OP-47 Low Noise, High Slew Rate Operational Amplifier

Features

- Very low noise
  Spectral noise density – 3.0 nV/$\sqrt{Hz}$
  1/f noise corner frequency – 2.7 Hz
- Very low V_{os} drift
  0.2 μV/Month
  0.2 μV/°C
- High gain – 1.8 million
- High output drive capability – ±12V into 600Ω load
- High slew rate – 50 V/μS
- High gain bandwidth product – 63 MHz
- Good common mode rejection ratio –126 dB
- Low input offset voltage – 10 μV
- Minimum low frequency noise –.08 μVp-p (0.1 Hz to 10 Hz)
- Low input bias and offset currents –10 nA
- Compensated for ac stability with AVCL ≥400

Description

The OP-47 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. The OP-47 is a decompensated version of the OP-27 and is ac stable in closed-loop gain configurations greater than or equal to 400.

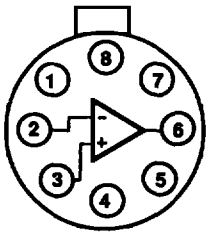
Digital nulling techniques performed at wafer sort make it feasible to guarantee temperature stable input offset voltages as low as 25 μV. Input bias current cancellation techniques are used to obtain 10 nA input bias currents.

The OP-47 design uniquely addresses the needs of the instrumentation designer. Power supply rejection and common mode rejection are both in excess of 120 dB. 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 metals 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-47 is available in LCC, 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.

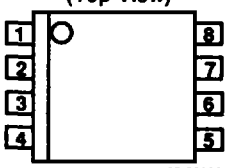
Connection Information

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



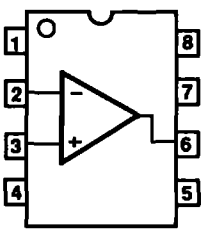
65-03205A

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



65-02668A

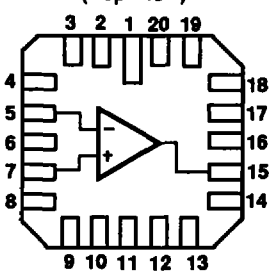
8-Lead Dual In-Line Package
(Top View)



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

20-Pad LCC
(Top View)



65-02657A

Pin	Function
2	V_{os} Trim
5	-Input
7	+Input
10	$-V_s$
15	Output
17	$+V_s$
20	V_{os} Trim

Ordering Information

Part Number	Package	Operating Temperature Range
OP-47EN	N	0°C to +70°C
OP-47FN	N	0°C to +70°C
OP-47GN	N	0°C to +70°C
OP-47EM	M	0°C to +70°C
OP-47FM	M	0°C to +70°C
OP-47GM	M	0°C to +70°C
OP-47ED	D	-25°C to +85°C
OP-47FD	D	-25°C to +85°C
OP-47GD	D	-25°C to +85°C
OP-47ET	T	-25°C to +85°C
OP-47FT	T	-25°C to +85°C
OP-47GT	T	-25°C to +85°C
OP-47AD	D	-55°C to +125°C
OP-47AD/883B	D	-55°C to +125°C
OP-47BD	D	-55°C to +125°C
OP-47BD/883B	D	-55°C to +125°C
OP-47CD	D	-55°C to +125°C
OP-47CD/883B	D	-55°C to +125°C
OP-47AT	T	-55°C to +125°C
OP-47AT/883B	T	-55°C to +125°C
OP-47BT	T	-55°C to +125°C
OP-47BT/883B	T	-55°C to +125°C
OP-47CT	T	-55°C to +125°C
OP-47CT/883B	T	-55°C to +125°C
OP-47AL/883B	L	-55°C to +125°C
OP-47BL/883B	L	-55°C to +125°C

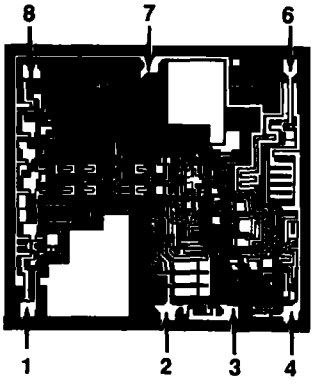
Notes:
/883B suffix denotes Mil-Std-883, Level B processing
N = 8-lead plastic DIP
D = 8 lead ceramic DIP
T = 8-lead metal can (TO-99)
L = 20-pad leadless chip carrier
M = 8-lead plastic SOIC
Contact a Raytheon sales office or representative for ordering information on special package/temperature range combinations.

