1. DESCRIPTION

The XLA128 and XLA129 are low-power, general purpose instrumentation amplifiers offering excellent accuracy. The versatile 3-op amp design and small size make these amplifiers ideal for a wide range of applications. Current-feedback input circuitry provides wide bandwidth even at high gain (200 kHz at G = 100).

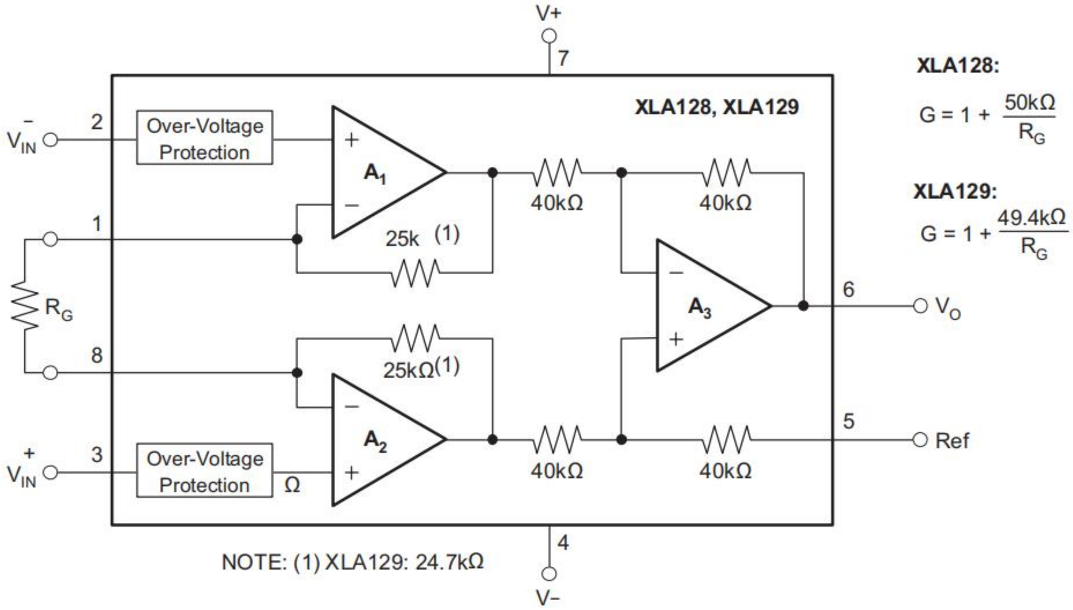
A single external resistor sets any gain from 1 to 10,000. The XLA128 provides an industry-standard gain equation.

2. FEATURES

- Low offset voltage: 50 µV maximum
- Low drift: 0.5 µV/°C maximum
- Low Input Bias Current: 5 nA maximum
- High CMR: 120 dB minimum
- Inputs protected to ±40 V
- Wide supply range: ±2.25 V to ±18 V
- Low quiescent current: 700 µA

3. APPLICATIONS

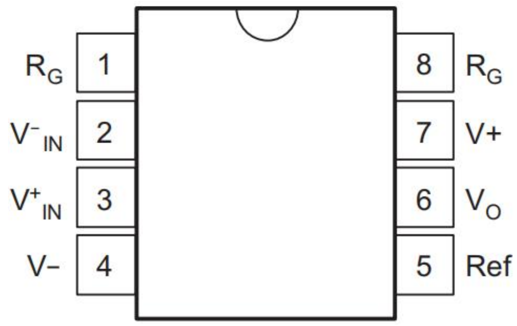
- Bridge amplifier
- Thermocouple amplifier
- RTD sensor amplifier
- Medical instrumentation
- Data acquisition



Simplified Schematic

4. PIN CONFIGURATIONS AND FUNCTIONS

Top View



Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
REF	5	I	Reference input. This pin must be driven by low impedance or connected to ground.
R_G	1.8	—	Gain setting pin. For gains greater than 1, place a gain resistor between pin 1 and pin 8.
V-	4	—	Negative supply
V+	7	—	Positive supply
V_{IN-}	2	I	Negative input
V_{IN+}	3	I	Positive input
V_O	6	I	Output

5. SPECIFICATIONS

5.1. Absolute Maximum Ratings

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

	MIN	MAX	UNIT
Supply voltage		±18	V
Analog input voltage		±40	V
Output short circuit (to ground)	continuous		
Operating temperature	-40	125	°C
Junction temperature		150	°C
Lead temperature (soldering, 10 seconds)		300	°C
Storage temperature, T_{stg}	-55	125	°C

(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

5.2. 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	

(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.

5.3. Recommended Operating Conditions

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

	MIN	MOM	MAX	UNIT
V power supply	±2.25	±15	±18	V
Input common-mode voltage range for V_O = 0	V-2V		V+-2V	
TA operating temperature XLA128UA	-40		85	°C
TA operating temperature XLA129UA	-40		85	°C

5.4. Thermal Information

THERMAL METRIC		XLA12x		UNIT
		SOP	DIP	
		8 PINS	8 PINS	
$R_{θJA}$	Junction-to-ambient thermal resistance	110	46.1	°CW
$R_{θJC(top)}$	Junction-to-case (top) thermal resistance	57	34.1	°CW
$R_{θJB}$	Junction-to-board thermal resistance	54	23.4	°CW
$ψ_{JT}$	Junction-to-top characterization parameter	11	11.3	°CW
$ψ_{JB}$	Junction-to-board characterization parameter	53	23.2	°CW

