



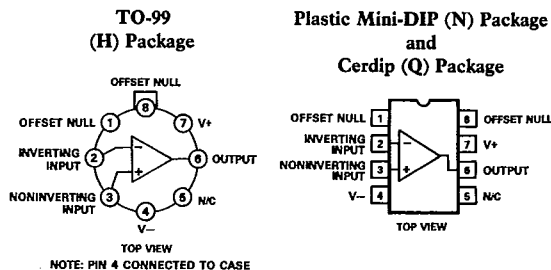
Ultralow Noise, Precision Op Amp

T-79-06-10 **AD OP-27**

FEATURES

Ultralow Noise: 80nV p-p (0.1Hz to 10Hz),
3nV/√Hz at 1kHz
Ultralow 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
Military Grade and Plus Parts Available
8-Pin Plastic Mini-DIP, Cerdip, TO-99 Hermetic
Metal Can or Chip Form
Available in Chip Form

CONNECTION DIAGRAMS



PRODUCT DESCRIPTION

The AD OP-27 offers the combined features of high precision, ultralow 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; typical input offset voltages of 10μV and typical 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 (typ) of 80nV (0.1Hz to 10Hz), an e_n (typ) of 3.0nV/√Hz (at 1kHz) and a 1/f noise corner frequency of 2.7Hz. AC specifications including a 2.8V/μs (typ) slew rate and an 8MHz (typ) 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 (typ) and an input offset current of 7nA (typ). An input bias current cancellation circuit limits bias and offset currents over the extended temperature range to ±20nA (typ) and 15nA (typ), 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 either the TO-99 hermetically sealed metal cans or the hermetically sealed cerdip packages, while the E, F and G grades are also available in plastic mini-DIPs.

PRODUCT HIGHLIGHTS

1. Precision amplification of very low level, low frequency voltage inputs is enhanced by ultralow 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.

AD OP-27—SPECIFICATIONS

(T_A = +25°C, V_S = ±15V, unless otherwise specified)

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Model Parameter	Symbol	AD OP-27G			AD OP-27F			AD OP-27E		
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
OPEN LOOP GAIN	A _{VO}	700 400 200 450	1,500 1,500 500 1,000		1,000 800 250 700	1,800 1,500 700 1,300		1,000 800 250 750	1,800 1,500 700 1,500	
OUTPUT CHARACTERISTICS Voltage Swing	V _O	±11.5 ±10.0 ±11.0	±13.5 ±11.5 ±13.3		±12.0 ±10.0 ±11.4	±13.8 ±11.5 ±13.5		±12.0 ±10.0 ±11.7	±13.8 ±11.5 ±13.6	
Open-Loop Output Resistance	R _O		70			70			70	
FREQUENCY RESPONSE Gain Bandwidth Product Slew Rate	GBW SR	5.0 1.7	8.0 2.8		5.0 1.7	8.0 2.8		5.0 1.7	8.0 2.8	
INPUT OFFSET VOLTAGE Initial	V _{OS}		30 55	100 220		20 40	60 140		10 20	25 60
Average Drift	TCV _{OS}		0.4	1.8		0.3	1.3		0.2	0.6
Long Term Stability Adjustment Range	V _{OS} /Time		0.4 ±4.0	2.0		0.3 ±4.0	1.5		0.2 ±4.0	1.0
INPUT BIAS CURRENT Initial	I _B		±15 ±25	±80 ±150		±12 ±18	±55 ±95		±10 ±14	±40 ±60
INPUT OFFSET CURRENT Initial	I _{OS}		12 20	75 135		9 14	50 85		7 10	35 50
INPUT NOISE Voltage Voltage Density	e _n p-p e _n		0.09 3.8 3.3	0.25 8.0 5.6		0.08 3.5 3.1	0.18 5.5 4.5		0.08 3.5 3.1	0.18 5.5 4.5
Current Density	i _n		3.2 1.7 1.0 0.4	4.5 — — 0.6		3.0 1.7 1.0 0.4	3.8 4.0 2.3 0.6		3.0 1.7 1.0 0.4	3.8 4.0 2.3 0.6
INPUT VOLTAGE RANGE Common Mode	CMVR		±11.0 ±10.5	±12.3 ±11.8		±11.0 ±10.5	±12.3 ±11.8		±11.0 ±10.5	±12.3 ±11.8
Common-Mode Rejection Ratio	CMRR		100 96	120 118		106 102	123 121		114 110	126 124
INPUT RESISTANCE Differential Common Mode	R _{IN} R _{INCM}		0.8 4 2			1.2 5 2.5			1.5 6 3	
POWER SUPPLY Rated Performance Operating Current, Quiescent Rejection	I _Q PSR		±15 ±(4-18)			±15 ±(4-18)			±15 ±(4-18)	
Power Consumption	P _d		3.3 2 2	5.6 20 32		3.0 1 2	4.6 10 16		3.0 1 2	4.6 10 15
OPERATING TEMPERATURE RANGE	T _{min} , T _{max}		-25	+85		-25	+85		-25	+85

