BURR - BROWN®

INA128
INA129

Precision, Low Power
INSTRUMENTATION AMPLIFIERS

FEATURES

- **LOW OFFSET VOLTAGE: 50μV max**
- **LOW DRIFT: 0.5μV/°C max**
- **LOW INPUT BIAS CURRENT: 5nA max**
- **HIGH CMR: 120dB min**
- **INPUTS PROTECTED TO ±40V**
- **WIDE SUPPLY RANGE: ±2.25 to ±18V**
- **LOW QUIESCENT CURRENT: 700μA**
- **8-PIN PLASTIC DIP, SO-8**

APPLICATIONS

- **BRIDGE AMPLIFIER**
- **THERMOCOUPLE AMPLIFIER**
- **RTD SENSOR AMPLIFIER**
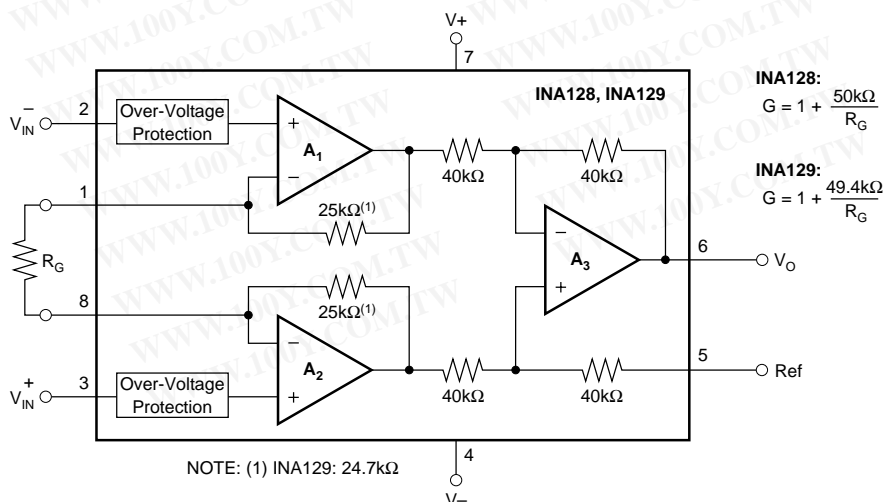- **MEDICAL INSTRUMENTATION**
- **DATA ACQUISITION**

DESCRIPTION

The INA128 and INA129 are low power, general purpose instrumentation amplifiers offering excellent accuracy. Their versatile 3-op amp design and small size make them ideal for a wide range of applications. Current-feedback input circuitry provides wide bandwidth even at high gain (200kHz at G = 100).

A single external resistor sets any gain from 1 to 10,000. INA128 provides an industry standard gain equation; INA129's gain equation is compatible with the AD620.

The INA128/INA129 is laser trimmed for very low offset voltage (50μV), drift (0.5μV/°C) and high common-mode rejection (120dB at G ≥ 100). It operates with power supplies as low as ±2.25V, and quiescent current is only 700μA—ideal for battery operated systems. Internal input protection can withstand up to ±40V without damage.

The INA128/INA129 is available in 8-pin plastic DIP, and SO-8 surface-mount packages, specified for the –40°C to +85°C temperature range. The INA128 is also available in dual configuration, the INA2128.


INA128:
$$G = 1 + \frac{50k\Omega}{R_G}$$

INA129:
$$G = 1 + \frac{49.4k\Omega}{R_G}$$

NOTE: (1) INA129: 24.7kΩ

PDS-1296C

SPECIFICATIONS

At $T_A = +25°C$, $V_S = ±15V$, $R_L = 10kΩ$, unless otherwise noted.

PARAMETER	CONDITIONS	INA128P, U INA129P, U MIN	TYP	MAX	INA128PA, UA INA129PA, UA MIN	TYP	MAX	UNITS
INPUT								
Offset Voltage, RTI								
Initial	$T_A = +25°C$		±10 ±100/G	±50 ±500/G		±25 ±100/G	±125 ±1000/G	µV
vs Temperature	$T_A = T_{MIN}$ to T_{MAX}		±0.2 ± 2/G	±0.5 ± 20/G		±0.2 ± 5/G	±1 ± 20/G	µV/°C
vs Power Supply	$V_S = ±2.25V$ to ±18V		±0.2 ±20/G	±1 ±100/G		*	±2 ±200/G	µV/V
Long-Term Stability			±0.1 ±3/G			*		µV/mo
Impedance, Differential			$10^{10} ∥ 2$			*		Ω ∥ pF
Common-Mode			$10^{11} ∥ 9$			*		Ω ∥ pF
Common-Mode Voltage Range[1]	$V_O = 0V$	(V+) − 2	(V+) − 1.4		*	*		V
		(V−) + 2	(V−) + 1.7		*	*		V
Safe Input Voltage				±40			*	V
Common-Mode Rejection	$V_{CM} = ±13V$, $ΔR_S = 1kΩ$							
G=1		80	86		73	*		dB
G=10		100	106		93	*		dB
G=100		120	125		110	*		dB
G=1000		120	130		110	*		dB
BIAS CURRENT			±2	±5		*	±10	nA
vs Temperature			±30			*		pA/°C
Offset Current			±1	±5		*	±10	nA
vs Temperature			±30			*		pA/°C
NOISE VOLTAGE, RTI	$G = 1000$, $R_S = 0Ω$							
f = 10Hz			10			*		nV/√Hz
f = 100Hz			8			*		nV/√Hz
f = 1kHz			8			*		nV/√Hz
f_B = 0.1Hz to 10Hz			0.2			*		µVp-p
Noise Current								
f=10Hz			0.9			*		pA/√Hz
f=1kHz			0.3			*		pA/√Hz
f_B = 0.1Hz to 10Hz			30			*		pAp-p
GAIN								
Gain Equation, INA128			$1 + (50kΩ/R_G)$			*		V/V
INA129			$1 + (49.4kΩ/R_G)$			*		V/V
Range of Gain		1		10000	*		*	V/V
Gain Error								
G=1			±0.01	±0.024		*	±0.1	%
G=10			±0.02	±0.4		*	±0.5	%
G=100			±0.05	±0.5		*	±0.7	%
G=1000			±0.5	±1		*	±2	%
Gain vs Temperature[2]	G=1		±1	±10		*	*	ppm/°C
50kΩ (or 49.4kΩ) Resistance[2, 3]			±25	±100		*	*	ppm/°C
Nonlinearity	$V_O = ±13.6V$, G=1		±0.0001	±0.001		*	±0.002	% of FSR
G=10			±0.0003	±0.002		*	±0.004	% of FSR
G=100			±0.0005	±0.002		*	±0.004	% of FSR
G=1000			±0.001	(Note 4)		*	*	% of FSR
OUTPUT								
Voltage: Positive	$R_L = 10kΩ$	(V+) − 1.4	(V+) − 0.9		*	*		V
Negative	$R_L = 10kΩ$	(V−) + 1.4	(V−) + 0.8		*	*		V
Load Capacitance Stability			1000			*		pF
Short-Circuit Current			+6/−15			*		mA
FREQUENCY RESPONSE								
Bandwidth, −3dB	G=1		1.3			*		MHz
G=10			700			*		kHz
G=100			200			*		kHz
G=1000			20			*		kHz
Slew Rate	$V_O = ±10V$, G=10		4			*		V/µs
Settling Time, 0.01%	G=1		7			*		µs
G=10			7			*		µs
G=100			9			*		µs
G=1000			80			*		µs
Overload Recovery	50% Overdrive		4			*		µs
POWER SUPPLY								
Voltage Range		±2.25	±15	±18	*	*	*	V
Current, Total	$V_{IN} = 0V$		±700	±750		*	*	µA
TEMPERATURE RANGE								
Specification		−40		85	*		*	°C
Operating		−40		125	*		*	°C
$θ_{JA}$ 8-Pin Dip			80			*		°C/W
SO-8 SOIC			150			*		°C/W