5.5. Electrical Characteristics

at T_A = 25°C, V_S = ±15 V, and R_L = 10 kΩ (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
INPUT							
Offset voltage, RT	Initia	T_A = 25°C	XLA128UA XLA129UA		±25±100/G	±125±1000/G	μV
	vs temperature	T_A = TMIN to T_{MAX}	XLA128UA XLA129UA		±0.2±5/G	±1±20/G	μV/°C
	vs power supply	V_S = ±2.25 V to ±18 V	XLA128UA XLA129UA			±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		
Common-mode voltage range(1)		V_O = 0 V		(V+) - 2	(V+) - 1.4		V
				(V...) + 2	(V−) + 1.7		
Safe input voltage						±40	V
Common-mode rejection		V_{CM} = ±13 V, $ΔR_S$= 1 kΩ, G=1	XLA128UA XLA129UA	73			dB
		G=10	XLA128UA XLA129UA	93			
		G=100	XLA128UA XLA129UA	110			
		G=1000	XLA128UA XLA129UA	110			
Bias current		XLA128UA XLA129UA				±10	nA
Bias current vs temperature					±30		pA/°C
Offset current		XLA128UA XLA129UA					
Offset current vs temperature							
Noise voltage,RTI	f = 10 Hz	G = 1000, RS = 0Ω			10		nV/√Hz
	f = 100 Hz				8		
	f = 1 kHz				8		
	fB = 0.1 Hz to 10 Hz				0.2		
Noise current	f = 10 Hz				0.9		pA/√Hz
	f = 1 kHz				0.3		
	FB = 0.1 Hz to 10 Hz				30		pA_{PP}
GANI(2)							
Gain equation	XLA128			1 + (50 kΩ/R_G)			V/V
	XLA129			1 + (49.4 kΩ/R_G)			
Range of gain				1		10000	V/V
Gain error		G=1	XLA128UA XLA129UA			±0.01%	
		G=10	XLA128UA XLA129UA			±0.5%	
		G=100	XLA128UA XLA129UA			±0.7%	
		G=1000	XLA128UA XLA129UA			±2%	
Gain vs temperature(3)		G = 1			±1	±10	ppm/°C
		50-kΩ (or 49.4-kΩ) Resistance(3)(4)			±25	±100	
Nonlinearity		V_O = ±13.6 V, G = 1				±0.002	% of FSR
		G = 10				±0.004	
		G = 100				±0.004	
		G = 1000			±0.001	/>	
OUTPUT(2)							
Voltage	Positive	R_L = 10 kΩ		(V+) – 1.4	(V+) – 0.9		V
	Negative	R_L = 10 kΩ		(V−) + 1.4	(V−) + 0.8		
Load capacitance stability					1000		pF
Short-circuit current					6/–15		mA
FREQUENCY RESPONSE							
Bandwidth, –3 dB		G=1			1.3		MHZ
		G=10			700		kHZ
		G=100			200		
		G=1000			20		

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Slew rate	V_O = ±10 V, G = 10		4		V/µs
Settling time, 0.01%	G=1		7		µs
	G=10		7		
	G=100		9		
	G=1000		80		
Overload recovery	50% overdrive		4		µs
POWER SUPPLY					
Voltage range		±2.25	±15	±18	V
Current, tota	V_{IN} = 0 V		±700	±750	µA
TEMPERATURE RANGE					
Specification		-40		85	°C
Operating		-40		125	°C

(3) Specified by wafer test.

(4) Temperature coefficient of the 50 kΩ (or 49.4 kΩ) term in the gain equation.

5.6. Typical Characteristics

at TA = 25°C and VS = ±15 V (unless otherwise noted)

