# INA128UA/2K5-HX 低功耗精密仪表放大器

INA128UA/2K5-HX 均为具备卓越精度的低功耗通用仪表放大器。这两款 放大器采用功能丰富的三级运算放大器设计，体积小巧，适用于各种应用场 景。即便在高达 200kHz 频率和增益为 100 的极端条件下，其电流反馈输入 电路仍能提供宽广的带宽。

INA128UA/2K5-HX 允许用户通过单个外部电阻器在 1 至 10,000 的范围 内自由设定所需的增益。其中，INA128UA/2K5-HX 提供了业界通用的增益公式，其内部集成了 50kΩ的电阻。

SOP-8

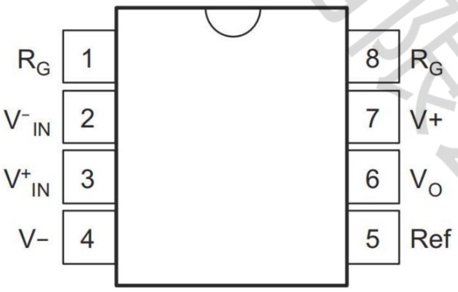
## 特点

- 低失调电压：50μV（最大值）
- 低漂移：0.5μV/°C（最大值）
- 低输入偏置电流：5nA（最大值）
- 低噪声：8nV/√Hz，0.2μVpp
- 高 CMR：120dB（最小值）
- 带宽：1.3 MHz (G = 1)
- 输入保护电压可达 ±40V
- 宽电源电压范围：±2.25V 至 ±18V
- 低静态电流：700μA
- 采用 SOP-8 封装

## 应用

- 压力变送器
- 温度变送器
- 称重计
- 心电图（ECG)
- 模拟输入模块
- 数据采集（DAQ)

## 引脚配置和功能




| 芯片引脚描述 | | | |
|---|---|---|---|
| 管脚 | 名称 | 类型 | 功能 |
| REF | 5 | 输入 | 参考输入，此引脚必须由低阻抗驱动或连接到地线。 |
| RG | 1,8 | | 增益设置引脚。对于大于 1 的增益，在引脚 1 和引脚 8 之间放置一个增益电阻。 |
| V – | 4 | 电源 | 负电源 |
| V+ | 7 | 电源 | 正电源 |
| V IN – | 2 | 输入 | 负输入 |
| V IN+ | 3 | 输入 | 正输入 |
| VO | 6 | 输出 | 输出 |

## 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 | | INA128UA/2K5-HX | UNIT |
|---|---|---|---|
| | | 8 PINS | |
| R θJA | Junction-to-ambient thermal resistance | 110 | °C/W |
| R θJC(top) | Junction-to-case (top) thermal resistance | 57 | °C/W |
| R θJB | Junction-to-board thermal resistance | 54 | °C/W |
| ψJT | Junction-to-top characterization parameter | 11 | °C/W |
| ψJB | Junction-to-board characterization parameter | 53 | °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 | INA128UA/2K5-HXP, INA128UA/2K5-HXU | | | ±2 | ±5 | nA |
| | | INA128UA/2K5-HXPA, INA128UA/2K5-HXUA | | | | ±10 | |
| | Input bias current drift | TA = -40°C to +85°C | | | ±30 | | pA/℃ |
| IOS | Input offset current | INA128UA/2K5-HXP, INA128UA/2K5-HXU | | | ±1 | ±5 | nA |
| | | INA128UA/2K5-HXPA, INA128UA/2K5-HXUA | | | | ±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 | INA128UA/2K5-HX | | 1+(50kΩ/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 |
| | | To 0.01%, G = 10 | | 12 | | |
| | | To 0.01%, G = 100 | | 12 | | |
| | | To 0.01%, 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)

