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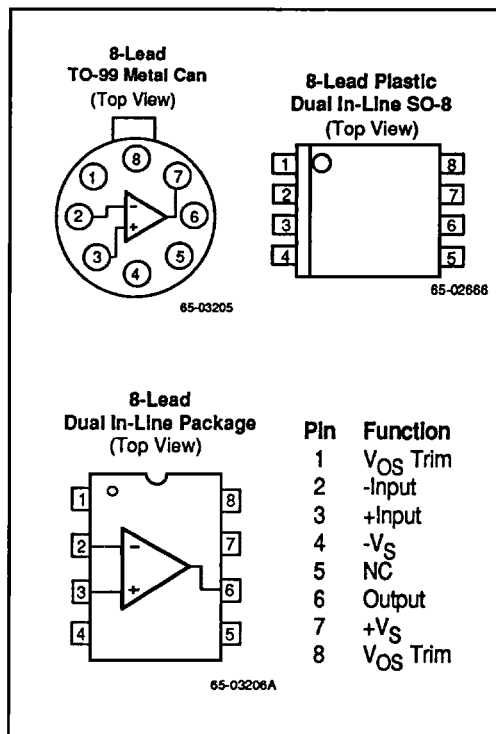
*By decoupling the load capacitance with a series resistor of 50Ω or more, load capacitances larger than 2000 pF can be accommodated.

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

Linear

OP-27

Connection Information

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

65-03205

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

65-02666

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

65-03206A

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

Raytheon Semiconductor   For More Information, call 1-800-722-7074.

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

Linear

OP-27

Electrical Characteristics

($V_S = \pm15V$ and $T_A = +25^\circ C$ unless otherwise noted)

Parameters	Test Conditions	OP-27A/E Min	Typ	Max	OP-27B/F Min	Typ	Max	OP-27C/G Min	Typ	Max	Units
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	nV
	$F_O = 30$ Hz		3.1	4.5		3.1	4.5		3.3	5.6	$\overline{\sqrt{Hz}}$
	$F_O = 1000$ 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		pA
	$F_O = 30$ Hz		1.0	2.3		1.0	2.3		1.0		$\overline{\sqrt{Hz}}$
	$F_O = 1000$ 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		$M\Omega$
Input Resistance (Com. Mode)			3.0			2.5			2.0		$G\Omega$
Input Voltage Range[3]		±11	±12.3		±11	±12.3		±11	±12.3		V
Common Mode Rejection Ratio	$V_{CM} = \pm11V$	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, $V_{OUT} = \pm10V$	1000	1800		1000	1800		700	1500		V/mV
	$R_L \geq 1$ kΩ, $V_{OUT} = \pm10V$	800	1500		800	1500			1500		
	$V_{OUT} = \pm1V$, $V_S = \pm4V$	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
	$R_L \geq 600\Omega$	±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.

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Electrical Characteristics

($V_S = \pm15V$, $-55°C \leq T_A \leq +125°C$ unless otherwise noted)

Parameters	Test Conditions	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	Units
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	$V_{CM} = \pm10V$	108	122		100	119		94	116		dB
Power Supply Rejection Ratio	$V_S = \pm4.5V$ to $\pm18V$	96	116		94	114		86	110		dB
Large Signal Voltage Gain	$R_L \geq 2 k\Omega$, $V_{OUT} = \pm10V$	600	1200		500	1000		300	800		V/mV
Output Voltage Swing	$R_L \geq 2 k\Omega$	±11.5	±13.5		±11	±13.2		±10.5	±13		V

Electrical Characteristics

($V_S = \pm15V$, $0°C \leq T_A \leq +70°C$ for plastic package unless otherwise noted)

Parameters	Test Conditions	OP-27E Min	OP-27E Typ	OP-27E Max	OP-27F Min	OP-27F Typ	OP-27F Max	OP-27G Min	OP-27G Typ	OP-27G Max	Units
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	$V_{CM} = \pm10V$	110	124		102	121		96	118		dB
Power Supply Rejection Ratio	$V_S = \pm4.5V$ to $\pm18V$	97	118		96	116		90	114		dB
Large Signal Voltage Gain	$R_L \geq 2 k\Omega$, $V_{OUT} = \pm10V$	750	1500		700	1300		450	1000		V/mV
Output Voltage Swing	$R_L \geq 2 k\Omega$	±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. $T_C V_{OS}$ performance is guaranteed untrimmed or when trimmed with $R_{TRIM} = 8.0 k\Omega$ to $20 k\Omega$.
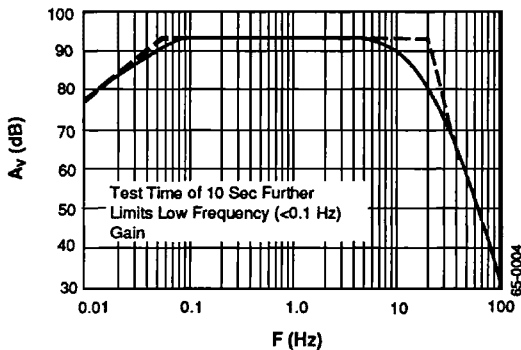
Linear

