OP-27
Low Noise Operational Amplifier

Description

The OP-27 is designed for instrumentation grade signal conditioning where low noise (both spectral density and burst), wide bandwidth, and high slew rate are required along with low input offset voltage, low input offset temperature coefficient, and low input bias currents. These features are all available in a device which is internally compensated for excellent phase margin (70°) in a unity gain configuration.

Digital nulling techniques performed at wafer sort make it feasible to guarantee temperature stable input offset voltages as low as 25 µV. Input bias current cancellation techniques are used to obtain 10 nA input bias currents.

The OP-27 design uniquely addresses the needs of the instrumentation designer. Power supply rejection and common mode rejection are both in excess of 120 dB. A phase margin of 70° at unity gain guards against peaking (and ringing) in low gain feedback circuits. Stable operation can be obtained with capacitive loads up to 2000 pF*. Input offset voltage can be externally trimmed without affecting input offset voltage drift with temperature or time. The drift performance is, in fact, so good that the system designer must be cautioned that stray thermoelectric voltages generated by dissimilar metal at the contacts to the input terminals are enough to degrade its performance. For this reason it is also important to keep both input terminals at the same relative temperature.

The OP-27 is available in SO-8 (small-outline), TO-99 can, plastic mini-DIP and ceramic mini-DIP packages, and can be ordered with Mil-Std-883 Level B processing.

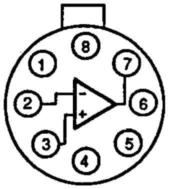
*By decoupling the load capacitance with a series resistor of 50Ω or more, load capacitances larger than 2000 pF can be accommodated.

Features

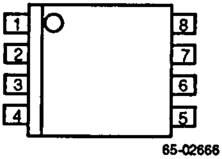
- Very low noise
  Spectral noise density — 3.0 nV/√Hz
  1/F noise corner frequency — 2.7 Hz
- Very low V_{OS} drift
  0.2 µV/Mo
  0.2 µV/°C
- High gain — 1800 V/mV
- High output drive capability — ±12V into 600Ω load
- High slew rate —2.8 V/µS
- Wide gain bandwidth product — 8 MHz
- Good CMRR — 126 dB
- Low V_{OS} — 10 µV
- Low noise — 0.08 μV_{p-p} (0.1 Hz to 10 Hz)
- Low input bias current — ±10 nA

Connection Information

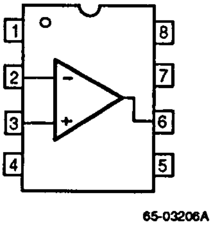
8-Lead
TO-99 Metal Can
(Top View)



8-Lead Plastic
Dual In-Line SO-8
(Top View)



8-Lead
Dual In-Line Package
(Top View)



Pin	Function
1	V_{OS} Trim
2	-Input
3	+Input
4	$-V_S$
5	NC
6	Output
7	$+V_S$
8	V_{OS} Trim

Ordering Information

Part Number	Package	Operating Temperature Range
OP-27EN	N	0°C to +70°C
OP-27FN	N	0°C to +70°C
OP-27GN	N	0°C to +70°C
OP-27EM	M	0°C to +70°C
OP-27FM	M	0°C to +70°C
OP-27GM	M	0°C to +70°C
OP-27AD	D	-55°C to +125°C
OP-27AD/883	D	-55°C to +125°C
OP-27BD	D	-55°C to +125°C
OP-27BD/883	D	-55°C to +125°C
OP-27CD	D	-55°C to +125°C
OP-27CD/883	D	-55°C to +125°C
OP-27AT	T	-55°C to +125°C
OP-27AT/883	T	-55°C to +125°C
OP-27BT	T	-55°C to +125°C
OP-27BT/883	T	-55°C to +125°C
OP-27CT	T	-55°C to +125°C
OP-27CT/883	T	-55°C to +125°C

Notes:
/883B suffix denotes Mil-Std-883, Level B processing
N = 8-lead plastic DIP
D = 8-lead ceramic DIP
T = 8-lead metal can (TO-99)
M = 8-lead plastic SOIC

Absolute Maximum Ratings

Supply Voltage	±22V
Input Voltage[1]	±22V
Differential Input Voltage	0.7V
Internal Power Dissipation[2]	658 mW
Output Short Circuit Duration	Indefinite
Storage Temperature Range	-65°C to +150°C
Operating Temperature Range	
OP-27A/B/C	-55°C to +125°C
OP-27E/F/G	0°C to +70°C
Lead Soldering Temperature	
(SO-8, 10 sec)	+260°C
(DIP,TO-99; 60 sec)	+300°C

Notes:
1. For supply voltages less than ±22V, the absolute maximum input voltage is equal to the supply voltage.
2. Observe package thermal characteristics.

Thermal Characteristics

	8-Lead Small Outline	8-Lead Ceramic DIP	8-Lead TO-99 Metal Can	8-Lead Plastic DIP
Max. Junction Temp.	+125°C	+175°C	+175°C	+125°C
Max. P_D T_A <50°C	300 mW	833 mW	658 mW	468 mW
Therm. Res θ_{JC}	—	45°C/W	50°C/W	—
Therm. Res. θ_{JA}	240°C/W	150°C/W	190°C/W	160°C/W
For T_A >50°C Derate at	4.17 mW/°C	8.33 mW/°C	5.26 mW/°C	6.25 mW/°C

Electrical Characteristics

(V_S = ±15V and T_A = +25°C unless otherwise noted)