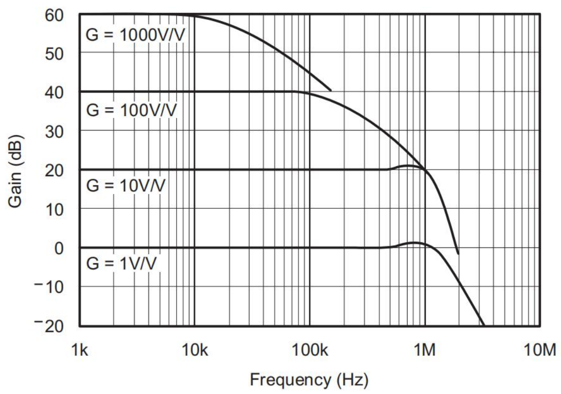


Figure 1. Gain vs Frequency

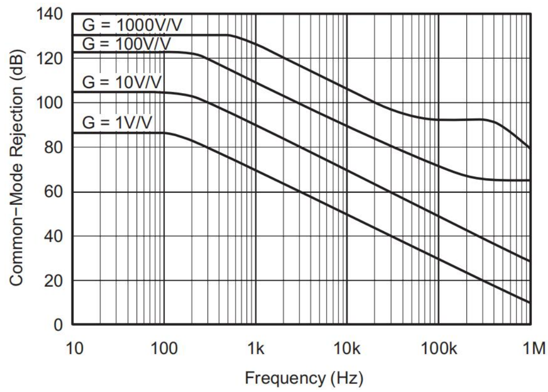


Figure 2. Common-Mode Rejection vs Frequency

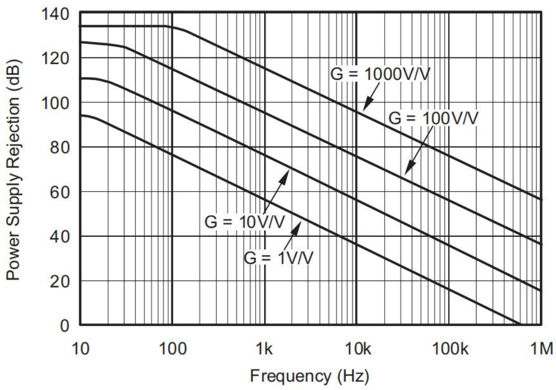


Figure 3. Positive Power Supply Rejection vs Frequency

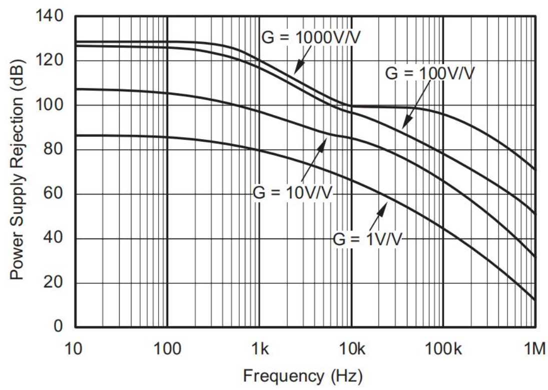


Figure 4. Negative Power Supply Rejection vs Frequency

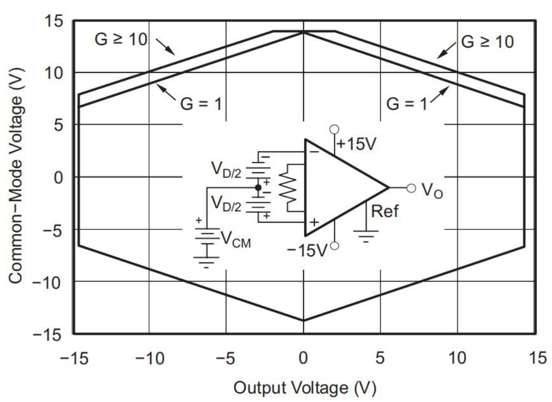


Figure 5. Input Common-Mode Range vs Output Voltage,VS = ±15 V

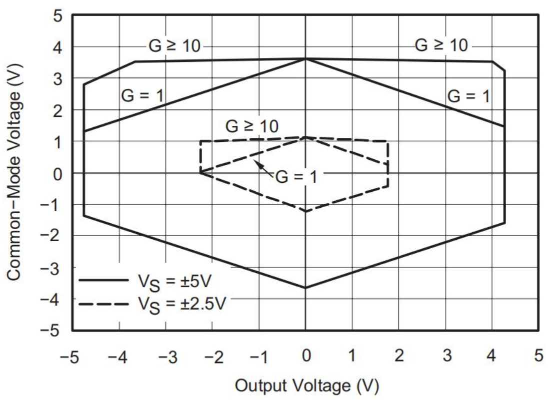


Figure 6. Input Common-Mode Range vs Output Voltage,VS = ±5 V, ±2.5 V

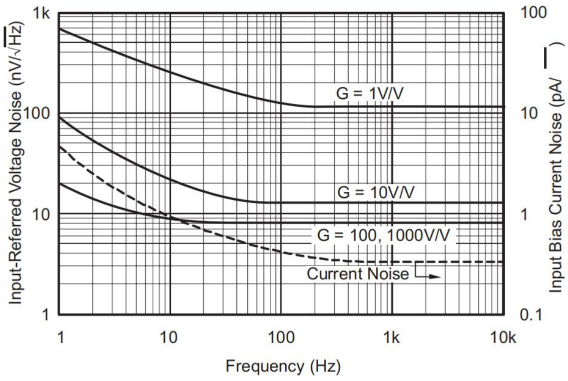


Figure 7. Input-Referred Noise vs Frequency

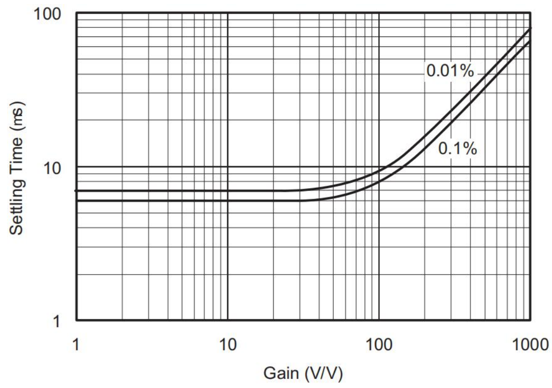


Figure 8. Settling Time vs Gain

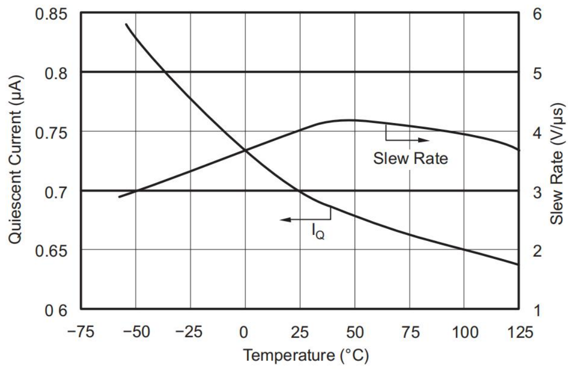


Figure 9. Quiescent Current and Slew Rate vs Temperature

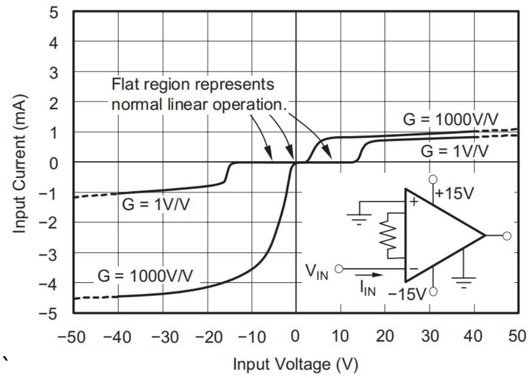


Figure 10. Input Overvoltage V/I Characteristics

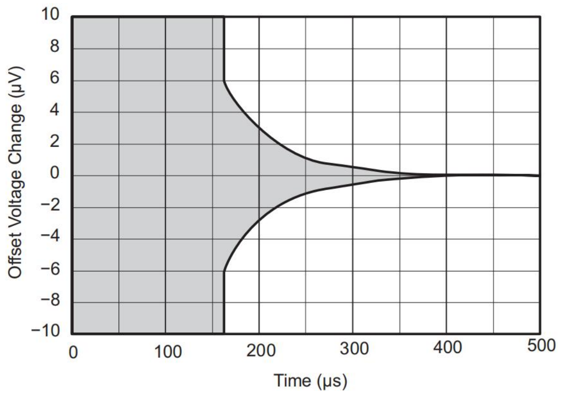