OP-27

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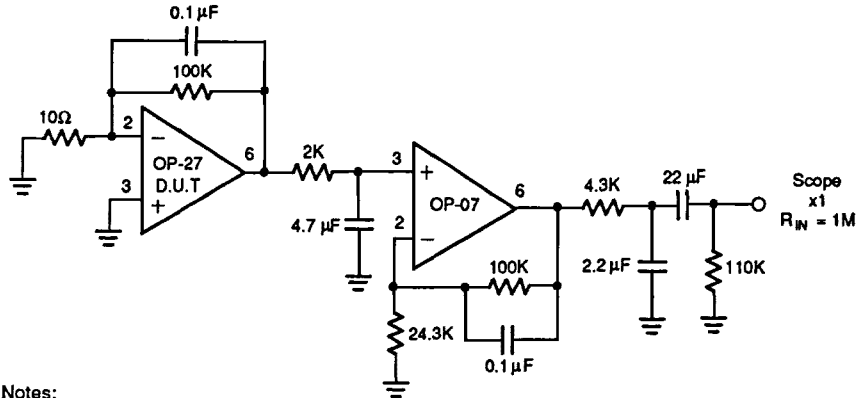
Notes:
1. Peak-to-peak noise measured in a 10-second interval.
2. The device under test should be warmed up for 3 minutes and shielded from air currents .
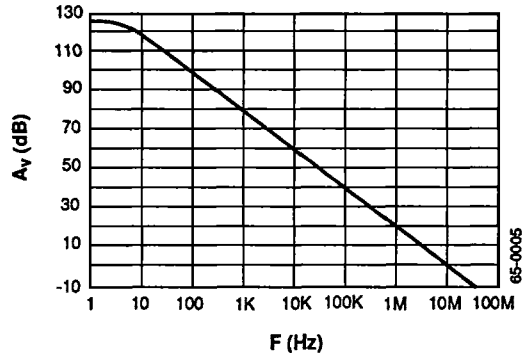3. Voltage gain = 50,000.

65-0003A

0.1 Hz to 10 Hz Noise Test Circuit

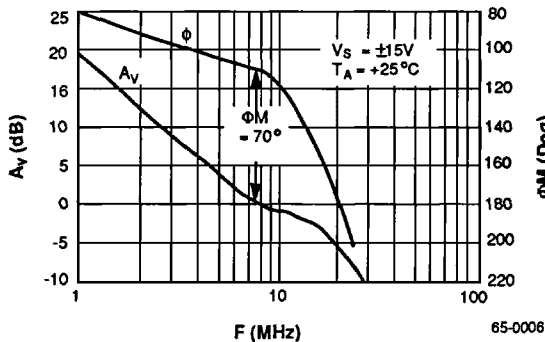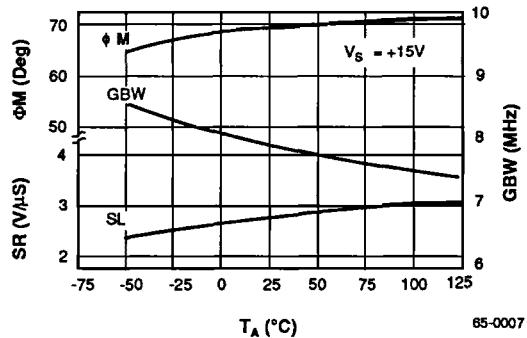0.1 Hz to 10 Hz Noise Gain vs. Frequency

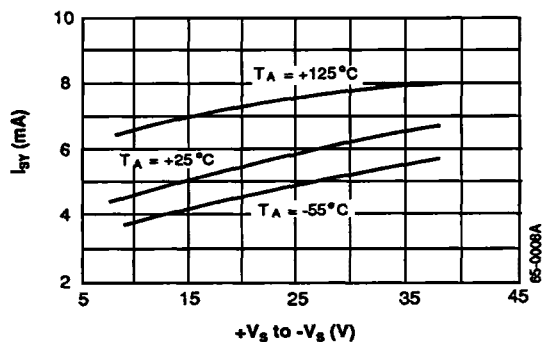Open Loop Gain vs. Frequency

Gain, Phase Shift vs. Frequency

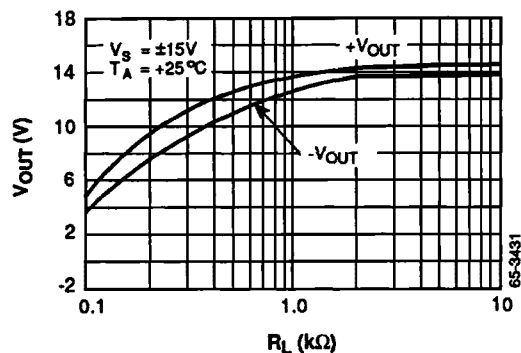Slew Rate, Gain Bandwidth Product, Phase Margin vs. Temperature