Parameters	Test Conditions	OP-27A/E			OP-27B/F			OP-27C/G			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage[5]			10	25		20	60		30	100	µV
Long Term Input Offset Voltage Stability[1, 4]			0.2	1.0		0.3	1.5		0.4	2.0	µV/Mo
Input Offset Current			7.0	35		9.0	50		12	75	nA
Input Bias Current			±10	±40		±12	±55		±15	±80	nA
Input Noise Voltage[2]	0.1 Hz to 10 Hz		0.08	0.18		0.08	0.18		0.09	0.25	μV_{p-p}
Input Noise Voltage Density[2]	F_O = 10 Hz		3.5	5.5		3.5	5.5		3.8	8.0	$\frac{nV}{\sqrt{Hz}}$
	F_O = 30 Hz		3.1	4.5		3.1	4.5		3.3	5.6	
	F_O = 1000 Hz		3.0	3.8		3.0	3.8		3.2	4.5	
Input Noise Current Density[2]	F_O = 10 Hz		1.7	4.0		1.7	4.0		1.7		$\frac{pA}{\sqrt{Hz}}$
	F_O = 30 Hz		1.0	2.3		1.0	2.3		1.0		
	F_O = 1000 Hz		0.4	0.6		0.4	0.6		0.4	0.6	
Input Resistance (Diff. Mode)[4]		1.5	6.0		1.2	5.0		0.8	4.0		MΩ
Input Resistance (Com. Mode)			3.0			2.5			2.0		GΩ
Input Voltage Range[3]		±11	±12.3		±11	±12.3		±11	±12.3		V
Common Mode Rejection Ratio	V_{CM} = ±11V	114	126		106	123		100	120		dB
Power Supply Rejection Ratio	V_S ±4V to ±18V	100	120		100	120		94	118		dB
Large Signal Voltage Gain	$R_L \geq 2$ kΩ, V_{OUT}= ±10V	1000	1800		1000	1800		700	1500		V/mV
	$R_L \geq 1$ kΩ, V_{OUT} = ±10V	800	1500		800	1500			1500		
	V_{OUT} = ±1V, V_S = ±4V	250	700		250	700		200	500		
Output Voltage Swing	$R_L \geq 2$ kΩ,	±12	±13.8		±12	±13.8		±11.5	±13.5		V
	$R_L \geq 600$Ω,	±11	±12		±11	±12		±11	±12		
Slew Rate[4]	$R_L \geq 2$ kΩ,	1.7	2.8		1.7	2.8		1.7	2.8		V/µS
Gain Bandwidth Product[4]		5.0	8.0		5.0	8.0		5.0	8.0		MHz
Open Loop Output Resistance	V_{OUT} = 0, I_{OUT} = 0		70			70			70		Ω
Power Consumption			90	140		90	140	100	170	mW	
Offset Adjustment Range	R_{TRIM} = 10 kΩ		±4.0			±4.0			±4.0		mV

Notes:

1. Long Term Input Offset Voltage Stability refers to the average trend line of V_{OS} vs. Time over extended periods after the first 30 days of operation. Excluding the initial hour of operation, changes in V_{OS} during the first 30 operating days are typically 2.5 µV.
2. This parameter is tested on a sample basis only.
3. Caution: The Common Mode Input Range is a function of supply voltage. See Typical Performance Curves. Also, the input protection diodes do not allow the device to be removed or inserted into the circuit without first removing power.
4. Parameter is guaranteed but not tested.
5. Input Offset Voltage measurements are performed by automated test equipment approximately 0.5 seconds after application of power.

Electrical Characteristics

(V_S = ±15V, -55°C ≤T_A ≤ +125°C unless otherwise noted)

Parameters	Test Conditions	OP-27A			OP-27B			OP-27C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage[1]			30	60		50	200		70	300	µV
Average Input Offset Voltage Drift[2]			0.2	0.6		0.3	1.3		0.4	1.8	µV/°C
Input Offset Current			15	50		22	85		30	135	nA
Input Bias Current			±20	±60		±28	±95		±35	±150	nA
Input Voltage Range		±10.3	±11.5		±10.3	±11.5		±10.2	±11.5		V
Common Mode Rejection Ratio	V_{CM} = ±10V	108	122		100	119		94	116		dB
Power Supply Rejection Ratio	V_S = ±4.5V to ±18V	96	116		94	114		86	110		dB
Large Signal Voltage Gain	R_L ≥ 2 kΩ, V_{OUT} = ±10V	600	1200		500	1000		300	800		V/mV
Output Voltage Swing	R_L ≥2 kΩ	±11.5	±13.5		±11	±13.2		±10.5	±13		V

Electrical Characteristics

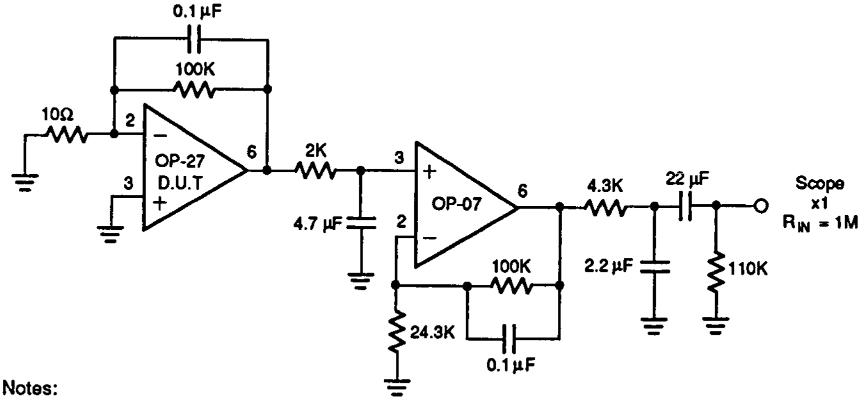
(V_S = ±15V, 0°C ≤ T_A ≤ +70°C for plastic package unless otherwise noted)

Parameters	Test Conditions	OP-27E			OP-27F			OP-27G			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage[1]			20	50		40	140		55	220	µV
Average Input Offset Voltage Drift[2]			0.2	0.6		0.3	1.3		0.4	1.8	µV/°C
Input Offset Current			10	50		14	85		20	135	nA
Input Bias Current			±14	±60		±18	±95		±25	±150	nA
Input Voltage Range		±10.5	±11.8		±10.5	±11.8		±10.5	±11.8		V
Common Mode Rejection Ratio	V_{CM} = ±10V	110	124		102	121		96	118		dB
Power Supply Rejection Ratio	V_S = ±4.5V to ±18V	97	118		96	116		90	114		dB
Large Signal Voltage Gain	R_L ≥ 2 kΩ, V_{OUT} = ±10V	750	1500		700	1300		450	1000		V/mV
Output Voltage Swing	R_L ≥2 kΩ	±11.7	±13.6		±11.4	±13.5		±11	±13.3		V

Notes:

1. Input Offset Voltage measurements are performed by automated test equipment approximately 0.5 seconds after application of power.
2. T_CV_{OS} performance is guaranteed untrimmed or when trimmed with R_{TRIM} = 8.0 kΩ to 20 kΩ.