NOTES

¹Input 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.

²Long-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.

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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		$R_L \geq 2k\Omega$, $V_{OUT} = \pm 10V$	V/mV
400	1,500		800	1,500		800	1,500		$R_L \geq 1k\Omega$, $V_{OUT} = \pm 10V$	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		$R_L \geq 2k\Omega$, $V_{OUT} = \pm 10V$, $T_a = \text{min to max}$	V/mV
± 11.5	± 13.5		± 12.0	± 13.8		± 12.0	± 13.8		$R_L \geq 2k\Omega$	V
± 10.0	± 11.5		± 10.0	± 11.5		± 10.0	± 11.5		$R_L \geq 600\Omega$	V
± 10.5	± 13.0		± 11.0	± 13.2		± 11.5	± 13.5		$R_L \geq 2k\Omega$, $T_a = \text{min to max}$	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		$R_L \geq 2k\Omega$	V/ μs
	30	100		20	60		10	25	(Note 1)	μV
	70	300		50	200		30	60	$T_a = \text{min to max}$	μV
	0.4	1.8		0.3	1.3		0.2	0.6	$T_a = \text{min to max}$	$\mu V/^{\circ}C$
	0.4	2.0		0.3	1.5		0.2	1.0	(Note 2)	$\mu V/\text{month}$
	± 4.0			± 4.0			± 4.0		$R_p = 10k\Omega$	mV
	± 15	± 80		± 12	± 55		± 10	± 40		nA
	± 35	± 150		± 28	± 95		± 20	± 60	$T_a = \text{min to max}$	nA
	12	75		9	50		7	35		nA
	30	135		22	85		15	50	$T_a = \text{min to max}$	nA
	0.09	0.25		0.08	0.18		0.08	0.18	0.1Hz to 10Hz	$\mu V \text{ p-p}$
	3.8	8.0		3.5	5.5		3.5	5.5	$f_o = 10Hz$	nV/ \sqrt{Hz}
	3.3	5.6		3.1	4.5		3.1	4.5	$f_o = 30Hz$	nV/ \sqrt{Hz}
	3.2	4.5		3.0	3.8		3.0	3.8	$f_o = 1000Hz$	nV/ \sqrt{Hz}
	1.7	—		1.7	4.0		1.7	4.0	$f_o = 10Hz$	pA/ \sqrt{Hz}
	1.0	—		1.0	2.3		1.0	2.3	$f_o = 30Hz$	pA/ \sqrt{Hz}
	0.4	0.6		0.4	0.6		0.4	0.6	$f_o = 1000Hz$	pA/ \sqrt{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		$T_a = \text{min to max}$	V
100	120		106	123		114	126		$V_{CM} = \pm 11V$	dB
94	116		100	119		108	122		$V_{CM} = \pm 10V$, $T_a = \text{min to max}$	dB
0.8	4		1.2	5		1.5	6			M Ω
	2			2.5			3			G Ω
	± 15			± 15			± 15			V
	$\pm(4-18)$			$\pm(4-18)$			$\pm(4-18)$			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 $\pm 18V$	$\mu V/V$
	4	51		2	20		2	16	$V_S = \pm 4.5V$ to $\pm 18V$, $T_a = \text{min to max}$	$\mu V/V$
	100	170		90	140		90	140	$V_{OUT} = 0V$	mW
-55		+125	-55		+125	-55		+125		$^{\circ}C$

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.