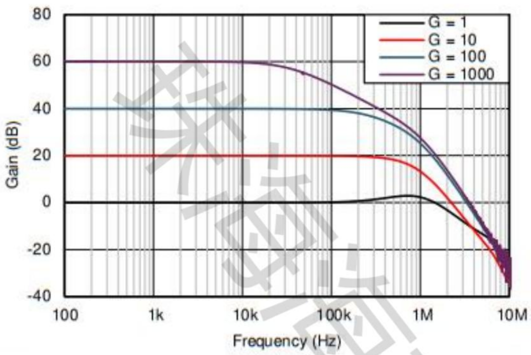



图 1. Gain vs Frequency

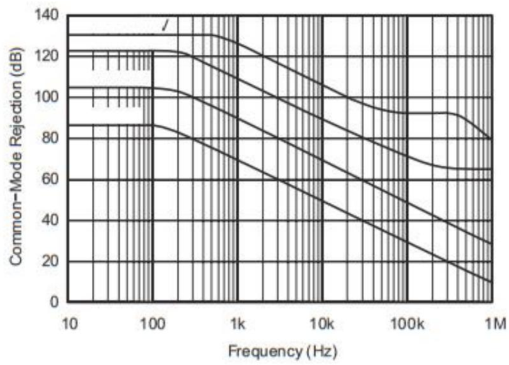



图 2. Common-Mode Rejection vs Frequency

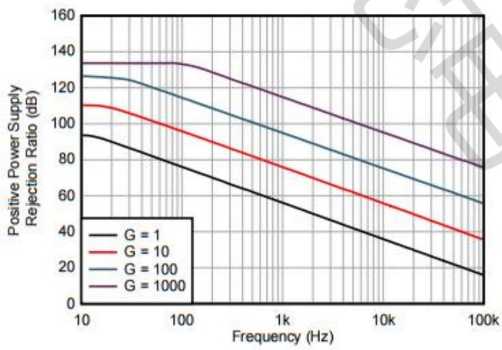



图 3. Positive Power Supply Rejection vs Frequency

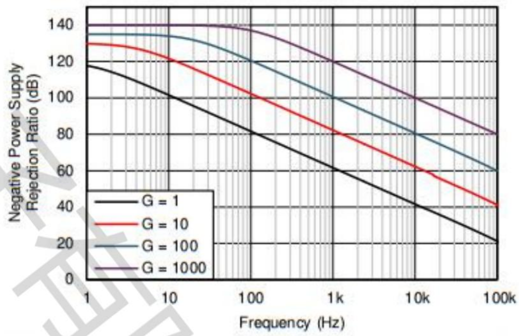
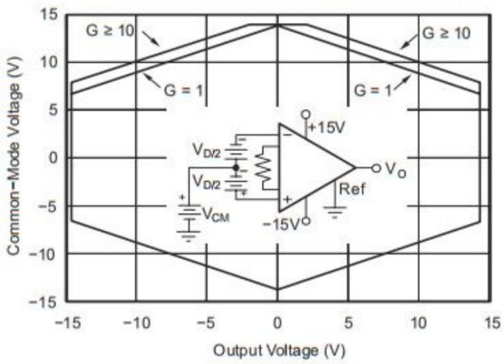
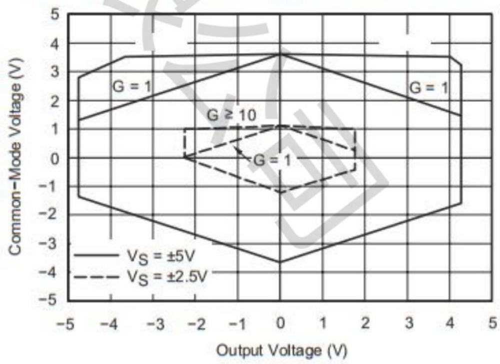