∗ Specification same as INA128P, U or INA129P, U.
NOTE: (1) Input common-mode range varies with output voltage—see typical curves. (2) Guaranteed by wafer test. (3) Temperature coefficient of the 50kΩ (or 49.4kΩ) term in the gain equation. (4) Nonlinearity measurements in G = 1000 are dominated by noise. Typical nonlinearity is ±0.001%.

PIN CONFIGURATION

8-Pin DIP and SO-8

Top View

R_G	1		8	R_G
V^-_{IN}	2		7	V+
V^+_{IN}	3		6	V_O
V–	4		5	Ref
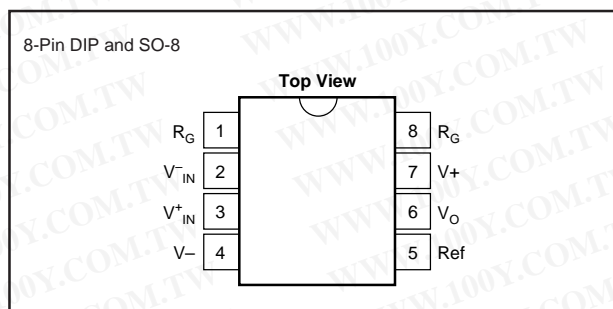
ABSOLUTE MAXIMUM RATINGS

Supply Voltage	±18V
Analog Input Voltage Range	±40V
Output Short-Circuit (to ground)	Continuous
Operating Temperature	–40°C to +125°C
Storage Temperature	–40°C to +125°C
Junction Temperature	+150°C
Lead Temperature (soldering, 10s)	+300°C

⚠ ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Burr-Brown recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

ORDERING INFORMATION

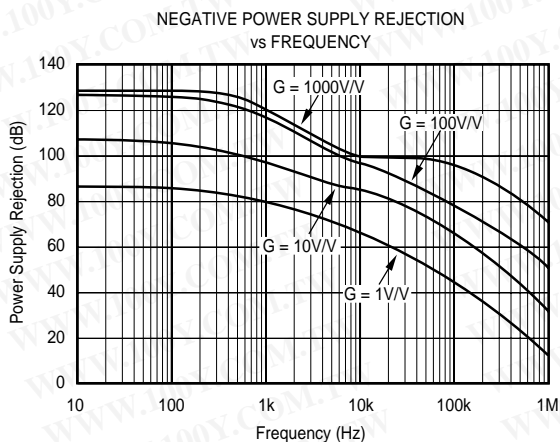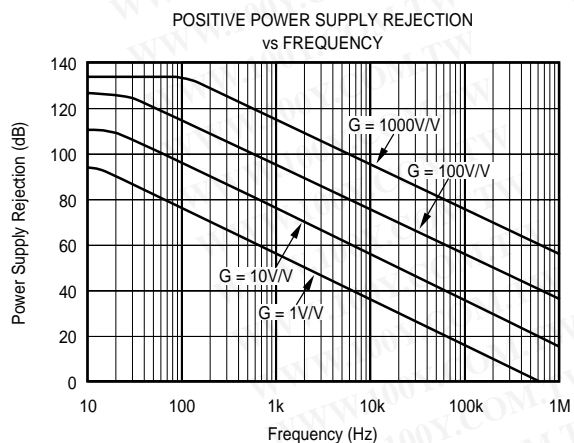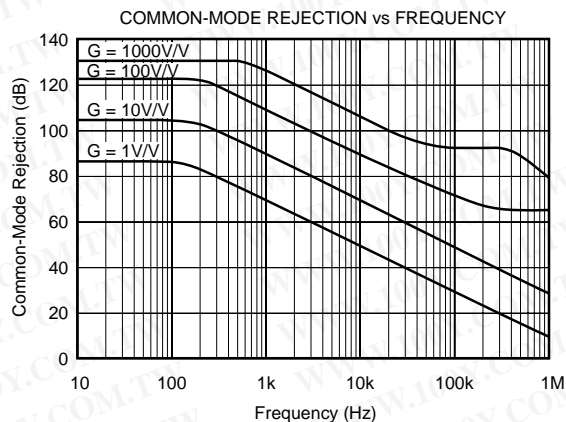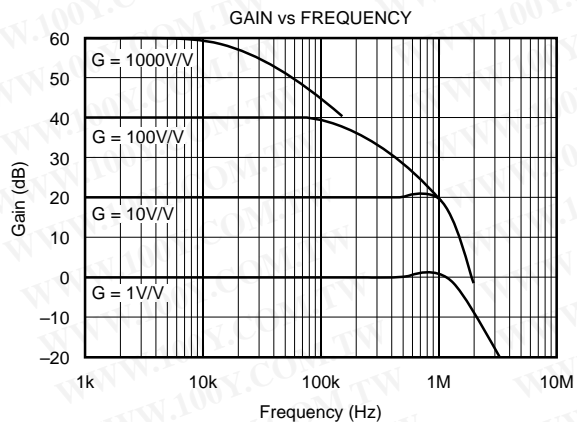| PRODUCT	PACKAGE	PACKAGE DRAWING NUMBER[1]	TEMPERATURE RANGE
INA128PA	8-Pin Plastic DIP	006	–40°C to +85°C
INA128P	8-Pin Plastic DIP	006	–40°C to +85°C
INA128UA	SO-8 Surface-Mount	182	–40°C to +85°C
INA128U	SO-8 Surface-Mount	182	–40°C to +85°C
INA129PA	8-Pin Plastic DIP	006	–40°C to +85°C
INA129P	8-Pin Plastic DIP	006	–40°C to +85°C
INA129UA	SO-8 Surface-Mount	182	–40°C to +85°C
INA129U	SO-8 Surface-Mount	182	–40°C to +85°C

