T_A	−55 to +125	°C
E,F and G Grades (Ceramic Package)		−25 to +85	
EP, FP and GP Grades (Plastic Package)		0 to +70	
Junction Temperature	T_J	+150	°C
Storage Temperature Range Ceramic Package Plastic Package	T_{stg}	 −65 to +150 −65 to +125	°C

NOTES:
1. For supply voltages less than ±22 V, the absolute maximum input voltage range is equal to the supply voltage.
2. The inputs are protected by back-to-back diodes. Current limiting resistors are not used in order to achieve low noise. If differential input voltage exceeds ±0.7 V, the input current must be limited to 25 mA.

ELECTRICAL CHARACTERISTICS ($V_{CC} = +15$ V, $V_{EE} = -15$ V, $T_A = +25°C$ unless otherwise noted.)

		OP-27A/E/EP			OP-27B/F/FP			OP-27C/G/GP			
Characteristic	Symbol	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Unit
Input Offset Voltage	V_{IO}	—	10	25	—	20	60	—	30	100	μV
Long Term Input Offset Voltage Stability (Note 3)	V_{IO}/t	—	0.2	1.0	—	0.3	1.5	—	0.4	2.0	μV/mo
Input Offset Current	I_{IO}	—	7.0	35	—	9.0	50	—	12	75	nA
Input Bias Current	I_{IB}	—	±10	±40	—	±12	±55	—	±15	±80	nA
Input Noise Voltage 0.1 to 10 Hz (Note 4)	e_{np-p}	—	0.08	0.18	—	0.08	0.18	—	0.09	0.25	μV_{p-p}
Input Noise Voltage Density	e_n										$nV/\sqrt{Hz}$
$f_O = 10$ Hz		—	3.5	5.5	—	3.5	5.5	—	3.8	8.0	
$f_O = 30$ Hz		—	3.1	4.5	—	3.1	4.5	—	3.3	5.6	
$f_O = 1000$ Hz (Note 4)		—	3.0	3.8	—	3.0	3.8	—	3.2	4.5	
Input Noise Current Density	i_n										$pA/\sqrt{Hz}$
$f_O = 10$ Hz		—	1.7	4.0	—	1.7	4.0	—	1.7	—	
$f_O = 30$ Hz		—	1.0	2.3	—	1.0	2.3	—	1.0	—	
$f_O = 1000$ Hz (Note 4)		—	0.4	0.6	—	0.4	0.6	—	0.4	0.6	
Input Resistance — Differential Mode	r_i	1.5	6.0	—	1.2	5.0	—	0.8	4.0	—	MΩ
Input Resistance — Common Mode	R_{incm}	—	3.0	—	—	2.5	—	—	2.0	—	GΩ
Input Voltage Range	V_{IR}	±11.0	±12.3	—	±11.0	±12.3	—	±11.0	±12.3	—	V

(continued)

ELECTRICAL CHARACTERISTICS (continued)

Characteristic	Symbol	OP-27A/E/EP Min	OP-27A/E/EP Typ	OP-27A/E/EP Max	OP-27B/F/FP Min	OP-27B/F/FP Typ	OP-27B/F/FP Max	OP-27C/G/GP Min	OP-27C/G/GP Typ	OP-27C/G/GP Max	Unit
Common Mode Rejection Ratio $V_{CM} = \pm 11$ V	CMRR	114	126	—	106	123	—	100	120	—	dB
Power Supply Rejection Ratio $V_{CC}/V_{EE} = \pm 4.0$ V to ± 18 V	PSRR	100	120	—	100	120	—	94	114	—	dB
Large-Signal Voltage Gain	A_{VOL}										V/mV
$R_L \geq 2.0$ kΩ, $V_O = \pm 10$ V		1000	1800	—	1000	1800	—	700	1500	—	
$R_L \geq 1.0$ kΩ, $V_O = \pm 10$ V		800	1500	—	800	1500	—	—	1500	—	
$R_L = 600$ Ω, $V_O = \pm 1.0$ V, $V_{CC}/V_{EE} = \pm 4.0$ V to ± 18 V		—	700	—	—	700	—	—	500	—	
Output Voltage Swing	V_O										V
$R_L \geq 2.0$ kΩ		±12	±13.8	—	±12	±13.8	—	±11.5	±13.5	—	
$R_L \geq 600$ Ω		±10	±11.5	—	±10	±11.5	—	±10	±11.5	—	
Slew Rate, $R_L \geq 2.0$ kΩ	SR	1.7	2.8	—	1.7	2.8	—	1.7	2.8	—	V/μs
Gain Bandwidth Product	GBW	5.0	8.0	—	5.0	8.0	—	5.0	8.0	—	MHz
Open Loop Output Resistance $V_O = 0$, $I_O = 0$	r_o	—	70	—	—	70	—	—	70	—	Ω
Power Dissipation $V_O = 0$, No Load	P_D	—	90	140	—	90	140	—	100	170	mW
Offset Adjustment Range $R_P = 10$ kΩ		—	±4.0	—	—	±4.0	—	—	±4.0	—	mV

NOTES (continued)

3. Long term input offset voltage stability for the OP-27 series, refers to the average trend line of V_{IO} versus time over extended periods after the first 30 days of operation. Excluding the first hour of operation, changes in V_{IO} during the first 30 days are typically 2.5 μV.
4. Sample tested.

