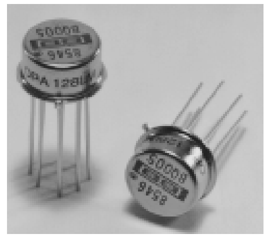
BURR - BROWN®



OPA128

Difet® Electrometer-Grade OPERATIONAL AMPLIFIER

FEATURES

- ULTRA-LOW BIAS CURRENT: 75fA max
- LOW OFFSET: 500μV max
- LOW DRIFT: 5μV/°C max
- HIGH OPEN-LOOP GAIN: 110dB min
- HIGH COMMON-MODE REJECTION: 90dB min
- IMPROVED REPLACEMENT FOR AD515 AND AD549

APPLICATIONS

- ELECTROMETER
- MASS SPECTROMETER
- CHROMATOGRAPH
- ION GAUGE
- PHOTODETECTOR
- RADIATION-HARD EQUIPMENT

DESCRIPTION

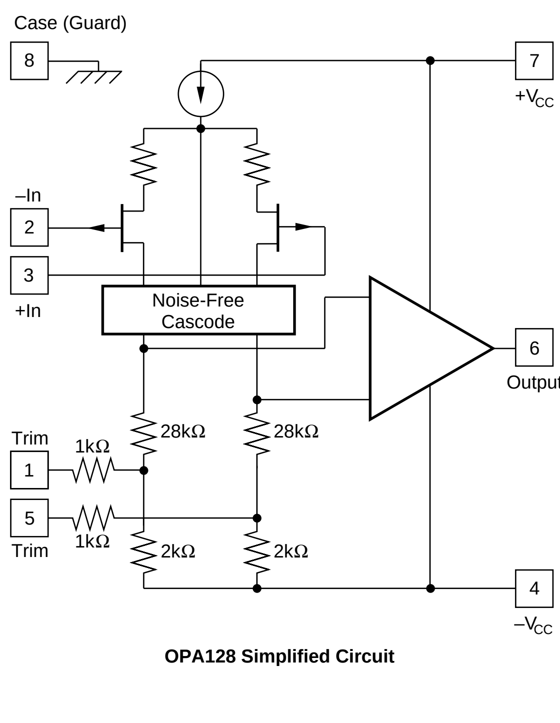
The OPA128 is an ultra-low bias current monolithic operational amplifier. Using advanced geometry dielectrically-isolated FET (***Difet®***) inputs, this monolithic amplifier achieves a performance level exceeding even the best hybrid electrometer amplifiers.

Laser-trimmed thin-film resistors give outstanding voltage offset and drift performance.

A noise-free cascode and low-noise processing give the OPA128 excellent low-level signal handling capabilities. Flicker noise is very low.

The OPA128 is an improved pin-for-pin replacement for the AD515.

Difet® Burr-Brown Corp.



OPA128 Simplified Circuit

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PDS-653E

Printed in U.S.A. May, 1995

SBOS148

SPECIFICATIONS

ELECTRICAL

At V_{CC} = ±15VDC and T_A = +25°C, unless otherwise noted. Pin 8 connected to ground.

PARAMETER	CONDITIONS	OPA128JM			OPA128KM			OPA128LM			OPA128SM			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
INPUT														
BIAS CURRENT(1)														
Input Bias Current	V_{CM} = 0VDC, R_L ≥ 10kΩ		±150	±300		±75	±150		±40	±75		±75	±150	fA
OFFSET CURRENT(1)														
Input Offset Current	V_{CM} = 0VDC, R_L ≥ 10kΩ		65			30			30			30		fA
OFFSET VOLTAGE(1)														
Input Offset Voltage	V_{CM} = 0VDC		±260	±1000		±140	±500		±140	±500		±140	±500	µV
Average Drift	T_A = T_{MIN} to T_{MAX}			±20			±10			±5			±10	µV/°C
Supply Rejection		80	120		90	120		90	120		90	120		dB
			±1	±100		±1	±32		±1	±32		±1	±32	µV/V
NOISE														
Voltage: f_O = 10Hz			92			92			92			92		nV/√Hz
f_O = 100Hz			78			78			78			78		nV/√Hz
f_O = 1kHz			27			27			27			27		nV/√Hz
f_O = 10kHz			15			15			15			15		nV/√Hz
f_B = 10Hz to 10kHz			2.4			2.4			2.4			2.4		µVrms
f_B = 0.1Hz to 10Hz			4			4			4			4		µVp-p
Current: f_B = 0.1Hz to 10Hz			4.2			3			2.3			3		fA, p-p
f_O = 0.1Hz to 20kHz			0.22			0.16			0.12			0.16		fA/√Hz
IMPEDANCE														
Differential			10^{13} || 1			10^{13} || 1			10^{13} || 1			10^{13} || 1		Ω || pF
Common-Mode			10^{15} || 2			10^{15} || 2			10^{15} || 2			10^{15} || 2		Ω || pF
VOLTAGE RANGE(4)														
Common-Mode Input Range		±10	±12		±10	±12		±10	±12		±10	±12		V
Common-Mode Rejection	V_{IN} = ±10VDC	80	118		90	118		90	118		90	118		dB
OPEN-LOOP GAIN, DC														
Open-Loop Voltage Gain	R_L ≥ 2kΩ	94	128		110	128		110	128		110	128		dB
FREQUENCY RESPONSE														
Unity Gain, Small Signal	(2)	0.5	1		0.5	1		0.5	1		0.5	1		MHz
Full Power Response	20Vp-p, R_L = 2kΩ		47			47			47			47		kHz
Slew Rate	V_O = ±10V, R_L = 2kΩ	0.5	3		1	3		1	3		1	3		V/µs
Settling Time, 0.1%	Gain = –1, R_L = 2kΩ		5			5			5			5		µs
0.01%	10V Step		10			10			10			10		µs
Overload Recovery, 50% Overdrive(3)	Gain = –1		5			5			5			5		µs
RATED OUTPUT														
Voltage Output	R_L = 2kΩ	±10	±13		±10	±13		±10	±13		±10	±13		V
Current Output	V_O = ±10VDC	±5	±10		±5	±10		±5	±10		±5	±10		mA
Output Resistance	DC, Open Loop		100			100			100			100		Ω
Load Capacitance Stability	Gain = +1		1000			1000			1000			1000		pF
Short Circuit Current		10	34	55	10	34	55	10	34	55	10	34	55	mA
POWER SUPPLY														
Rated Voltage			±15			±15			±15			±15		VDC
Voltage Range, Derated Performance		±5		±18	±5		±18	±5		±18	±5		±18	VDC
Current, Quiescent	I_O = 0mADC		0.9	1.5		0.9	1.5		0.9	1.5		0.9	1.5	mA
TEMPERATURE RANGE														
Specification	Ambient Temp.	0		+70	0		+70	0		+70	–55		+125	°C
Operating	Ambient Temp.	–55		+125	–55		+125	–55		+125	–55		+125	°C
Storage	Ambient Temp.	–65		+150	–65		+150	–65		+150	–65		+150	°C
θ Junction-Ambient			200			200			200			200		°C/W