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OP-27

Supply Current vs. Total Supply Voltage

I_{SY} (mA)

10
8
6
4
2

$T_A = +125°C$
$T_A = +25°C$
$T_A = -55°C$

5   15   25   35   45

+V_s to -V_s (V)

65-0008A

Maximum Output Swing vs. Load Resistance

V_{OUT} (V)

18
14
10
6
2
-2

$V_S = ±15V$
$T_A = +25°C$
+V_{OUT}
-V_{OUT}

0.1   1.0   10

R_L (kΩ)

65-3431

Short Circuit Current vs. Time

I_{SC} (mA)

60
50
40
30
20
10

I_{SC} (+)
I_{SC} (-)
$V_S = ±15V$
$T_A = +25°C$

0   1   2   3   4   5

Time (Min)

65-0010
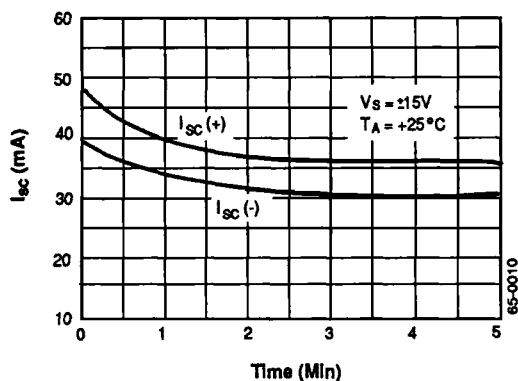
Open Loop Gain vs. Supply Voltage

A_{VOL} (V/µV)

2.5
2.0
1.5
1.0
0.5
0

$T_A = +25°C$
$R_L = 2 kΩ$
$R_L = 1 kΩ$

0   ±5   ±10   ±15   ±20   ±25

±V_S (Volts)

65-3432

Gain, Phase Shift vs. Frequency

$V_{OUT P-P}$ (V)

28
24
20
16
12
8
4
0

$V_S = ±15V$
$T_A = +25°C$

1K   10K   100K   1M   10M

F (Hz)

65-0012
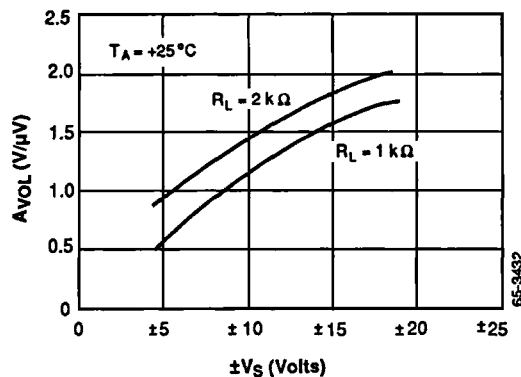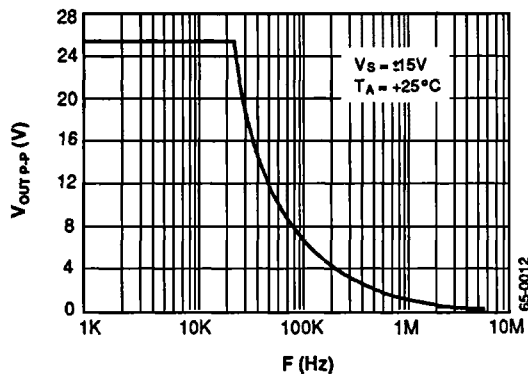
Common Mode Input Range vs. Supply Voltage

V_{CM} (V)

16
12
8
4
0
-4
-8
-12
-16

$T_A = -55°C$
$T_A = +25°C$
$T_A = +125°C$
$T_A = -55°C$
$T_A = +25°C$
$T_A = +125°C$

0   ±5   ±10   ±15   ±20

±V_s (V)

65-0013

Linear

OP-27
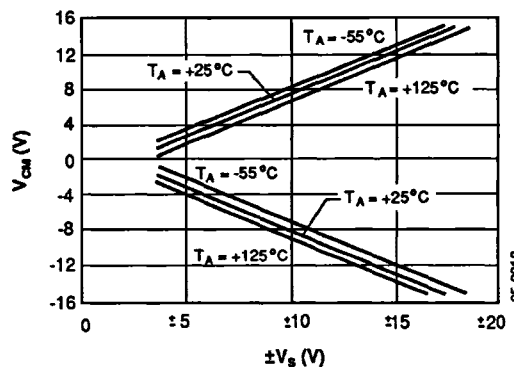
Typical Performance Characteristics (Continued)