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ABSOLUTE MAXIMUM RATINGS

Supply Voltage	± 18V
Internal Power Dissipation (Note 1)	500mW
Input Voltage	± V _S
Output Short Circuit Duration	Indefinite
Differential Input Voltage (Note 2)	± 0.7V

Differential Input Current (Note 2)	± 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
Cerdip (Q)	75°C	6.7mW/°C

Note 2: 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.

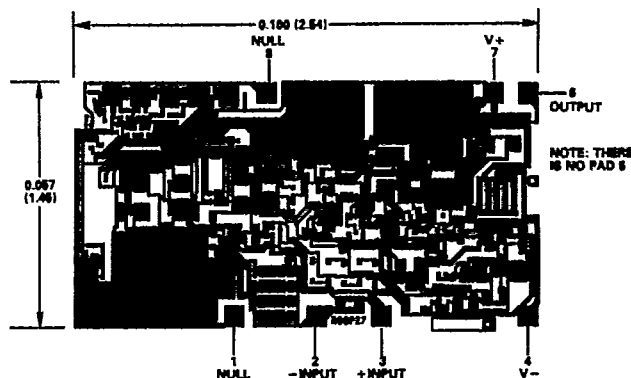
ORDERING GUIDE

Model	Package Description	Temperature Range (°C)	Max Initial Offset (μV)	Max Offset Drift (μV/°C)	Package Option*
ADOP-27GH	TO-99	-25 to +85	100	1.8	H-08A
ADOP-27GN	Mini-DIP	-25 to +85	100	1.8	N-8
ADOP-27GQ	Cerdip	-25 to +85	100	1.8	Q-8
ADOP-27FH	TO-99	-25 to +85	60	1.3	H-08A
ADOP-27FN	Mini-DIP	-25 to +85	60	1.3	N-8
ADOP-27FQ	Cerdip	-25 to +85	60	1.3	Q-8
ADOP-27EH	TO-99	-25 to +85	25	0.6	H-08A
ADOP-27EN	Mini-DIP	-25 to +85	25	0.6	N-8
ADOP-27EQ	Cerdip	-25 to +85	25	0.6	Q-8
ADOP-27CH	TO-99	-55 to +125	100	1.8	H-08A
ADOP-27CQ	Cerdip	-55 to +125	100	1.8	Q-8
ADOP-27BH	TO-99	-55 to +125	60	1.3	H-08A
ADOP-27BQ	Cerdip	-55 to +125	60	1.3	Q-8
ADOP-27AH	TO-99	-55 to +125	25	0.6	H-08A
ADOP-27AQ	Cerdip	-55 to +125	25	0.6	Q-8
ADOP-27A Chips	Die	-55 to +125	25	0.6	
ADOP-27C Chips	Die	-55 to +125	100	1.8	
ADOP-27G Chips	Die	-25 to +85	100	1.8	

*For outline information see Package Information section.

CHIP DIMENSIONS AND BONDING DIAGRAM

Contact factory for latest dimensions.
Dimensions shown in inches and (mm).



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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 10k Ω potentiometer will be ± 4 mV. 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 1k Ω pot in series with two 4.7k Ω resistors will yield a $\pm 280\mu$ V range.

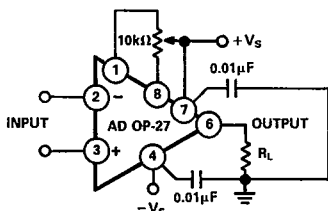


Figure 1. Optional Offset Nulling Circuit and Power Supply Bypassing

Zeroing the initial offset with potentiometers other than 10k Ω , but between 1k Ω and 1M Ω , will introduce an additional input offset voltage temperature drift error of from 0.1 to 0.2 μ V/ $^{\circ}$ 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 $^{\circ}$ C divided by 300 (in μ V/ $^{\circ}$ 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 ± 10 V output swings. Larger capacitances should be decoupled with a 50 Ω resistor.