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

TYPICAL PERFORMANCE CURVES

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

GAIN vs FREQUENCY

COMMON-MODE REJECTION vs FREQUENCY

POSITIVE POWER SUPPLY REJECTION vs FREQUENCY

NEGATIVE POWER SUPPLY REJECTION vs FREQUENCY

INPUT COMMON-MODE RANGE vs OUTPUT VOLTAGE, V_S = ±15V

INPUT COMMON-MODE RANGE vs OUTPUT VOLTAGE, V_S = ±5, ±2.5V

TYPICAL PERFORMANCE CURVES (CONT)

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

INPUT- REFERRED NOISE vs FREQUENCY

G = 1V/V

G = 10V/V

G = 100, 1000V/V

Current Noise

SETTLING TIME vs GAIN

0.01%

0.1%

QUIESCENT CURRENT and SLEW RATE vs TEMPERATURE

Slew Rate

I_Q

INPUT OVER-VOLTAGE V/I CHARACTERISTICS

Flat region represents normal linear operation.

G = 1000V/V

G = 1V/V

G = 1V/V

G = 1000V/V

V_{IN}

I_{IN}

+15V

−15V

INPUT OFFSET VOLTAGE WARM-UP

INPUT BIAS CURRENT vs TEMPERATURE

I_{OS}

I_B

Typical I_B and I_{OS}
Range ±2nA at 25°C
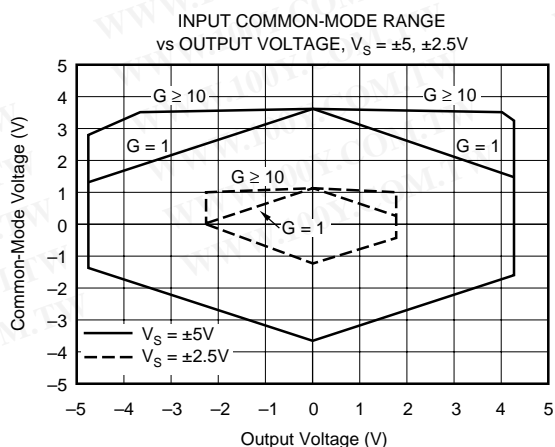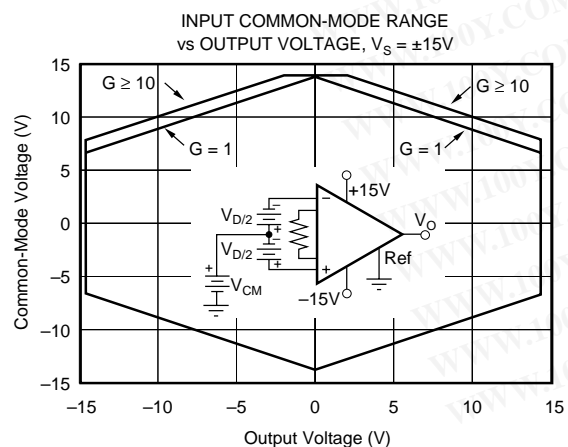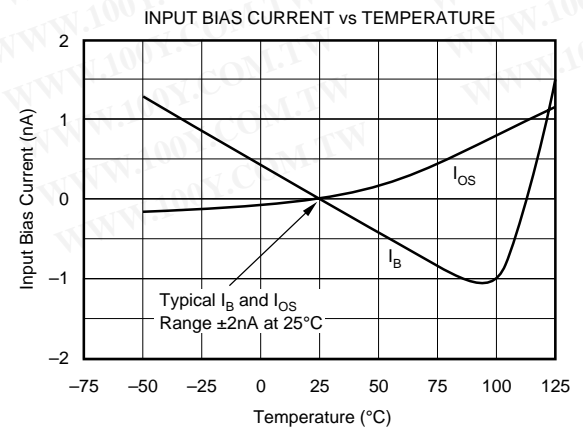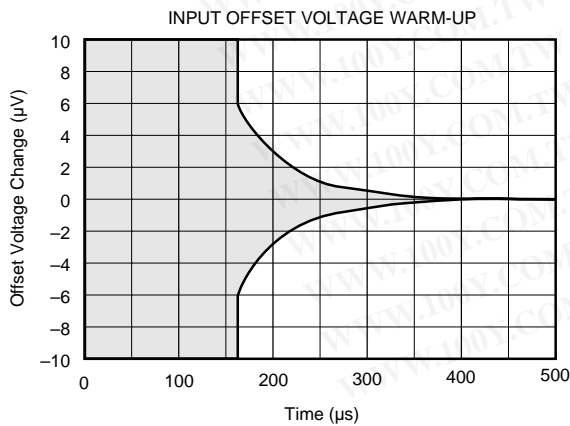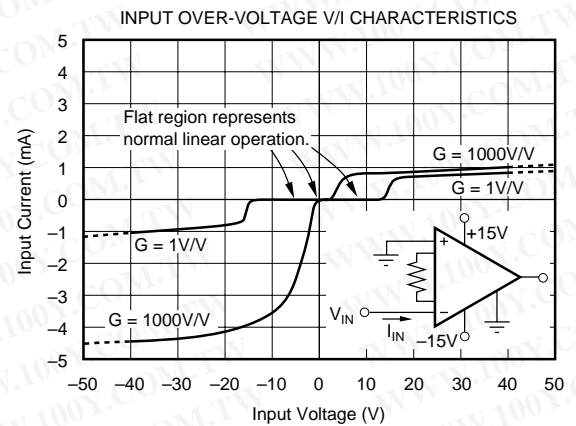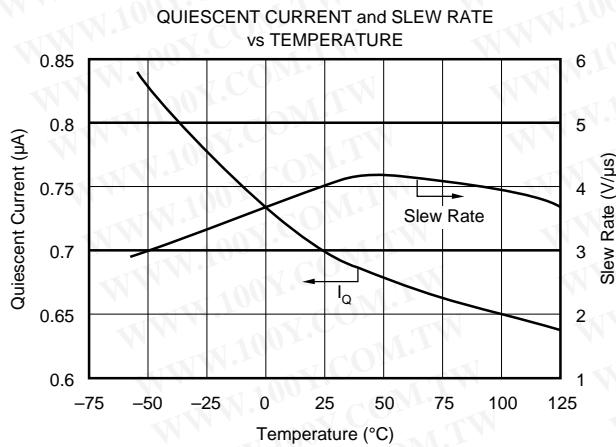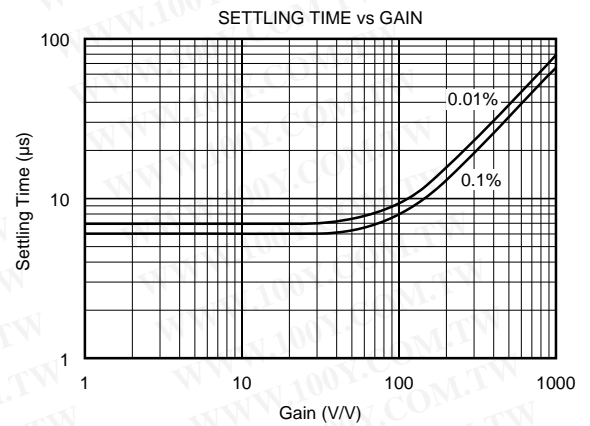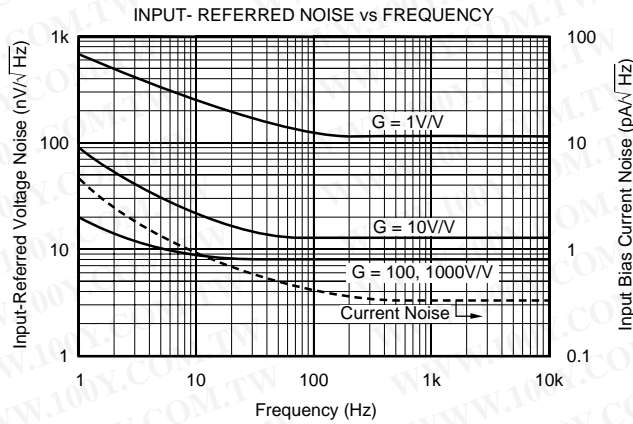
TYPICAL PERFORMANCE CURVES (CONT)

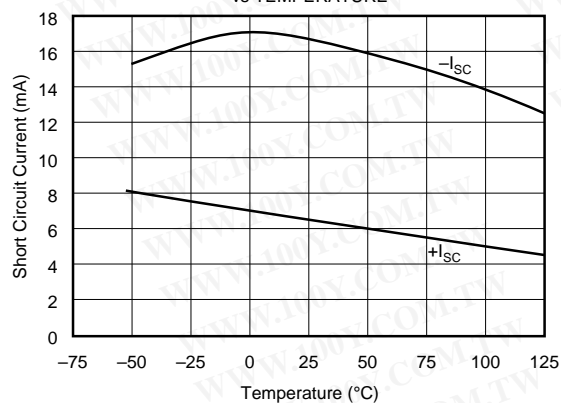At T_A = +25°C, V_S = ±15V, unless otherwise noted.