ELECTRICAL CHARACTERISTICS ($V_{CC} = +15$ V, $V_{EE} = -15$ V, $T_A = T_{low}$ to T_{high} [Note 5])

Characteristic	Symbol	OP-27A Min	OP-27A Typ	OP-27A Max	OP-27B Min	OP-27B Typ	OP-27B Max	OP-27C Min	OP-27C Typ	OP-27C Max	Unit
Input Offset Voltage	V_{IO}	—	30	60	—	50	200	—	70	300	μV
Average Input Offset Drift (Note 6)	TCV_{IO}	—	0.2	0.6	—	0.3	1.3	—	0.4	1.8	μV/°C
Input Offset Current	I_{IO}	—	15	50	—	22	85	—	30	135	nA
Input Bias Current	I_{IB}	—	±20	±60	—	±28	±95	—	±35	±150	nA
Input Voltage Range	V_{IR}	±10.3	±11.5	—	±10.3	±11.5	—	±10.2	±11.5	—	V
Common Mode Rejection Ratio $V_{CM} = \pm 10$ V	CMRR	108	122	—	100	119	—	94	116	—	dB
Power Supply Rejection Ratio $V_{CC}/V_{EE} = \pm 4.5$ V to ± 18 V	PSRR	96	114	—	94	114	—	86	108	—	dB
Large-Signal Voltage Gain $R_L \geq 2$ kΩ, $V_O = \pm 10$ V	A_{VOL}	600	1200	—	500	1000	—	300	800	—	V/mV
Output Voltage Swing $R_L \geq 2$ kΩ	V_O	±11.5	±13.5	—	±11.0	±13.2	—	±10.5	±13.0	—	V

ELECTRICAL CHARACTERISTICS (V_{CC} = +15 V, V_{EE} = −15 V, T_A = T_{low} to T_{high} [Note 5])

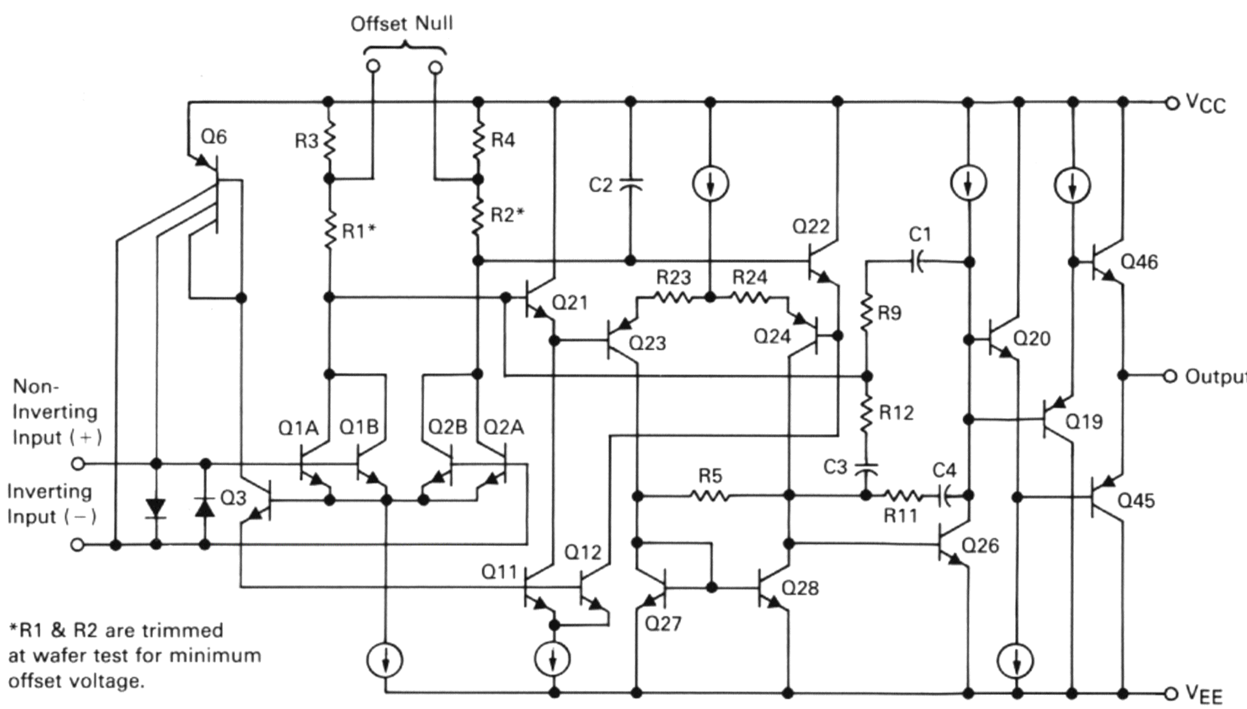
Characteristic	Symbol	OP-27E/EP			OP-27F/FP			OP-27G/GP			Unit
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	V_{IO}	—	20	50	—	40	140	—	55	220	μV
Average Input Offset Drift (Note 6)	TCV_{IO}	—	0.2	0.6	—	0.3	1.3	—	0.4	1.8	μV/°C
Input Offset Current	I_{IO}	—	10	50	—	14	85	—	20	135	nA
Input Bias Current	I_{IB}	—	±14	±60	—	±18	±95	—	±25	±150	nA
Input Voltage Range	V_{IR}	±10.5	±11.8	—	±10.5	±11.8	—	±10.5	±11.8	—	V
Common Mode Rejection Ratio V_{CM} = ±10 V	CMRR	110	124	—	102	121	—	96	118	—	dB
Power Supply Rejection Ratio V_{CC}/V_{EE} = ±4.5 V to ±18 V	PSRR	97	114	—	96	114	—	90	114	—	dB
Large-Signal Voltage Gain $R_L \geq 2.0$ kΩ, V_O = ±10 V	A_{VOL}	750	1500	—	700	1300	—	450	1000	—	V/mV
Output Voltage Swing $R_L \geq 2.0$ kΩ	V_O	±11.7	±13.6	—	±11.4	±13.5	—	±11	±13.3	—	V