Absolute Maximum Ratings

Supply Voltage ..... ±22V
Input Voltage* ..... ±22V
Differential Input Voltage 0.7V
Internal Power Dissipation** ..... 658 mW
Output Short Circuit Duration ..... Indefinite
Storage Temperature
  Range ..... -65°C to +150°C
Operating Temperature Range
  OP-47A/B/C ..... -55°C to +125°C
  OP-47E/F/G (Hermetic) ..... -25°C to +85°C
  OP-47E/F/G (Plastic) ..... 0°C to +70°C
Lead Soldering Temperature
  (SO-8, 10 sec) ..... +260°C
  (DIP, LCC, TO-99; 60 sec) ..... +300°C

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

Mask Pattern



Die Size: 75 x 80 mils
Min Pad Dimensions: 4 x 4 mils
65-01681A

Thermal Characteristics

	8-Lead Small Outline	8-Lead Ceramic DIP	TO-99 8-Lead Metal Can	20-Pad LCC	8-Lead Plastic DIP
Max. Junction Temp.	125°C	175°C	175°C	175°C	125°C
Max. P_D T_A <50°C	300 mW	833 mW	658 mW	925 mW	468 mW
Therm. Res θ_{JC}	—	45°C/W	50°C/W	37°C/W	—
Therm. Res. θ_{JA}	240°C/W	150°C/W	190°C/W	105°C/W	160°C/W
For T_A >50°C Derate at	4.17 mW/°C	8.33 mW/°C	5.26 mW/°C	7.0 mW/°C	6.25 mW/°C

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

Parameters	Test Conditions	OP-47A/E			OP-47B/F			OP-47C/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_O = ±10V	1000	1800		1000	1800		700	1500		V/mV
	$R_L \geq 1$ kΩ, V_O = ±10V	800	1500		800	1500			1500		
	V_O = ±1V, V_S = ±4V[4]	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$600Ω	±11	±12		±11	±12		±11	±12		
Slew Rate[4]	$R_L \geq 2$ kΩ	35	50		35	50		35	50		V/µS
Gain Bandwidth Product[4]	F_O = 10 kHz	45	70		45	70		45	70		MHz
	F_O = 1 MHz		45			45			45		
Open Loop Output Resistance	V_O = 0, I_O = 0		70			70			70		Ω
Power Consumption			90	140		90	140		100	170	mW
Offset Adjustment Range	R_p = 10 kΩ		±4.0			±4.0			±4.0		mV

Notes:
1. Long Term Input Offset Voltage Supply 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-47A			OP-47B			OP-47C			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_O = ±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, -25°C ≤T_A ≤ +85°C for hermetic package types, 0°C ≤ T_A ≤ +70°C for plastic package types unless otherwise noted)

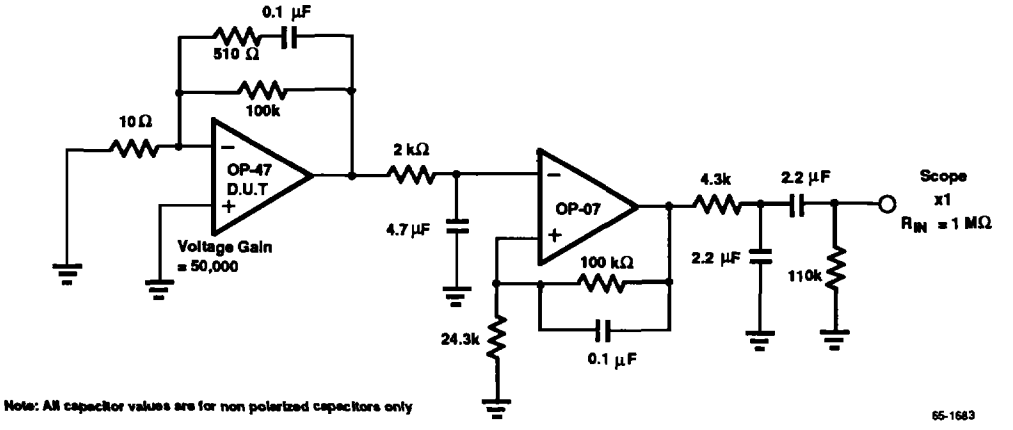
Parameters	Test Conditions	OP-47E			OP-47F			OP-47G			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage[1]			20	50		40	140		55	220	µV
Average Input Offset Voltage Drift[2]			0.2	0.6		0.3	1.3		0.4	1.8	µV/°C
Input Offset Current			10	50		14	85		20	135	nA
Input Bias Current			±14	±60		±18	±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_O = ±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. $T_C V_{OS}$ performance is guaranteed unnulled or when nulled with R_P = 8.0 kΩ to 20 kΩ.