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

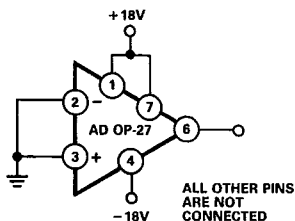


Figure 2. Burn-In Circuit

SLEW RATE DISCUSSION

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

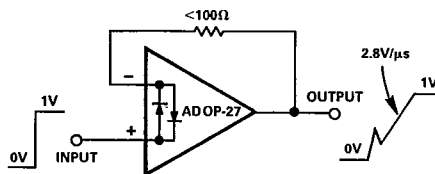


Figure 3. Unity Gain Buffer/Pulsed Operation

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/ μ s. With feedback resistances of more than 500 Ω 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 2k Ω 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.

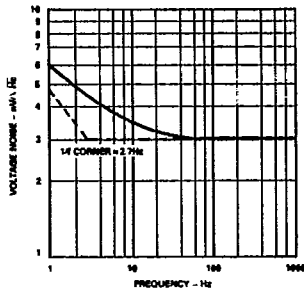
(2) Warm-up for a least five minutes will eliminate temperature induced effects. During the first few minutes the offset voltage typically increases 4 μ V. In a 10 second measurement interval prior to temperature stabilization the reading could include several nanovolts of warm-up offset error in addition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

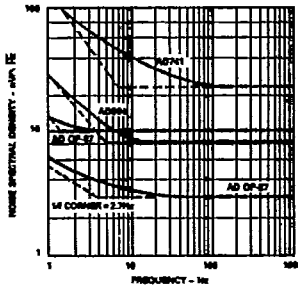
An input voltage noise spectral density test is recommended when measuring noise on a large number of units. Because the 1/f noise corner frequency is around 3Hz, a 1kHz noise voltage density measurement combined with a 0.1Hz to 10Hz peak-to-peak noise reading will guarantee 1/f and white noise performance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

AD OP-27—Typical Performance Curves ($T_A = +25^\circ\text{C}$, $V_S = \pm 15\text{V}$)

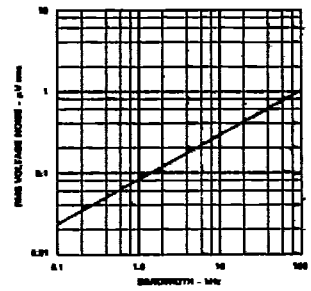
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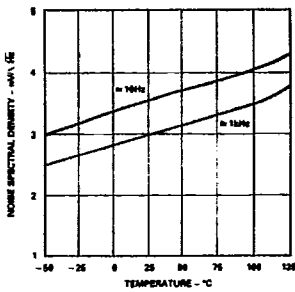
Input Voltage Noise Spectral Density



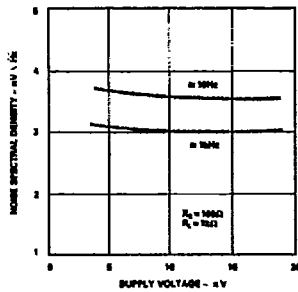
Comparison of Op Amp Input Voltage Noise Spectrums



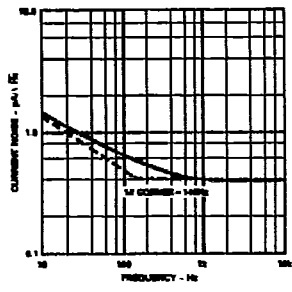
Input Wideband Noise vs. Bandwidth (0.1 Hz to Frequency Indicated)