Typical Performance Characteristics

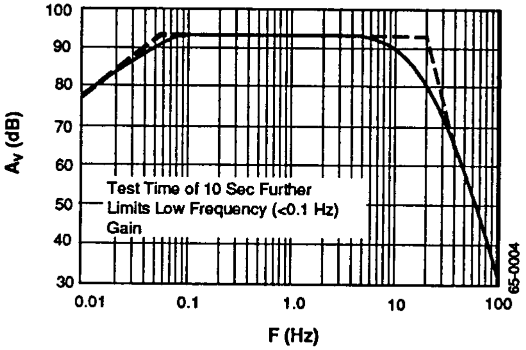


Notes:
1. Peak-to-peak noise measured in a 10-second interval.
2. The device under test should be warmed up for 3 minutes and shielded from air currents .
3. Voltage gain = 50,000.

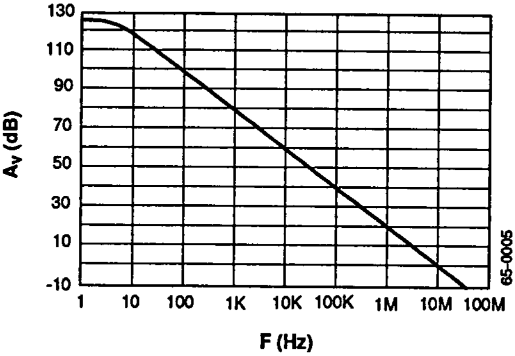
65-0003A

0.1 Hz to 10 Hz Noise Test Circuit

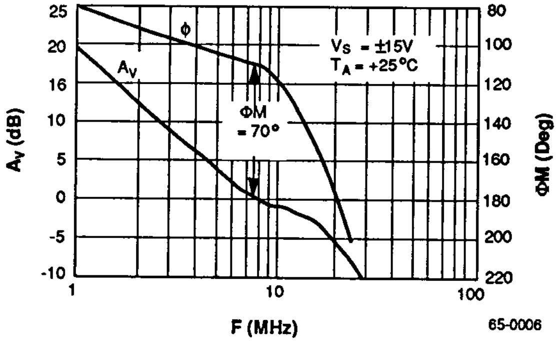
0.1 Hz to 10 Hz Noise Gain vs. Frequency



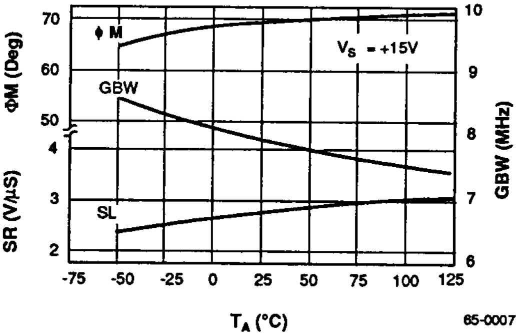
Open Loop Gain vs. Frequency



Gain, Phase Shift vs. Frequency

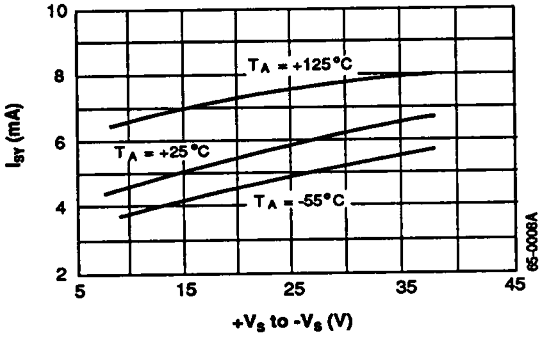


Slew Rate, Gain Bandwidth Product,
Phase Margin vs. Temperature

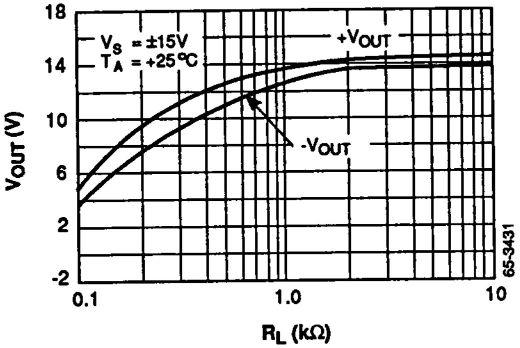


Typical Performance Characteristics (Continued)

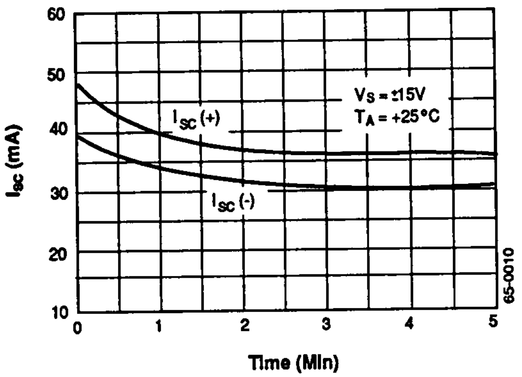
Supply Current vs. Total Supply Voltage



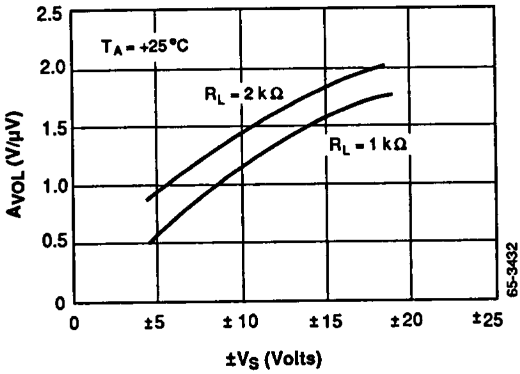
Maximum Output Swing vs. Load Resistance