Input Noise Voltage Density vs. Frequency
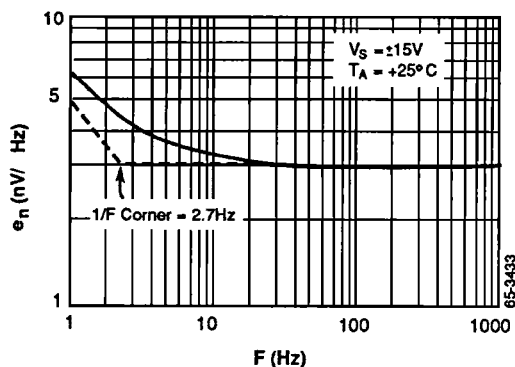
Op Amp Comparison
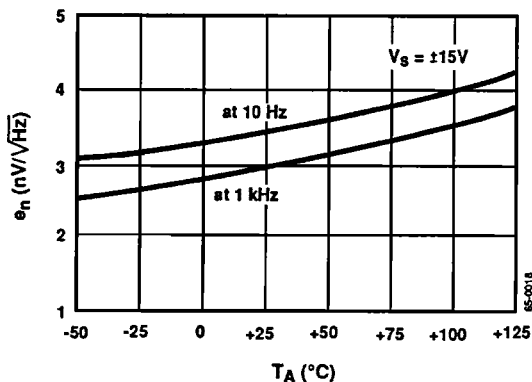Input Noise Voltage Density vs. Frequency
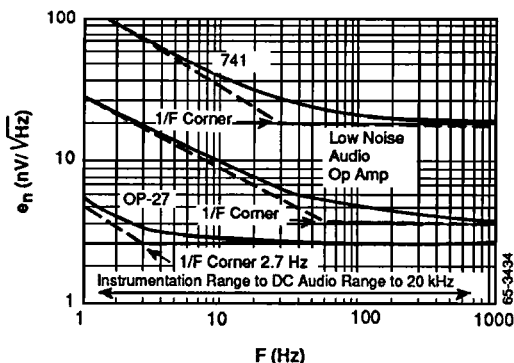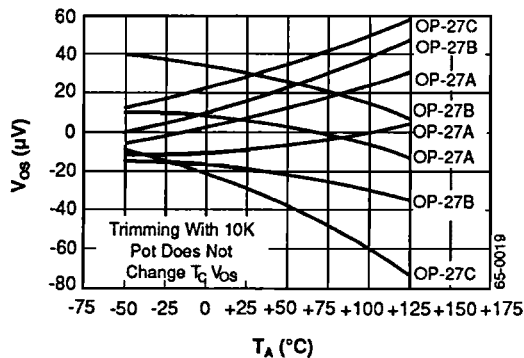

Input Noise Current Density vs. Frequency
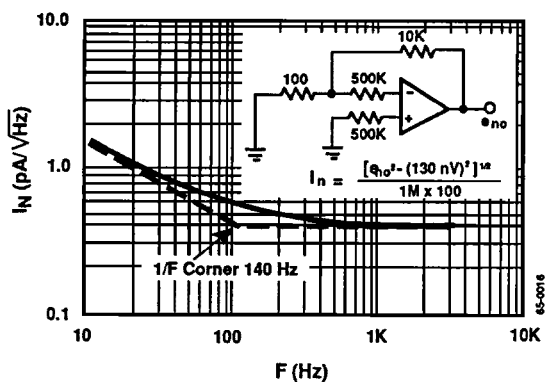
Input Noise Voltage Density vs. Supply Voltage
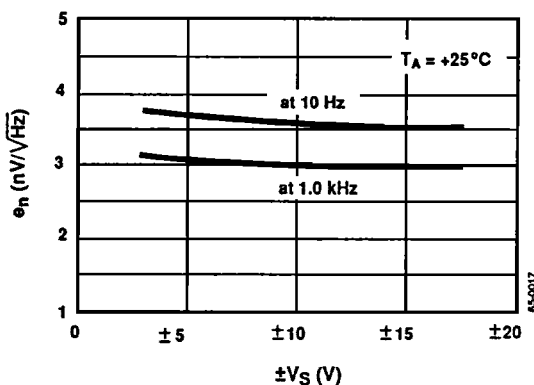
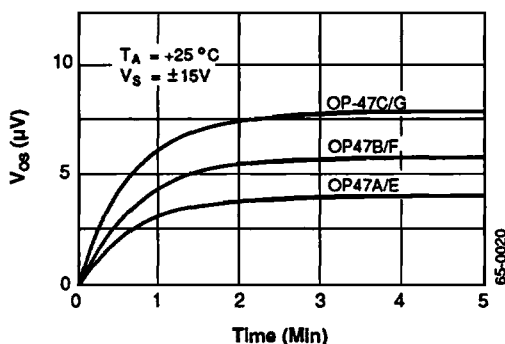Input Noise Voltage Density vs. Temperature
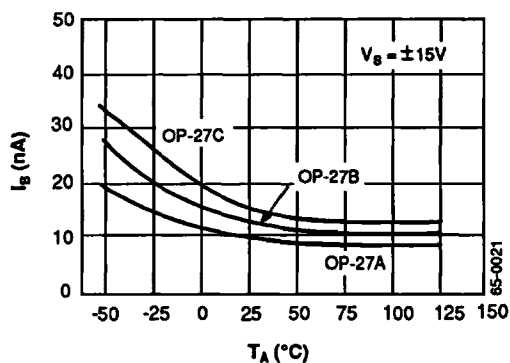