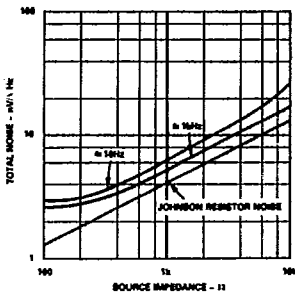
Input Voltage Noise vs. Temperature



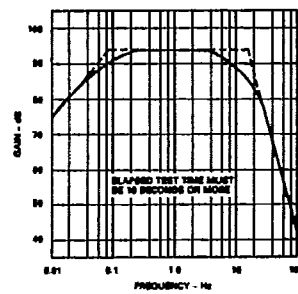
Input Voltage Noise vs. Supply Voltage



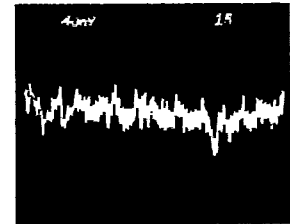
Input Current Noise Spectral Density



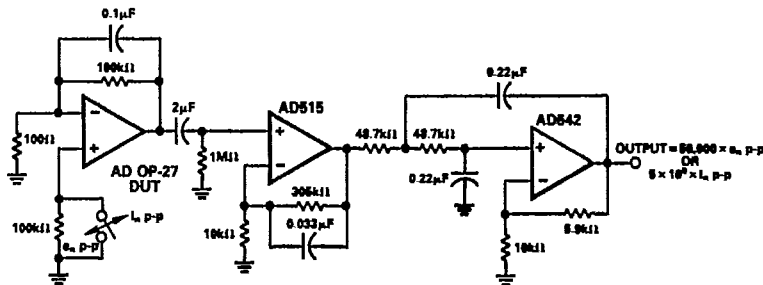
Total Noise vs. Source Impedance



0.1 Hz to 10 Hz Noise Test Frequency Response

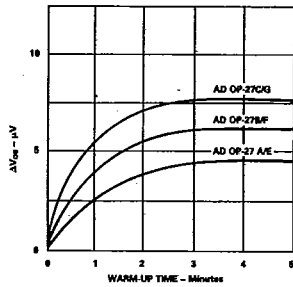


0.1 Hz to 10 Hz p-p Voltage Noise

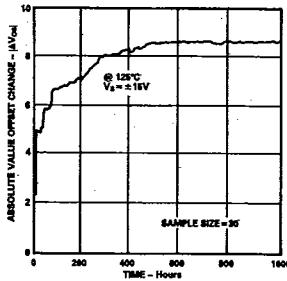


NOTE: ALL CAPACITORS MUST BE NONPOLARIZED

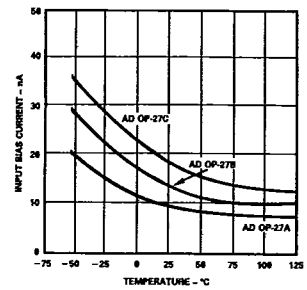
0.1 Hz to 10 Hz Noise Test Bandpass Filter (Voltage Gain = 50,000)



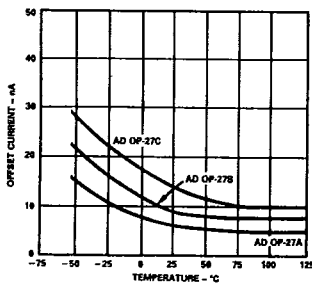
Input Offset Voltage Turn-On Drift vs. Warm-Up Time



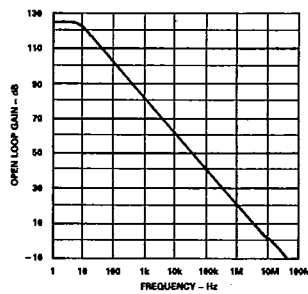
Long Term Offset Stability @ Temperature



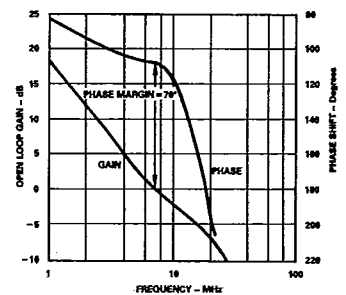
Input Bias Current vs. Temperature



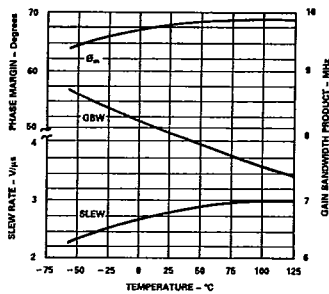
Input Offset Current vs. Temperature



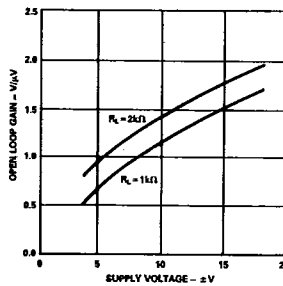
Open Loop Frequency Response



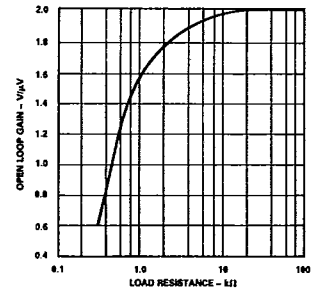
Open Loop Gain and Phase Shift vs. Frequency



