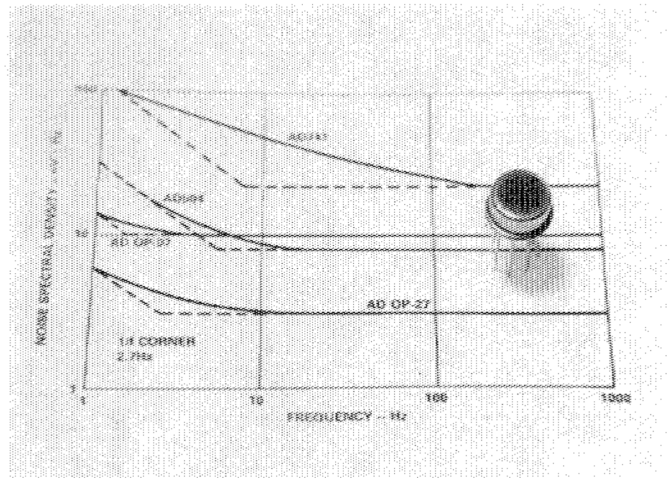
ANALOG DEVICES

Ultra-Low Noise Precision Op Amp

AD OP-27

FEATURES
- Ultra-Low Noise: 80nV p-p (0.1Hz to 10Hz), $3nV/\sqrt{Hz}$ at 1kHz
- Ultra-Low Offset Voltage Drift: 0.2μV/°C
- High Offset Stability Over Time: 0.2μV/month
- High Slew Rate: 2.8V/μs
- High Gain Bandwidth Product: 8MHz
- Low Offset Voltage: 10μV
- High CMRR: 126dB over ±11V Input Voltage Range
- Fits OP-07, OP-05, OP-06, 5534, 725, 714 and 741 Sockets



PRODUCT DESCRIPTION

The AD OP-27 offers the combined features of high precision, ultra-low noise and high speed in a monolithic bipolar operational amplifier. State-of-the-art performance for high accuracy amplification of very low level signals, where inherent device noise can be the limiting factor, is attainable with the AD OP-27. As a device directly compatible with other low noise op amps, the AD OP-27 features industry standard dc performance; input offset voltages of 10μV and input offset voltage temperature coefficients of 0.2μV/°C. The super low input voltage noise performance of the AD OP-27 is characterized by an e_n p-p of 80nV (0.1Hz to 10Hz), an e_n of $3.0nV/\sqrt{Hz}$ (at 1kHz) and a 1/f noise corner frequency of 2.7Hz. AC specifications including a 2.8V/μs slew rate and an 8MHz gain bandwidth product are possible without sacrificing dc accuracy. Long term stability is assured by an input offset voltage drift specification of 0.2μV/month.

Source resistance related errors with the AD OP-27 are minimized by a low input bias current at ambient of ±10nA and an input offset current of 7nA. An input bias current cancellation circuit limits bias and offset currents over the extented temperature range to ±20nA and 15nA, respectively. Other factors inducing input referred errors such as power supply variations and common-mode voltages are attenuated by a PSRR and CMRR of at least 120dB.

The AD OP-27 is available in six performance grades. The AD OP-27E, AD OP-27F and AD OP-27G are specified for operation over the −25°C to +85°C temperature range, while the AD OP-27A, AD OP-27B and AD OP-27C are specified for −55°C to +125°C operation. All devices are available in TO-99 hermetically sealed metal cans, while the E, F and G grades are also packaged in plastic mini-DIPs.

PRODUCT HIGHLIGHTS

1. Precision amplification of very low level, low frequency voltage inputs is enhanced by ultra-low input voltage noise.
2. The AD OP-27 maintains high dc accuracy over an extended temperature range due to ultra-low offset voltage, offset voltage drift and input bias current.
3. Internal frequency compensation, factory adjusted offset voltage and full device protection eliminate the need for additional components. Circuit size and complexity are reduced while reliability is increased.
4. Long-term stability and accuracy is assured with low offset voltage drift over time.
5. Input referred errors are greatly reduced by superior common mode and power supply rejection characteristics.
6. Monolithic construction along with advanced circuit design and processing techniques result in low cost.