OUTPUT VOLTAGE SWING
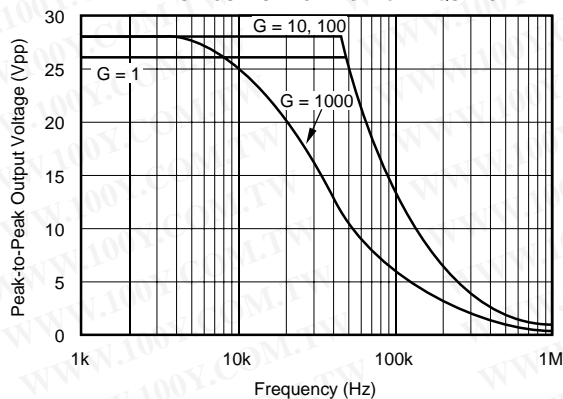vs OUTPUT CURRENT
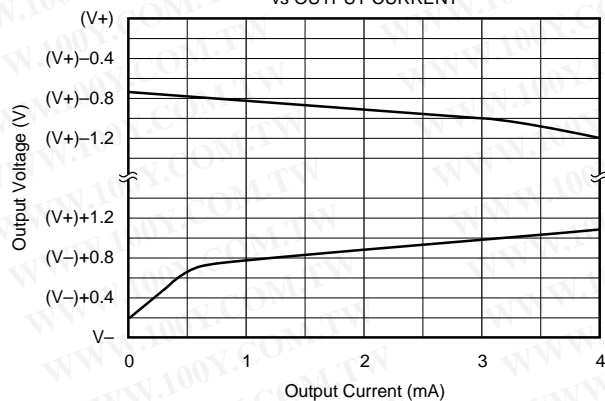
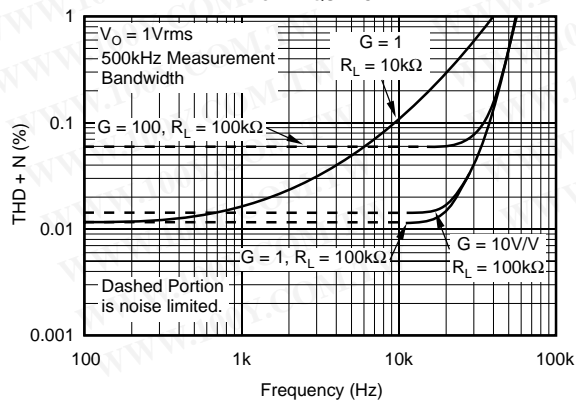OUTPUT VOLTAGE SWING
vs POWER SUPPLY VOLTAGE
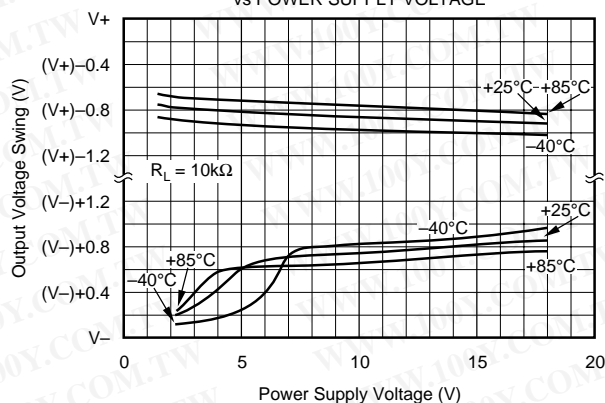
SHORT-CIRCUIT OUTPUT CURRENT
vs TEMPERATURE

MAXIMUM OUTPUT VOLTAGE vs FREQUENCY

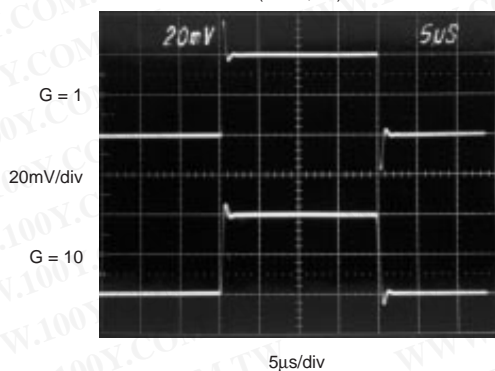TOTAL HARMONIC DISTORTION + NOISE
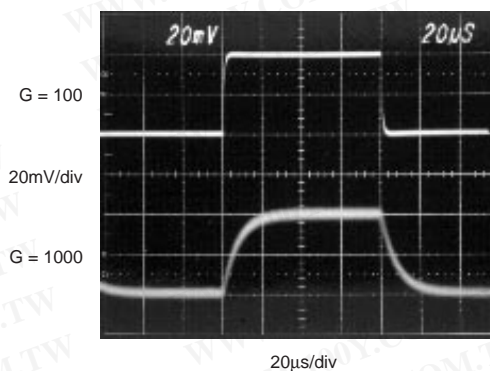vs FREQUENCY

TYPICAL PERFORMANCE CURVES (CONT)

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

SMALL-SIGNAL
(G = 1, 10)

G = 1
20mV/div
G = 10

5µs/div

SMALL-SIGNAL
(G = 100, 1000)

G = 100
20mV/div
G = 1000

20µs/div

LARGE-SIGNAL
(G = 1, 10)

G = 1
5V/div
G = 10

5µs/div

LARGE-SIGNAL
(G = 100, 1000)

G = 100
5V/div
G = 1000

20µs/div
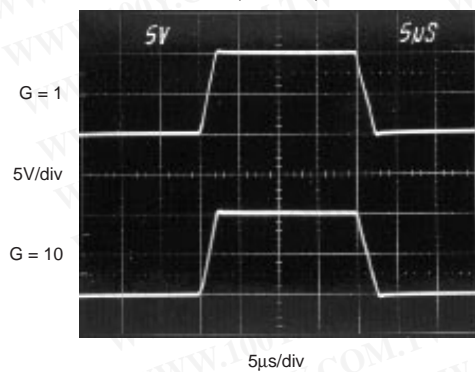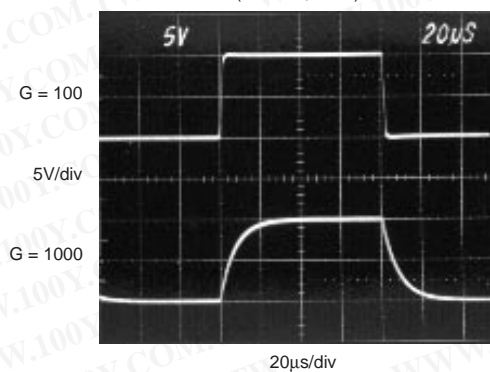
VOLTAGE NOISE 0.1 to 10Hz
INPUT-REFERRED, G ≥ 100

0.1µV/div

1s/div
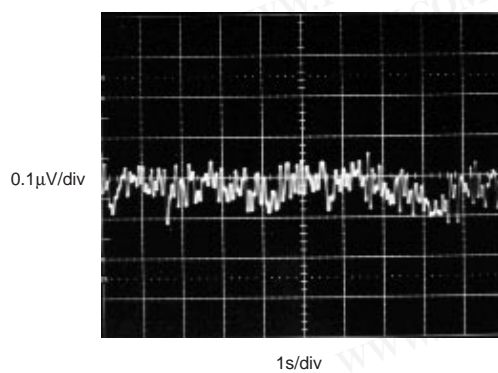
APPLICATION INFORMATION

Figure 1 shows the basic connections required for operation of the INA128/INA129. Applications with noisy or high impedance power supplies may require decoupling capacitors close to the device pins as shown.