NOTES: (1) Offset voltage, offset current, and bias current are measured with the units fully warmed up. Bias current doubles approximately every 11°C. (2) Sample tested. (3) Overload recovery is defined as the time required for the output to return from saturation to linear operation following the removal of a 50% input overdrive. (4) If it is possible for the input voltage to exceed the supply voltage, a series protection resistor should be added to limit input current to 0.5mA. The input devices can withstand overload currents of 0.3mA indefinitely without damage.

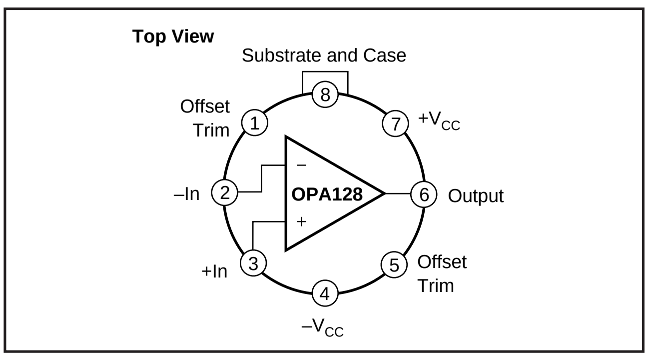
ELECTRICAL (FULL TEMPERATURE RANGE SPECIFICATIONS)

At V_{CC} = ±15VDC and T_A = T_{MIN} and T_{MAX}, unless otherwise noted.

		OPA128JM			OPA128KM			OPA128LM			OPA128SM			
PARAMETER	CONDITIONS	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	UNITS
TEMPERATURE RANGE														
Specification Range	Ambient Temp.	0		+70	0		+70	0		+70	–55		+125	°C
INPUT														
BIAS CURRENT(1)														
Input Bias Current	V_{CM} = 0VDC		±2.5	±8		±1.3	±4		±0.7	±2		±43	±170	pA
OFFSET CURRENT(1)														
Input Offset Current	V_{CM} = 0VDC		1.1			0.6			0.6			18		pA
OFFSET VOLTAGE(1)														
Input Offset Voltage	V_{CM} = 0VDC			±2.2mV			±1mV			±750			±1.5mV	µV
Average Drift				±20			±10			±5			±10	µV/°C
Supply Rejection		74	114		80	114		80	114		80	106		dB
			±2	±200		±2	±100		±2	±100		±5	±100	µV/V
VOLTAGE RANGE(2)														
Common-Mode Input Range		±10	±11		±10	±11		±10	±11		±10	±11		V
Commmon-Mode Rejection	V_{IN} = ±10VDC	74	112		80	112		80	112		74	104		dB
OPEN-LOOP GAIN, DC														
Open-Loop Voltage Gain	R_L ≥ 2kΩ	90	125		104	125		104	125		90	122		dB
RATED OUTPUT														
Voltage Output	R_L = 2kΩ	±10			±10			±10			±10			V
Current Output	V_O = ±10VDC	±5			±5			±5			±5			mA
Short Circuit Current	V_O = 0VDC	10	22		10	22		10	22		10	18		mA
POWER SUPPLY														
Current, Quiescent	I = 0mADC		0.9	1.8		0.9	1.8		0.9	1.8		0.9	2	mA

NOTES: (1) Offset voltage, offset current, and bias current are measured with the units fully warmed up. (2) If it is possible for the input voltage to exceed the supply voltage, a series protection resistor should be added to limit input current to 0.5mA. The input devices can withstand overload currents of 0.3mA indefinitely without damage.

CONNECTION DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Supply .... ±18VDC
Internal Power Dissipation(1) 500mW
Differential Input Voltage .... ±36VDC
Input Voltage Range .... ±18VDC
Storage Temperature Range .... –65°C to +150°C
Operating Temperature Range .... –55°C to +125°C
Lead Temperature (soldering, 10s) .... +300°C
Output Short Circuit Duration(2) .... Continuous
Junction Temperature .... +175°C

NOTES: (1) Packages must be derated based on θ_{CA} = 150°C/W or θ_{JA} = 200°C/W. (2) Short circuit may be to power supply common only. Rating applies to +25°C ambient. Observe dissipation limit and T_J.