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SPECIFICATIONS ($T_A = +25°C$, $V_S = \pm 15V$, unless otherwise specified)

MODEL		AD OP-27G			AD OP-27F			AD OP-27E		
PARAMETER	SYMBOL	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX
OPEN LOOP GAIN	A_{VO}	**700**	1,500		**1,000**	1,800		**1,000**	1,800	
		–	1,500		**800**	1,500		**800**	1,500	
		200	500		250	700		250	700	
		450	1,000		700	1,300		**750**	1,500	
OUTPUT CHARACTERISTICS										
Voltage Swing	V_O	**±11.5**	±13.5		**±12.0**	±13.8		**±12.0**	±13.8	
		±10.0	±11.5		**±10.0**	±11.5		**±10.0**	±11.5	
		±11.0	±13.3		±11.4	±13.5		**±11.7**	±13.6	
Open-Loop Output Resistance	R_O		70			70			70	
FREQUENCY RESPONSE										
Gain Bandwidth Product	GBW	5.0	8.0		5.0	8.0		5.0	8.0	
Slew Rate	SR	1.7	2.8		1.7	2.8		1.7	2.8	
INPUT OFFSET VOLTAGE										
Initial	V_{OS}		30	**100**		20	**60**		10	**25**
			55	220		40	140		20	**50**
Average Drift	TCV_{OS}		0.4	1.8		0.3	1.3		0.2	**0.6**
Long Term Stability	V_{OS}/Time		0.4	2.0		0.3	1.5		0.2	1.0
Adjustment Range			±4.0			±4.0			±4.0	
INPUT BIAS CURRENT										
Initial	I_B		±15	**±80**		±12	**±55**		±10	**±40**
			±25	±150		±18	±95		±14	**±60**
INPUT OFFSET CURRENT										
Initial	I_{OS}		12	75		9	**50**		7	**35**
			20	135		14	85		10	**50**
INPUT NOISE										
Voltage	e_n p-p		0.09	0.25		0.08	0.18		0.08	0.18
Voltage Density	e_n		3.8	8.0		3.5	5.5		3.5	5.5
			3.3	5.6		3.1	4.5		3.1	4.5
			3.2	4.5		3.0	3.8		3.0	3.8
Current Density	i_n		1.7	–		1.7	4.0		1.7	4.0
			1.0	–		1.0	2.3		1.0	2.3
			0.4	0.6		0.4	0.6		0.4	0.6
INPUT VOLTAGE RANGE										
Common Mode	CMVR	**±11.0**	±12.3		**±11.0**	±12.3		**±11.0**	±12.3	
		±10.5	±11.8		±10.5	±11.8		**±10.5**	±11.8	
Common-Mode Rejection Ratio	CMRR	**100**	120		**106**	123		**114**	126	
		96	118		102	121		**110**	124	
INPUT RESISTANCE										
Differential	R_{IN}	0.8	4		1.2	5		1.5	6	
Common Mode	R_{INCM}		2			2.5			3	
POWER SUPPLY										
Rated Performance			±15			±15			±15	
Operating			±(4–18)			±(4–18)			±(4–18)	
Current, Quiescent	I_Q		3.3	5.6		3.0	4.6		3.0	4.6
Rejection	PSR		2	**20**		1	**10**		1	**10**
			2	32		2	16		2	15
Power Consumption	P_d		100	**170**		90	**140**		90	**140**
OPERATING TEMPERATURE RANGE										
T_{MIN}, T_{MAX}		−25		+85	−25		+85	−25		+85

NOTES

[1]Input Offset Voltage measurements are performed by automated test equipment approximately 0.5 seconds after application of power. A and E grades are guaranteed fully warmed up.

[2]The TCV_{OS} performance is within the specifications unnulled or when nulled with $R_p = 8k\Omega$ to $20k\Omega$.

[3]Long Term Input Offset Voltage Stability refers to the average trend line of V_{OS} vs. time after the first 30 days.

Specifications subject to change without notice.