Input Offset Voltage Drift of Representative Units

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Typical Performance Characteristics (Continued)

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

$T_A = +25\,^\circ C$
$V_S = \pm 15V$

OP-47C/G
OP47B/F
OP47A/E

V_{OS} (μV)

Time (Min)

65-0020

Input Bias Current vs. Temperature

$V_S = \pm 15V$

OP-27C
OP-27B
OP-27A

I_B (nA)

T_A (°C)

65-0021

Input Offset Current vs. Temperature

$V_S = \pm 15V$

OP-27C
OP-27B
OP-27A

I_{OS} (nA)

T_A (°C)

65-0022
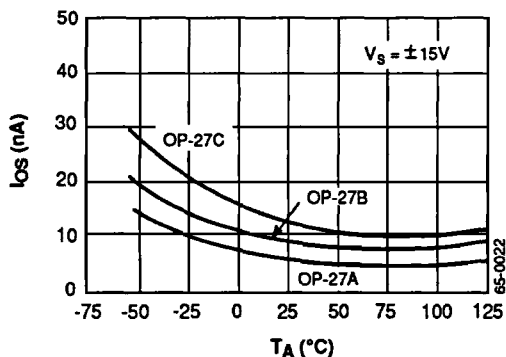
Open Loop Gain vs. Load Resistance
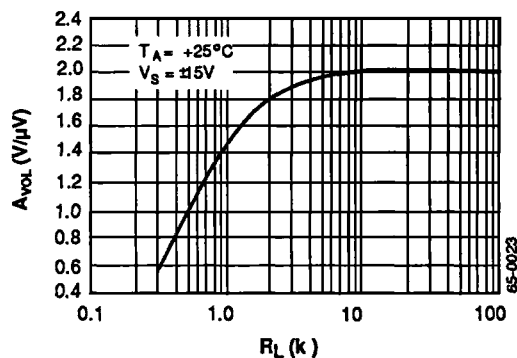
$T_A = +25\,^\circ C$
$V_S = \pm 15V$

A_{VOL} (V/μV)

R_L (k)

65-0023

PSRR vs. Frequency

$T_A = +25\,^\circ C$

$-V_S$
$+V_S$

PSRR (dB)

F (Hz)

65-0024

CMRR vs. Frequency

$V_S = \pm 15V$
$T_A = +25\,^\circ C$
$V_{CM} = \pm 10V$
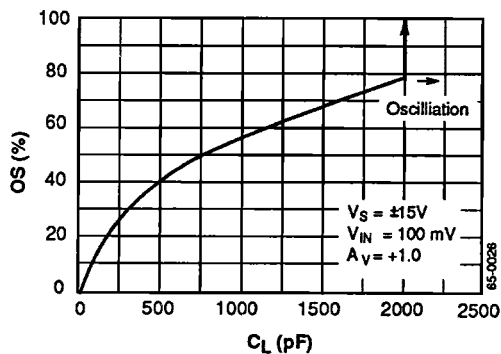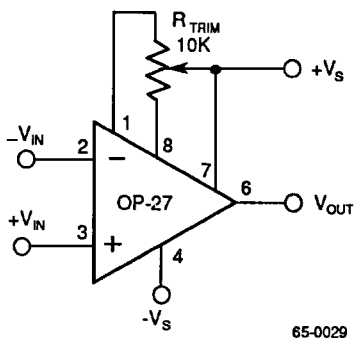
CMRR (dB)

F (Hz)

65-0025
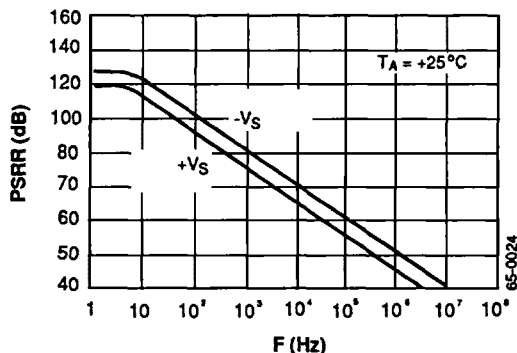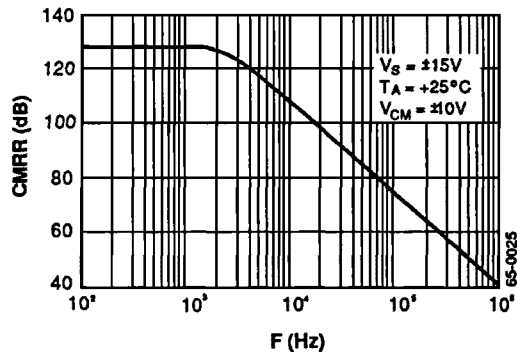
Linear