Figure 11. Input Offset Voltage Warm-Up

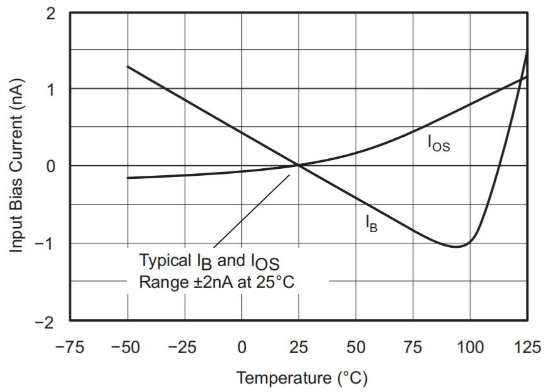


Figure 12. Input Bias Current vs Temperature

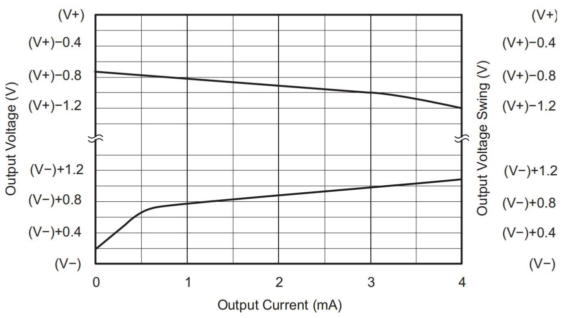


Figure 13. Output Voltage Swing vs Output Current

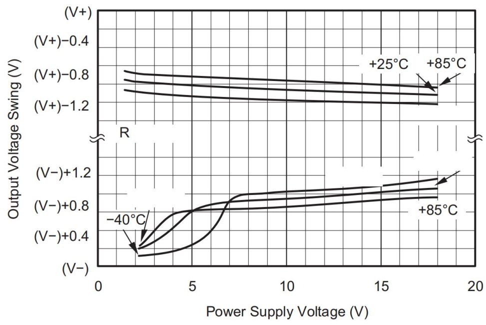


Figure 14. Output Voltage Swing vs Power Supply Voltage

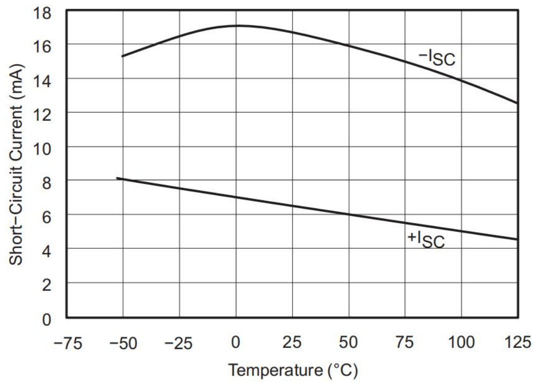


Figure 15. Short Circuit Output Current vs Temperature

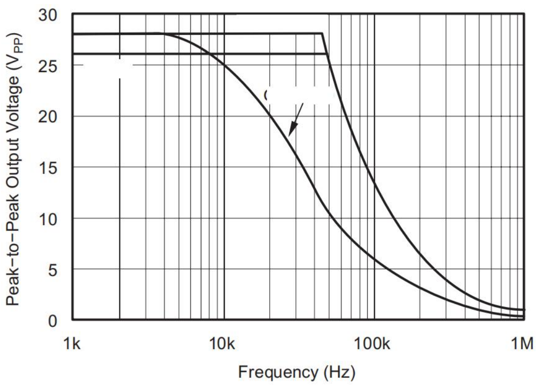


Figure 16. Maximum Output Voltage vs Frequency

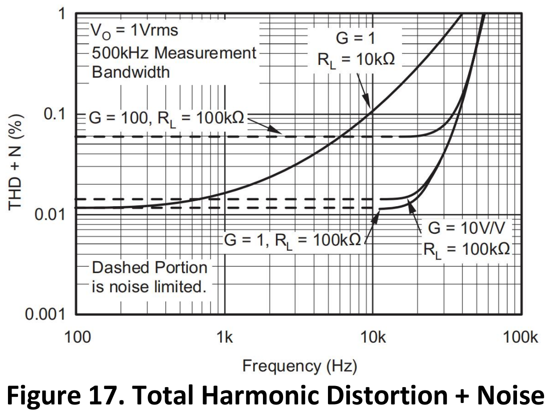


Figure 17. Total Harmonic Distortion + Noise vs Frequency

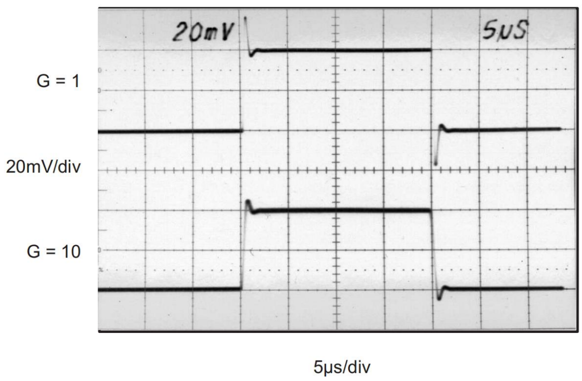


Figure 18. Small Signal (G = 1, 10)

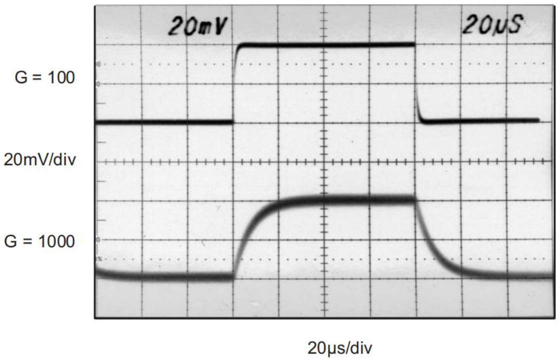


Figure 19. Small Signal (G = 100, 1000)

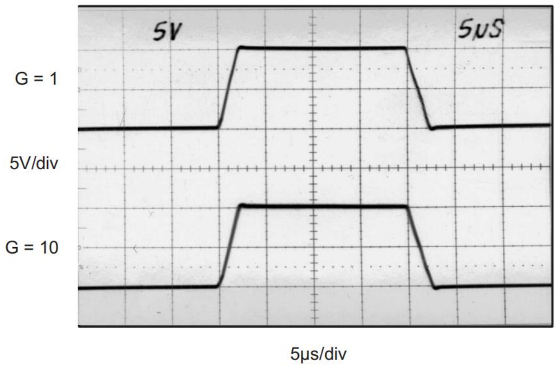


Figure 20. Large Signal (G = 1, 10)

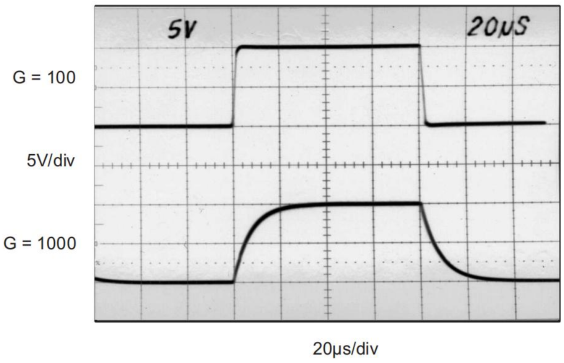


Figure 21. Large Signal (G = 100, 1000)