NOTES (continued)

5. T_{low} = −55°C for OP-27A, OP-27B, OP-27C; = −25°C for OP-27E, OP-27F, OP-27G; = 0°C for OP-27EP, OP-27FP, OP-27GP.
   T_{high} = +125°C for OP-27A, OP-27B, OP-27C; = +85°C for OP-27E, OP-27F, OP-27G; = +70°C for OP-27EP, OP-27FP, OP-27GP.

6. TCV_{IO} performance is within specifications unnulled or when nulled with a potentiometer R_P = 8.0 kΩ to 20 kΩ.

ABBREVIATED CIRCUIT SCHEMATIC



TYPICAL CHARACTERISTICS

FIGURE 1 — VOLTAGE NOISE TESTER GAIN versus FREQUENCY

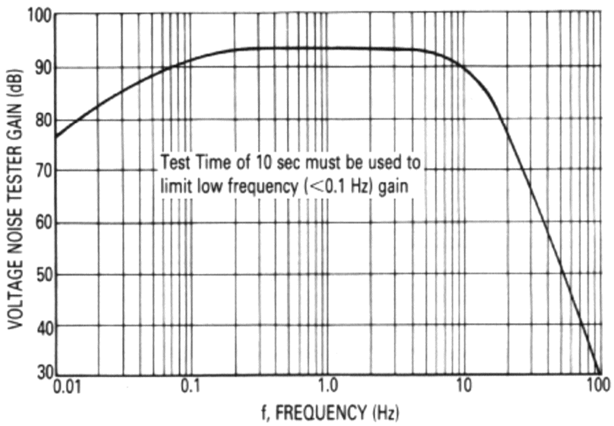
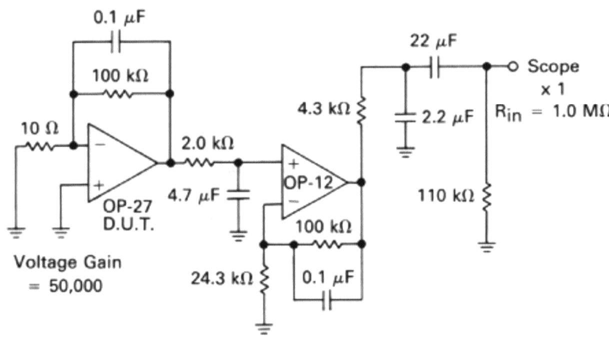


FIGURE 2 — VOLTAGE NOISE TEST CIRCUIT (0.1 Hz-TO-10 Hz)



Note: All capacitor values are for non polarized capacitors only.

FIGURE 3 — VOLTAGE NOISE versus FREQUENCY

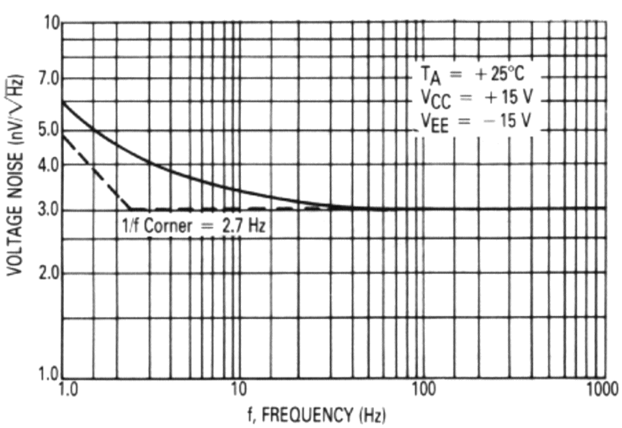


FIGURE 4 — INPUT WIDEBAND VOLTAGE NOISE versus BANDWIDTH (0.1 Hz TO FREQUENCY INDICATED)

