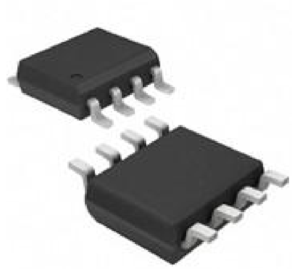
HX128-S/HX129-S Low-power precision instrumentation amplifier

The HX128-S and HX129-S are both general-purpose instrumentation amplifiers with excellent precision and low power consumption. These amplifiers feature a function-rich three-stage operational amplifier design, are compact in size, and are suitable for a wide range of applications. Even under extreme conditions of up to 200kHz frequency and a gain of 100, their current feedback input circuitry still provides a wide bandwidth.

The HX128-S/HX129-S allows users to freely set the desired gain within the range of 1 to 10,000 through a single external resistor. Among them, the HX128-S provides the industry-standard gain formula, with an integrated 50k Ω resistor inside. The HX129-S, on the other hand, uses a 49.4kΩ resistor, and its gain formula enables the amplifier to directly replace similar devices, offering great convenience to users.



SOP-8

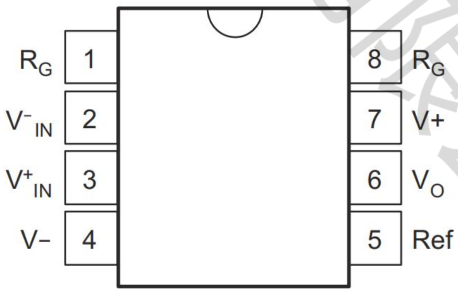
Features

- Low offset voltage: 50μV (Max)
- Low drift: 0.5μV/°C (Max)
- Low input bias current: 5nA (Max)
- Low noise: 8nV/√Hz, 0.2μVpp
- High CMR: 120dB (Min)
- Bandwidth: 1.3 MHz (G = 1)
- The input protection voltage can reach±40V
- Wide power supply voltage range: ±2.25V to ±18V
- Low quiescent current: 700μA
- Adopting SOP-8 encapsulation

Application

- Pressure transmitter
- Temperature transmitter
- weightometer
- electrocardiogram(ECG)
- Analog input module
- Data acquisition(DAQ)

Pin configuration and functions



Chip pin description			
Pin	Name	Type	Function
REF	5	Input	This pin must be driven by a low impedance source or connected to ground.
RG	1,8		Gain setting pin. For gains greater than 1, place a gain resistor between pin 1 and pin 8.。
V –	4	Power supply	Negative power supply
V+	7	Power supply	Positive power supply
V IN –	2	Input	negative input
V IN+	3	Input	positive input
VO	6	Output	Output

Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

			MIN	MAX	UNIT
VS	Supply voltage	Dual supply, VS = (V+) – (V –)		±18	V
		Single supply, VS = (V+) – 0 V		36	
	Analog input voltage			±40	V
	Output short-circuit(2)		Continuous		
TA	Operating temperature		-40	125	°C
	Junction temperature			150	°C
	Lead temperature (soldering, 10 s)			300	°C
Tstg	Storage temperature		-55	125	°C

Notes

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) Short-circuit to VS / 2

ESD Ratings

			VALUE	UNIT
V(ESD)	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±2000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101(2)	±50	

Notes

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

			MIN	TYP	MAX	UNIT
VS	Supply voltage	Single-supply	4.5	30	36	V
		Dual-supply	±2.25	±15	±18	
	Input common-mode voltage range for VO = 0 V		(V-)+2		(V+)-2	V
TA	Specified temperature		-40		85	°C

Thermal Information

THERMAL METRIC		HX128-S	HX129-S	UNIT
		8 PINS	8 PINS	
R θJA	Junction-to-ambient thermal resistance	110	46.1	°C/W
R θJC(top)	Junction-to-case (top) thermal resistance	57	34.1	°C/W
R θJB	Junction-to-board thermal resistance	54	23.4	°C/W
ψJT	Junction-to-top characterization parameter	11	11.3	°C/W
ψJB	Junction-to-board characterization parameter	53	23.2	°C/W

Electrical Characteristics

at TA = 25°C, VS = ±15 V, RL = 10 kΩ, VREF = 0 V, VCM = VS / 2, and G = 1 (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
INPUT							
VOS	Offset voltage (RTI)	1 三 G 三 10000			±10±100/G	±50±500/G	μV
					±25±100/G	±125±1000/G	
	Offset voltage drift (RTI)	TA = -40°C to +85°C			±0.2±2/G	±0.5±20/G	μV/°C
					±0.2±5/G	±1±20/G	
PSRR	Power-supply rejection ratio (RTI)	VS = ±2.25 V to ±18 V			±0.2±20/G	±1±100/G	μV/V
						±2±200/G	
	Long-term stability				±0.2±3/G		μV/mo
	Input impedance	Differential			10||2		GΩ || pF
		Common-mode			100||9		
V CM	Common-mode voltage[2]	VO = 0 V		(V–)+2		(V+)–2	V
	Safe input voltage	RS = 0 Ω				±40	V
CMRR	Common-mode rejection ratio	ΔRS = 1 kΩ, V CM = ±13 V	G = 1	80	86		dB
				73			
			G = 10	100	106		
				93			
			G = 100	120	125		
				110			
			G = 1000	120	130		
				110			
INPUT BIAS CURRENT							
IB	Input bias current	HX128-S/HX129-SP, HX128-S/HX129-SU			±2	±5	nA
		HX128-S/HX129-SPA, HX128-S/HX129-SUA				±10	
	Input bias current drift	TA = -40°C to +85°C			±30		pA/℃
IOS	Input offset current	HX128-S/HX129-SP, HX128-S/HX129-SU			±1	±5	nA
		HX128-S/HX129-SPA, HX128-S/HX129-SUA				±10	nA
	Input offset current drift	TA = -40°C to +85°C			±30		pA/℃
NOISE							
eN	Voltage noise (RTI)	G = 1000 RS = 0Ω	f = 10 Hz		10		nV/Hz
			f = 100 Hz		8		
			f = 1 kHz		8		