Typical Performance Characteristics

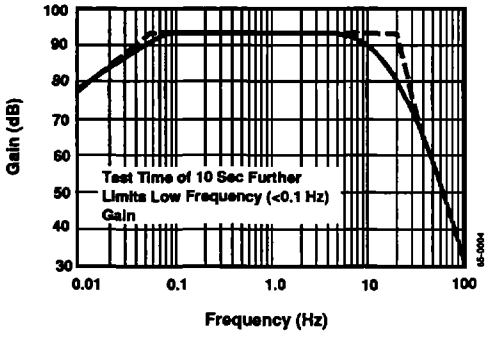
0.1 Hz to 10 Hz Noise Test Circuit



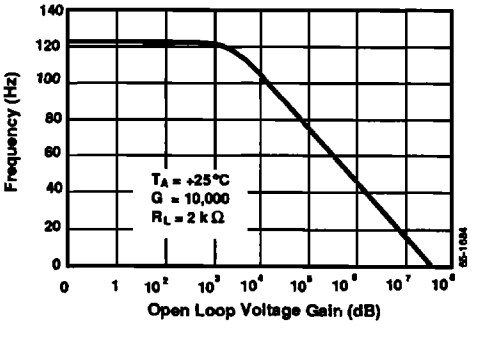
Note: All capacitor values are for non polarized capacitors only

65-1683

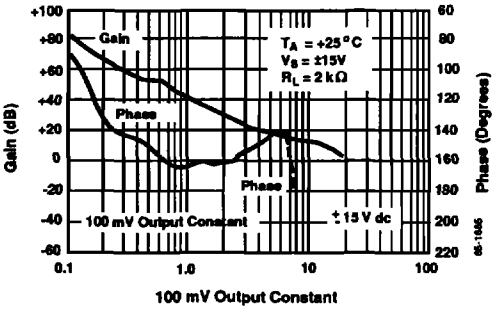
0.1 Hz to 10 Hz Peak-to-Peak Noise Tester Frequency Response



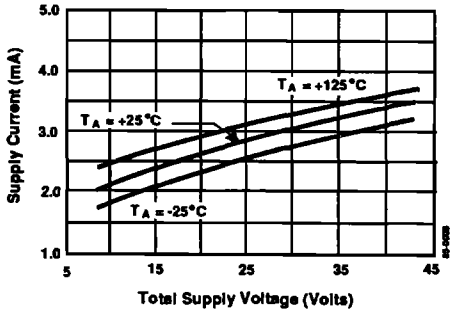
Open Loop Gain vs. Frequency



Gain and Phase Shift vs. Frequency

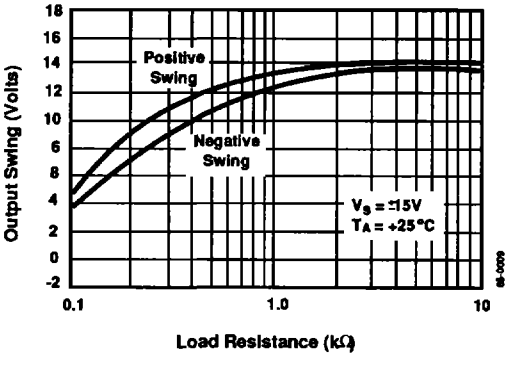


Supply Current vs. Supply Voltage

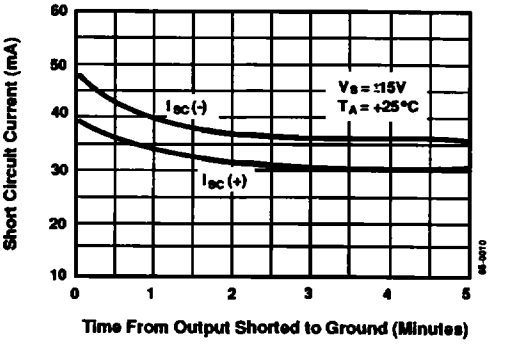


Typical Performance Characteristics (Continued)