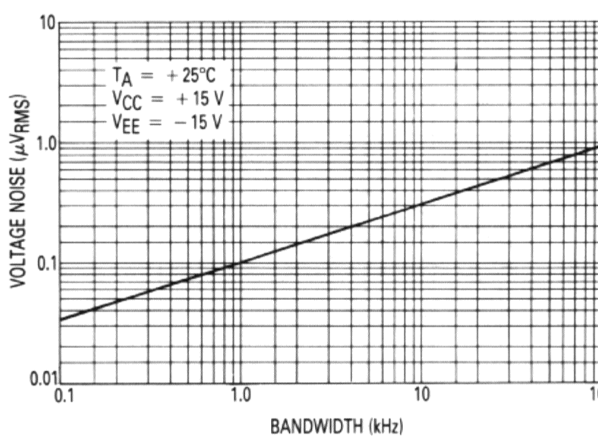


FIGURE 5 — TOTAL NOISE versus SOURCE RESISTANCE

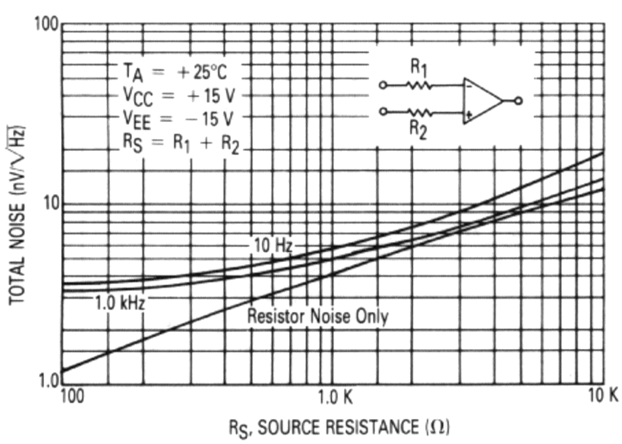


FIGURE 6 — VOLTAGE NOISE versus TEMPERATURE

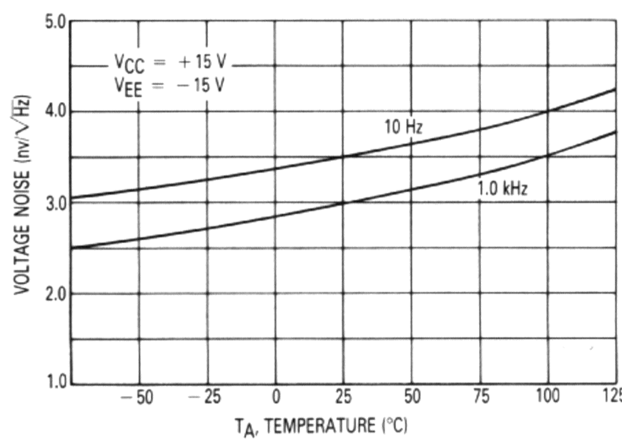


FIGURE 7 — VOLTAGE NOISE versus SUPPLY VOLTAGE

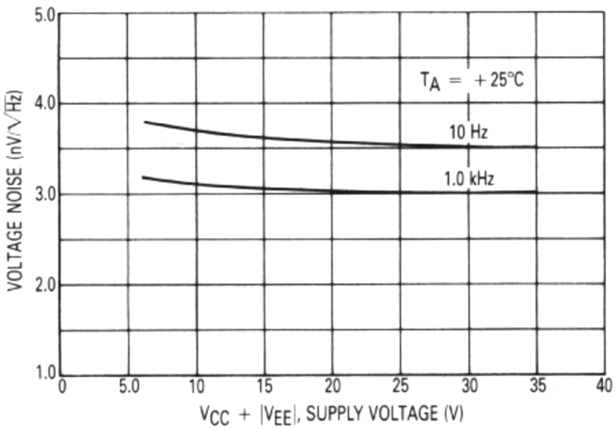


FIGURE 8 — CURRENT NOISE versus FREQUENCY

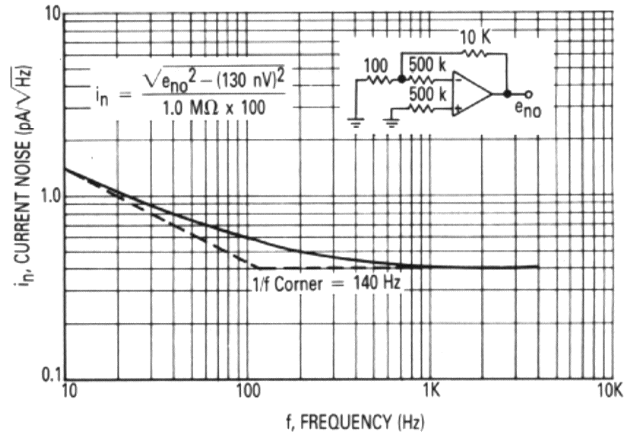


FIGURE 9 — SUPPLY CURRENT versus SUPPLY VOLTAGE

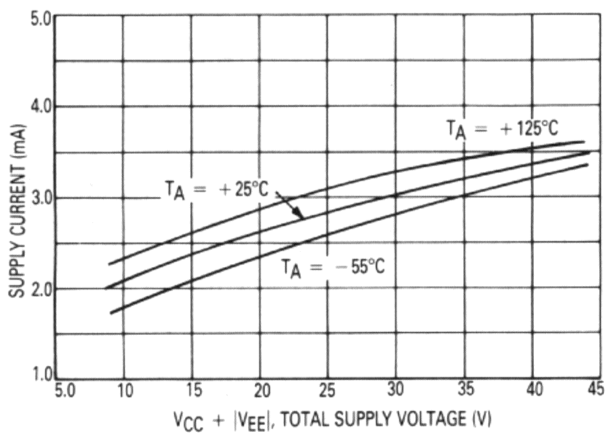