		fB=0.1 Hz to 10Hz		0.2		μVPP
In	Current noise	f = 10 Hz		0.9		pA/Hz
		f = 1 kHz		0.3		
		fB = 0.1 Hz to 10 Hz		30		pAPP

Electrical Characteristics (continued)

at TA = 25°C, VS = ±15 V, RL = 10 kΩ, VREF = 0 V, VCM = VS / 2, and G = 1 (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
	Gain equation	HX128-S			1+(50kΩ/RG)		V/V
		HX129-S			1+(49.4kΩ/RG)		V/V
G	Gain			1		10000	
GE	Gain error	G = 1			±0.01	±0.024	%
		G = 10			±0.02	±0.4	
		G = 100			±0.05	±0.5	
		G = 1000			±0.5	±1	
	Gain nonlinearity(1)	G = 1, VO = ±13.6 V			±0.0001	±0.001	%ofFSR
		G = 10			±0.0003	±0.002	
		G = 100			±0.0005	±0.002	
		G = 1000			±0.001		
	Positive output voltage swing			(V+)–1.4			V
	Negative output voltage swing			(V–)+1.4			V
CL	Load capacitance	Stable operation			1000		pF
ISC	Short-circuit current	Continuous to VS / 2			+6/–15		mA
BW	Bandwidth, –3 dB	G = 1			1.3		MHz
		G = 10			640		kHz
		G = 100			200		
		G = 1000			20		
SR	Slew rate	G = 5, VO = ±10 V			1.2		V/μs
tS	Settling time	To 0.01%	G = 1		12		μs
			G = 10		12		
			G = 100		12		
			G = 1000		80		
	Overload recovery	50% input overload			4		μs
IQ	Quiescent current	VIN = 0 V			±700	±750	μA

Notes

(1) Nonlinearity measurements in G = 1000 are dominated by noise. Typical nonlinearity is ±0.001%

(2) Input common-mode voltage varies with output voltage; see *Typical Characteristics*.

(3) Temperature coefficient of the 50-kΩor 49.4-kΩterm in the gain equation.

(4) Specified by wafer test.

Typical Characteristics

at TA = 25°C, VS = ±15 V, RL = 10 kΩ, VREF = 0 V, VCM = VS / 2, and G = 1 (unless otherwise noted)