ORDERING INFORMATION

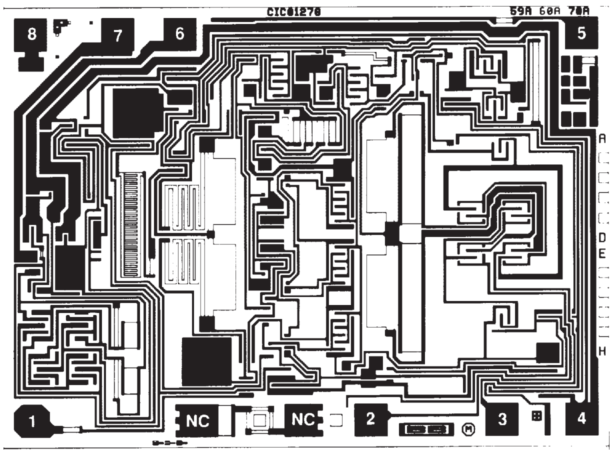
PRODUCT	PACKAGE	TEMPERATURE RANGE	BIAS CURRENT, max (fA)
OPA128JM	TO-99	0°C to +70°C	±300
OPA128KM	TO-99	0°C to +70°C	±150
OPA128LM	TO-99	0°C to +70°C	±75
OPA128SM	TO-99	–55°C to +125°C	±150

PACKAGE INFORMATION

PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER(1)
OPA128JM	TO-99	001
OPA128KM	TO-99	001
OPA128LM	TO-99	001
OPA128SM	TO-99	001

NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix C of Burr-Brown IC Data Book.

DICE INFORMATION



OPA128 DIE TOPOGRAPHY

PAD	FUNCTION
1	Offset Trim
2	–In
3	+In
4	$-V_{CC}$
5	Offset Trim
6	Output
7	$+V_{CC}$
8	Substrate
NC	No Connection

Substrate Bias: Isolated, normally connected to common.

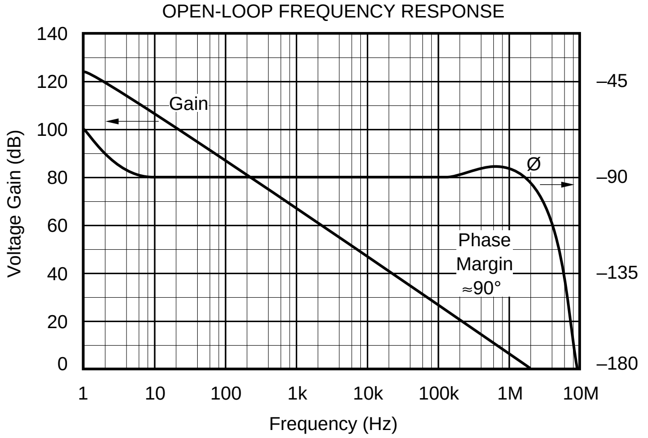
MECHANICAL INFORMATION

	MILS (0.001")	MILLIMETERS
Die Size	96 x 71 ±5	2.44 x 1.80 ±0.13
Die Thickness	20 ±3	0.51 ±0.08
Min. Pad Size	4 x 4	0.10 x 0.10
Backing		None

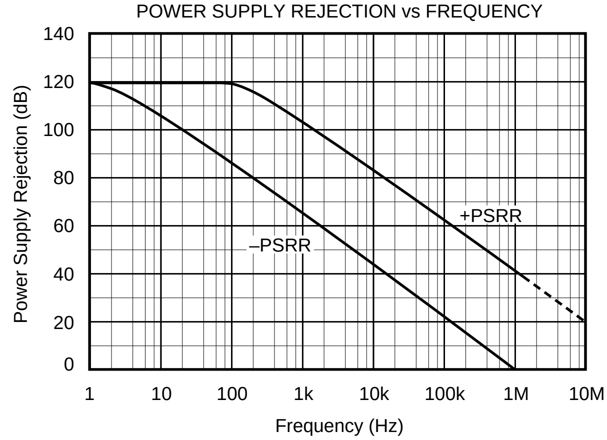
TYPICAL PERFORMANCE CURVES

At T_A = +25°C, ±15VDC, unless otherwise noted.