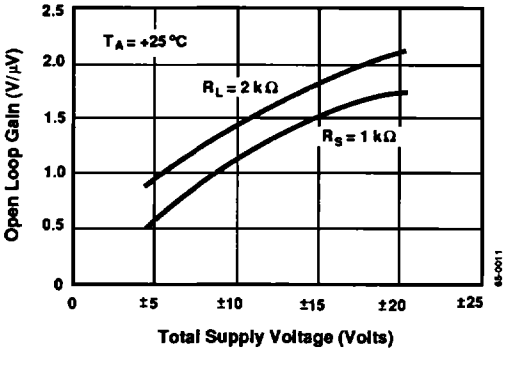
Maximum Output Swing vs. Resistive Load



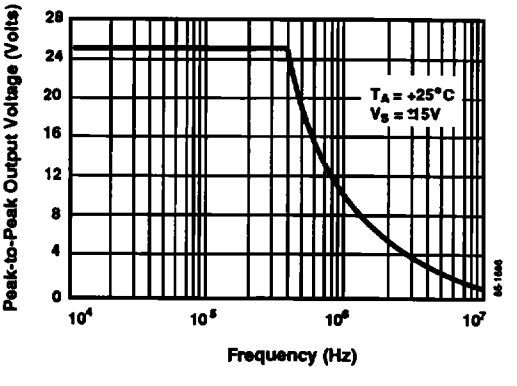
Short Circuit Current vs. Time



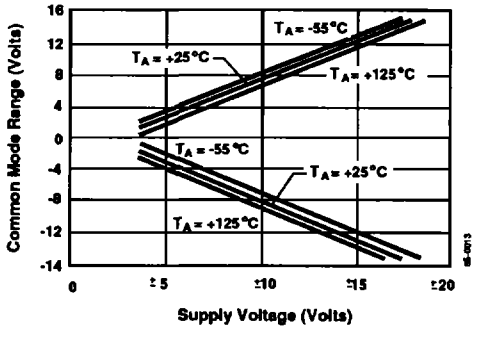
Open Loop Voltage Gain vs. Supply Voltage



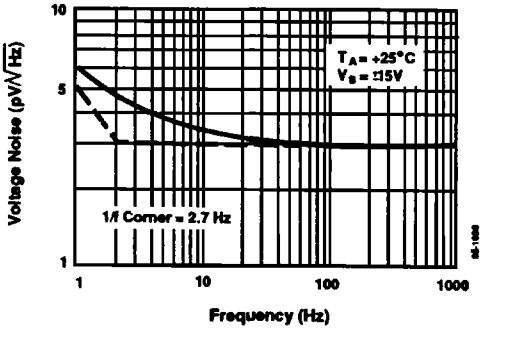
Maximum Undistorted Output vs. Frequency



Common Mode Input Range vs. Supply Voltage

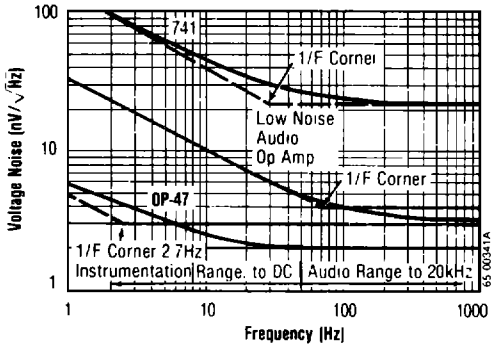


OP-47 Voltage Noise vs. Frequency

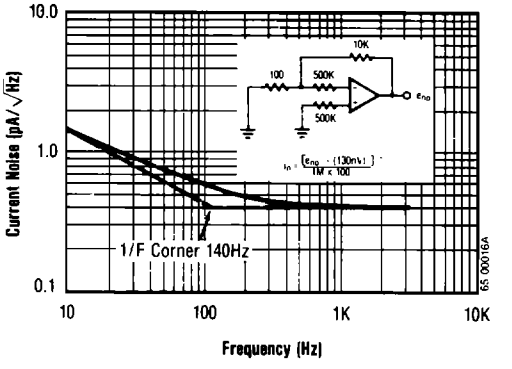


Typical Performance Characteristics (Continued)