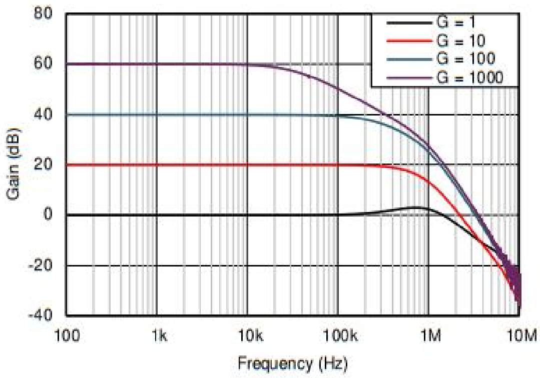


Figure 1. Gain vs Frequency

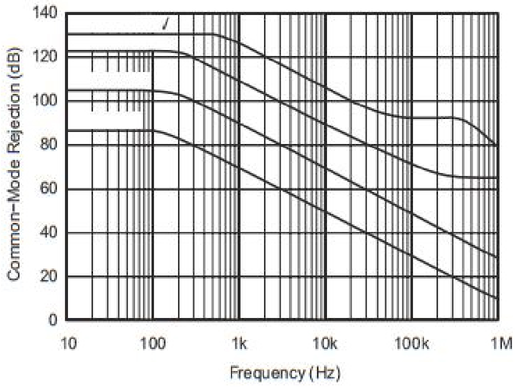


Figure 2. Common-Mode Rejection vs Frequency

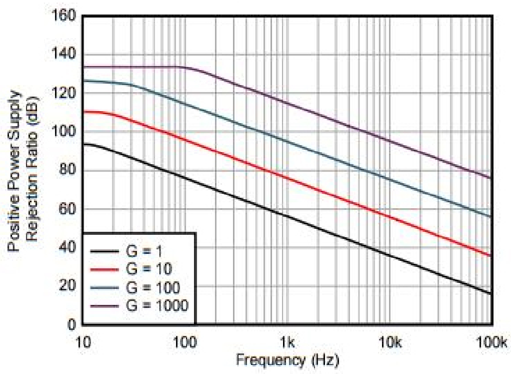


Figure 3. Positive Power Supply Rejection vs Frequency

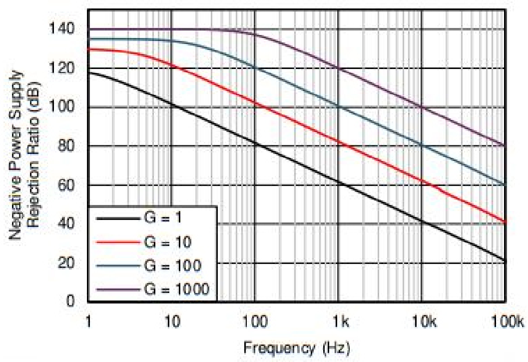


Figure 4. Negative Power Supply Rejection vs Frequency

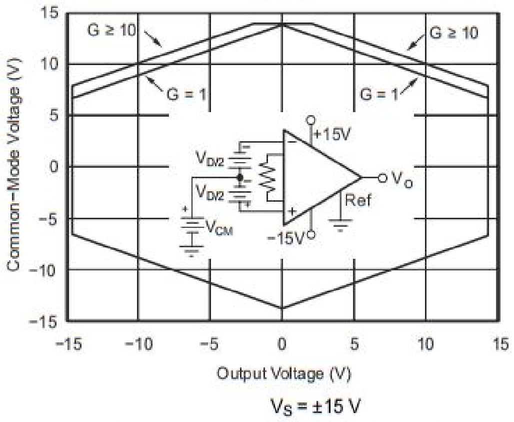
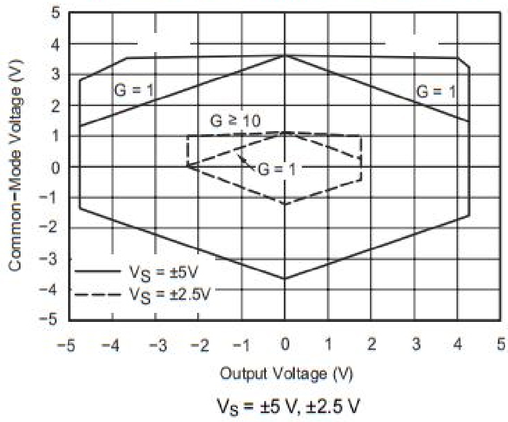