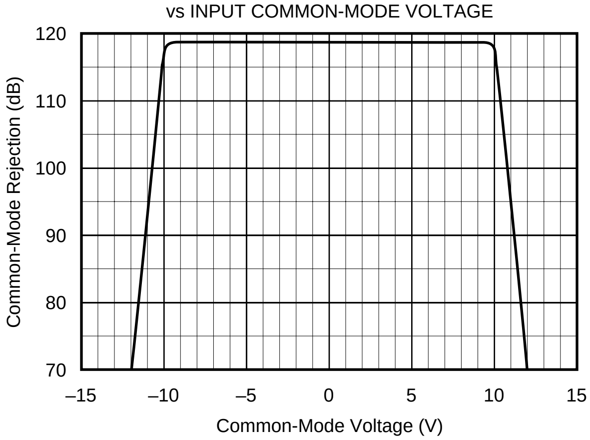
OPEN-LOOP FREQUENCY RESPONSE



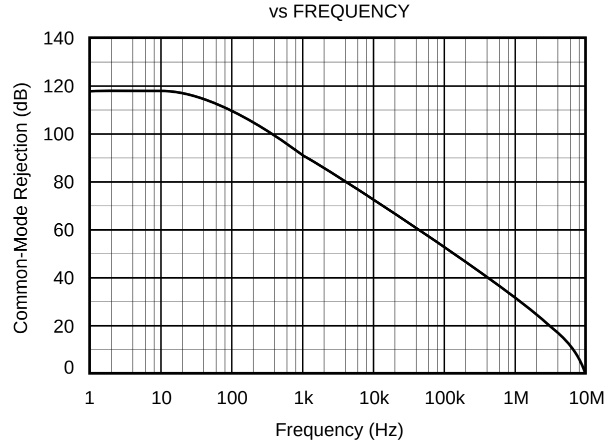
POWER SUPPLY REJECTION vs FREQUENCY



COMMON-MODE REJECTION
vs INPUT COMMON-MODE VOLTAGE

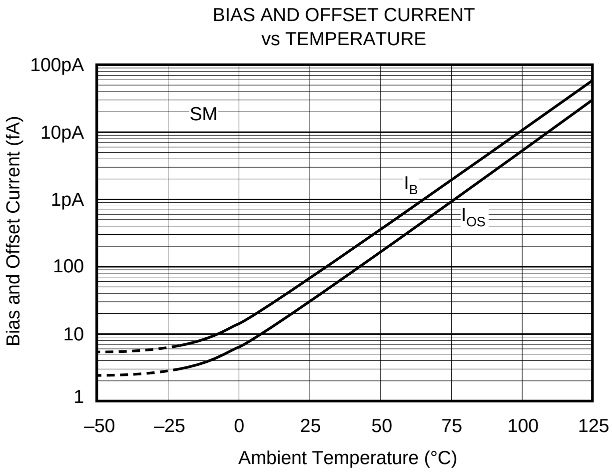


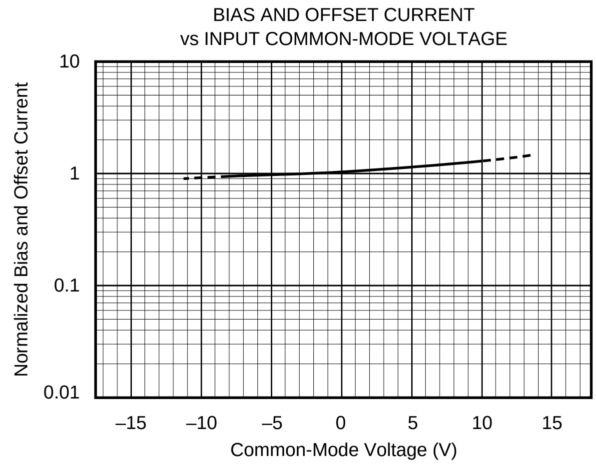
COMMON-MODE REJECTION
vs FREQUENCY

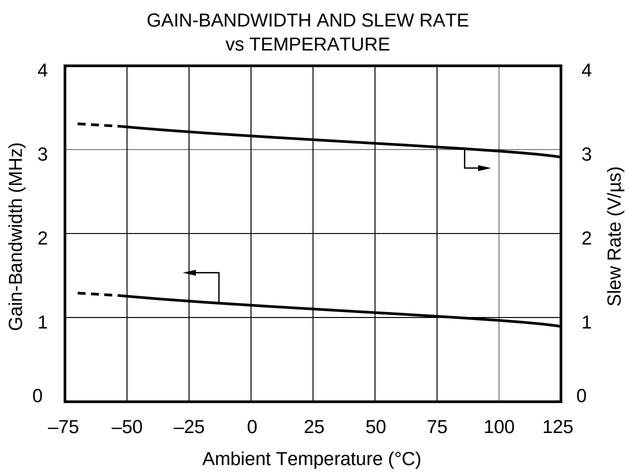


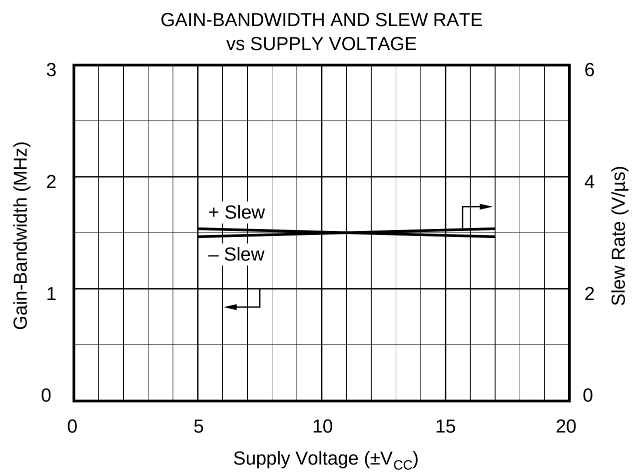
TYPICAL PERFORMANCE CURVES (CONT)

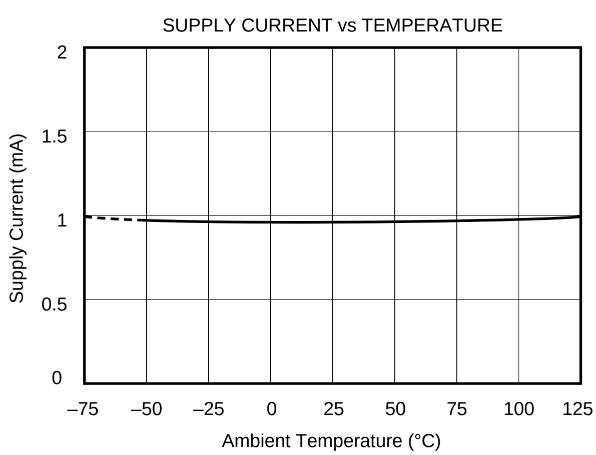
At T_A = +25°C, +15VDC, unless otherwise noted.