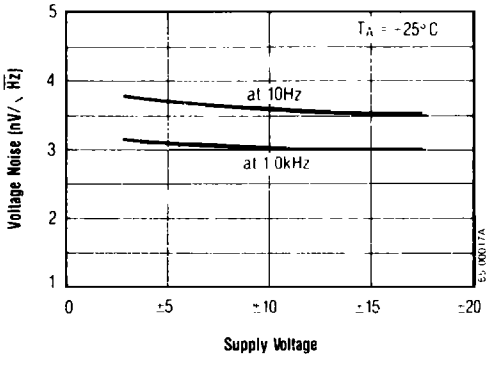
A Comparison of Op Amp Voltage Noise Spectrums



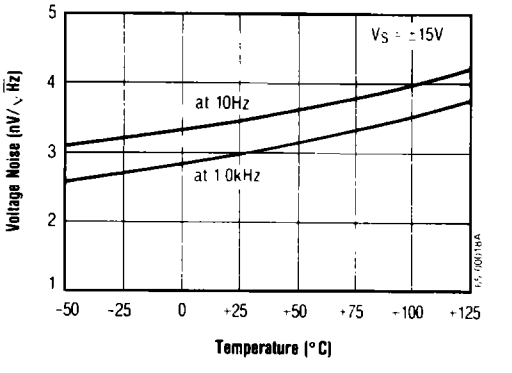
Current Noise vs. Frequency



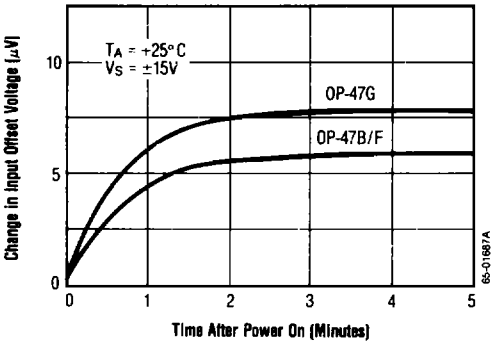
Voltage Noise vs. Supply Voltage



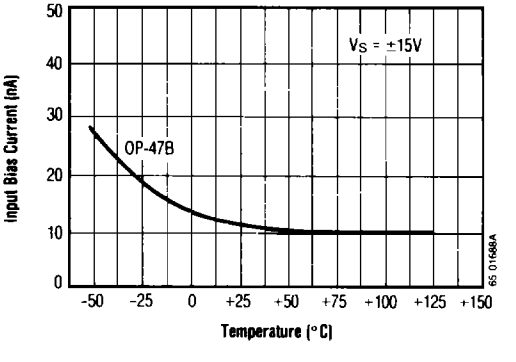
Voltage Noise vs. Temperature



Warm-Up Drift

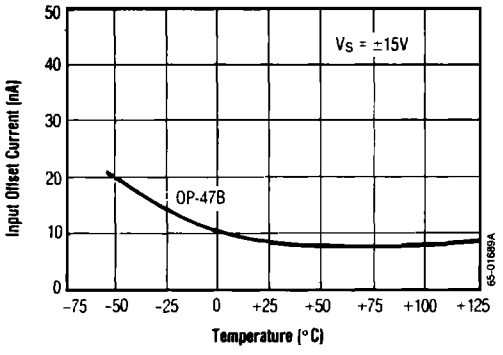


Input Bias Current vs. Temperature

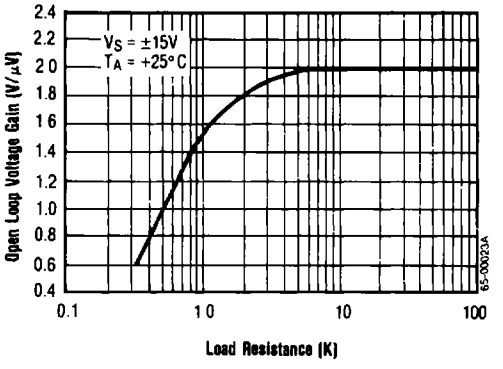


Typical Performance Characteristics (Continued)