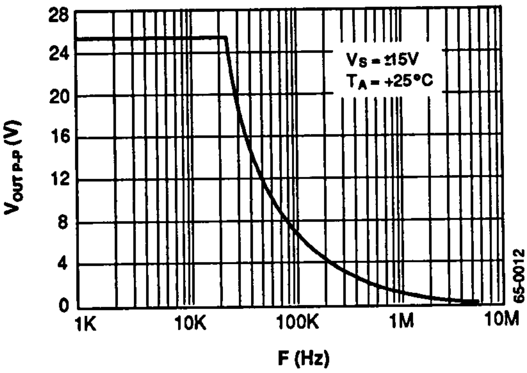
Short Circuit Current vs. Time



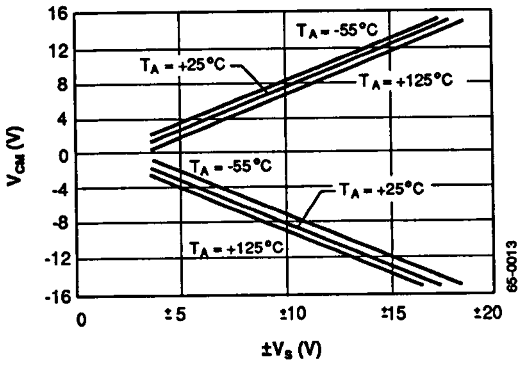
Open Loop Gain vs. Supply Voltage



Gain, Phase Shift vs. Frequency

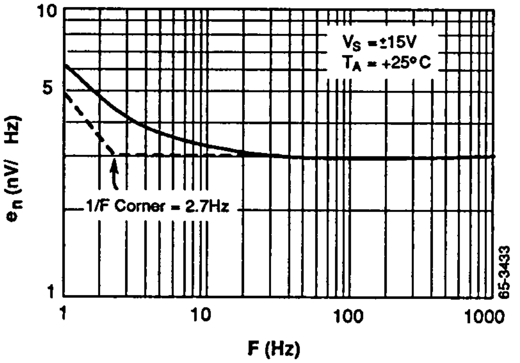


Common Mode Input Range vs. Supply Voltage

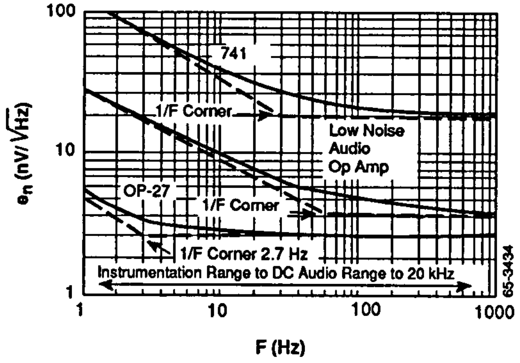


Typical Performance Characteristics (Continued)

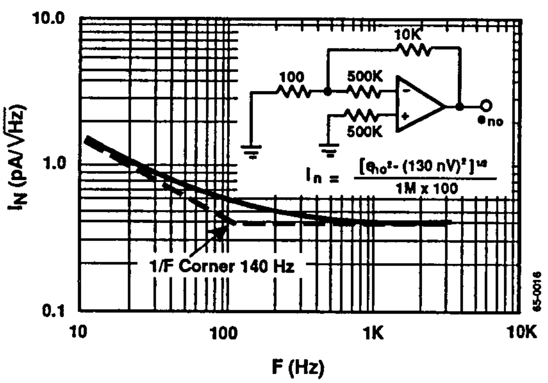
Input Noise Voltage Density vs. Frequency



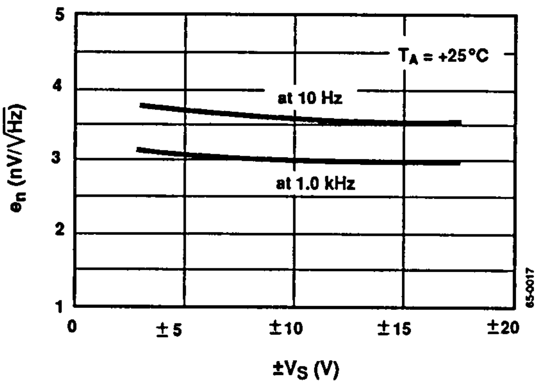
Op Amp Comparison
Input Noise Voltage Density vs. Frequency



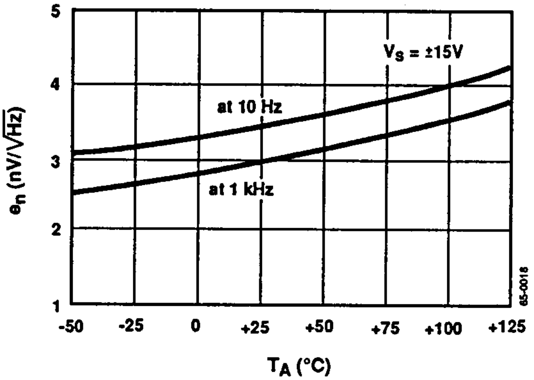
Input Noise Current Density vs. Frequency



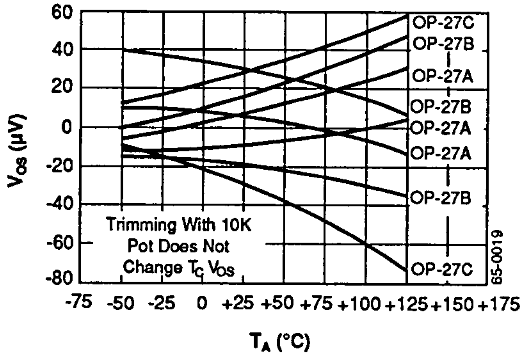
Input Noise Voltage Density vs. Supply Voltage