AD OP-27C			AD OP-27B			AD OP-27A			CONDITIONS	UNITS
MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX		
700	1,500		**1,000**	1,800		**1,000**	1,800		$R_L \geqslant 2k\Omega$, $V_{OUT} = \pm 10V$	V/mV
–	1,500		**800**	1,500		**800**	1,500		$R_L \geqslant 1k\Omega$, $V_{OUT} = \pm 10V$	V/mV
200	500		250	700		250	700		$R_L = 600\Omega$, $V_{OUT} = \pm 1V$, $V_S = \pm 4V$	V/mV
300	800		**500**	1,000		**600**	1,200		$R_L \geqslant 2k\Omega$, $V_{OUT} = \pm 10V$, T_a = min to max	V/mV
±11.5	±13.5		**±12.0**	±13.8		**±12.0**	±13.8		$R_L \geqslant 2k\Omega$	V
±10.0	±11.5		**±10.0**	±11.5		**±10.0**	±11.5		$R_L \geqslant 600\Omega$	V
±10.5	±13.0		**±11.0**	±13.2		**±11.5**	±13.5		$R_L \geqslant 2k\Omega$, T_a = min to max	V
	70			70			70		$I_{OUT} = 0A$, $V_{OUT} = 0V$	Ω
5.0	8.0		5.0	8.0		5.0	8.0			MHz
1.7	2.8		1.7	2.8		1.7	2.8		$R_L \geqslant 2k\Omega$	V/μs
	30	**100**		20	**60**		10	**25**	(Note 1)	μV
	70	**300**		50	**200**		30	**60**	T_a = min to max	μV
	0.4	**1.8**		0.3	**1.3**		0.2	**0.6**	T_a = min to max (Note 2)	μV/°C
	0.4	2.0		0.3	1.5		0.2	1.0	(Note 3)	μV/month
	±4.0			±4.0			±4.0		$R_p = 10k\Omega$	mV
	±15	**±80**		±12	**±55**		±10	**±40**		nA
	±35	**±150**		±28	**±95**		±20	**±60**	T_a = min to max	nA
	12	**75**		9	**50**		7	**35**		nA
	30	**135**		22	**85**		15	**50**	T_a = min to max	nA
	0.09	0.25		0.08	0.18		0.08	0.18	0.1Hz to 10Hz	μV p-p
	3.8	8.0		3.5	5.5		3.5	5.5	$f_o = 10Hz$	nV/√Hz
	3.3	5.6		3.1	4.5		3.1	4.5	$f_o = 30Hz$	nV/√Hz
	3.2	4.5		3.0	3.8		3.0	3.8	$f_o = 1000Hz$	nV/√Hz
	1.7	–		1.7	4.0		1.7	4.0	$f_o = 10Hz$	pA/√Hz
	1.0	–		1.0	2.3		1.0	2.3	$f_o = 30Hz$	pA/√Hz
	0.4	0.6		0.4	0.6		0.4	0.6	$f_o = 1000Hz$	pA/√Hz
±11.0	±12.3		**±11.0**	±12.3		**±11.0**	±12.3			V
±10.2	±11.5		**±10.3**	±11.5		**±10.3**	±11.5		T_a = min to max	V
100	120		**106**	123		**114**	126		$V_{CM} = \pm 11V$	dB
94	116		**100**	119		**108**	122		$V_{CM} = \pm 10V$, T_a = min to max	dB
0.8	4		1.2	5		1.5	6			MΩ
	2			2.5			3			GΩ
	±15			±15			±15			V
	±(4–18)			±(4–18)			±(4–18)			V
	3.3	5.6		3.0	4.6		3.0	4.6	$V_S = \pm 15V$	mA
	2	**20**		1	**10**		1	**10**	$V_S = \pm 4V$ to $\pm 18V$	μV/V
	4	**51**		2	**20**		2	**16**	$V_S = \pm 4.5V$ to $\pm 18V$, T_a = min to max	μV/V
	100	**170**		90	**140**		90	**140**	$V_{OUT} = 0V$	mW
−55		+125	−55		+125	−55		+125		°C

Specifications shown in boldface are tested on all production units at final electrical test. Results from those tests are used to calculate outgoing quality levels. All min and max specifications are guaranteed, although only those shown in boldface are tested on all production units.

ABSOLUTE MAXIMUM RATINGS

Supply Voltage	±18V
Internal Power Dissipation (Note 1)	500mW
Input Voltage (Note 2)	±18V
Output Short Circuit Duration	Indefinite
Differential Input Voltage (Note 3)	±0.7V
Differential Input Current (Note 3)	±25mA
Storage Temperature Range	−65°C to +150°C
Operating Temperature Range	
AD OP-27A, AD OP-27B, AD OP-27C	−55°C to +125°C
AD OP-27E, AD OP-27F, AD OP-27G	−25°C to +85°C
Lead Temperature Range (Soldering 60sec)	300°C

NOTES:

Note 1: Maximum package power dissipation vs. ambient temperature.

Package Type	Maximum Ambient Temperature for Rating	Derate Above Maximum Ambient Temperature
TO-99 (H)	80°C	7.1mW/°C
MINI-DIP (N)	36°C	5.6mW/°C

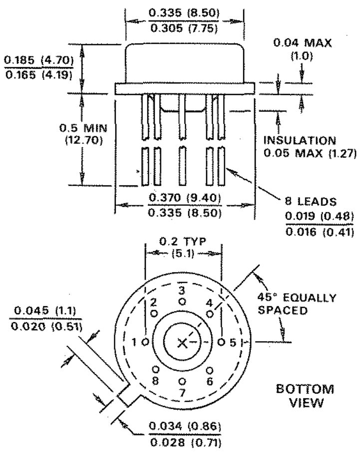
Note 2: For supply voltages less than ±18V, the absolute maximum input voltage is equal to the supply voltage.

Note 3: The AD OP-27's inputs are protected by back-to-back diodes. To achieve low noise current limiting resistors could not be used. If the differential input voltage exceeds ±0.7V, the input current should be limited to 25mA.