FIGURE 10 — INPUT BIAS CURRENT versus TEMPERATURE

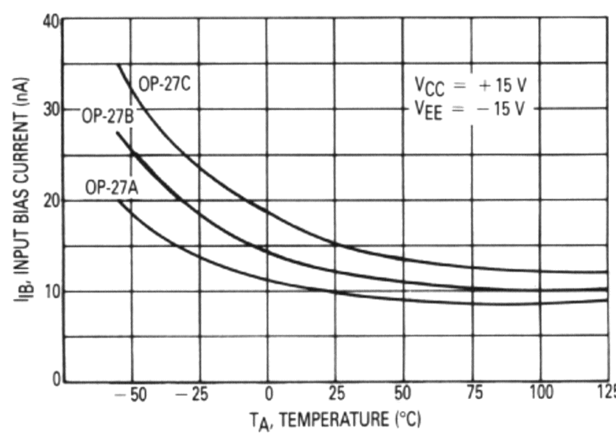


FIGURE 11 — INPUT OFFSET CURRENT versus TEMPERATURE

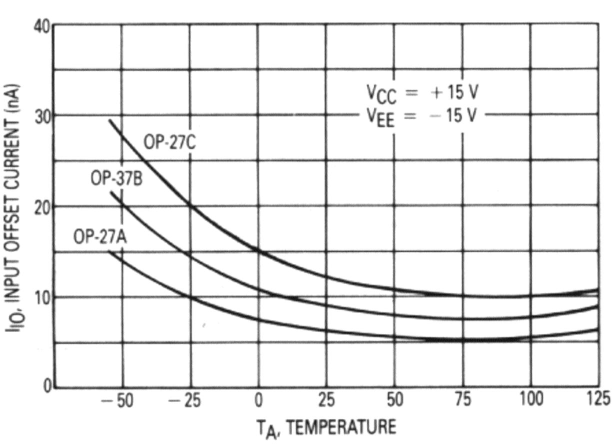


FIGURE 12 — COMMON MODE INPUT RANGE versus SUPPLY VOLTAGE

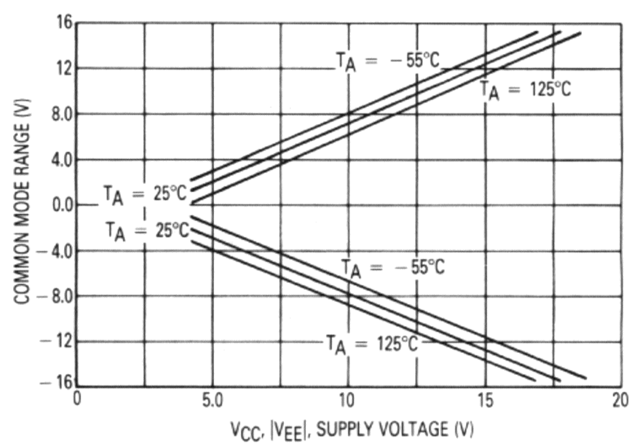


FIGURE 13 — OPEN LOOP VOLTAGE GAIN versus SUPPLY VOLTAGE

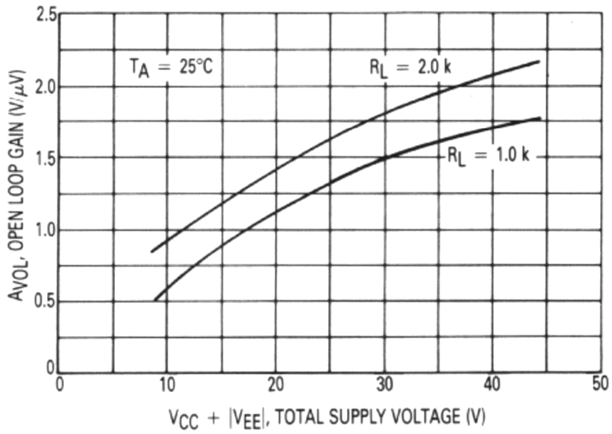


FIGURE 14 — OPEN LOOP VOLTAGE GAIN versus LOAD RESISTANCE

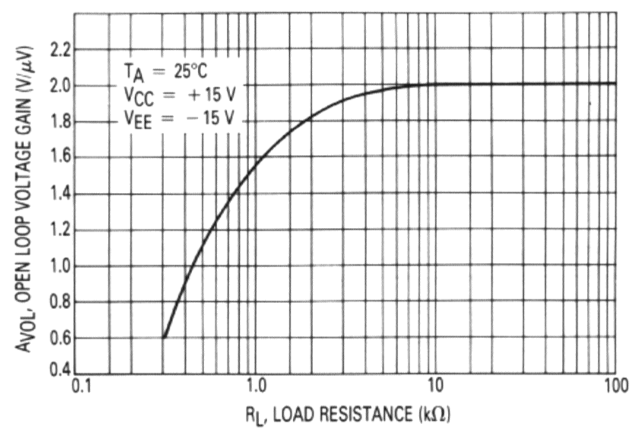