The output is referred to the output reference (Ref) terminal which is normally grounded. This must be a low-impedance connection to assure good common-mode rejection. A resistance of 8Ω in series with the Ref pin will cause a typical device to degrade to approximately 80dB CMR (G = 1).

SETTING THE GAIN

Gain is set by connecting a single external resistor, R_G, connected between pins 1 and 8:

$$\text{INA128:} \quad G = 1 + \frac{50k\Omega}{R_G} \tag{1}$$

$$\text{INA129:} \quad G = 1 + \frac{49.4k\Omega}{R_G} \tag{2}$$

Commonly used gains and resistor values are shown in Figure 1.

The 50kΩ term in Equation 1 (49.4kΩ in Equation 2) comes from the sum of the two internal feedback resistors of A_1 and A_2. These on-chip metal film resistors are laser trimmed to accurate absolute values. The accuracy and temperature coefficient of these internal resistors are included in the gain accuracy and drift specifications of the INA128/INA129.

The stability and temperature drift of the external gain setting resistor, R_G, also affects gain. R_G's contribution to gain accuracy and drift can be directly inferred from the gain equation (1). Low resistor values required for high gain can make wiring resistance important. Sockets add to the wiring resistance which will contribute additional gain error (possibly an unstable gain error) in gains of approximately 100 or greater.

DYNAMIC PERFORMANCE

The typical performance curve "Gain vs Frequency" shows that, despite its low quiescent current, the INA128/INA129 achieves wide bandwidth, even at high gain. This is due to the current-feedback topology of the input stage circuitry. Settling time also remains excellent at high gain.

NOISE PERFORMANCE

The INA128/INA129 provides very low noise in most applications. Low frequency noise is approximately 0.2µVp-p measured from 0.1 to 10Hz (G ≥ 100). This provides dramatically improved noise when compared to state-of-the-art chopper-stabilized amplifiers.

INA128: $G = 1 + \dfrac{50k\Omega}{R_G}$ INA129: $G = 1 + \dfrac{49.4k\Omega}{R_G}$

DESIRED GAIN (V/V)	INA128 R_G (Ω)	INA128 NEAREST 1% R_G (Ω)	INA129 R_G (Ω)	INA129 NEAREST 1% R_G (Ω)
1	NC	NC	NC	NC
2	50.00k	49.9k	49.4k	49.9k
5	12.50k	12.4k	12.35k	12.4k
10	5.556k	5.62k	5489	5.49k
20	2.632k	2.61k	2600	2.61k
50	1.02k	1.02k	1008	1k
100	505.1	511	499	499
200	251.3	249	248	249
500	100.2	100	99	100
1000	50.05	49.9	49.5	49.9
2000	25.01	24.9	24.7	24.9
5000	10.00	10	9.88	9.76
10000	5.001	4.99	4.94	4.87

NC: No Connection.

NOTE: (1) INA129: 24.7kΩ

$V_O = G \cdot (V_{IN}^+ - V_{IN}^-)$
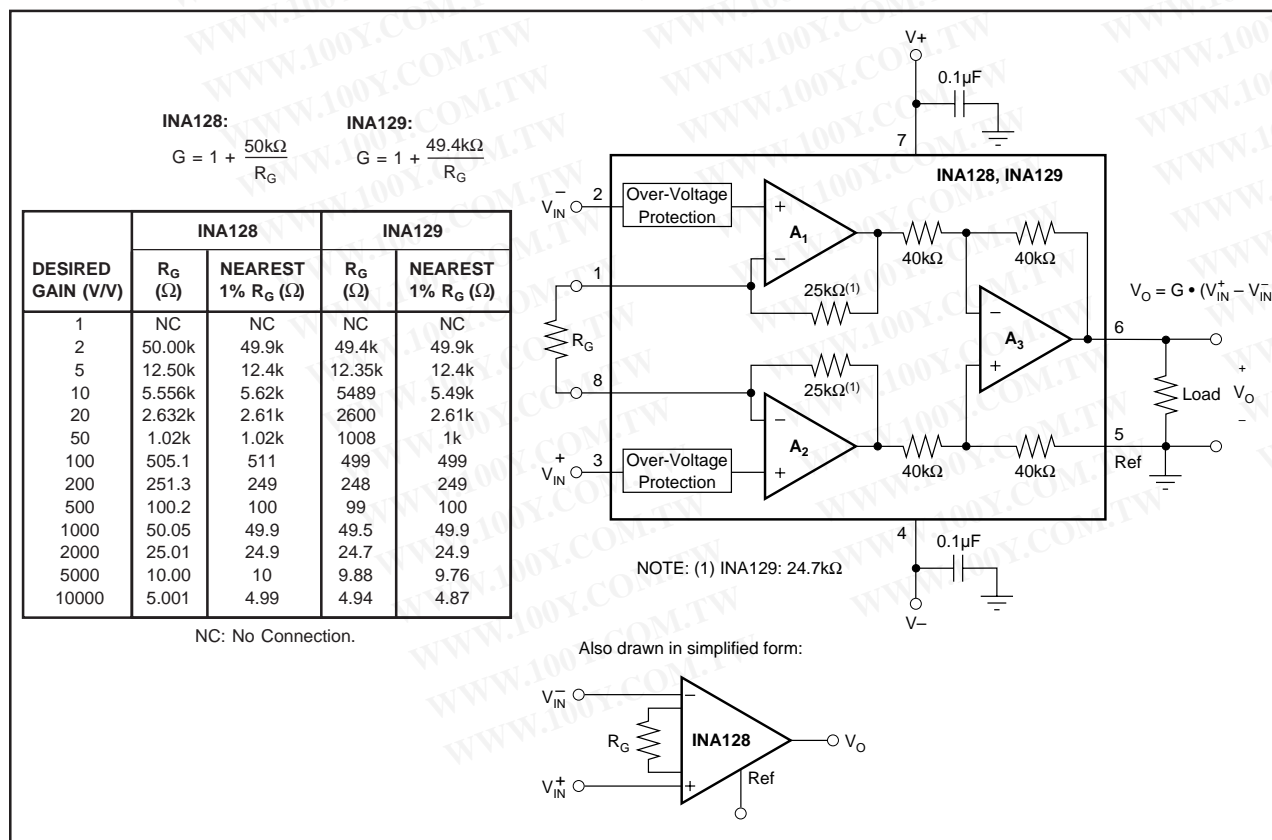
Also drawn in simplified form:

FIGURE 1. Basic Connections.