图 4. Negative Power Supply Rejection vs Frequency




$V_S = \pm 15$ V

图 5. Input Common-Mode Range vs Output Voltage




$V_S = \pm 5$ V, ±2.5 V

图 6. Input Common-Mode Range vs Output Voltage

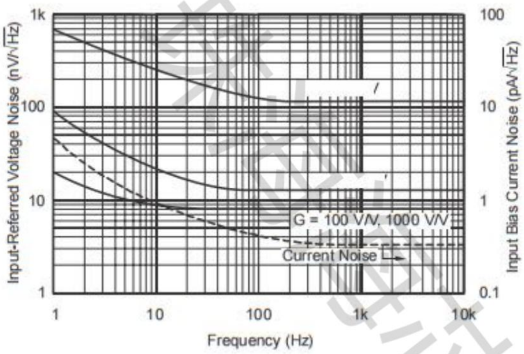



图 7. Input-Referred Noise vs Frequency

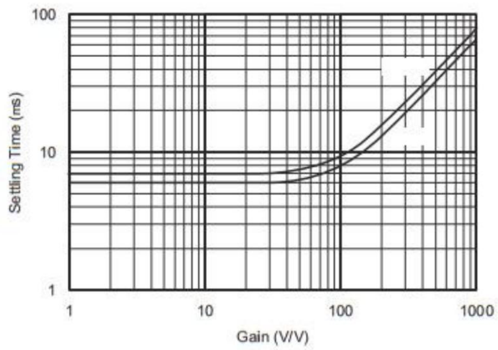



图 8. Settling Time vs Gain

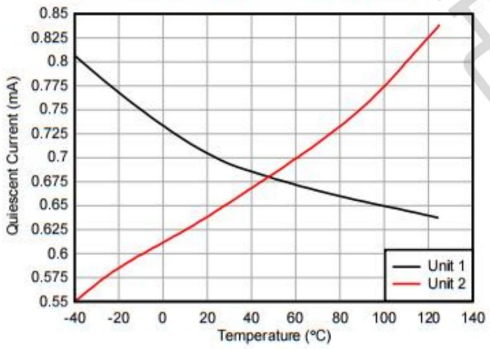



图 9. Quiescent Current vs Temperature

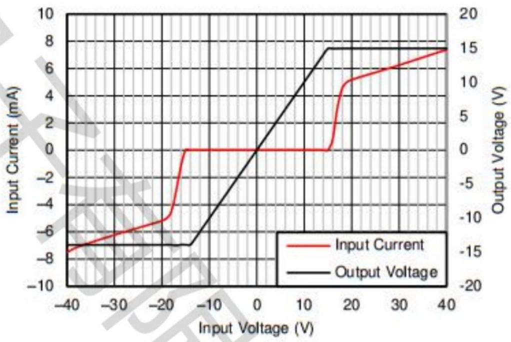



图 10. Input Overvoltage V/I Characteristics

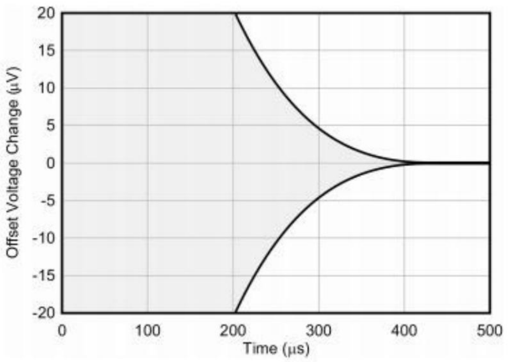



图 11. Input Offset Voltage Warm-Up

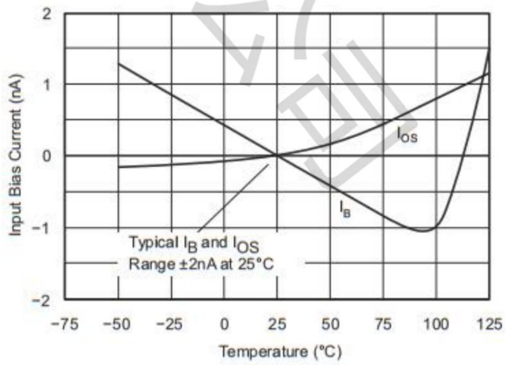