Input Noise Voltage Density vs. Temperature

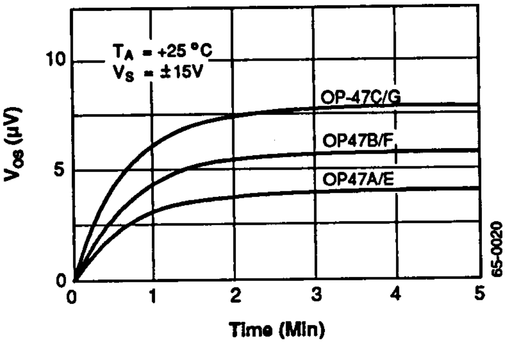


Input Offset Voltage Drift of Representative Units

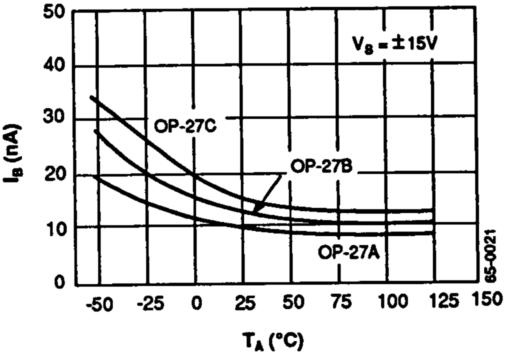


Typical Performance Characteristics (Continued)

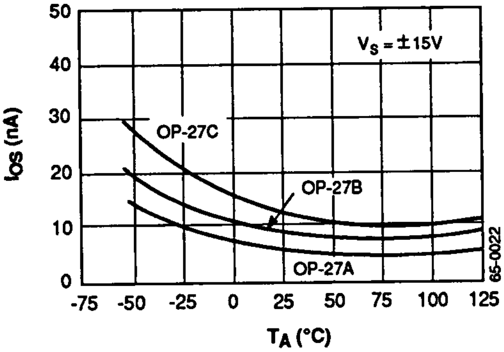
Input Offset Voltage vs. Time
(Warm-Up Drift)



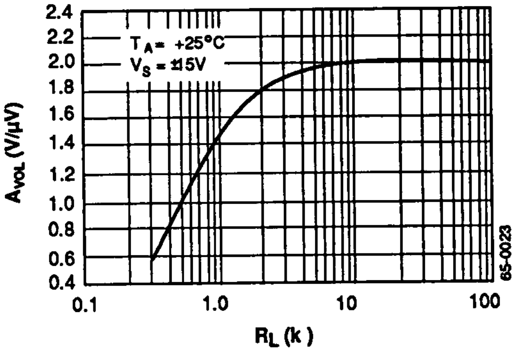
Input Bias Current vs. Temperature



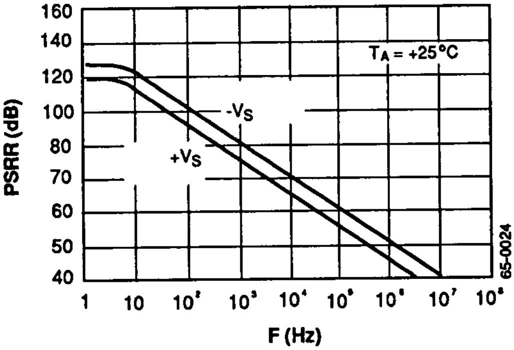
Input Offset Current vs. Temperature



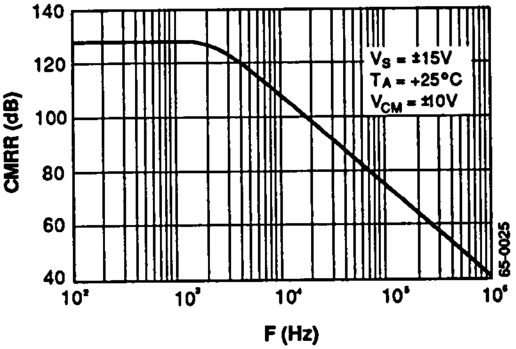
Open Loop Gain vs. Load Resistance



PSRR vs. Frequency

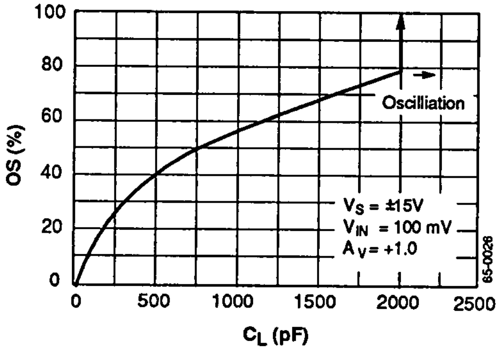


CMRR vs. Frequency

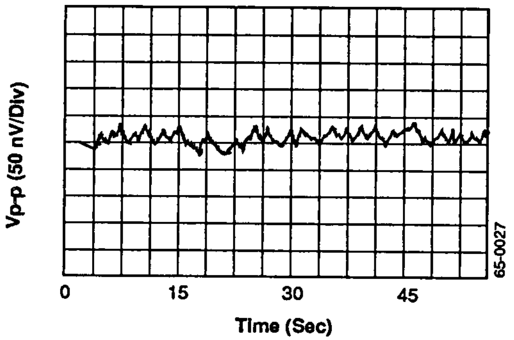


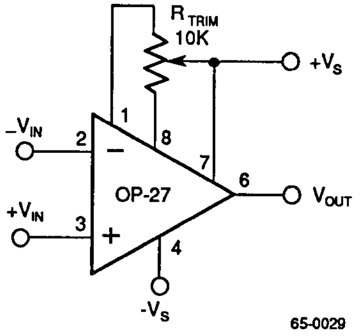
Typical Performance Characteristics (Continued)