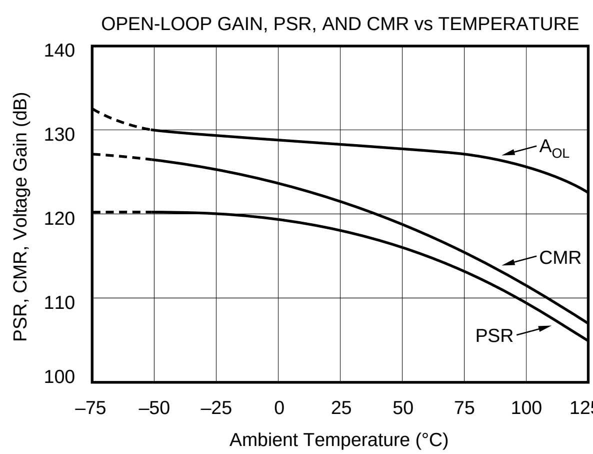








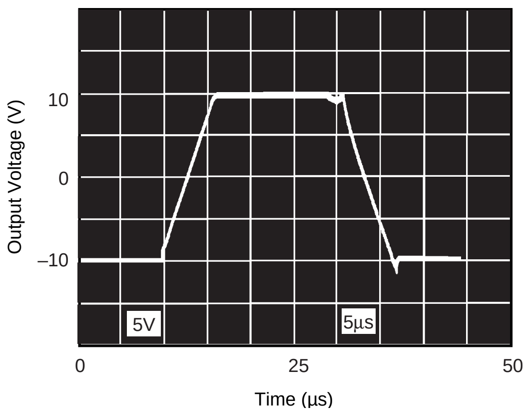




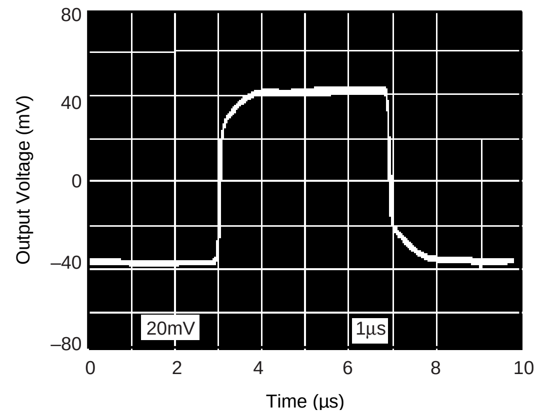
TYPICAL PERFORMANCE CURVES (CONT)

At T_A = +25°C, +15VDC, unless otherwise noted.

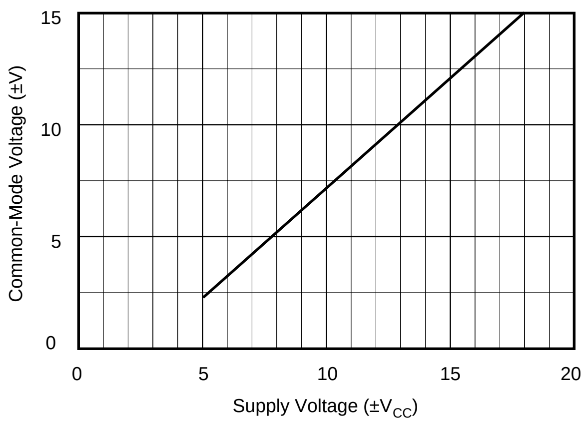
LARGE SIGNAL TRANSIENT RESPONSE



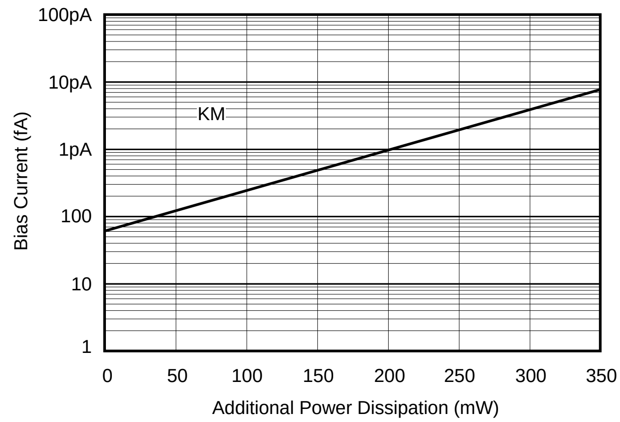
SMALL SIGNAL TRANSIENT RESPONSE



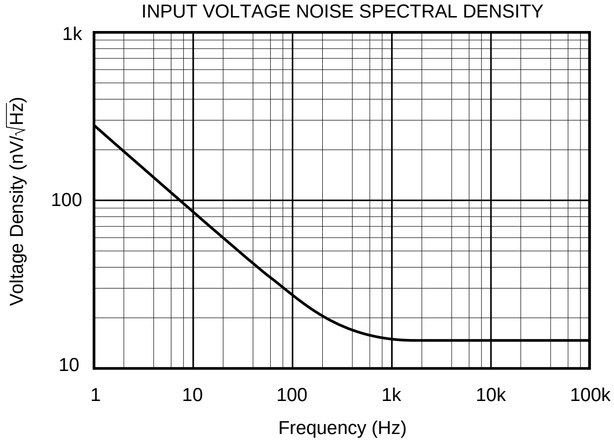
COMMON-MODE INPUT RANGE vs SUPPLY VOLTAGE



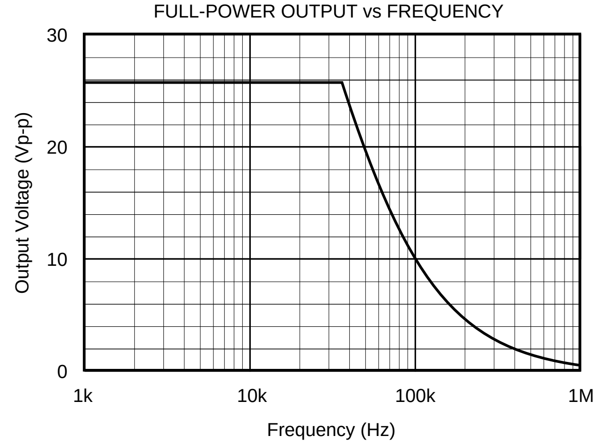
BIAS CURRENT vs ADDITIONAL POWER DISSIPATION



INPUT VOLTAGE NOISE SPECTRAL DENSITY



FULL-POWER OUTPUT vs FREQUENCY



APPLICATIONS INFORMATION

OFFSET VOLTAGE ADJUSTMENT

The OPA128 offset voltage is laser-trimmed and will require no further trim for most applications. As with most amplifiers, externally trimming the remaining offset can change drift performance by about 0.3µV/°C for each 100µV of adjusted effort. Note that the trim (Figure 1) is similar to operational amplifiers such as HA-5180 and AD515. The OPA128 can replace many other amplifiers by leaving the external null circuit unconnected.