图 12. Input Bias Current vs Temperature

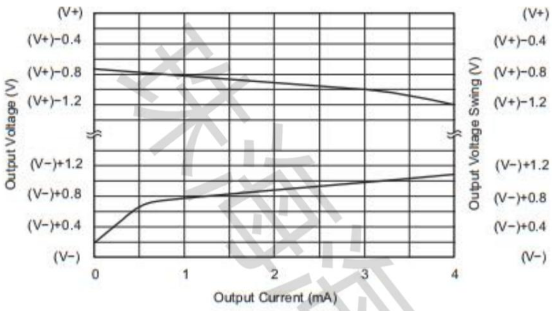



图 13. Output Voltage Swing vs Output Current

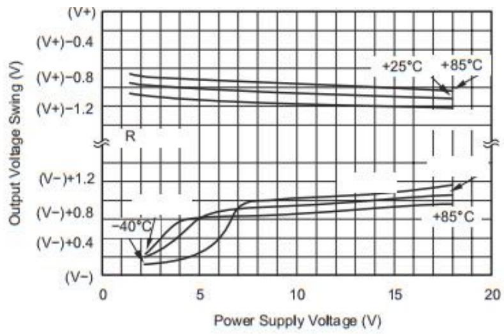



图 14. Output Voltage Swing vs Power Supply Voltage

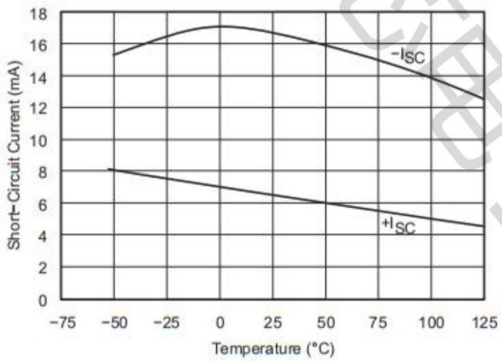



图 15. Short Circuit Output Current vs Temperature

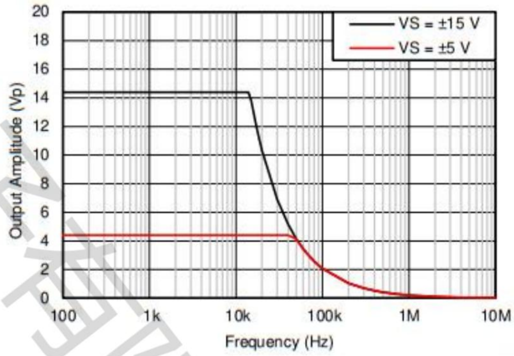



图 16. Maximum Output Voltage vs Frequency

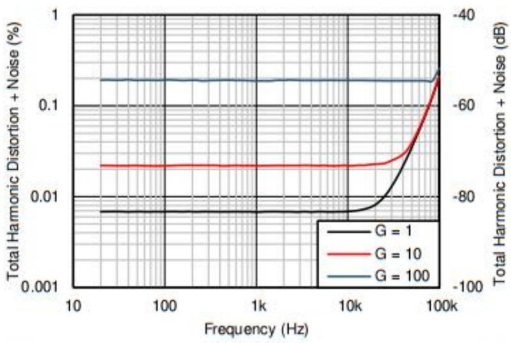



图 17. Total Harmonic Distortion + Noise vs Frequency

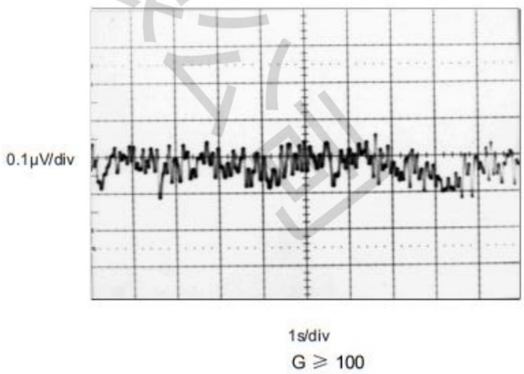
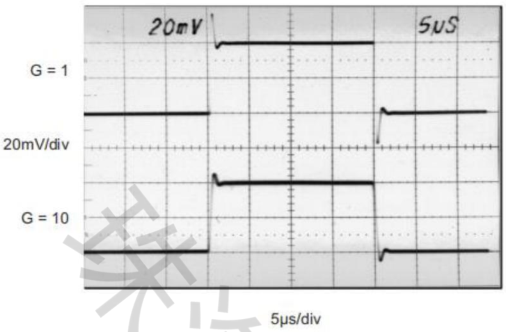
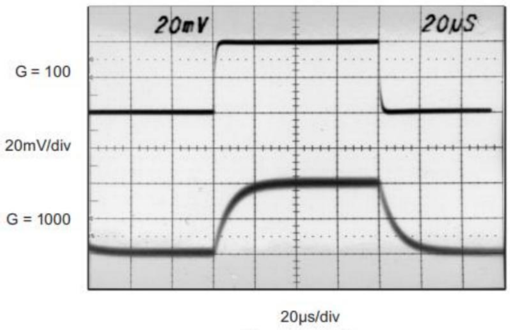