Small Signal Overshoot vs. Capacitive Load

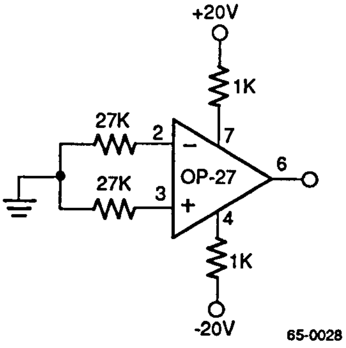


0.1 Hz to 10 Hz Peak-to-Peak Noise vs. Time

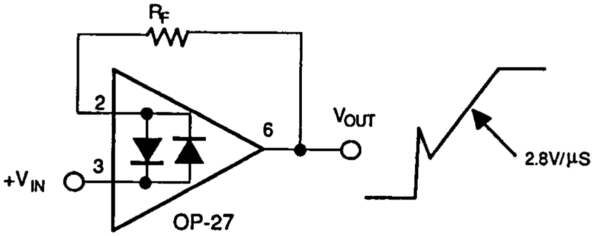




Input Offset Trimming Circuit



Burn-In Circuit



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

Note: Pin numbers shown are for 8-lead packages.

Large Signal Transient Response

Typical Applications

RIAA Phono Preamplifier (Figure 1)

The new moving coil magnetic phono cartridges have sensitivities that are an order of magnitude lower than the sensitivity of a typical moving magnet cartridge (0.1 mV per CM/S versus 1.0 mV per CM/S). This places a greater burden on the preamplifier to achieve more gain and less noise. The OP-27 is ideally suited for this task. The object in designing an RIAA phono preamp is to achieve the RIAA gain-frequency response curve while contributing as little noise as possible to avoid masking the very small signal generated by the cartridge. The circuit shown is adjusted to match a 40 dB RIAA curve as shown in Figure 2. Note that by convention the RIAA gain is specified at 1 kHz. With the "break points" of the curves specified at 50,500 and 2.1 kHz, respectively, the entire curve is fixed by the specified gain at 1kHz.

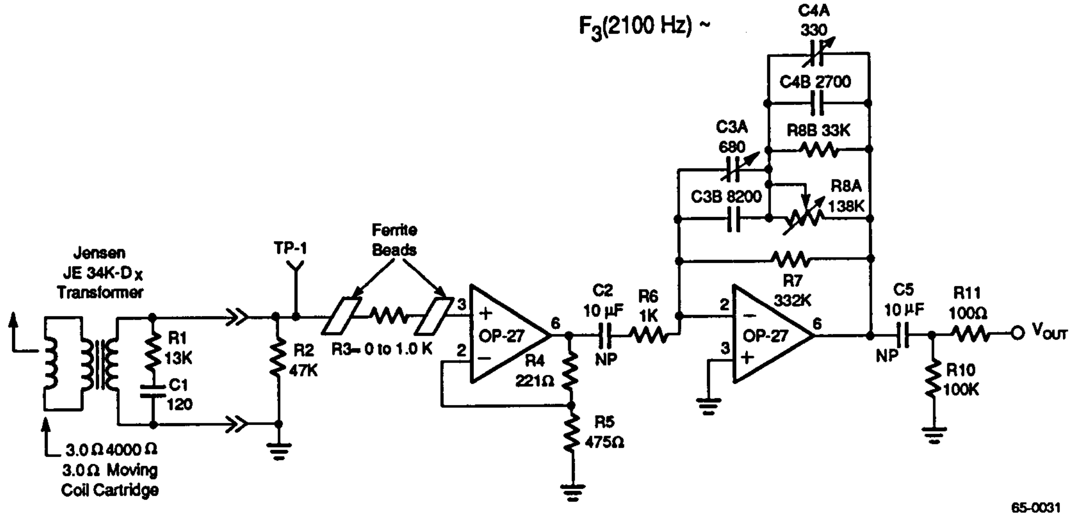
The circuit is designed to operate with a 3/4000Ω step-up transformer to present the optimum source impedance to the amplifier for best noise figure. The optimum source impedance is obtained as the ratio of the spectral noise voltage en to the spectral noise current I_N (when e_n has dimensions of nV/√Hz and I_N has dimensions of pA/√Hz and the ratio has dimensions of kΩ). The circuit is designed to be tested and adjusted independent of the transformer. For testing, introduce a very low level signal of 1 mV at test point TP-1. The first stage is a wideband stage which provides a small amount of gain (1 + R4/R5) approximately equal to 10 dB. Low value feedback resistors must be used to prevent additional noise due to the spectral current noise or excessive Johnson noise. The gain of the first stage reduces the noise contribution of the second stage. The RIAA transfer curve poles and zeros are due entirely to the feedback network of the second stage.

The poles and zeros of the RIAA feedback network are sufficiently separated in frequency that they may be estimated with the following equations:

$$F_1(50\ \text{Hz}) \sim \frac{1}{2\pi R7C3}$$

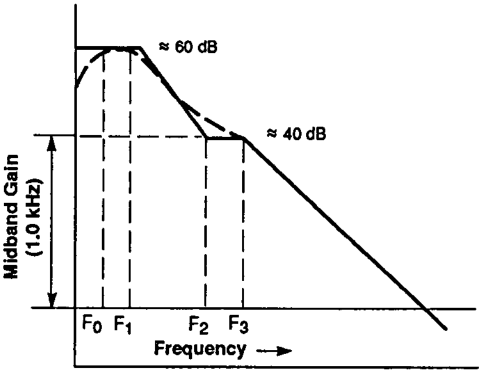
$$F_2(500\ \text{Hz}) \sim \frac{1}{2\pi R8C3}$$

$$F_3(2100\ \text{Hz}) \sim \frac{1}{2\pi R8C2}$$



Notes:
1. To test, disconnect transformer and inject signal at TP-1.
2. Pin numbers shown are for 8-lead packages.