FIGURE 15 — MAXIMUM OUTPUT SWING versus RESISTIVE LOAD

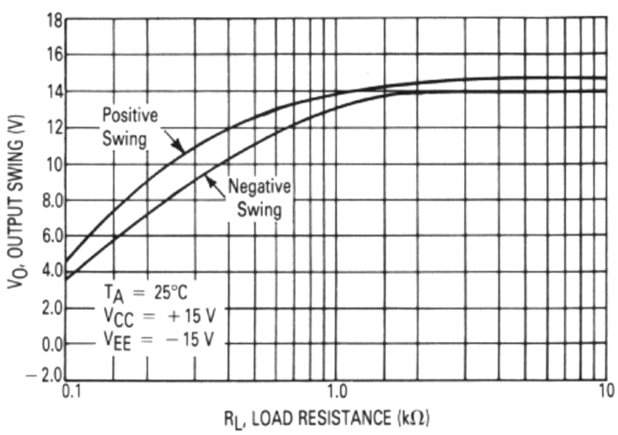


FIGURE 16 — POWER SUPPLY REJECTION RATIO versus FREQUENCY

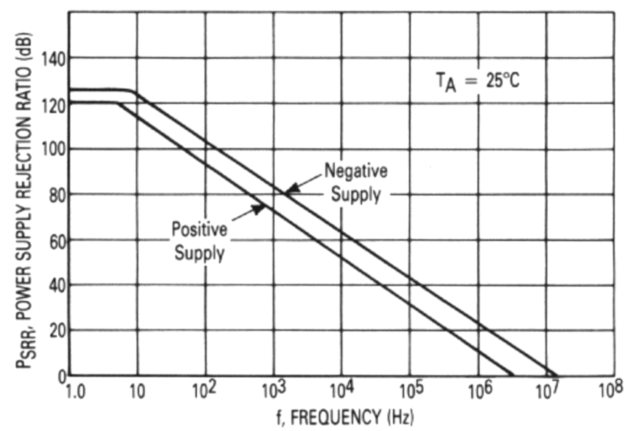


FIGURE 17 — COMMON MODE REJECTION RATIO versus FREQUENCY

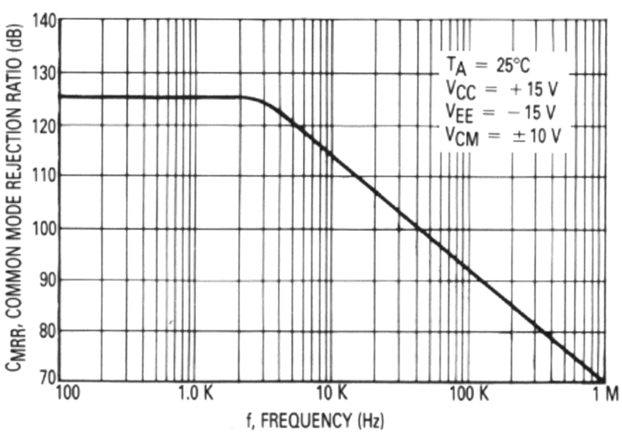


FIGURE 18 — OPEN LOOP GAIN versus FREQUENCY

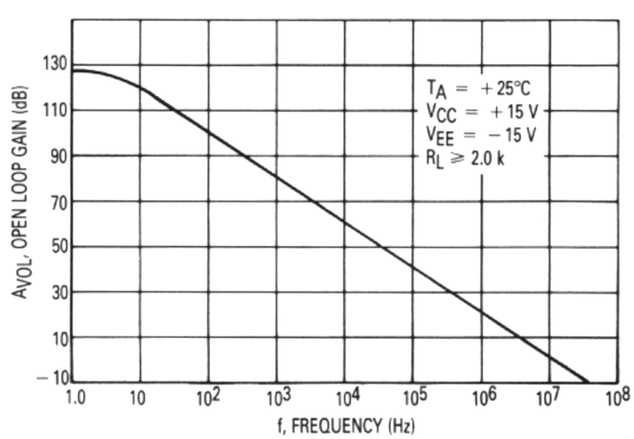


FIGURE 19 — MAXIMUM UNDISTORTED OUTPUT versus FREQUENCY

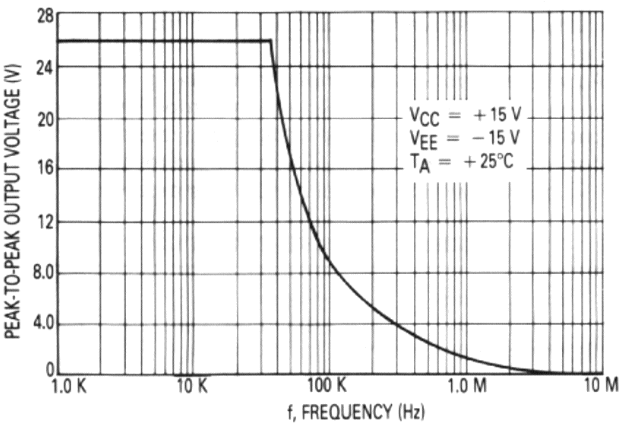
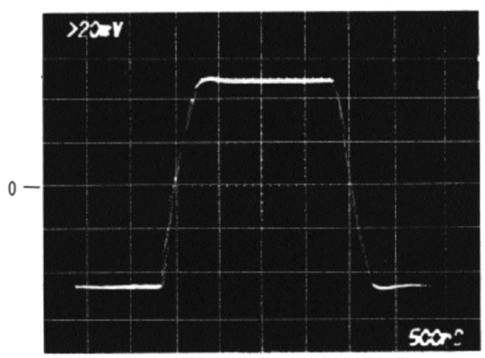