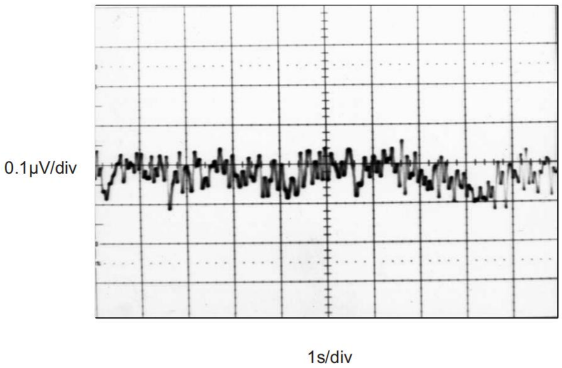


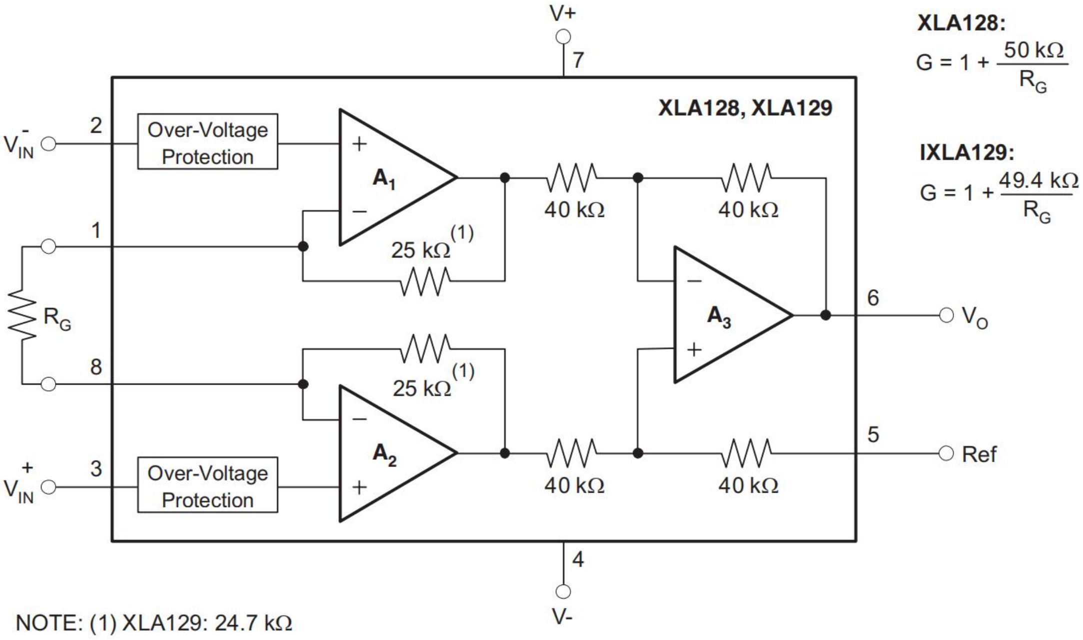
Figure 22. Voltage Noise 0.1 to 10-Hz Input-Referred, G ≥100

6. DEAILED DESCRIPTION

6.1. Overview

The XLA12x instrumentation amplifier is a type of differential amplifier that has been outfitted with input protectioncircuit and input buffer amplifiers, which eliminate the need for input impedance matching and make the amplifierparticularly suitable for use in measurement and test equipment. Additional characteristics of the XLA128 includea very low DC offset, low drift, low noise, very high open-loop gain, very high common-mode rejection ratio, andvery high input impedances. The XLA12x is used where great accuracy and stability of the circuit both short andlong term are required.

6.2. Functional Block Diagram



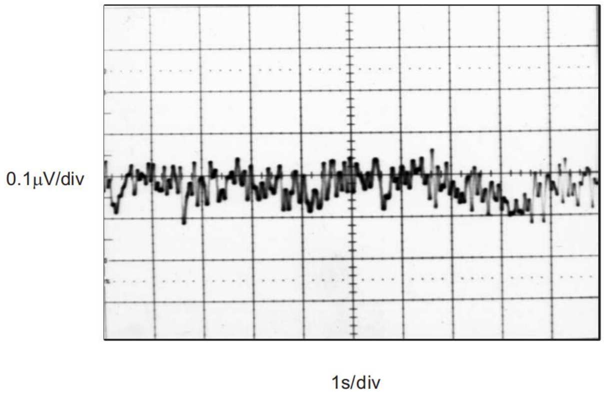
6.3. Feature Description

The XLA12x devices are low power, general-purpose instrumentation amplifiers offering excellent accuracy. The versatile three-operational-amplifier design and small size make the amplifiers ideal for a wide range of applications. Current-feedback input circuitry provides wide bandwidth, even at high gain. A single external resistor sets any gain from 1 to 10,000. The INA128 is laser trimmed for very low offset voltage (25 µV typical) and high common-mode rejection (93 dB at G ≥ 100). These devices operate with power supplies as low as ±2.25 V, and quiescent current of 2 mA, typically. The internal input protection can withstand up to ±40 V without damage.

6.4. Device Functional Modes

6.4.1. Noise Performance

The XLA12x provides very low noise in most applications. Low-frequency noise is approximately 0.2 µVPP measured from 0.1 to 10 Hz (G ≥ 100). This provides dramatically improved noise when compared to state-ofthe-art chopper-stabilized amplifiers.



G ≥ 100

Figure 23. 0.1-Hz to 10-Hz Input-Referred Voltage Noise

6.4.2. Input Common-Mode Range

The linear input voltage range of the input circuitry of the XLA12x is from approximately 1.4 V below the positive supply voltage to 1.7 V above the negative supply. As a differential input voltage causes the output voltage increase, however, the linear input range is limited by the output voltage swing of amplifiers A1 and A2 . Thus 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 curve Figure 6).

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 A3 will be near 0 V even though both inputs are overloaded.

7. Application and Implementation

NOTE:

Information in the following applications sections is not part of the component specification, and does not warrant its accuracy or completeness.Needresponsible for determining suitability of components for their purposes. Customers shouldvalidate and test their design implementation to confirm system functionality.

7.1. Application Information

The XLA12x measures small differential voltage with high common-mode voltage developed between the noninverting and inverting input. The high-input voltage protection circuit in conjunction with high input impedance make the XLA12x suitable for a wide range of applications. The ability to set the reference pin to adjust the functionality of the output signal offers additional flexibility that is practical for multiple configurations.