Figure 1. RIAA Phono Preamplifier



F_0 = Low end rolloff frequency (user selected)
F_1 = 50 Hz
F_2 = 500 Hz
F_3 = 2.1 kHz

65-0032

Figure 2. RIAA Phono Playback Equalication Curve

These equations are only approximations. Final tuning is performed with the adjustable capacitors and potentiometers. The following sequence can be used to adjust for the RIAA response after injecting a low level signal into TP-1 (transformer disconnected).

1. At 100 Hz adjust C3A for an output level 6 dB lower than the low frequency output.
2. At 1000 Hz adjust R8A for an output level 20 dB lower than the low frequency output.
3. At 21 kHz adjust C4A for an output 40 dB less than the low frequency output.

Low Impedance Microphone Preamp (Figure 3)

In this preamp the transformer converts the low microphone impedance up to a value that is close to the optimum source impedance required by the OP-27 for best noise performance. The optimum source impedance can be calculated as the ratio of e_n/I_N, which for the OP-27 is approximately 7000Ω. Fortunately the noise performance does not degrade appreciably until the source impedance is four or five times this optimum value and the source impedance at the output of this transformer, approximately 15 kΩ, still provides near optimum noise performance. (A high quality audio transformer with a step-up ratio of 6.7 to one is not available.) The voltage gain of the amplifier, not including the transformer step-up, is unity up to about 1.5 Hz. It may be desirable to reduce the size of this capacitor to minimize burst noise even though the OP-27 has a 1/F noise corner below 3 Hz. C2 rolls off the high frequency response at 90 kHz giving a noise power bandwidth of 140 kHz.

Instrumentation

The OP-27 is particularly adaptable to instrumentation applications. When wired into a single op amp difference amplifier configuration, the OP-27 exhibits outstanding common mode rejection ratio. The spot voltage noise is so low that it is dominated almost entirely by the resistor Johnson noise. (Figures 4 through 7).

The three op amp instrumentation amplifier of Figure 8 avoids the low input impedance characteristics of difference amplifiers at the expense of two more operational amplifiers and a slight degradation in noise performance. The noise increases because two amplifiers are contributing to the input voltage spectral noise instead of one. Thus the noise contribution, exclusive of resistor Johnson noise, increases by slightly more than $\sqrt{2}$. The spectral noise voltage increases from approximately 3 nV/$\sqrt{\text{Hz}}$ to approximately 4.9 nV/$\sqrt{\text{Hz}}$, with the third amplifier contributing about 10% of the noise. The gain of the input amplifier is set at 25 and the second stage at 40 for an overall gain of 1000. R7 is trimmed to optimize the common mode rejection ratio (CMRR) with frequency. With balanced source resistors a CMRR of 100 dB is achieved. With a 1 kΩ source impedance imbalance CMRR is degraded to 80 dB at 5 kHz due to the finite (3 GΩ) input impedance.

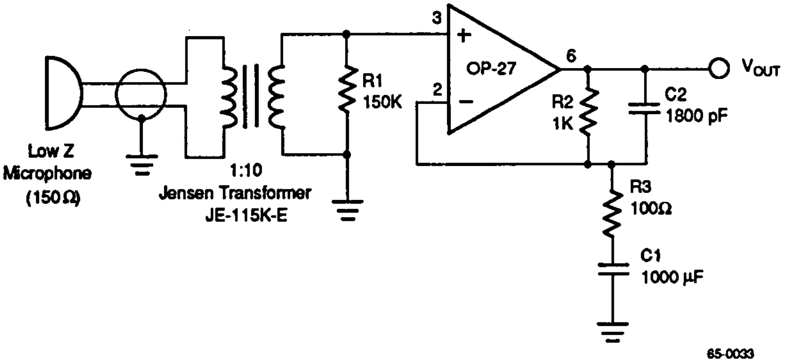
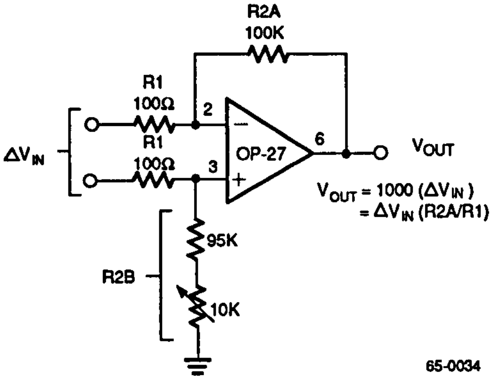


Figure 3. Low Impedance Microphone Preamplifier



Note:
Pin numbers shown are for 8-lead packages.