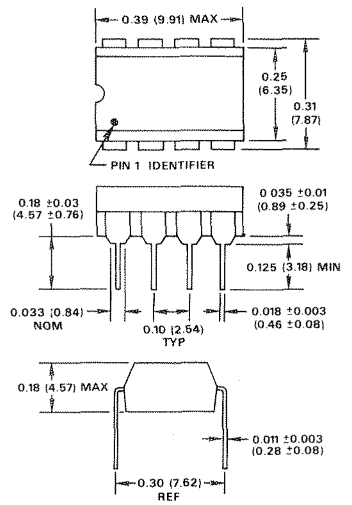
PHYSICAL DIMENSIONS

Dimensions shown in inches and (mm).

TO-99 (H)

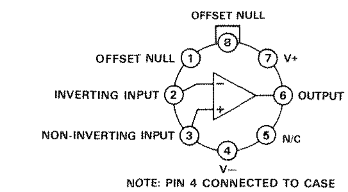


MINI-DIP (N)

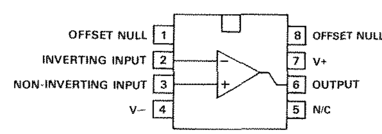


CONNECTION DIAGRAMS (Top View)

TO-99 (H Package)

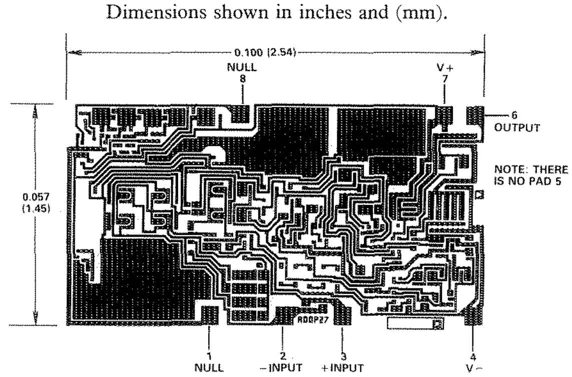


MINI-DIP (N Package)



CHIP DIMENSIONS AND BONDING DIAGRAM

Dimensions shown in inches and (mm).



THE AD OP-27 IS AVAILABLE IN WAFER-TRIMMED CHIP FORM. CONSULT THE FACTORY FOR DETAILS.

AD OP-27 ORDERING GUIDE

Model	Package Option	Temperature Range (°C)	Max Initial Offset (μV)	Max Offset Drift (μV/°C)
AD OP-27-GH	TO-99	−25 to +85	100	1.8
AD OP-27-GN	MINI-DIP (N8A)	−25 to +85	100	1.8
AD OP-27-FH	TO-99	−25 to +85	60	1.3
AD OP-27-FN	MINI-DIP (N8A)	−25 to +85	60	1.3
AD OP-27-EH	TO-99	−25 to +85	25	0.6
AD OP-27-EN	MINI-DIP (N8A)	−25 to +85	25	0.6
AD OP-27-CH	TO-99	−55 to +125	100	1.8
AD OP-27-BH	TO-99	−55 to +125	60	1.3
AD OP-27-AH	TO-99	−55 to +125	25	0.6

APPLICATION NOTES FOR THE AD OP-27

The AD OP-27 can be used in the sockets of many of the popular precision bipolar input operational amplifiers on the market. Elimination of external frequency compensation or nulling circuitry may be possible in many cases. In 741 replacement situations, if nulling has been implemented, it should be modified or removed for optimum AD OP-27 performance.

In applications where the initial factory adjusted input offset voltage provides insufficient accuracy, further offset trimming can be accomplished with the resistor network shown in Figure 1. The adjustment range attainable using a 10kΩ potentiometer will be ±4mV. If a smaller adjustment range is required, the sensitivity of the nulling can be increased by using a smaller potentiometer in series with fixed resistor(s). For example, a 1kΩ pot in series with two 4.7kΩ resistors will yield a ±280μV range.

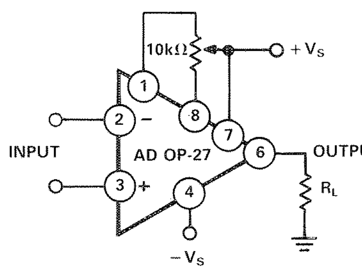


Figure 1. Optional Offset Nulling Circuit

Zeroing the initial offset with potentiometers other than 10kΩ, but between 1kΩ and 1MΩ, will introduce an additional input offset voltage temperature drift error of from 0.1 to 0.2μV/°C. Additionally, by intentionally trimming in a dc level shift a voltage dependent offset drift will be created. It will be approximately the input offset voltage at 25°C divided by 300 (in μV/°C).

Parasitic thermocouple EMF's can be generated where dissimilar metals meet the contacts to the input terminals of the AD OP-27. These temperature dependent voltages can manifest themselves as drift type errors. Optimized temperature performance will be obtained when both contacts are maintained at the same temperature—a temperature close to the device's package.