7.2. Typical Application

Figure 24 shows the basic connections required for operation of the XLA12x. 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 8 Ω in series with the Ref pin will cause a typical device to degrade to approximately 80dB CMR (G = 1),

XLA128: $G \quad 1 \quad \frac{50k}{R_G}$

XLA129: $G \quad 1 \quad \frac{49.4k}{R_G}$

DESIRED GAIN (V/V)	XLA128 R_G (Ω)	XLA128 NEAREST 1% R_G (Ω)	XLA129 R_G (Ω)	XLA129 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

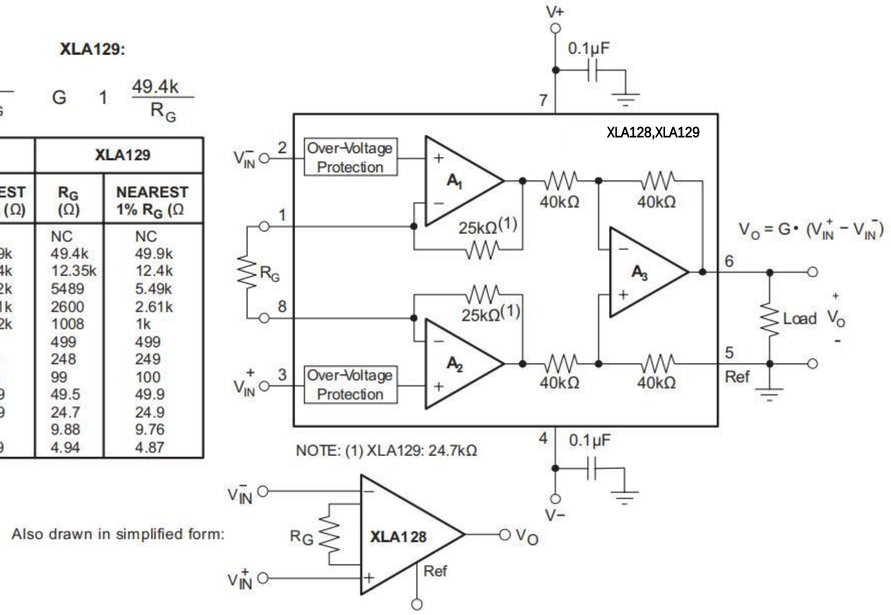


Figure 24. Basic Connections

7.2.1. Design Requirements

The device can be configured to monitor the input differential voltage when the gain of the input signal is set by the external resistor RG. The output signal references to the Ref pin. The most common application is where the output is referenced to ground when no input signal is present by connecting the Ref pin to ground, as Figure 24 shows. When the input signal increases, the output voltage at the OUT pin increases, too.

7.2.2. Detailed Design Procedure

7.2.2.1. Setting the Gain

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

XLA128: g = 1 + 50 kΩ/RG

Commonly used gains and resistor values are shown in Figure 24

The 50-kΩ term in Equation 1 comes from the sum of the two internal feedback resistors of A1 and A2 . 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 XLA128.

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

7.2.2.2. Dynamic Performance

The typical performance curve Figure 1 shows that, despite its low quiescent current, the XLA12x 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.

7.2.2.3. Offset Trimming

The XLA12x is laser-trimmed for low-offset voltage and offset voltage drift. Most applications require no external offset adjustment. Figure 25 shows an optional circuit for trimming the output offset voltage. The voltage applied to the Ref terminal is summed with the output. The op amp buffer provides low impedance at the Ref terminal to preserve good common-mode rejection.

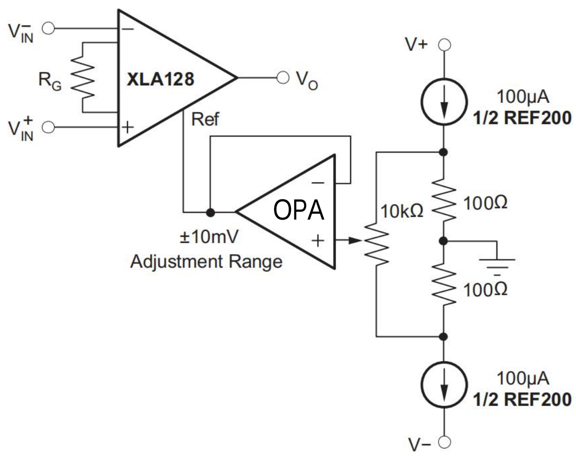


Figure 25. Optional Trimming of Output Offset Voltage

7.2.2.4. Input Bias Current Return Path

The input impedance of the XLA12x is extremely high: approximately 10^{10} Ω. However, a path must be provided for the input bias current of both inputs. This input bias current is approximately ±2 nA. 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 26 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 26). 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.