Figure 5. Input Common-Mode Range vs Output Voltage



Figuree 6. Input Common-Mode Range vs Output Voltage

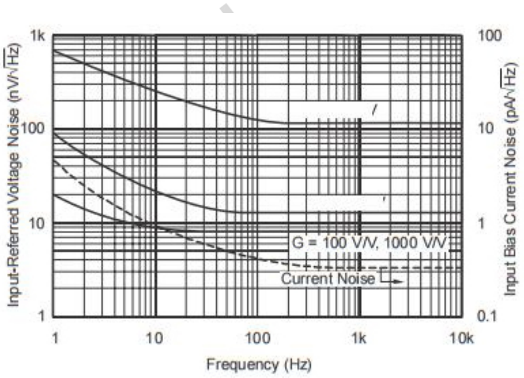


Figure 7. Input-Referred Noise vs Frequency

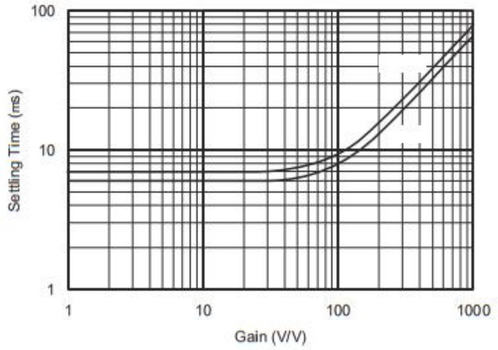


Figure 8. Settling Time vs Gain

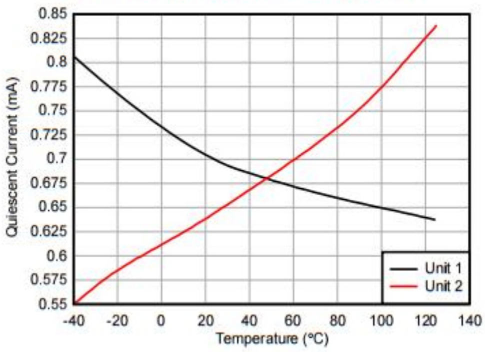


Figure 9. Quiescent Current vs Temperature

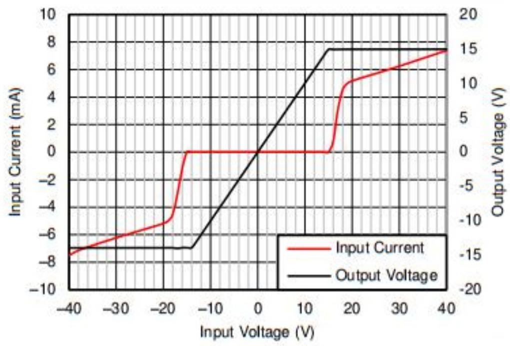


Figure 10. Input Overvoltage V/I Characteristics

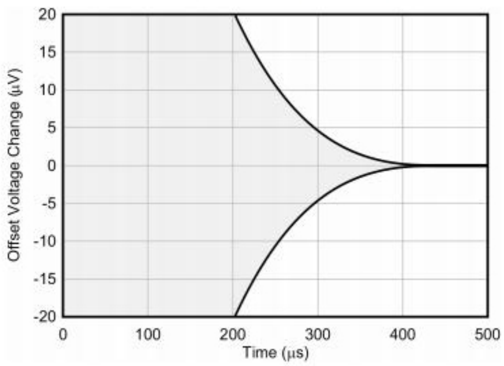


Figure 11. Input Offset Voltage Warm-Up

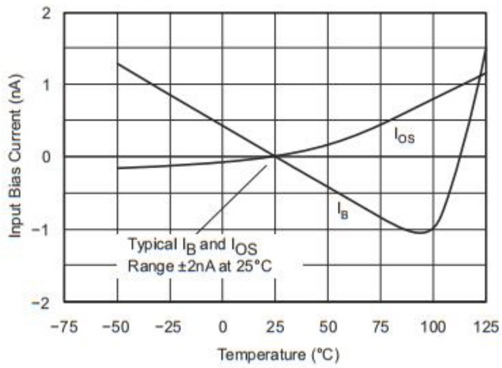


Figure 12. Input Bias Current vs Temperature

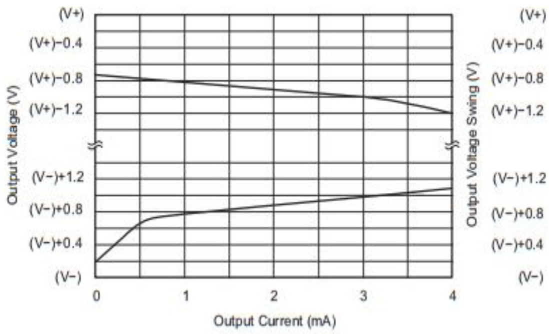


Figure 13. Output Voltage Swing vs Output Current

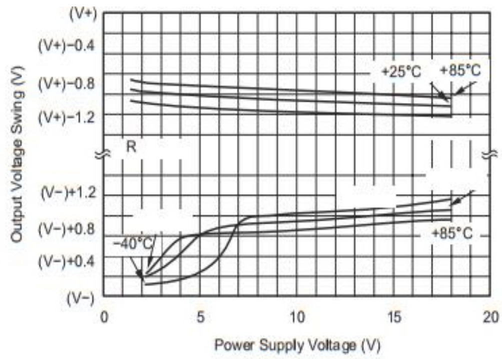


Figure 14. Output Voltage Swing vs Power Supply Voltage

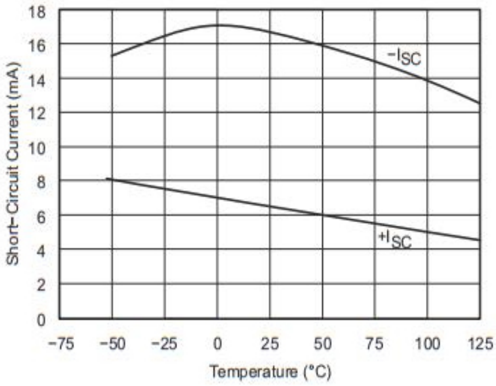


Figure 15. Short Circuit Output Current vs Temperature

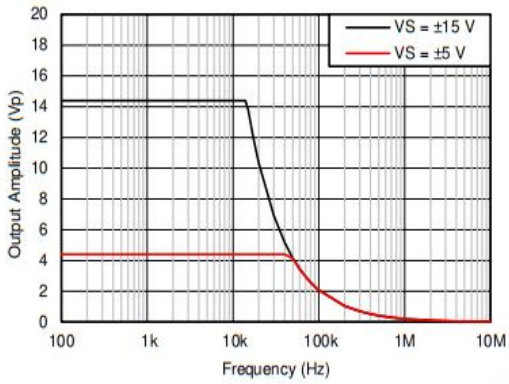


Figure 16. Maximum Output Voltage vs Frequency

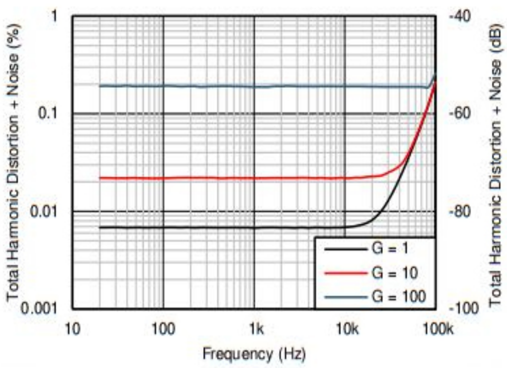


Figure 17. Total Harmonic Distortion + Noise vs Frequency

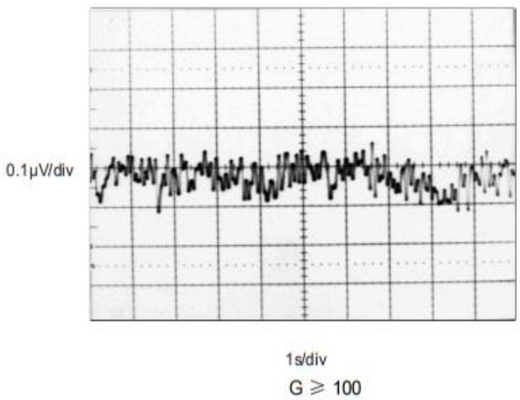
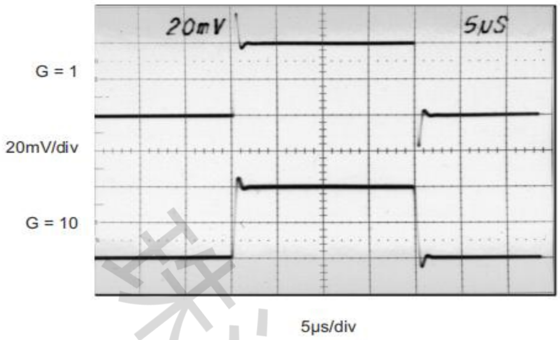
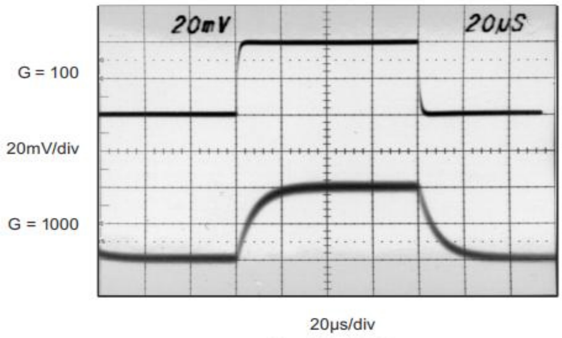