OP-27

Typical Performance Characteristics (Continued)

Small Signal Overshoot vs. Capacitive Load

$V_S = \pm 15V$
$V_{IN} = 100\ mV$
$A_V = +1.0$

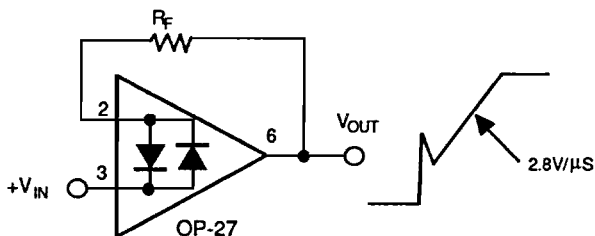### 0.1 Hz to 10 Hz Peak-to-Peak Noise vs. Time
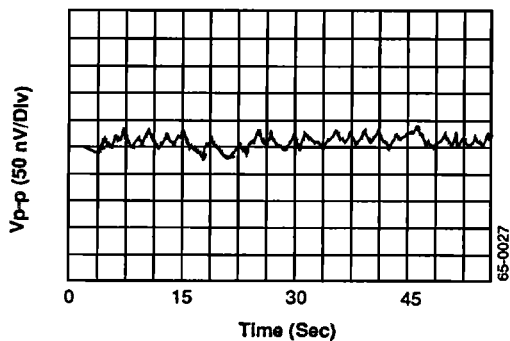
Input Offset Trimming Circuit
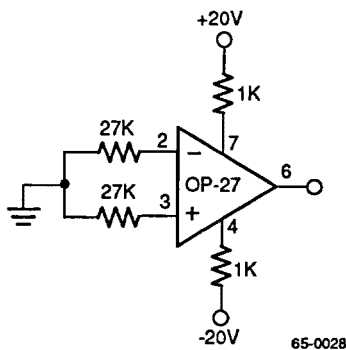
Burn-In Circuit

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

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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 $3/4000\Omega$ 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:

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

$$F_2(500\ Hz) \sim \frac{1}{2\pi R8C3}$$
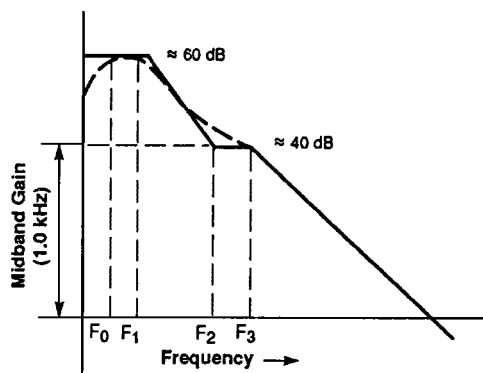
$$\frac{1}{2\pi R8C2}$$

$$F_3(2100\ Hz) \sim$$

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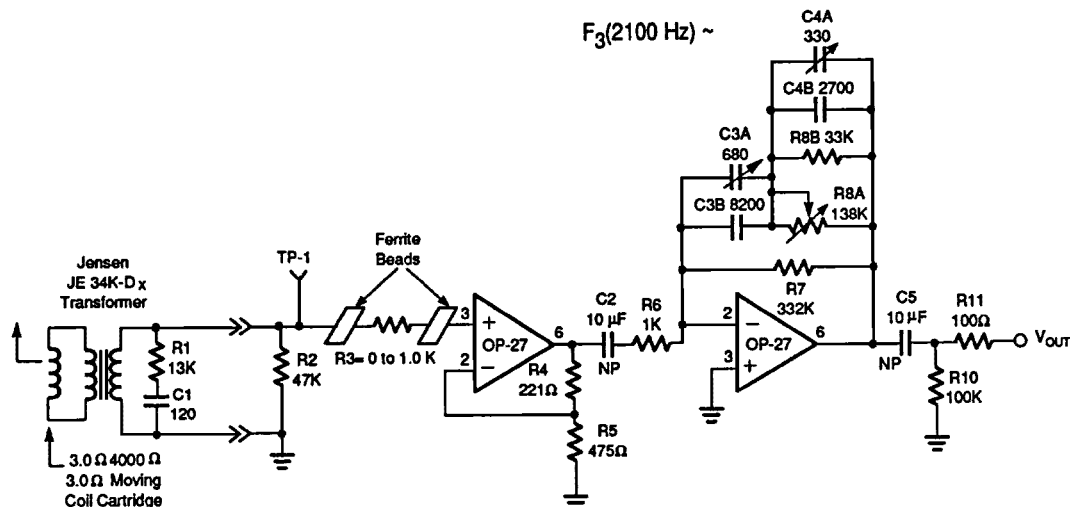
Notes:
1. To test, disconnect transformer and inject signal at TP-1.
2. Pin numbers shown are for 8-lead packages.