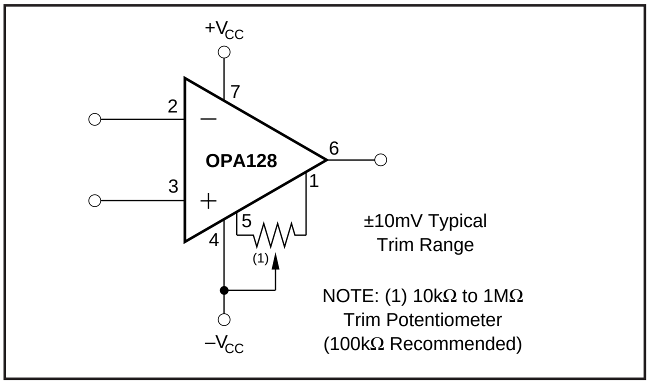


FIGURE 1. Offset Voltage Trim.

INPUT PROTECTION

Conventional monolithic FET operational amplifiers' inputs must be protected against destructive currents that can flow when input FET gate-to-substrate isolation diodes are forward-biased. Most BIFET® amplifiers can be destroyed by the loss of $-V_{CC}$.

Because of its dielectric isolation, no special protection is needed on the OPA128. Of course, the differential and common-mode voltage limits should be observed.

Static damage can cause subtle changes in amplifier input characteristics without necessarily destroying the device. In precision operational amplifiers (both bipolar and FET types), this may cause a noticeable degradation of offset voltage and drift.

Static protection is recommended when handling any precision IC operational amplifier.

GUARDING AND SHIELDING

As in any situation where high impedances are involved, careful shielding is required to reduce "hum" pickup in input leads. If large feedback resistors are used, they should also be shielded along with the external input circuitry. Leakage currents across printed circuit boards can easily exceed the bias current of the OPA128. To avoid leakage problems, it is recommended that the signal input lead of the OPA128 be wired to a Teflon standoff. If the input is to be soldered directly into a printed circuit board, utmost care must be used in planning the board layout. A "guard" pattern should completely surround the high impedance input leads and should be connected to a low impedance point which is at the signal input potential.

The amplifier case should be connected to any input shield or guard via pin 8. This insures that the amplifier itself is fully surrounded by guard potential, minimizing both leakage and noise pickup (see Figure 2).

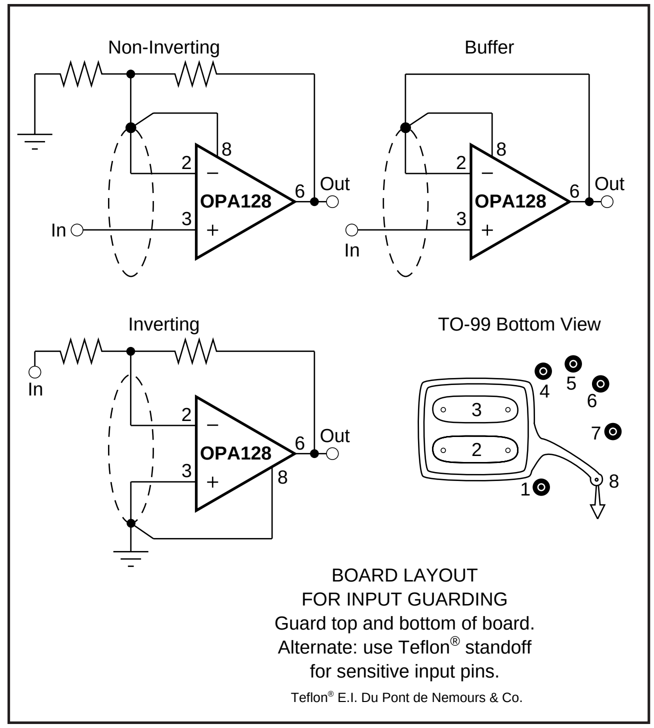


FIGURE 2. Connection of Input Guard.

Triboelectric charge (static electricity generated by friction) can be a troublesome noise source from cables connected to the input of an electrometer amplifier. Special low-noise cable will minimize this effect but the optimum solution is to mount the signal source directly at the electrometer input with short, rigid, wiring to preclude microphonic noise generation.

TESTING

Accurately testing the OPA128 is extremely difficult due to its high level of performance. Ordinary test equipment may not be able to resolve the amplifier's extremely low bias current.

Inaccurate bias current measurements can be due to:

1. Test socket leakage
2. Unclean package
3. Humidity or dew point condensation
4. Circuit contamination from fingerprints or anti-static treatment chemicals
5. Test ambient temperature
6. Load power dissipation

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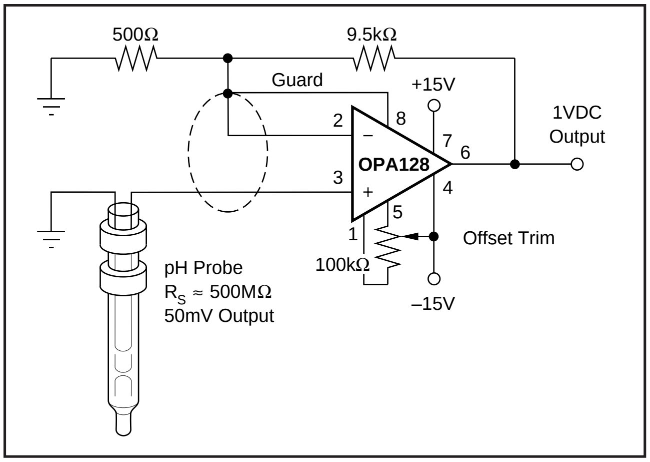

FIGURE 3. High Impedance ($10^{15}\Omega$) Amplifier.