Figure 18. 0.1 to 10-Hz Input-Referred Voltage Noise



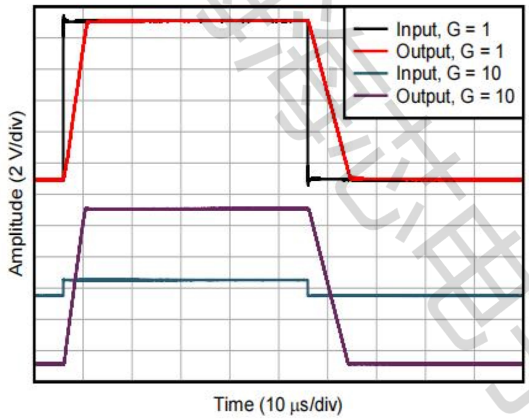
G = 1, 10

Figure 19. Small Signal



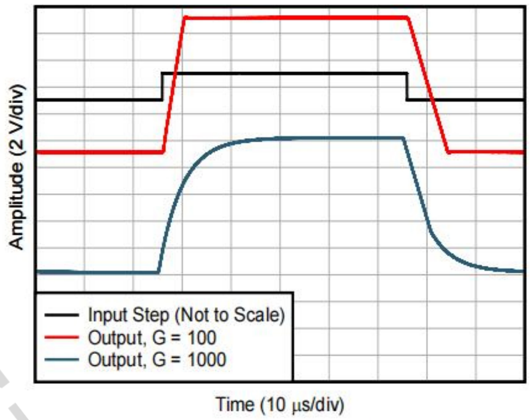
G = 100, 1000

Figure 20. Small Signal



G = 1, 10

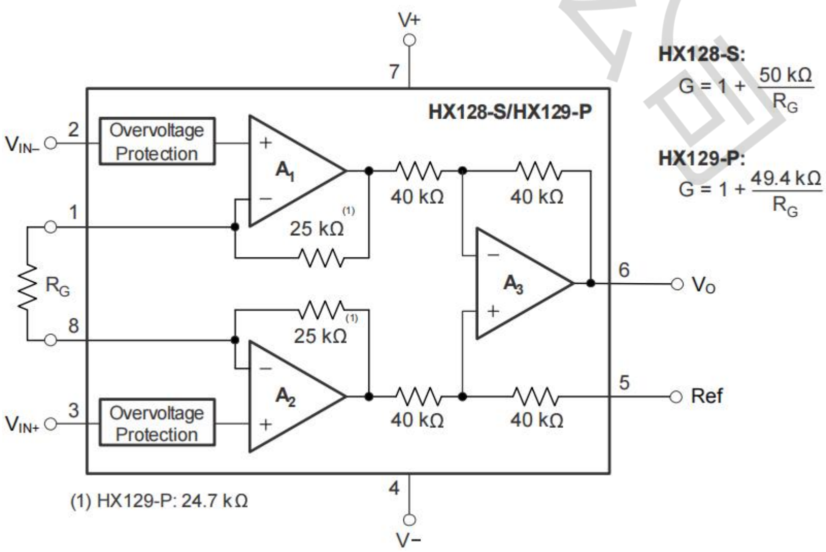
Figure 21. Large Signal



G = 100, 1000

Figure 22. Large Signal

Schematic diagram

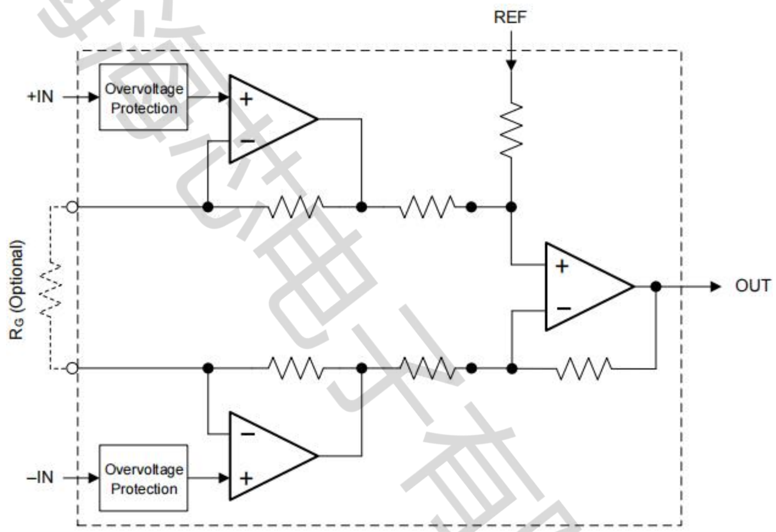


Detailed Description

Overview

The HX128-S/HX129-S instrumentation amplifiers are equipped with both an input protection circuit and input buffer amplifiers. These unique features negate the need for input impedance matching, making them an ideal choice for use in both measurement and test equipment. Additional noteworthy characteristics of the HX128-S/HX129-S include its extremely low dc offset, minimal drift, reduced noise, exceptionally high open-loop gain, and outstanding common-mode rejection ratio. Furthermore, it boasts very high input impedances. The HX128-S/HX129-S is often utilized in scenarios where a high level of accuracy and stability, both in the short and long term, are paramount for the circuit.

Functional Block Diagram



Feature Description

The HX128-S/HX129-S series of instrumentation amplifiers are low-power, general-purpose devices renowned for their outstanding accuracy. Their flexible three-op-amp design and compact size render them an ideal choice for a diverse array of applications. The amplifiers feature current-feedback input circuitry, ensuring a wide bandwidth even at elevated gain levels. An easy-to-use external resistor allows for precise gain adjustment, ranging from 1 to 10,000. The HX128-S/HX129-S amplifiers have undergone laser trimming to achieve ultra-low offset voltages (typically 25 μV) and exceptional common-mode rejection capabilities (93 dB at G ≥ 100). These devices can operate reliably with power supplies as low as ±2.25 V, typically consuming a quiescent current of 2 mA. Furthermore, the internal input protection mechanism ensures resilience against voltages up to ±40 V without any damage, as demonstrated in Figure 10.

Noise Performance

The HX128-S/HX129-S amplifiers offer exceptionally low noise in a wide range of applications. Specifically, their low-frequency noise is approximately 0.2μVPP, measured from 0.1 to 10 Hz (at G ≥ 100). This outstanding noise performance significantly surpasses that of modern chopper-stabilized amplifiers, making the HX128-S/HX129-S a clear choice for noise-sensitive applications.