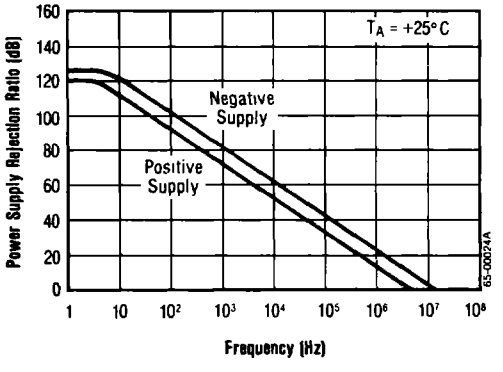
Input Offset Current vs. Temperature



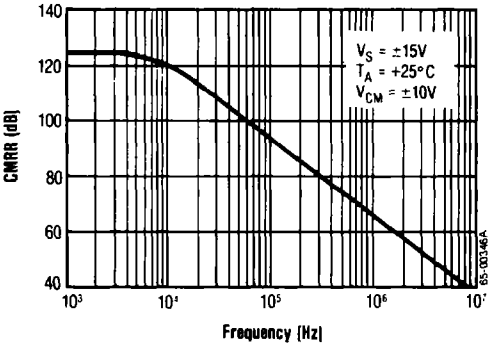
Open Loop Voltage Gain vs. Load Resistance



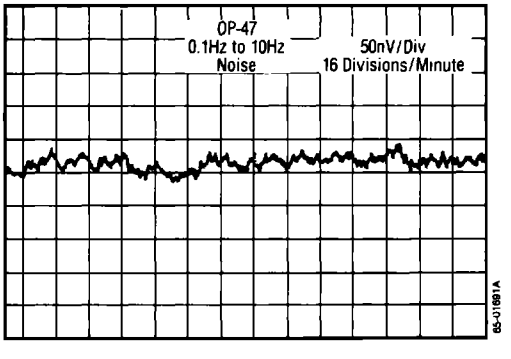
PSRR vs. Frequency



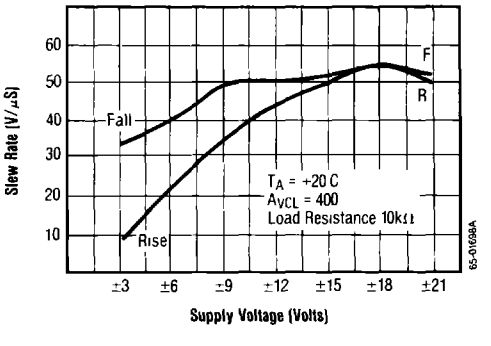
CMRR vs. Frequency



OP-47 0.1Hz to 10Hz Peak-to-Peak Noise Vertical Scale 50nV/Division Recorder Speed 8 Divisions/Min

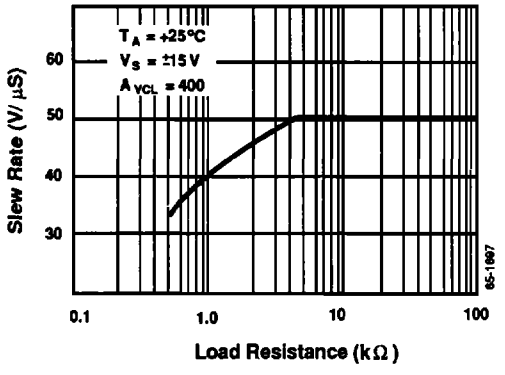


Supply Voltage vs. Slew Rate

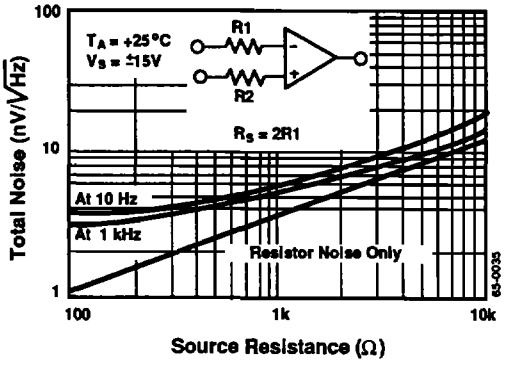


Typical Performance Characteristics (Continued)