Output stability with the AD OP-27 is possible with capacitive loads of up to 2000pF and ±10V output swings. Larger capacitances should be decoupled with a 50Ω resistor.

High closed loop gain and excellent linearity can be achieved by operating the AD OP-27 within an output current range of ±10mA. Minimizing output current will provide the highest linearity.

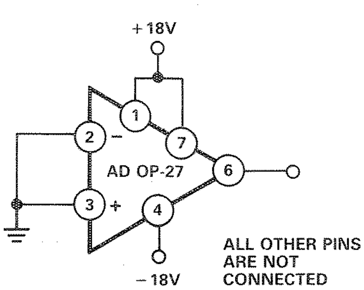


Figure 2. Burn-In Circuit

SLEW RATE DISCUSSION

In unity gain buffer applications with feedback resistances of less than 100Ω where the input is driven with a fast, large (greater than 1V) pulse, the output waveform will appear as in Figure 3.

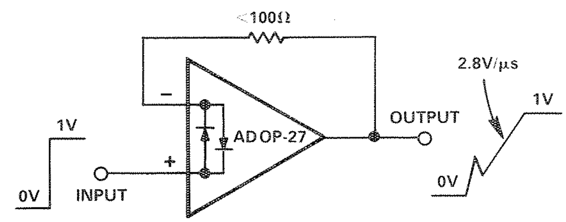


Figure 3. Unity Gain Buffer/Pulsed Operation

During the initial portion of the output slew the input protection back-to-back diodes effectively short the output to the input. A current limited only by the output short circuit protection will be drawn from the source. After the input diodes saturate, the amplifier will slew at its nominal 2.8V/μs. With feedback resistances of more than 500Ω the output is capable of handling the current requirements without limiting (less than 20mA at 10V) and the amplifier will stay in the linear region.

As with all operational amplifiers a feedback resistance of greater than 2kΩ will create a pole with the input capacitance (8pF). Additional phase shift will be introduced and the phase margin will be reduced. A small capacitor (20 to 50pF) in parallel with the feedback resistor will alleviate this problem.

CAUTION: NOISE MEASUREMENTS

Precise measurement of the extremely low input noise associated with the AD OP-27 is a difficult task. In order to observe the rated noise in the 0.1Hz to 10Hz frequency range the following cautions should be exercised.

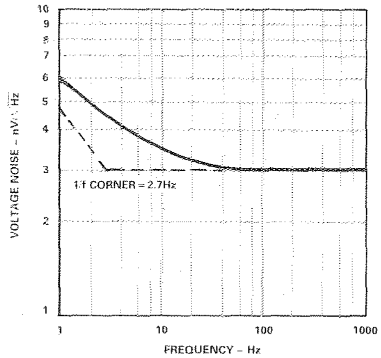
(1) The test time to measure 0.1Hz to 10Hz noise should not exceed 10 seconds. As shown in the noise test frequency response plot in this data sheet the 0.1Hz corner is only defined by a single zero. A test time of 10 seconds acts as an additional zero to eliminate noise contributions from frequencies lower than 0.1Hz.

(2) Warm-up for a least five minutes will eliminate temperature induced effects. During the first few minutes the offset voltage typically increases 4μV. In a 10 second measurement interval prior to temperature stabilization the reading could include several nanovolts of warm-up offset error in addition to the noise.

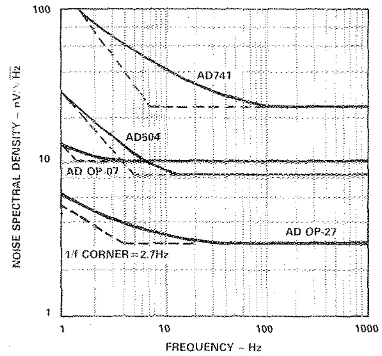
(3) For reasons similar to (2) the device under test should be well shielded from air currents or other heat sinks to eliminate the possibility of temperature changes over time invalidating the measurements. Sudden motion in the vicinity or physical contact with the package can also increase the observed noise.

An input voltage noise spectral density test is recommended when measuring noise on a large number of units. Because the l/f noise corner frequency is around 3Hz, a 1kHz noise voltage density measurement combined with a 0.1Hz to 10Hz peak-to-peak noise reading will guarantee l/f and white noise performance over the rated frequency spectrum.