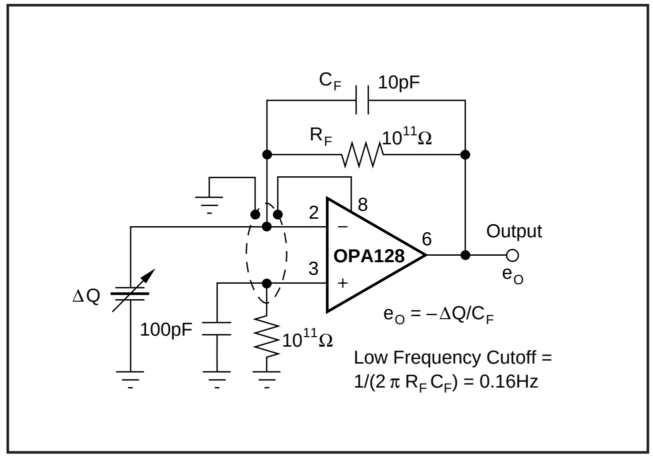

FIGURE 4. Piezoelectric Transducer Charge Amplifier.

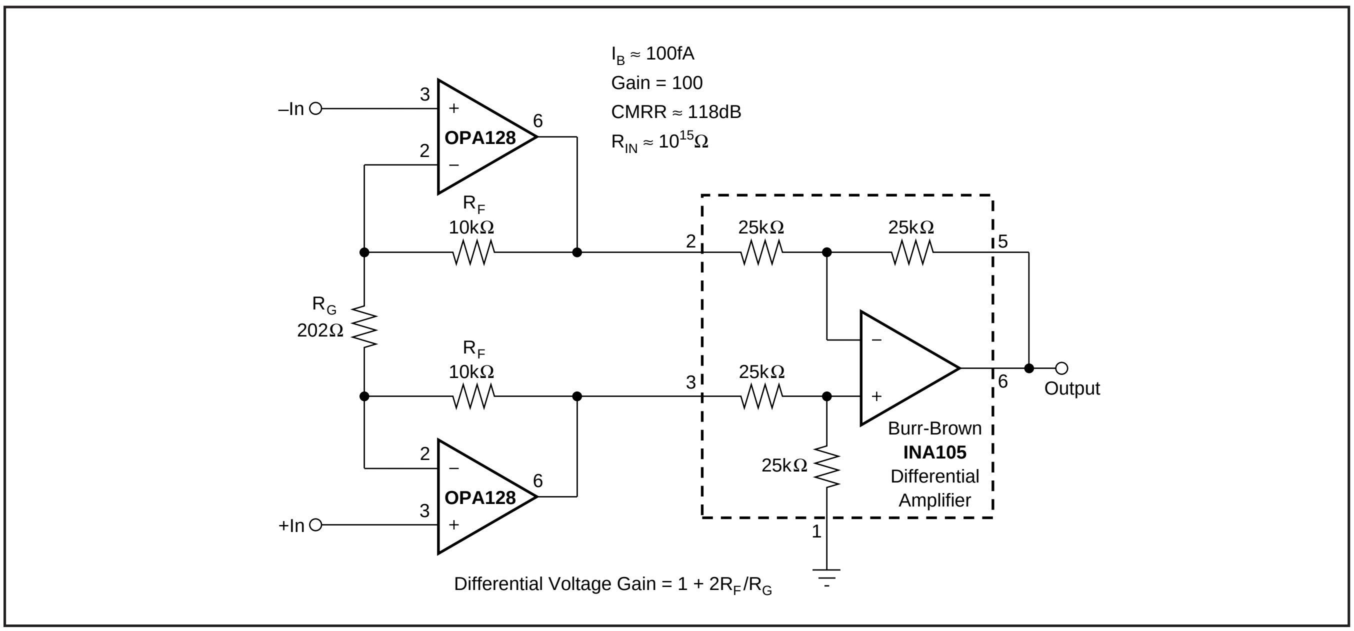

FIGURE 5. FET Input Instrumentation Amplifier for Biomedical Applications.

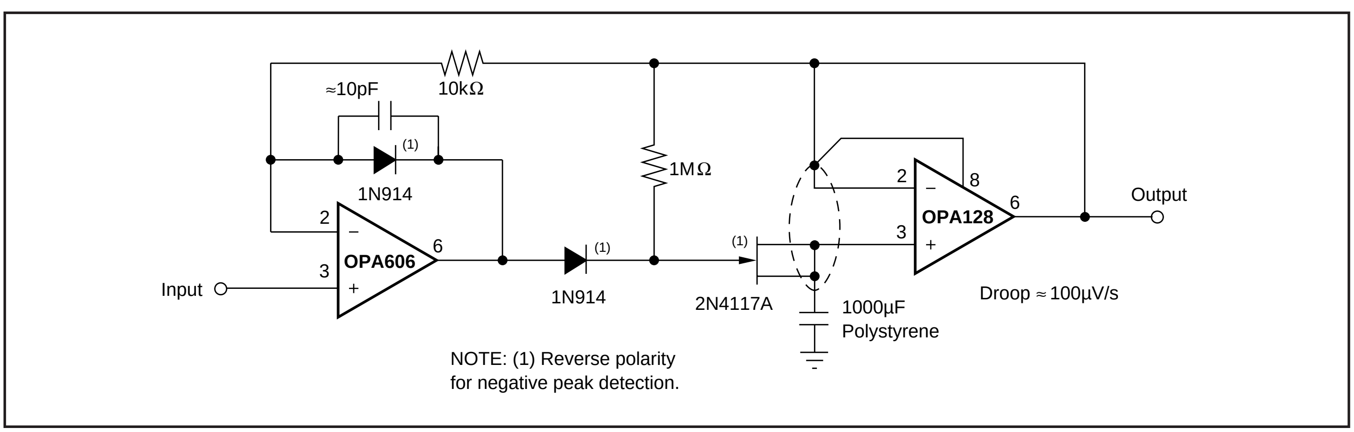

FIGURE 6. Low-Droop Positive Peak Detector.