65-0031

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.

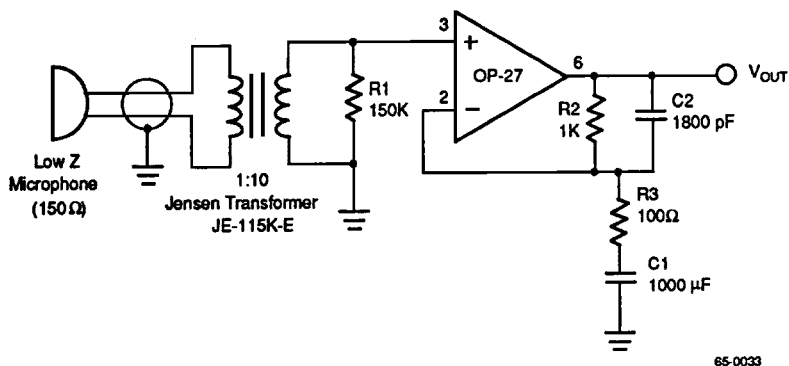## Low Impedance Microphone Preamp (Figure 3)

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/$\sqrt{Hz}$ to approximately 4.9 nV/$\sqrt{Hz}$, 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.

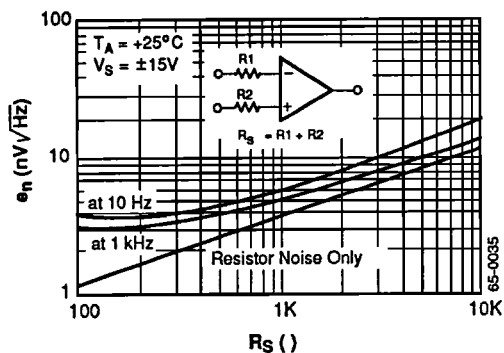**Raytheon Semiconductor**

Figure 3. Low Impedance Microphone Preamplifier
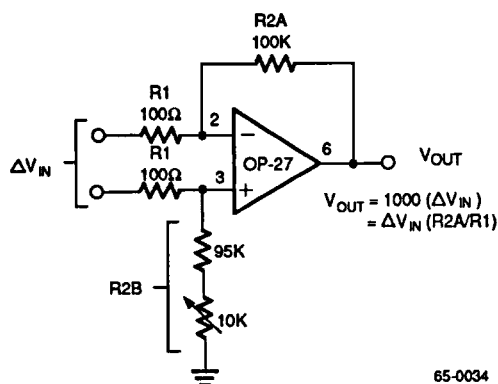
Note:
Pin numbers shown are for 8-lead packages.