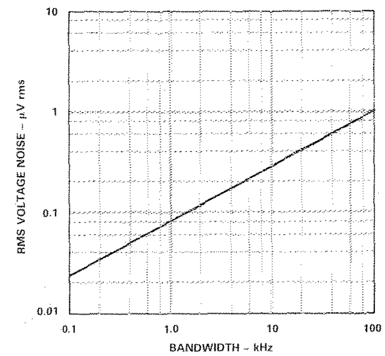
Typical Performance Curves (@ $T_A = +25°C$, $V_S = \pm15V$)



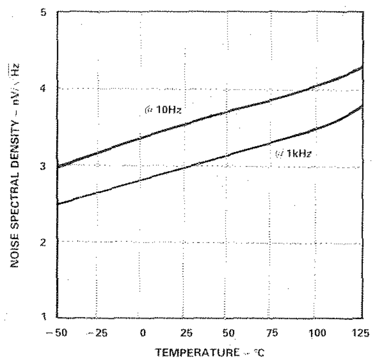
Input Voltage Noise Spectral Density



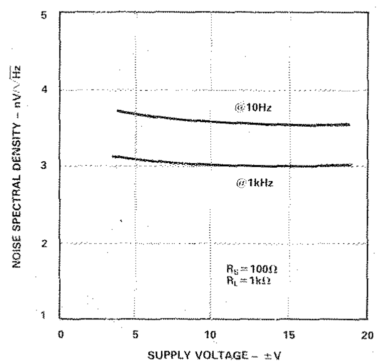
Comparison of Op Amp Input Voltage Noise Spectrums



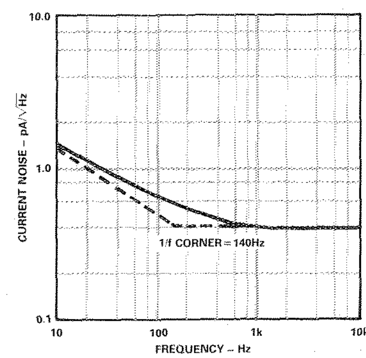
Input Wideband Noise vs. Bandwidth (0.1Hz to Frequency Indicated)