OFFSET TRIMMING

The INA128/INA129 is laser trimmed for low offset voltage and offset voltage drift. Most applications require no external offset adjustment. Figure 2 shows an optional circuit for trimming the output offset voltage. The voltage applied to Ref terminal is summed with the output. The op amp buffer provides low impedance at the Ref terminal to preserve good common-mode rejection.
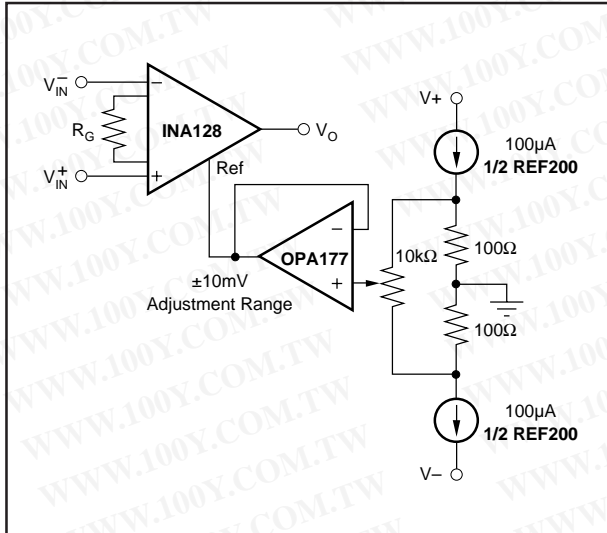

FIGURE 2. Optional Trimming of Output Offset Voltage.

FIGURE 3. Providing an Input Common-Mode Current Path.

INPUT BIAS CURRENT RETURN PATH

The input impedance of the INA128/INA129 is extremely high—approximately $10^{10}\Omega$. However, a path must be provided for the input bias current of both inputs. This input bias current is approximately ±2nA. High input impedance means that this input bias current changes very little with varying input voltage.

Input circuitry must provide a path for this input bias current for proper operation. Figure 3 shows various provisions for an input bias current path. Without a bias current path, the inputs will float to a potential which exceeds the common-mode range, and the input amplifiers will saturate.

If the differential source resistance is low, the bias current return path can be connected to one input (see the thermocouple example in Figure 3). With higher source impedance, using two equal resistors provides a balanced input with possible advantages of lower input offset voltage due to bias current and better high-frequency common-mode rejection.

INPUT COMMON-MODE RANGE

The linear input voltage range of the input circuitry of the INA128/INA129 is from approximately 1.4V below the positive supply voltage to 1.7V above the negative supply. As a differential input voltage causes the output voltage increase, however, the linear input range will be limited by the output 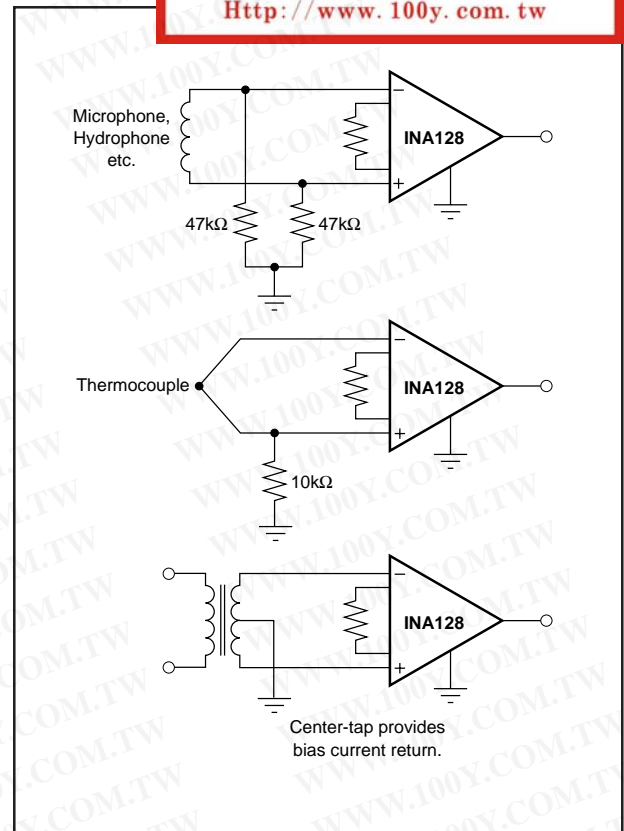voltage swing of amplifiers A_1 and A_2. So the linear common-mode input range is related to the output voltage of the complete amplifier. This behavior also depends on supply voltage—see performance curves "Input Common-Mode Range vs Output Voltage".

Input-overload can produce an output voltage that appears normal. For example, if an input overload condition drives both input amplifiers to their positive output swing limit, the difference voltage measured by the output amplifier will be near zero. The output of A_3 will be near 0V even though both inputs are overloaded.