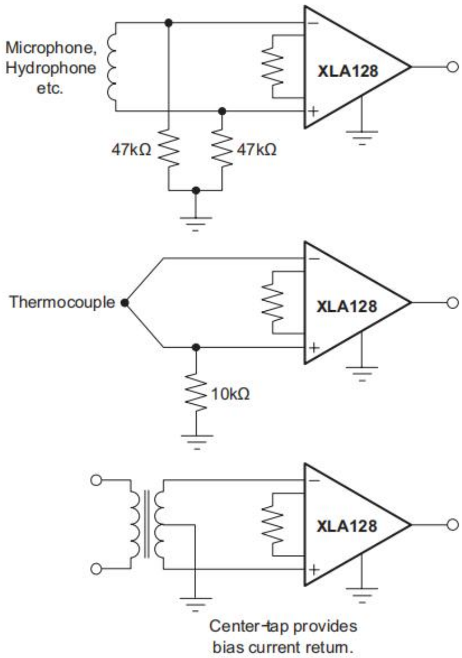


Figure 26. Providing an Input Common-Mode Current Path

7.2.3. Application Curves

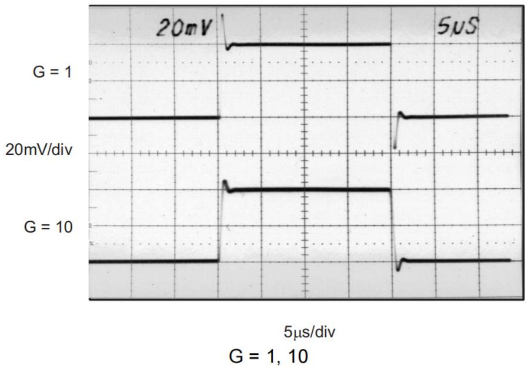


Figure 27. Small Signal

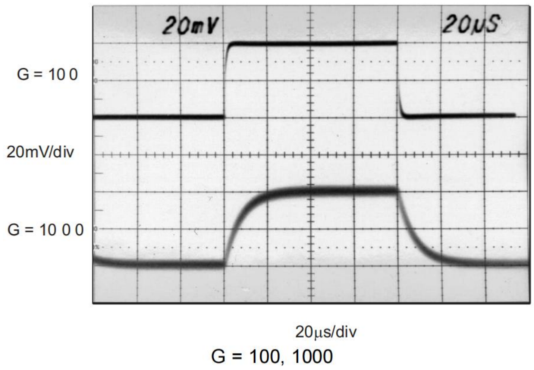


Figure 28. Small Signa

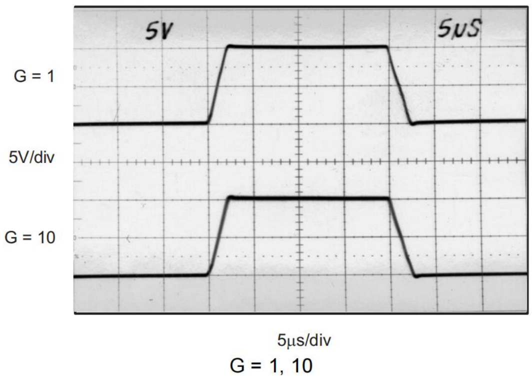


Figure 29. Large Signal

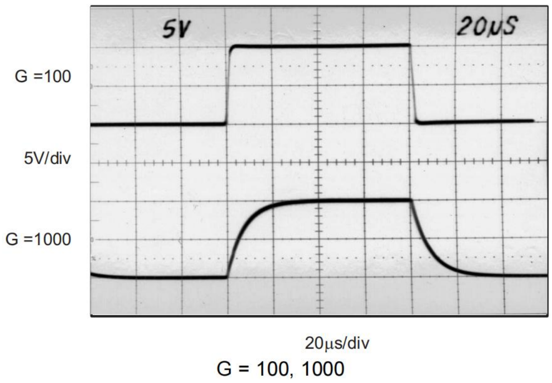


Figure 30. Large Signal

8. POWER SUPPLY RECOMMENDATIONS

The minimum power supply voltage for XLA12x is ±2.25 V and the maximum power supply voltage is ±18 V. This minimum and maximum range covers a wide range of power supplies; but for optimum performance, ±15 V is recommended. Recommends adding a bypass capacitor at the input to compensate for the layout and power supply source impedance.

8.1. Low Voltage Operation

The XLA12x can be operated on power supplies as low as ±2.25 V. Performance remains excellent with power supplies ranging from ±2.25 V to ±18 V. Most parameters vary only slightly throughout this supply voltage range—see TypicalCharacteristics.

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. Figure 6 shows the range of linear operation for ±15-V, ±5-V, and ±2.5-V supplies.

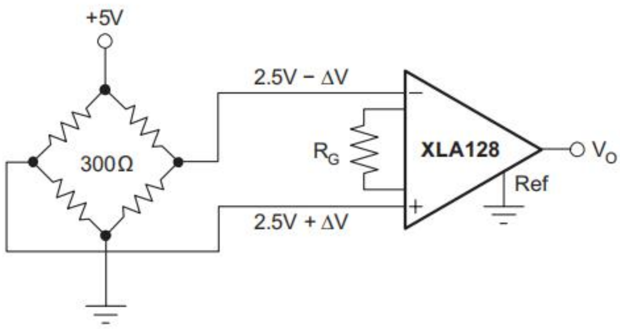


Figure 31. Bridge Amplifier

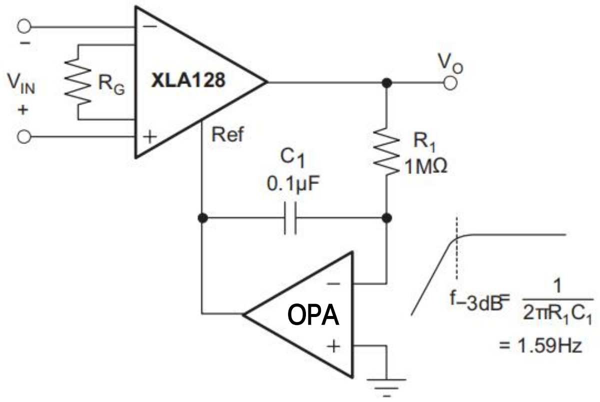
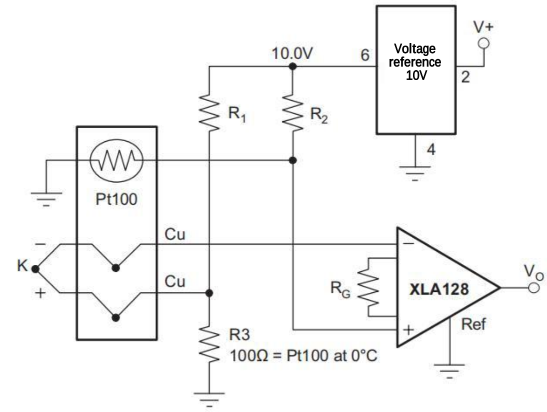


Figure 32. AC-Coupled Instrumentation Amplifier



ISA TYPE	MATERIAL	SEEBECK COEFFICIENT (C)	R1, R2
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 33. Thermocouple Amplifier With RTD Cold-Junction Compensation