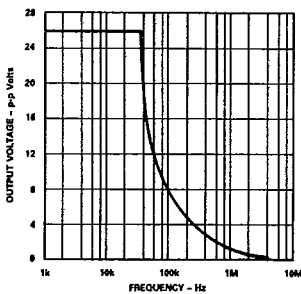
Slew Rate, Gain Bandwidth Product and Phase Margin vs. Temperature



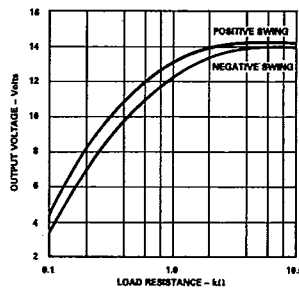
Open Loop Gain vs. Supply Voltage



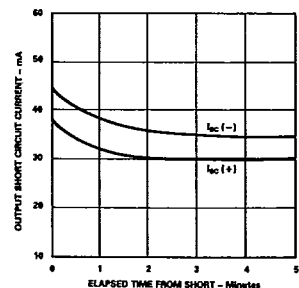
Open Loop Gain vs. Load Resistance



Undistorted Output Swing vs. Frequency



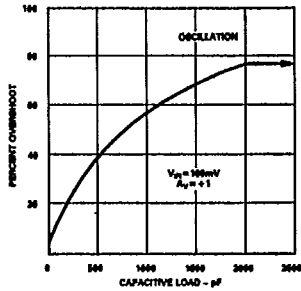
Output Swing vs. Load Resistance



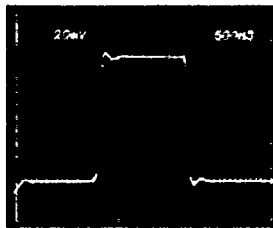
Output Short Circuit Current vs. Time

AD OP-27

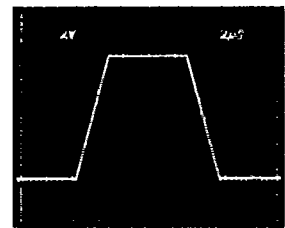
T-79-06-10



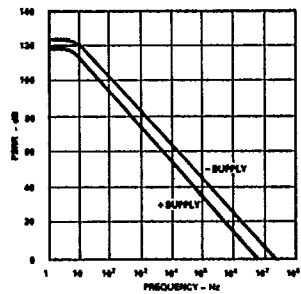
Small Signal Overshoot vs. Capacitive Load



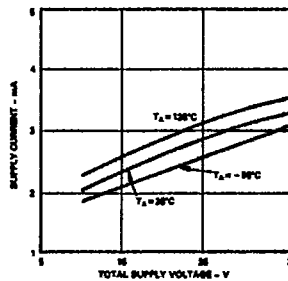
Unity Gain Follower Pulse Response (Small Signal)



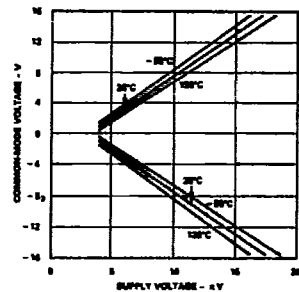
Unity Gain Follower Pulse Response (Large Signal)



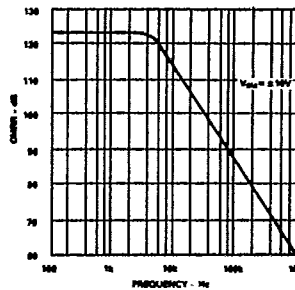
Power Supply Rejection Ratio vs. Frequency



Supply Current vs. Supply Voltage



Common-Mode Input Range vs. Supply Voltage



CMRR vs. Frequency