LOW VOLTAGE OPERATION

The INA128/INA129 can be operated on power supplies as low as ±2.25V. Performance remains excellent with power supplies ranging from ±2.25V to ±18V. Most parameters vary only slightly throughout this supply voltage range—see typical performance curves. Operation at very low supply voltage requires careful attention to assure that the input voltages remain within their linear range. Voltage swing requirements of internal nodes limit the input common-mode range with low power supply voltage. Typical performance curves, "Input Common-Mode Range vs Output Voltage" show the range of linear operation for ±15V, ±5V, and ±2.5V supplies.
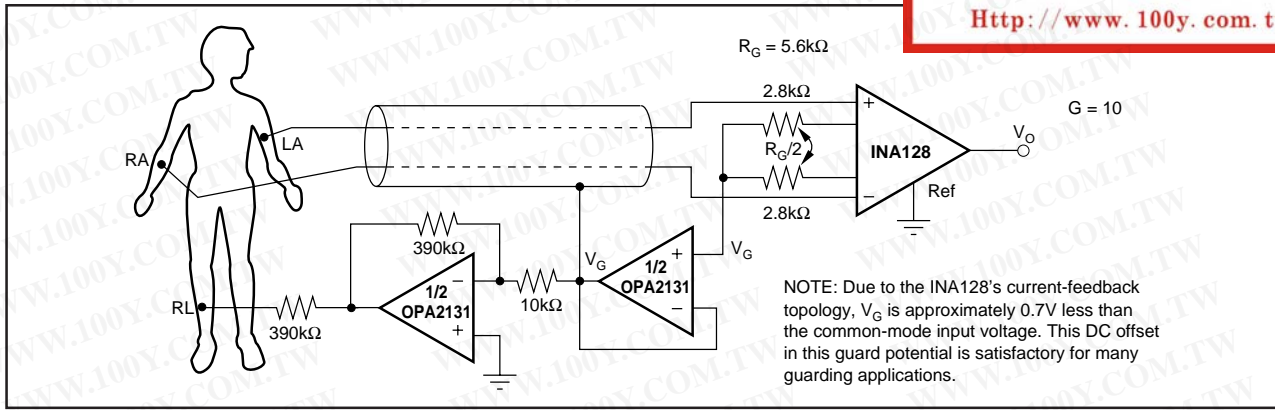
FIGURE 4. ECG Amplifier With Right-Leg Drive.
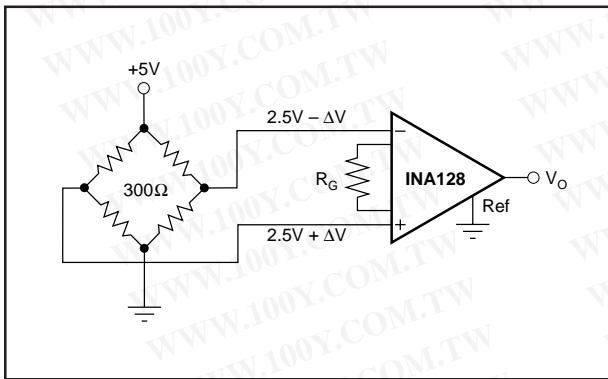
FIGURE 5. Bridge Amplifier.
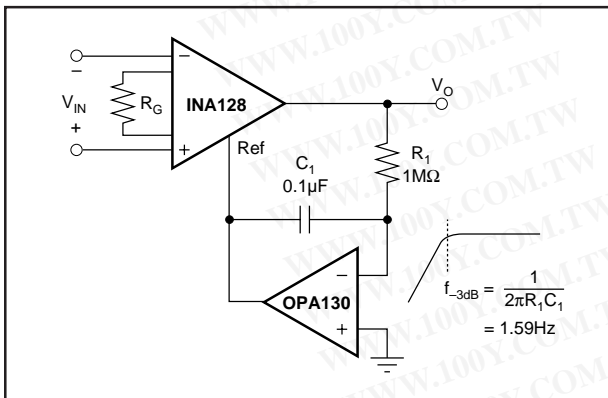
FIGURE 6. AC-Coupled Instrumentation Amplifier.

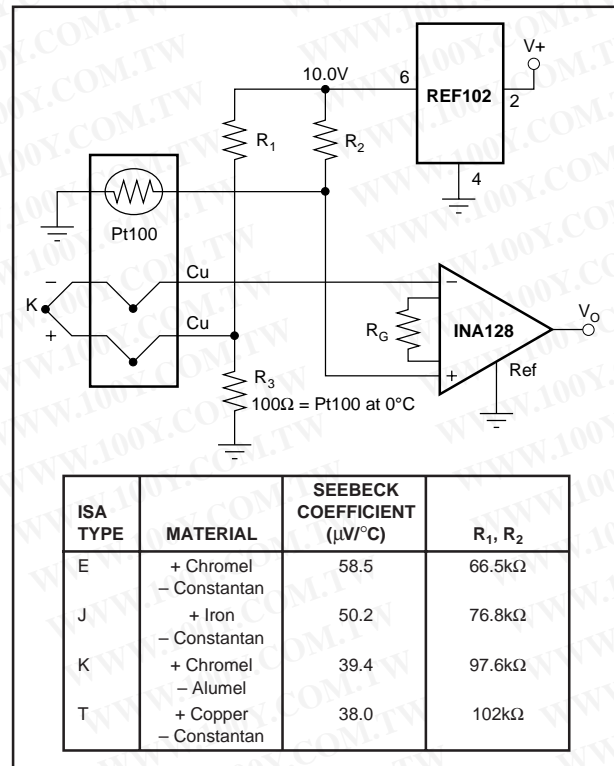|		SEEBECK COEFFICIENT (µV/°C)	
ISA TYPE	MATERIAL		R_1, R_2
E	+ Chromel – Constantan	58.5	66.5kΩ
J	+ Iron – Constantan	50.2	76.8kΩ
K	+ Chromel – Alumel	39.4	97.6kΩ
T	+ Copper – Constantan	38.0	102kΩ

FIGURE 7. Thermocouple Amplifier With RTD Cold-Junction Compensation.

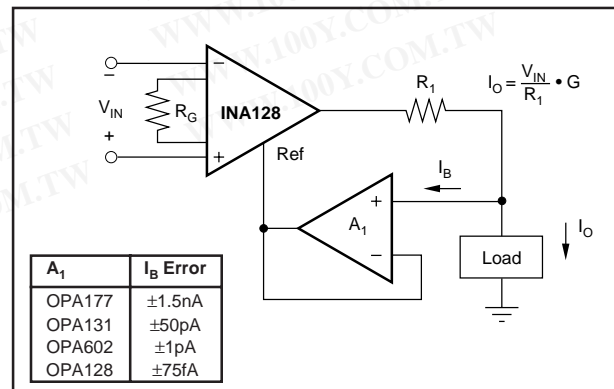| A_1	I_B Error
OPA177	±1.5nA
OPA131	±50pA
OPA602	±1pA
OPA128	±75fA

FIGURE 8. Differential Voltage to Current Converter.