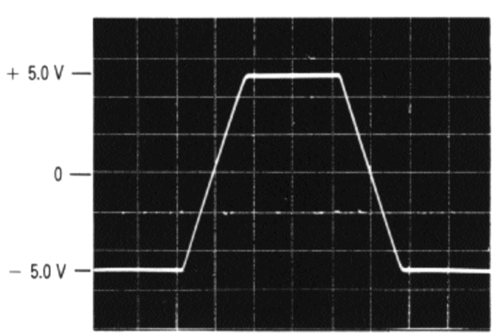
FIGURE 20 — SMALL-SIGNAL TRANSIENT RESPONSE



t, TIME (500 ns/DIV)

$A_V = +1.0$ $V_{EE} = -15$ V
$T_A = +25°C$ $C_L = 15$ pF
$V_{CC} = +15$ V $R_L = \infty$

FIGURE 21 — LARGE-SIGNAL TRANSIENT RESPONSE



t, TIME (2.0 μs/DIV)

$A_V = +1.0$ $V_{EE} = -15$ V
$T_A = +25°C$ $C_L = 12$ pF
$V_{CC} = +15$ V $R_L = \infty$

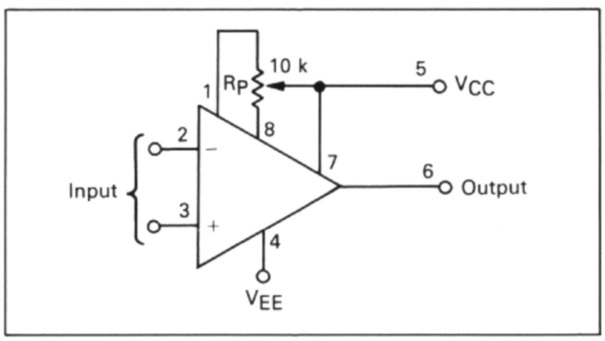
APPLICATIONS INFORMATION

The designer is cautioned that stray thermoelectric voltages generated by dissimilar metals at the contacts to the input terminals can prevent realization of the drift performance indicated. Best operation will be obtained when both input contacts are maintained at the same temperature, preferably close to the temperature of the device's package.

OFFSET VOLTAGE ADJUSTMENT

The input offset voltage and drift over temperature are permanently trimmed at wafer testing. However, if further adjustment of V_{IO} is required, nulling with a 10 kΩ potentiometer as shown in Figure 22 will not degrade TCV_{IO}. Other potentiometer values from 1.0 kΩ to 1.0 MΩ can be used with a slight degradation (0.1 to 0.2 μV/°C) of TCV_{IO}. Trimming to a value other than zero creates a drift of (V_{IO}/300) μV/°C, e.g. if V_{IO} is adjusted to 100 μV, the change in TCV_{IO} will be 0.33 μV/°C. The offset voltage adjustment range with a 10 kΩ potentiometer is ±4.0 mV. If a smaller adjustment range is required, the sensitivity and/or resolution of the nulling can be increased by using a smaller pot in conjunction with fixed resistors.

FIGURE 22 — OFFSET NULLING CIRCUIT



NOISE MEASUREMENTS

The extremely low noise of these devices can make accurate measurement a difficult task. In order to realize the 80 nV peak-to-peak noise specification of the op amp in the 0.1 Hz to 10 Hz frequency range, the following guidelines must be observed:

(1) The device has to be warmed up for at least five minutes. As the op amp warms up, its offset voltage changes typically 4.0 μV due to its chip temperature increasing 14 to 20°C from the moment the power supplies are turned on. In the 10 sec measurement interval these temperature-induced effects can easily exceed tens of nanovolts.

(2) For similar reasons, the device has to be well shielded from air currents to eliminate the possibility of thermoelectric effects in excess of several nanovolts.

(3) Sudden motion in the vicinity of the device can also "feed-through" to increase the observed noise.

(4) The test time to measure 0.1 Hz to 10 Hz noise should not exceed 10 sec. As shown in the noise tester frequency response curve (Figure 1) the 0.1 Hz corner is defined by only one zero. The test time of 10 sec acts as an additional zero to eliminate noise contributions from the frequency band below 0.1 Hz.

A noise-voltage density test is recommended when measuring noise on a large number of units. A 10 Hz noise-voltage density measurement will correlate well with a 0.1 Hz-to-10 Hz peak-to-peak noise reading since both results are determined by the white noise and the location of the 1/f corner frequency.