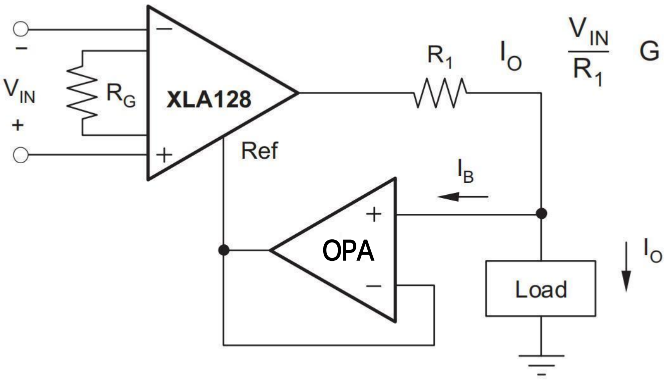


Figure 34. Differential Voltage to Current Converter

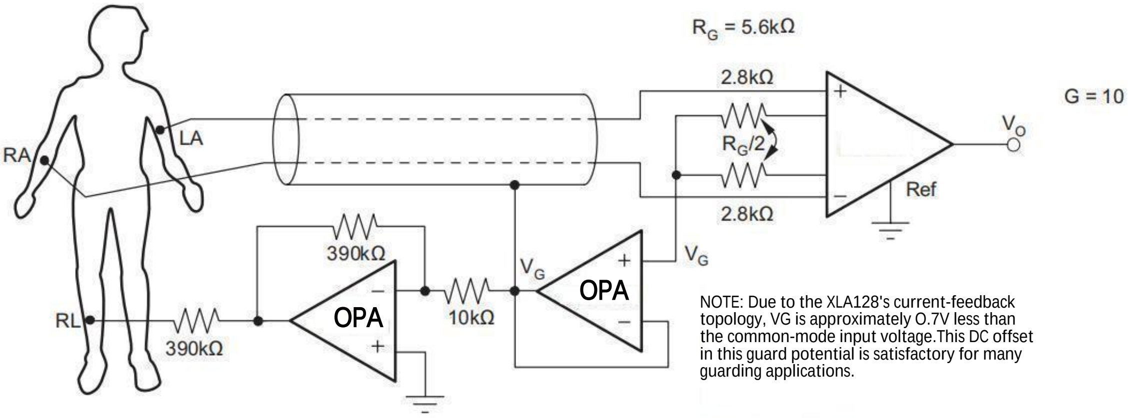


Figure 35. ECG Amplifier With Right-Leg Drive

9. LAYOUT

9.1. Layout Guidelines

Place the power-supply bypass capacitor as closely as possible to the supply and ground pins. The recommended value of this bypass capacitor is 0.1 µF to 1 µF. If necessary, additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies. These decoupling capacitors must be placed between the power supply and INA12x devices.

The gain resistor must be placed close to pin 1 and pin 8. This placement limits the layout loop and minimizes any noise coupling into the part.

9.2. Layout Example

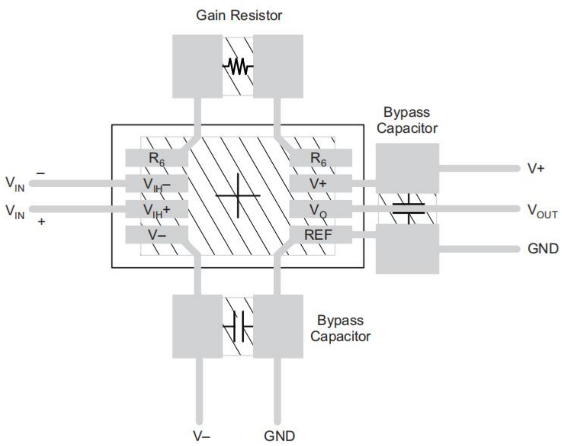


Figure 36. Recommended Layout

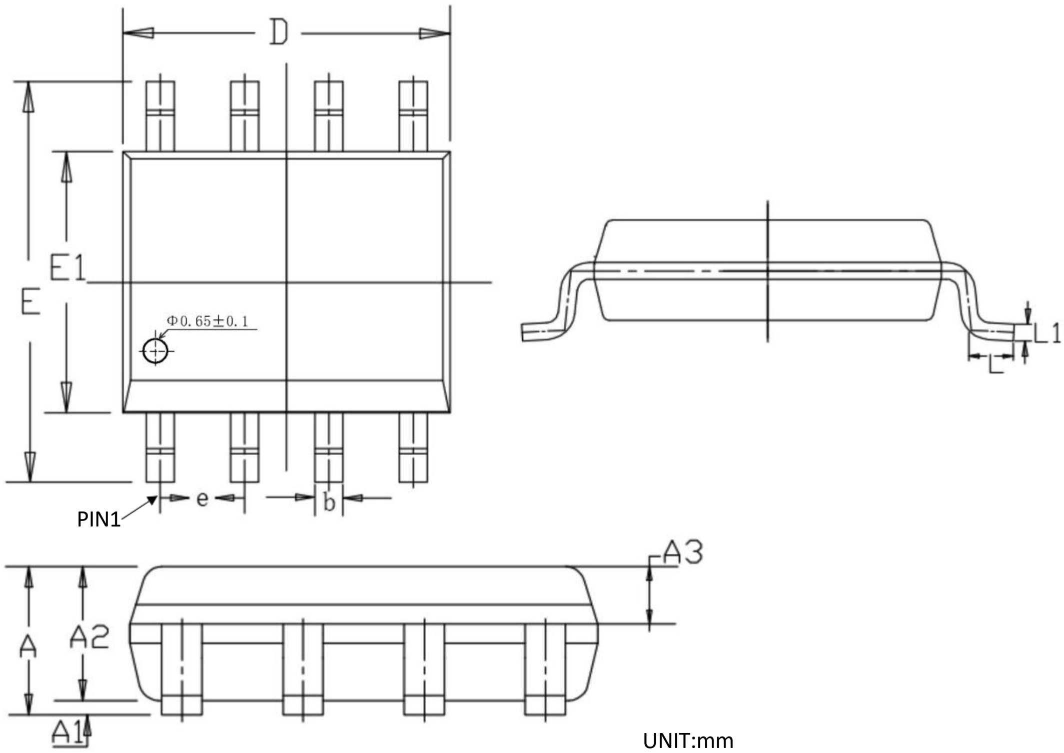
10. ORDERING INFORMATION

Ordering Information

Part Number	Device Making	Package type	Body size (mm)	Temperate (°C)	MSL	Transpo Rt	Package Quantit
XLA128UA/2K5	XL128UA	SOP-8	4.90*3.90	-40 to +85	MSL3	T&R	2500
XLA129UA/2K5	XL129UA	SOP-8	4.90*3.90	-40 to +85	MSL3	T&R	2500

11. DIMENSIONAL DRAWINGS

SOP8



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	—