Device Functional Modes

The HX128-S/HX129-S have a single functional mode and operate when the power-supply voltage is greater than 4.5 V (±2.25 V). The maximum power-supply voltage for the HX128-S/HX129-S is 36 V (±18 V).

Application and Implementation

Application Information

The HX128-S/HX129-S amplifiers excel at measuring small differential voltages even in the presence of a high common-mode voltage developed between the noninverting and inverting inputs. Their combination of high input-voltage protection circuitry and exceptional input impedance makes them an outstanding choice for a diverse array of applications. Furthermore, the ability to adjust the functionality of the output signal by setting the reference pin adds additional flexibility, making the HX128-S/HX129-S amplifiers practical for multiple configurations.

Input Common-Mode Range

The linear input voltage range of the HX128-S/HX129-S input circuitry spans from approximately 2 V below the positive supply voltage to 2 V above the negative supply voltage. When a differential input voltage is applied, the output voltage increases; however, the linear input range is constrained by the output voltage swing capabilities of amplifiers A1 and A2. Consequently, the linear common-mode input range is intimately linked to the output voltage of the complete amplifier, and this behavior is influenced by the supply voltage (as illustrated in Figure 6).

It's noteworthy that input overload can result in an output voltage that appears normal. For instance, if an input-overload condition forces both input amplifiers to reach their positive output swing limit, the difference voltage measured by the output amplifier will be close to zero. In such a scenario, even though both inputs are overloaded, the output of A3 will be near 0 V.

Typical Application

The figure below depicts the fundamental connections necessary for the operation of the HX128-S/HX129-S. In applications involving noisy or high-impedance power supplies, decoupling capacitors should be placed close to the device pins, as illustrated. The output is referenced to the REF pin, which is typically grounded. To ensure excellent common-mode rejection, this connection must maintain a low impedance. Placing a resistance of 8 Ω in series with the REF pin can lead to a degradation in the typical device's CMR to approximately 80 dB (at G = 1).

HX128-S:

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

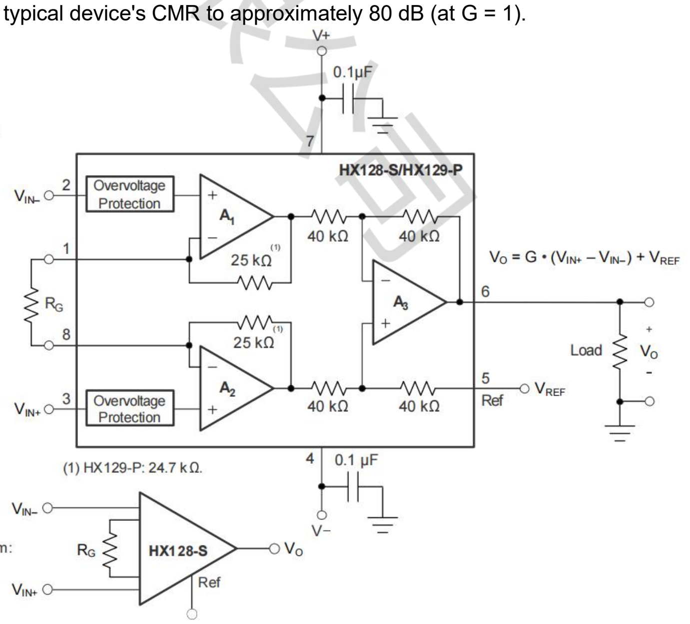
HX129-P:

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

DESIRED GAIN (V/V)	HX128-S		HX129-P	
	R_G (Ω)	NEAREST 1% R_G (Ω)	R_G (Ω)	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

Also drawn in simplified form:



Basic Connections

Design Requirements

The HX128-S/HX129-S devices are designed to monitor the input differential voltage, with the signal gain adjustable through an external resistor, RG. The output signal is measured relative to the voltage present on the reference pin, REF. In the most common application scenario, the REF pin is connected to ground, ensuring that the output is referenced to ground in the absence of an input signal, as shown in the preceding figure.

In single-supply operation, it can be advantageous to offset the output signal to a precise mid-supply level (e.g., 2.5 V in a 5-V supply setup). To achieve this level shift, a voltage source is connected to the REF pin, effectively adjusting the output to enable the device to drive a single-supply ADC.

Voltage reference devices are a highly suitable choice for providing a low-impedance voltage source to the reference pin. However, if a resistor voltage divider is utilized to generate the reference voltage, it is crucial to buffer the voltage using an op amp to prevent any degradation in the common-mode rejection ratio (CMRR).

Detailed Design Procedure

Setting the Gain

The gain (G) is configured by connecting a single external resistor, RG, between pins 1 and 8. The gain settings for the HX128-S/HX129-S are determined by the following equations:

$$\text{HX128-S: } G = 1 + 50\ k\Omega / RG \quad (1)$$

$$\text{HX129-S: } G = 1 + 49.4\ k\Omega / RG \quad (2)$$

Commonly used gain values and their corresponding resistor values are illustrated in Figure 9-1.

The 50-kΩ term in equation 1 and the 49.4-kΩ term in equation 2 arise from the combined internal feedback resistors of A1 and A2. These on-chip metal film resistors are laser trimmed to achieve precise, absolute values. The accuracy and temperature coefficient of these internal resistors contribute to the overall gain accuracy and drift specifications outlined in the Electrical Characteristics table.

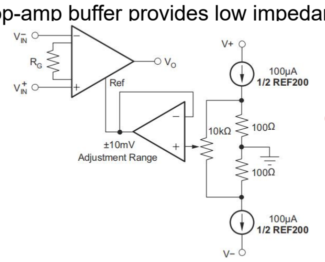
The stability and temperature drift of the external gain-setting resistor, RG, also impact the gain. The contribution of RG to gain accuracy and drift can be directly inferred from equations 1 and 2. For high gain settings, low resistor values are required, which can make wiring resistance significant. The use of sockets adds to the wiring resistance, potentially introducing additional gain error (possibly an unstable one) in gains approaching or exceeding 100.

Dynamic Performance Characteristics

The typical performance curve in Figure 1 demonstrates that despite their low quiescent current, the HX128-S/HX129-S devices achieve a wide bandwidth even at high gain. This performance is attributed to the current-feedback topology employed in the input stage circuitry. The settling time remains excellent even at high gain settings.

Offset Trimming

The HX128-S/HX129-S devices are laser trimmed to minimize offset voltage and offset voltage drift. In most applications, no external offset adjustment is required. However, an optional circuit for trimming the output offset voltage is shown in the accompanying figure. The voltage applied to the REF pin is summed with the output. The op-amp buffer provides low impedance at the REF pin, preserving good common-mode rejection.



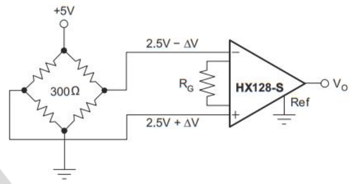
Optional Trimming of Output Offset Voltage

Input Bias Current Return Path

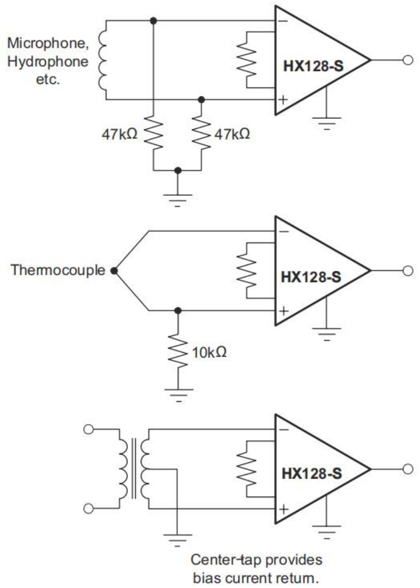
The HX128-S/HX129-S devices possess an exceptionally high input impedance, approximately 10 GΩ. However, it is crucial to establish a path for the input bias current of both inputs, which stands at approximately ±2 nA. Due to the high input impedance, this bias current remains relatively stable even with varying input voltages.