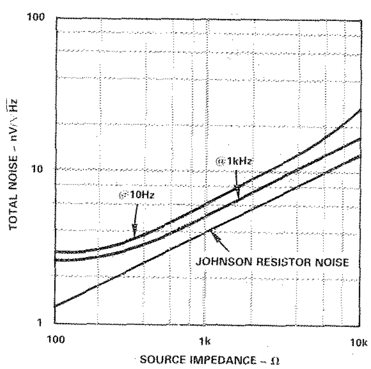
Input Voltage Noise vs. Temperature



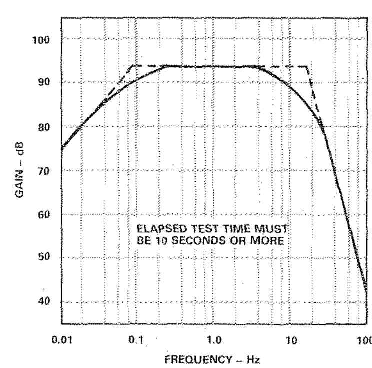
Input Voltage Noise vs. Supply Voltage



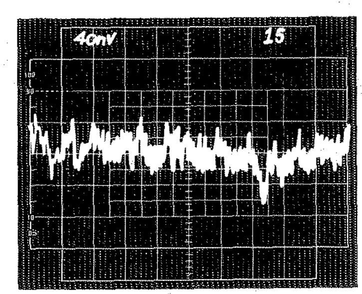
Input Current Noise Spectral Density



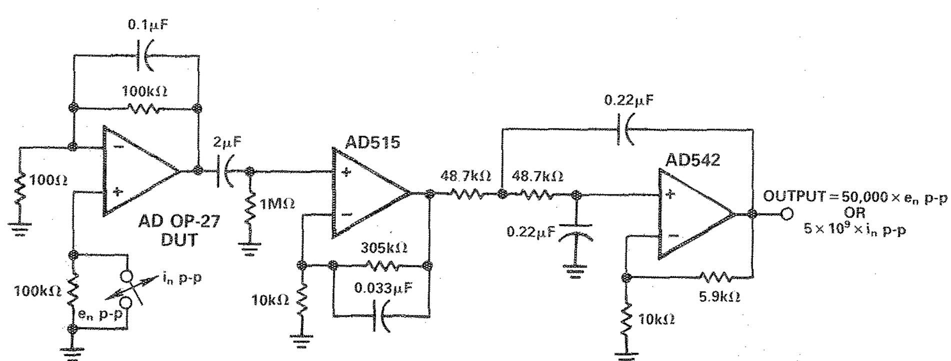
Total Noise vs. Source Impedance



0.1Hz to 10Hz Noise Test Frequency Response

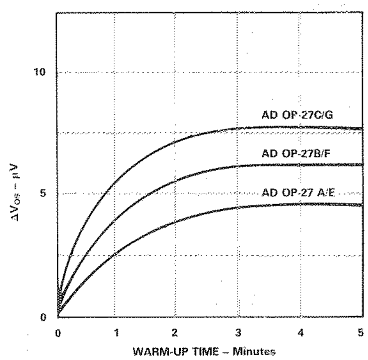


0.1Hz to 10Hz p-p Voltage Noise

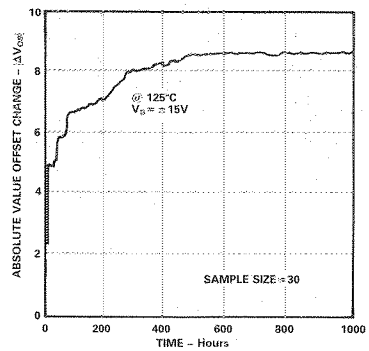


NOTE: ALL CAPACITORS MUST BE NONPOLARIZED

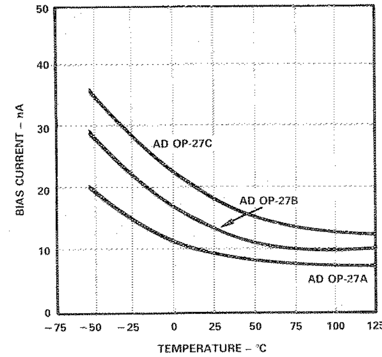
0.1Hz to 10Hz Noise Test Bandpass Filter (Voltage Gain = 50,000)



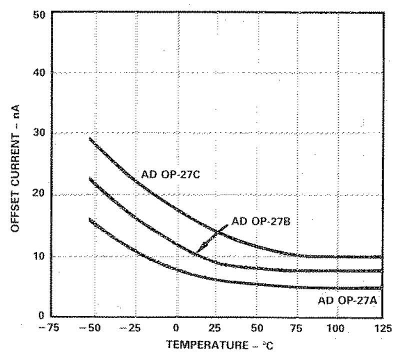
Input Offset Voltage Turn-On Drift vs. Time



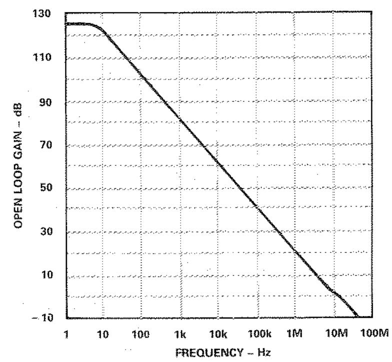
Long Term Offset Stability @ Temperature



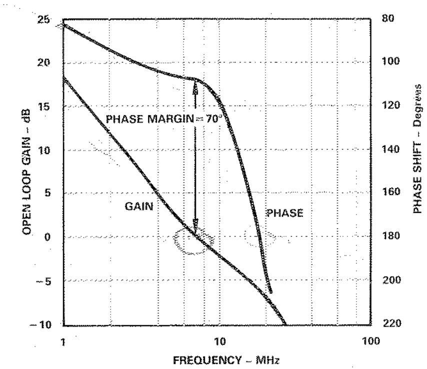
Input Bias Current vs. Temperature



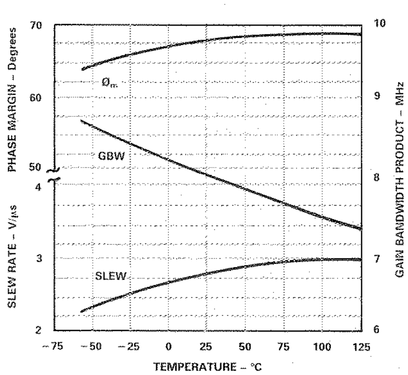
Input Offset Current vs. Temperature



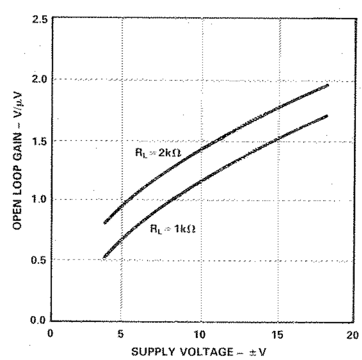
Open Loop Frequency Response



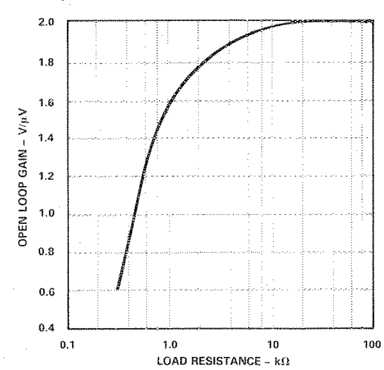
Open Loop Gain and Phase Shift vs. Frequency



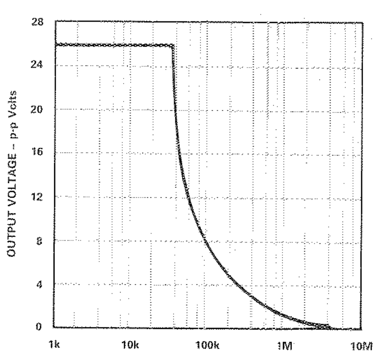
Slew Rate, Gain Bandwidth Product and Phase Margin vs. Temperature