Figure 4. Difference Amplifier

Figure 5. Difference Amplifier
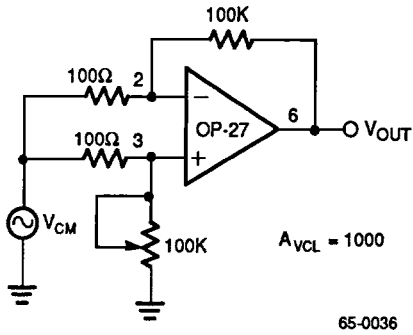Input Voltage Noise Density vs. Source Resistance
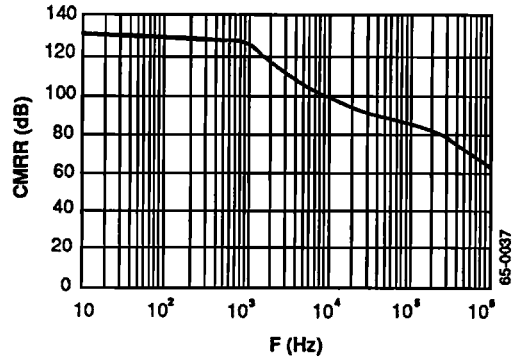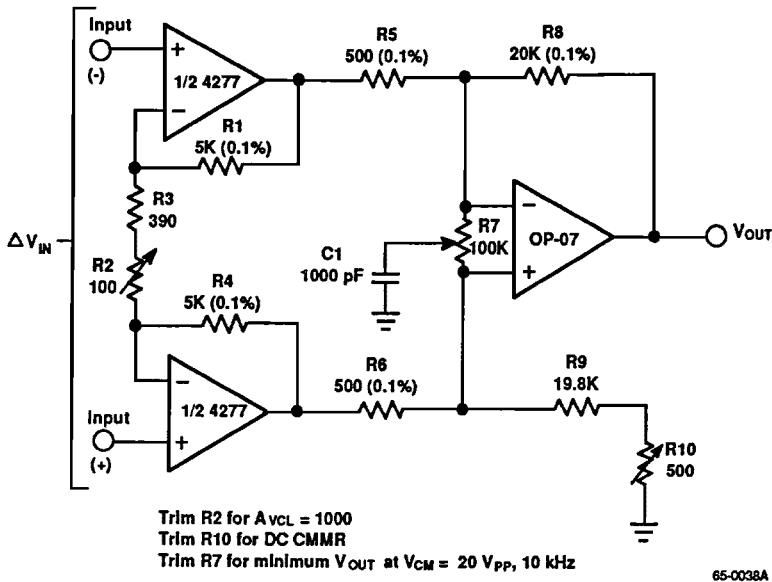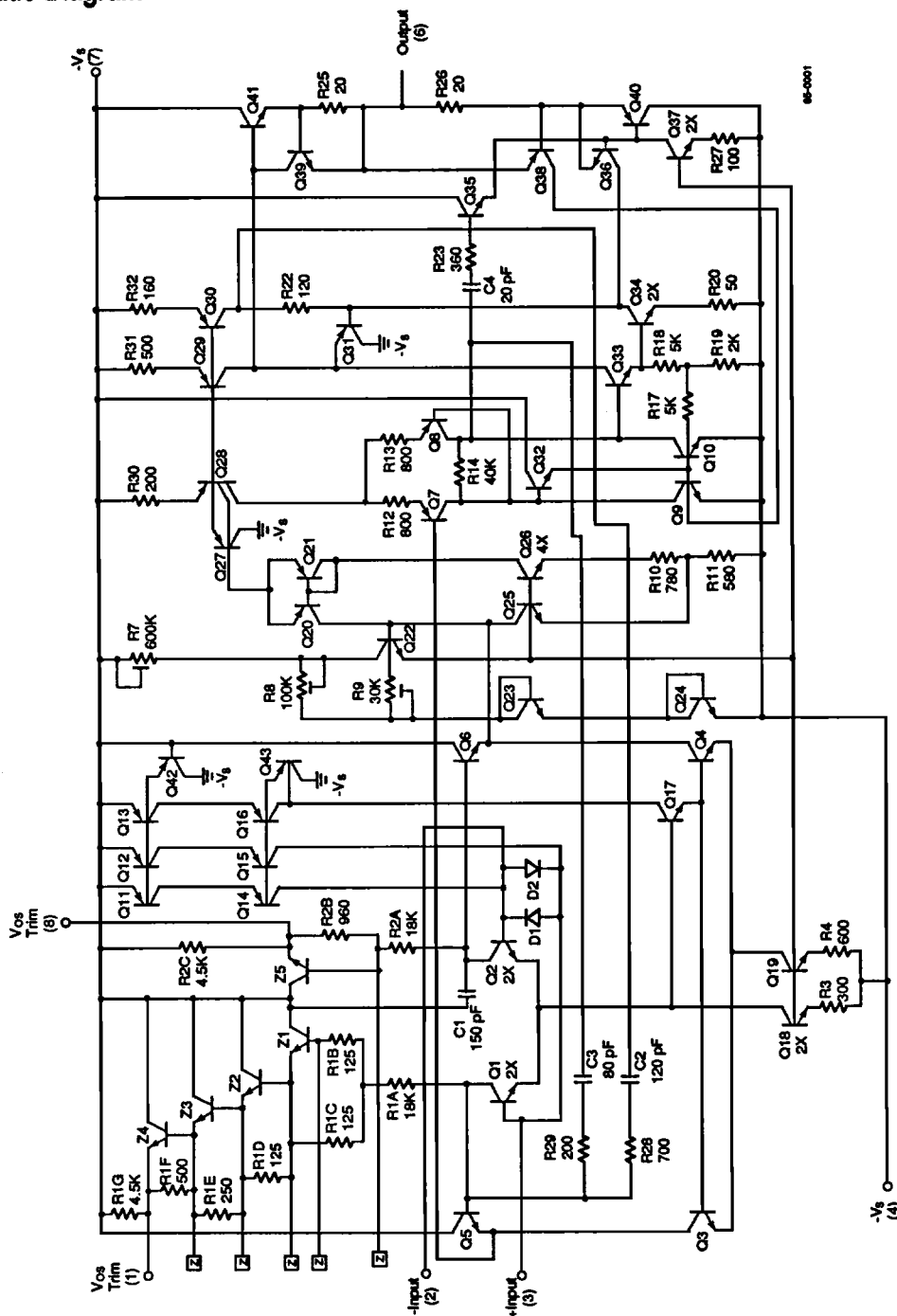
OP-27

Figure 6. CMRR Test Circuit

Figure 7. Difference Amplifier
CMRR vs. Frequency

Trim R2 for $A_{VCL} = 1000$
Trim R10 for DC CMMR
Trim R7 for minimum V_{OUT} at $V_{CM} = 20 V_{PP}$, 10 kHz

65-0038A

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

Figure 8. Three Op Amp Instrumentation Amplifier

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OP-27

Schematic Diagram

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