For proper operation, the input circuitry must incorporate a mechanism that allows for the flow of this input bias current. The accompanying figure illustrates various methods for establishing a bias current path. Without such a path, the inputs would float to a potential beyond the common-mode range, leading to saturation of the input amplifiers.

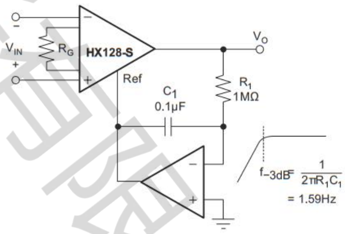
In cases where the differential source resistance is relatively low, connecting the bias current return path to one input is sufficient (as demonstrated in the thermocouple example in the figure). However, with higher source impedance, it is advisable to employ two equal resistors to create a balanced input. This approach can offer advantages such as reduced input offset voltage due to bias current and improved high-frequency common-mode rejection.



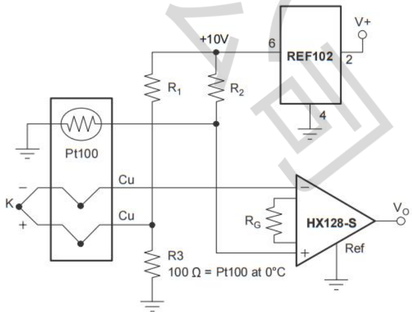
Bridge Amplifier



Providing an Input Common-Mode Current Path



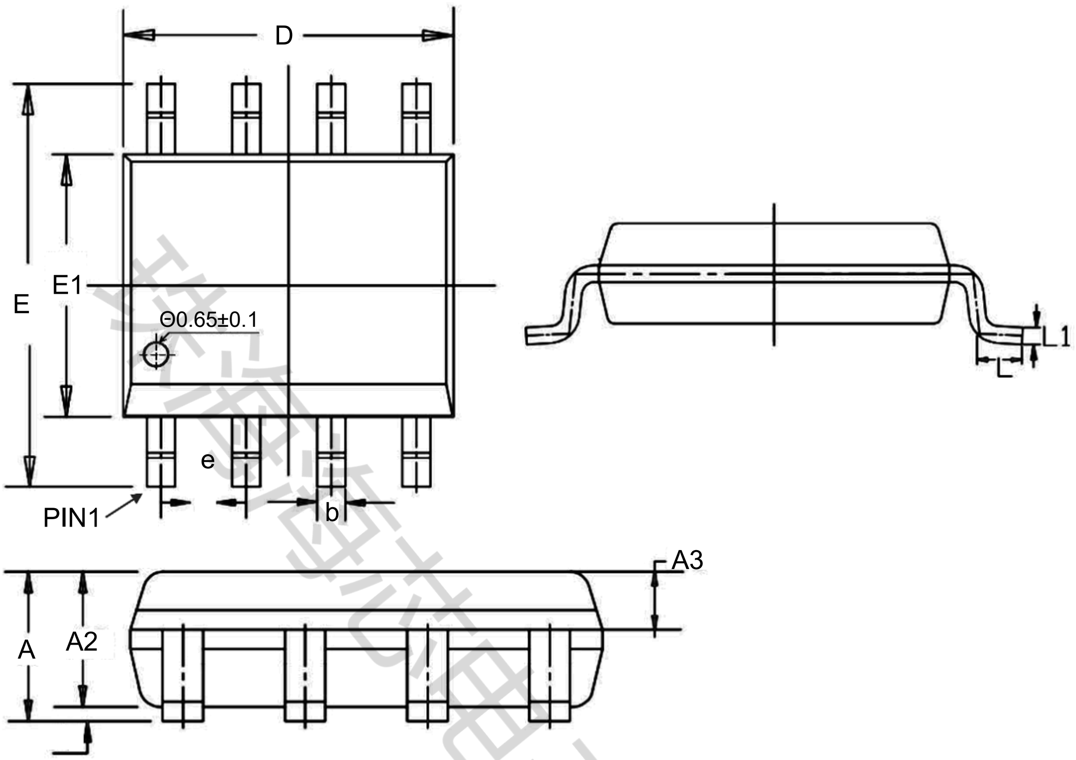
AC-Coupled Instrumentation Amplifier



ISA TYPE	MATERIAL	SEEBECK COEFICIENT (μV/°C)	R1, R2
E	+ Chromel − Constantan	58.5	66.5 kΩ
J	+ Iron − Constantan	50.2	76.8 kΩ
K	+ Chromel − Alumel	39.4	97.6 kΩ
T	+ Copper − Constantan	38.0	102 kΩ

Thermocouple Amplifier With RTD Cold-Junction Compensation

DIMENSIONAL DRAWINGS



SOP-8

UNIT:mm

	MIN	NOM	MAX
A	1.450	1.550	1.650
A1	0.100	0.150	0.200
A2	1.300	1.400	1.500
A3	0.600	0.650	0.700
b	0.380		0.510
e	1.240	1.270	1.300
D	4.800	4.900	5.000
E	5.800	6.000	6.200
E1	3.800	3.900	4.000
L	0.450	0.600	0.750
L1	_	0.25BSC	

Part Number	Package Type	Package	quantity
HX128-S	SOP-8	Taping	2500
HX129-S	SOP-8	Taping	2500