图 18. 0.1 to 10-Hz Input-Referred Voltage Noise



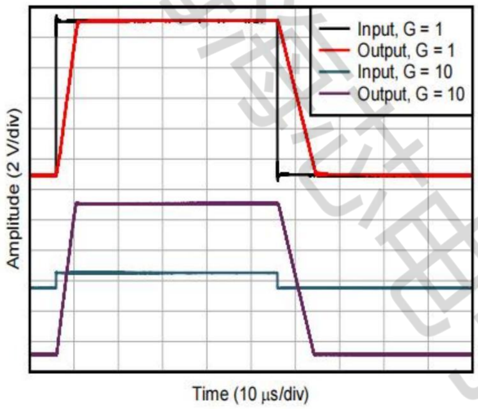

G = 1, 10

**图 19. Small Signal**



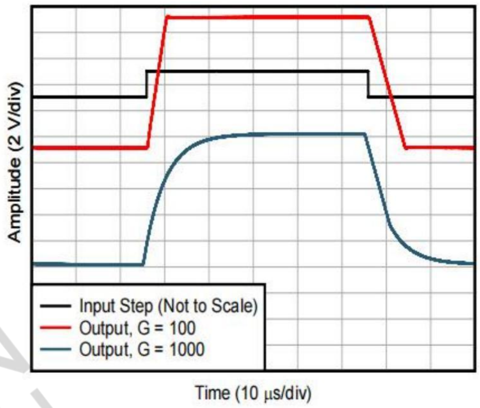

G = 100, 1000

**图 20. Small Signal**




G = 1, 10

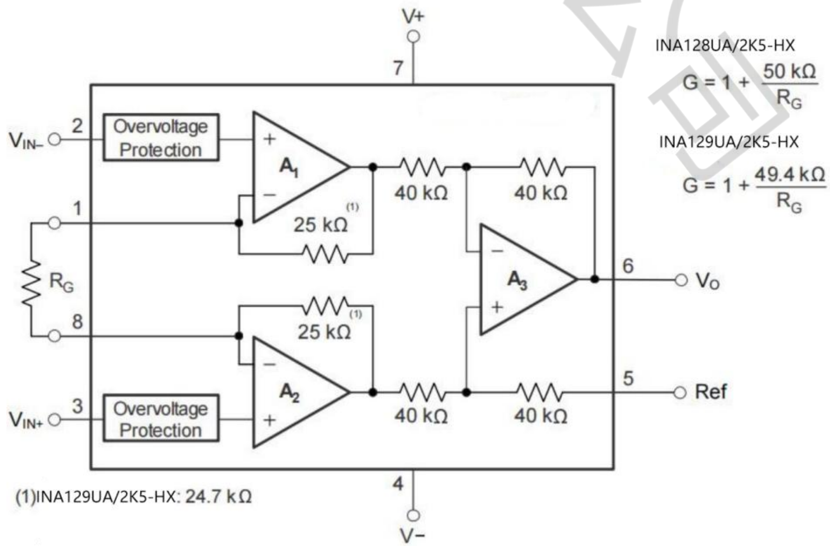
**图 21. Large Signal**




G = 100, 1000

**图 22. Large Signal**

## 原理图

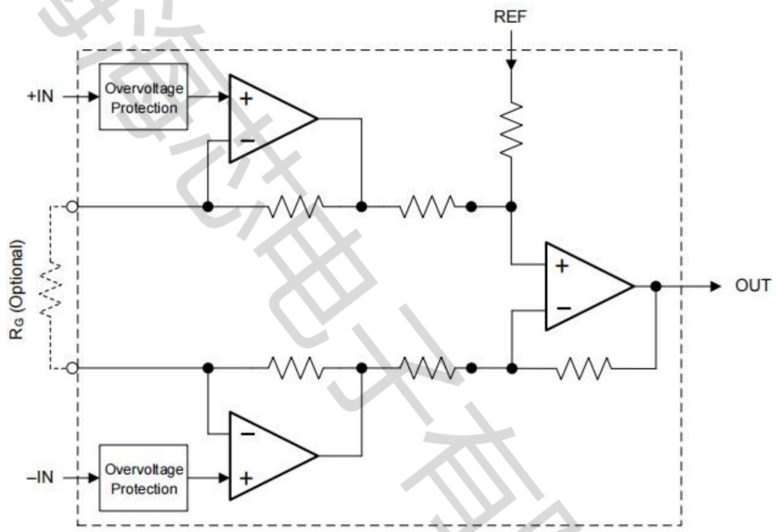


# Detailed Description

## Overview

The INA128UA/2K5-HX 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 INA128UA/2K5-HX 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 INA128UA/2K5-HX 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 INA128UA/2K5-HX 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 INA128UA/2K5-HX 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 INA128UA/2K5-HX 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 INA128UA/2K5-HX a clear choice for noise-sensitive applications.

## Device Functional Modes

The INA128UA/2K5-HX 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 INA128UA/2K5-HX is 36 V (±18 V).

# Application and Implementation

## Application Information

The INA128UA/2K5-HX 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 INA128UA/2K5-HX amplifiers practical for multiple configurations.