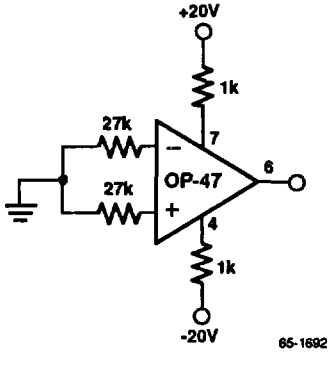
Load Resistance vs. Slew Rate



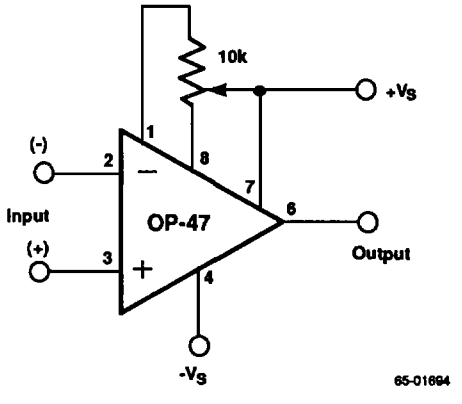
Total Noise vs. Source Resistance



Burn-In Circuit



Offset Nulling Circuit



Typical Applications

Low Impedance Microphone Preamp (Figure 1)

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-47 for best noise performance. The optimum source impedance can be calculated as the ratio of e_n/i_n which for the OP-47 is approximately 7000Ω. Fortunately the noise performance does not degrade appreciably until the source impedance is four or five times this optimum value.The source impedance at the output of this transformer, of 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.) . C1 rolls off the high frequency response at 90 kHz giving a noise power bandwidth of 140 kHz.

Instrumentation

The OP-47 is particularly adaptable to instrumentation applications. When wired into a single op amp difference amplifier configuration, the OP-47 exhibits outstanding common mode rejection ratio. The spot voltage noise is so low that it is dominated almost entirely by the resistor Johnson noise.

The three op amp instrumentation amplifier of Figure 2. avoids the low input impedance characteristics of difference amplifiers .The noise increases because two amplifiers are contributing to the input voltage spectral noise. The noise contribution, exclusive of resistor Johnson noise, increases by slightly more than the $\sqrt{2}$. 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 400 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.

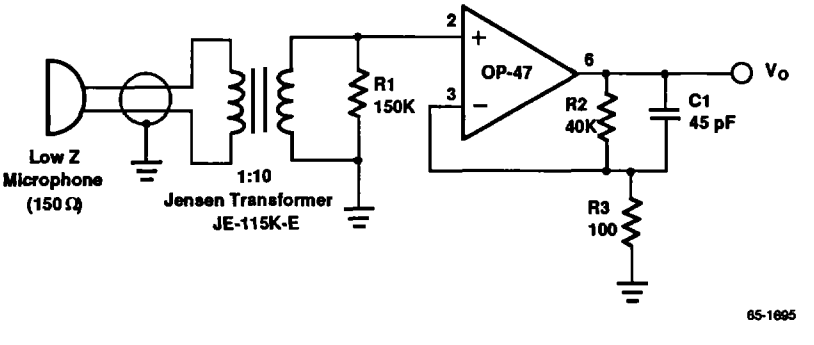


Figure 1. Low Impedance Microphone Preamplifier

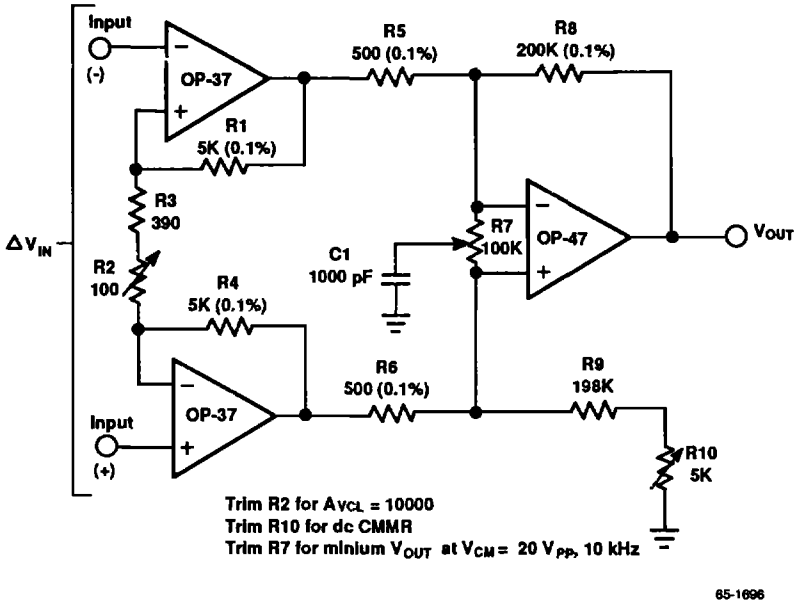


Figure 2. Three Op Amp IC Instrumentation Amplifier

Schematic Diagram