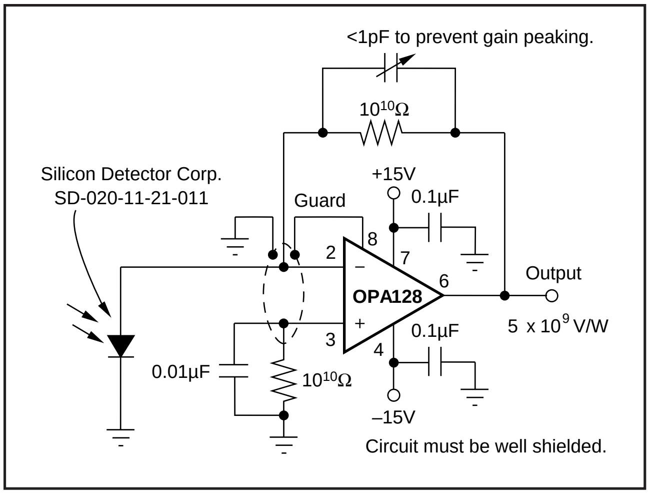

FIGURE 7. Sensitive Photodiode Amplifier.

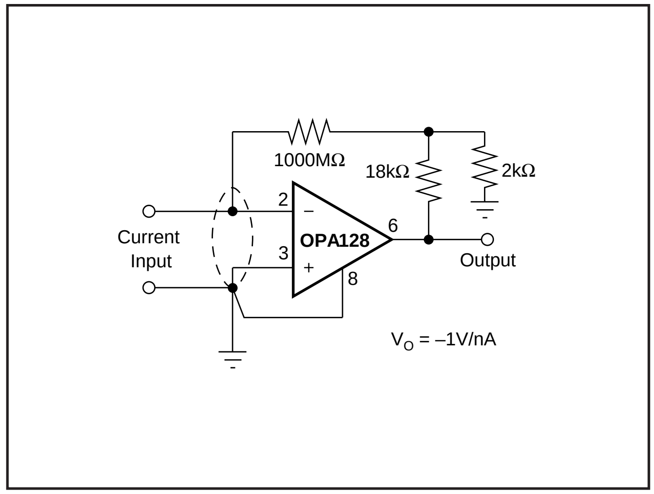

FIGURE 8. Current-to-Voltage Converter.

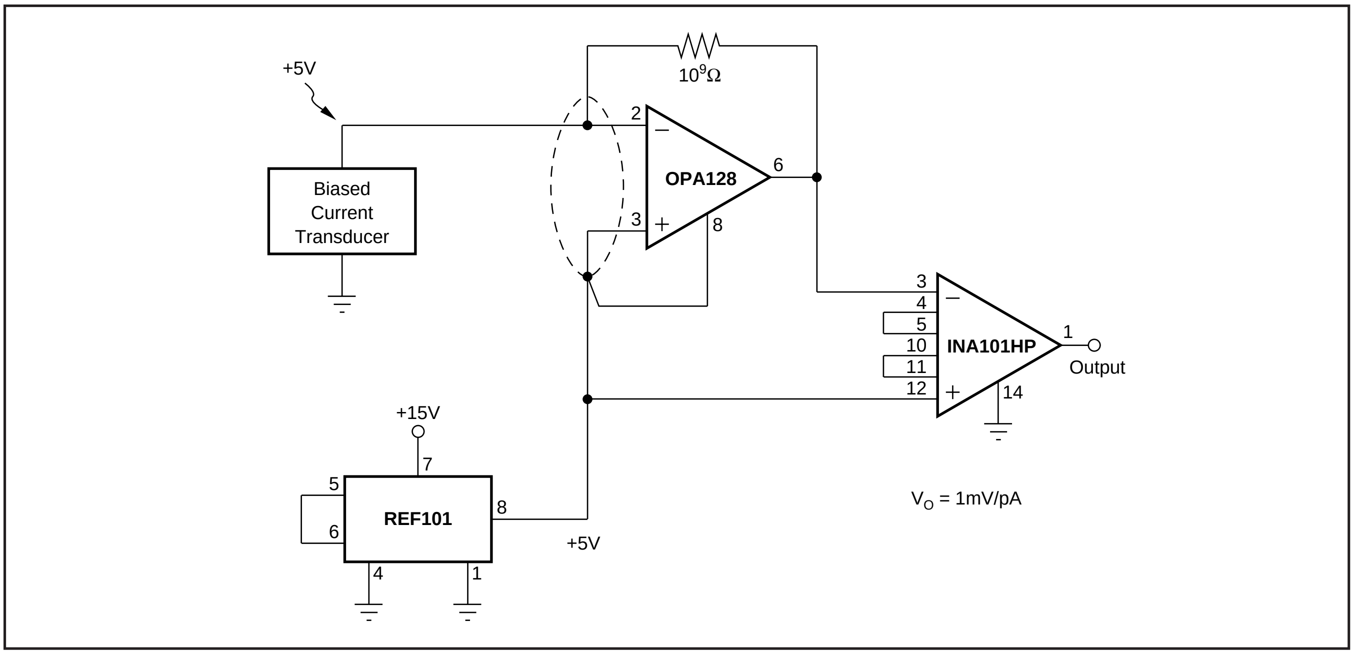

FIGURE 9. Biased Current-to-Voltage Converter.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
OPA128JM	NRND	TO-99	LMC	8	20	Green (RoHS & no Sb/Br)	Call TI	N / A for Pkg Type
OPA128KM	NRND	TO-99	LMC	8	20	Green (RoHS & no Sb/Br)	Call TI	N / A for Pkg Type
OPA128LM	NRND	TO-99	LMC	8	20	Green (RoHS & no Sb/Br)	Call TI	N / A for Pkg Type
OPA128SM	NRND	TO-99	LMC	8	20	Green (RoHS & no Sb/Br)	AU	N / A for Pkg Type

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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