Figure 4. Difference Amplifier

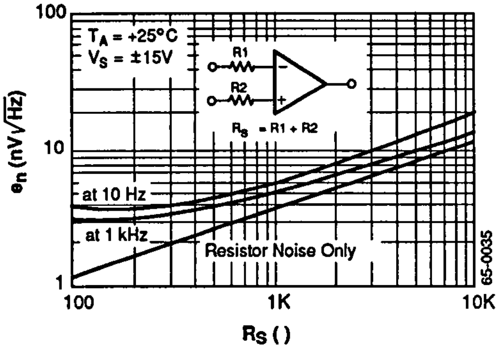


Figure 5. Difference Amplifier
Input Voltage Noise Density vs. Source Resistance

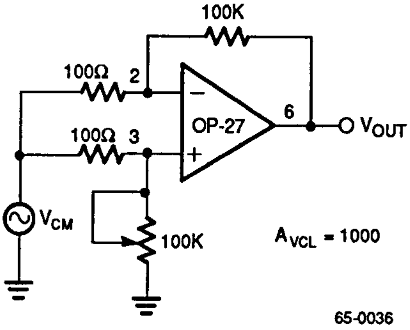


Figure 6. CMRR Test Circuit

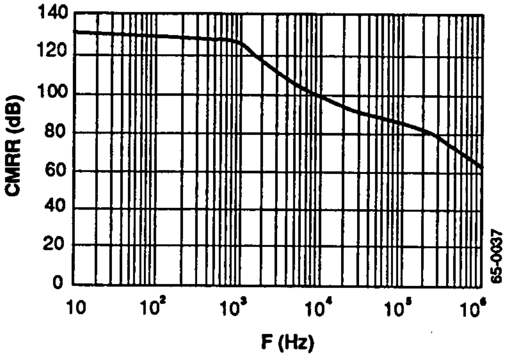
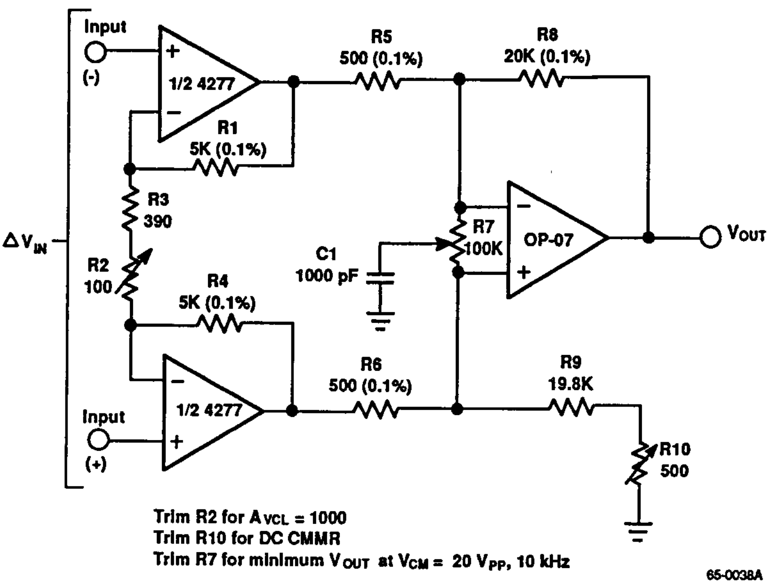


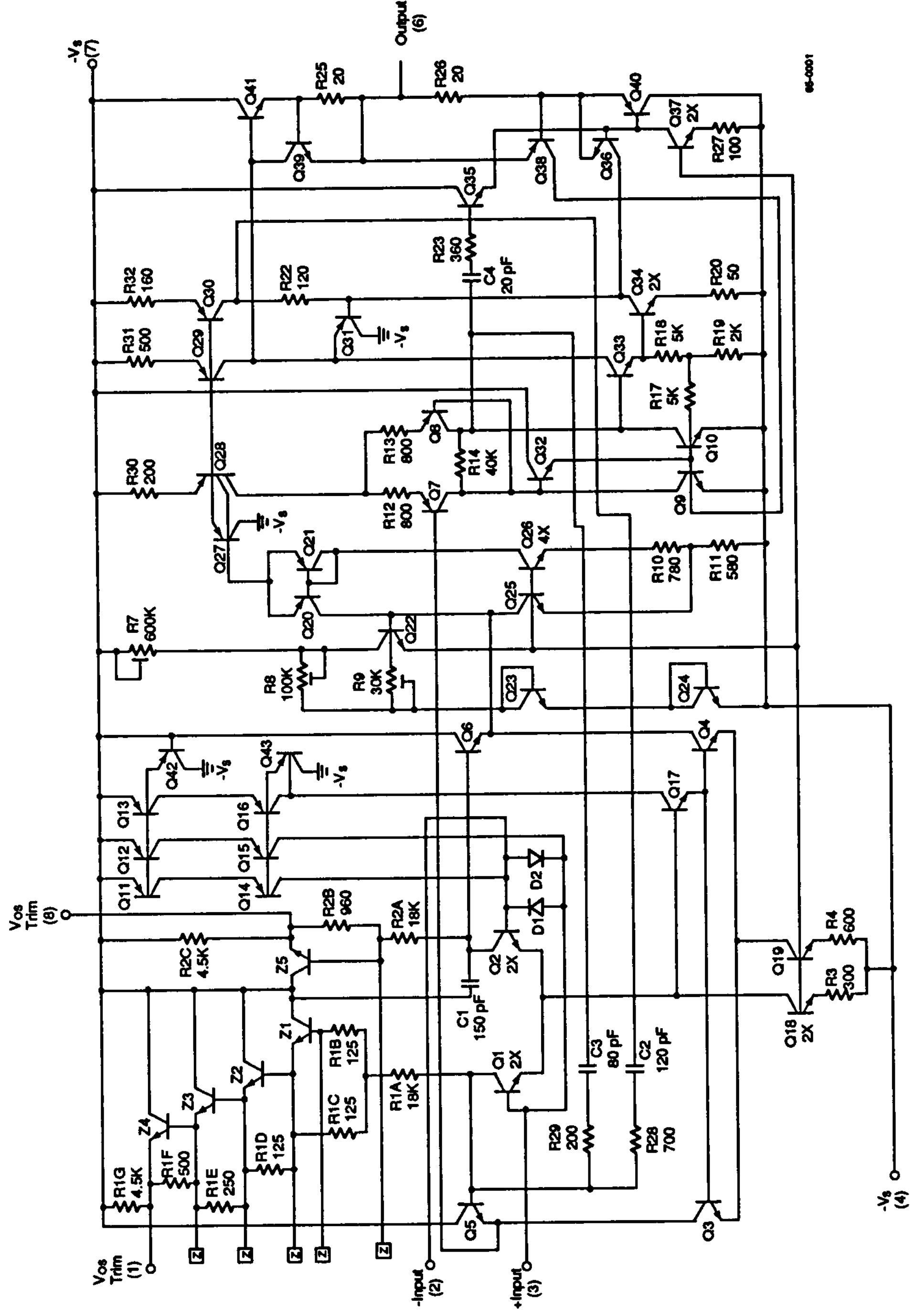
Figure 7. Difference Amplifier CMRR vs. Frequency



Note: Pin numbers shown are for 8-lead packages.

Figure 8. Three Op Amp Instrumentation Amplifier

Schematic Diagram



Note: Pin numbers shown are for 8-lead packages.