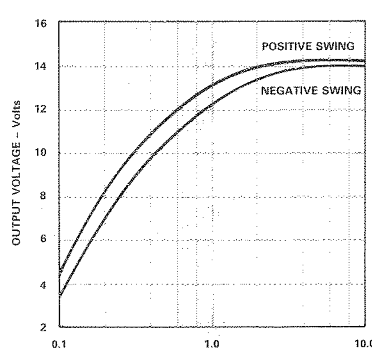
Open Loop Gain vs. Supply Voltage



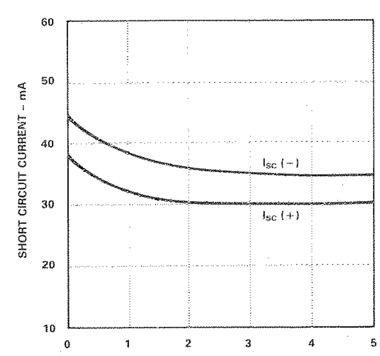
Open Loop Gain vs. Resistive Load



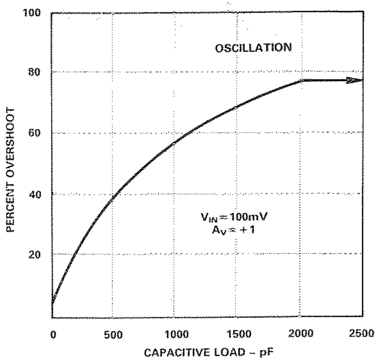
Undistorted Output Swing vs. Frequency



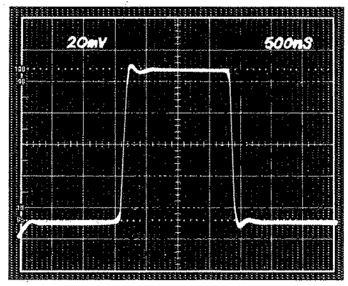
Output Swing vs. Resistive Load



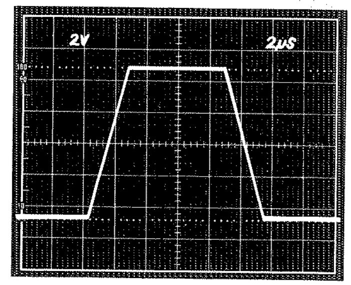
Output Short Circuit Current vs. Time



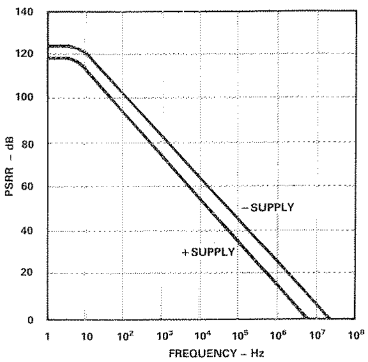
Small Signal Overshoot vs. Capacitive Load



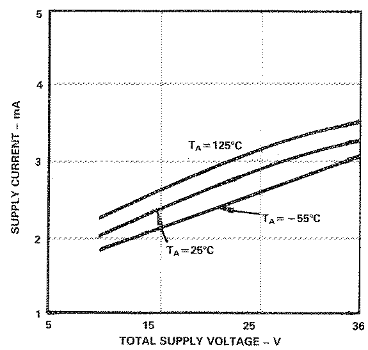
Unity Gain Follower Pulse Response (Small Signal)



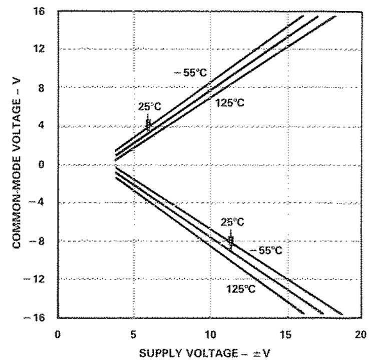
Unity Gain Follower Pulse Response (Large Signal)



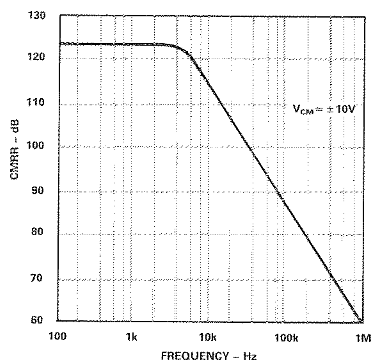
Power Supply Rejection Ratio vs. Frequency



Supply Current vs. Supply Voltage



Common-Mode Input Range vs. Supply Voltage



CMRR vs. Frequency

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