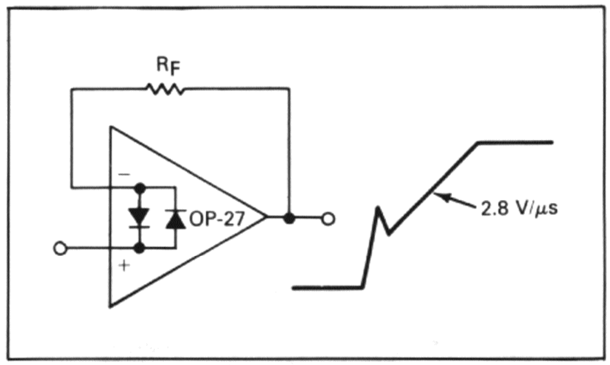
UNITY GAIN BUFFER APPLICATIONS

When $R_F \leq 100\ \Omega$ and the input is driven with a fast, large signal pulse (> 1.0 V), the output waveform will look as shown in Figure 23.

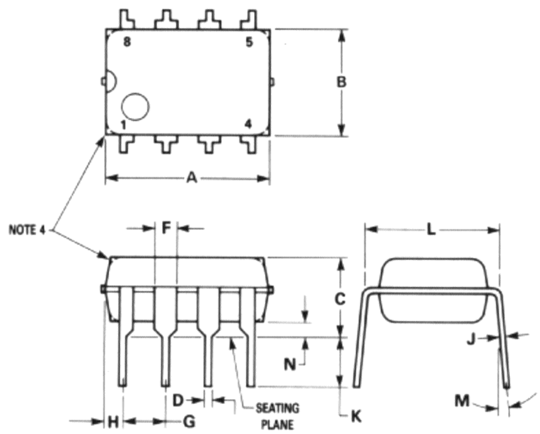
During the initial fast input step, the input protection diodes effectively short the output to the input and current limit only by the output short circuit protection of the op amp and the source resistance of the generator. With $R_F \geq 500\ \Omega$, the output is capable of handling the current requirements ($I_L \leq 20$ mA at 10 V) and the amplifier stays in its active mode and a smooth transition will occur.

As with all operational amplifiers when $R_F > 2.0\ k\Omega$, a pole will be created with R_F and the amplifier's input capacitance (8.0 pF), creating additional phase shift and reducing the phase margin. A small capacitor (20 to 50 pF) in parallel with R_F will eliminate this problem.

FIGURE 23 — PULSED OPERATION



OUTLINE DIMENSIONS

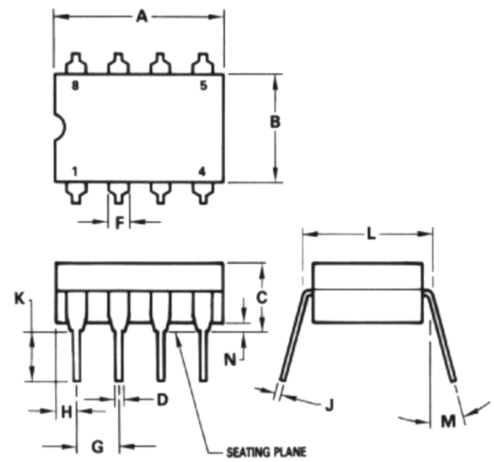


NOTES:
1. LEAD POSITIONAL TOLERANCE:
   | ⌖ | φ 0.13 (0.005) Ⓜ | T | A Ⓜ | B Ⓜ |
2. DIMENSION L TO CENTER OF LEADS WHEN FORMED PARALLEL.
3. PACKAGE CONTOUR OPTIONAL (ROUND OR SQUARE CORNERS).
4. DIMENSIONS A AND B ARE DATUMS.
5. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	9.40	10.16	0.370	0.400
B	6.10	6.60	0.240	0.260
C	3.94	4.45	0.155	0.175
D	0.38	0.51	0.015	0.020
F	1.02	1.52	0.040	0.060
G	2.54 BSC		0.100 BSC	
H	0.76	1.27	0.030	0.050
J	0.20	0.30	0.008	0.012
K	2.92	3.43	0.115	0.135
L	7.62 BSC		0.300 BSC	
M	—	10°	—	10°
N	0.76	1.01	0.030	0.040

STYLE 1:
PIN 1. AC IN
2. DC + IN
3. DC − IN
4. AC IN
5. GROUND
6. OUTPUT
7. AUXILIARY
8. V_{CC}

CASE 626-05
P SUFFIX
PLASTIC PACKAGE



NOTES:
1. LEADS WITHIN 0.13 mm (0.005) RAD OF TRUE POSITION AT SEATING PLANE AT MAXIMUM MATERIAL CONDITION.
2. DIMENSION "L" TO CENTER OF LEADS WHEN FORMED PARALLEL.

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	9.91	10.92	0.390	0.430
B	6.22	6.99	0.245	0.275
C	4.32	5.08	0.170	0.200
D	0.41	0.51	0.016	0.020
F	1.40	1.65	0.055	0.065
G	2.54 BSC		0.100 BSC	
H	1.14	1.65	0.045	0.065
J	0.20	0.30	0.008	0.012
K	3.18	4.06	0.125	0.160
L	7.37	7.87	0.290	0.310
M	—	15°	—	15°
N	0.51	1.02	0.020	0.040

CASE 693-02
Z SUFFIX
CERAMIC PACKAGE

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