### Input Common-Mode Range

The linear input voltage range of the INA128UA/2K5-HX 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 INA128UA/2K5-HX. 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).

INA128UA/2K5-HX

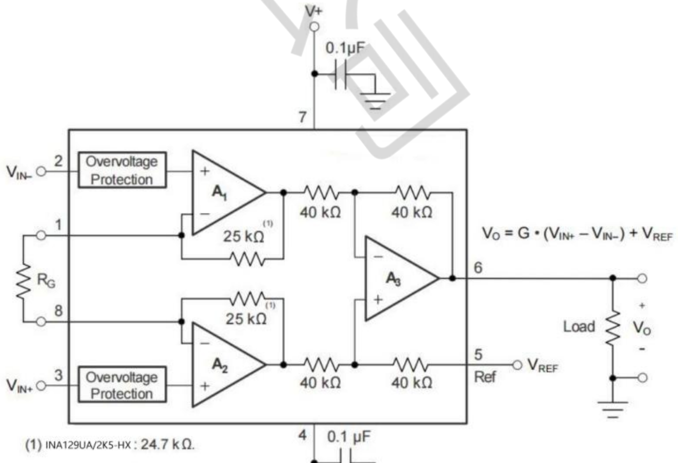
$$G = 1 + \frac{50\ k\Omega}{R_G}$$

INA129UA/2K5-HX

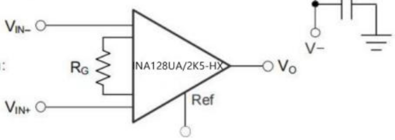
$$G = 1 + \frac{49.4\ k\Omega}{R_G}$$

| | INA128UA/2K5-HX | | INA129UA/2K5-HX | |
|---|---|---|---|---|
| DESIRED GAIN (V/V) | $R_G$ (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 INA128UA/2K5-HX 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 INA128UA/2K5-HX are determined by the following equations:

$$\text{INA128UA/2K5-HX: } G = 1 + 50\ \text{k}\Omega / RG \quad (1)$$

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

The 50-kΩ term in equation 1 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 . 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.

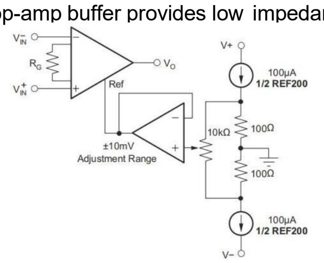
#### Dynamic Performance Characteristics

The typical performance curve in Figure 1 demonstrates that despite their low quiescent current, the INA128UA/2K5-HX 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 INA128UA/2K5-HX 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.



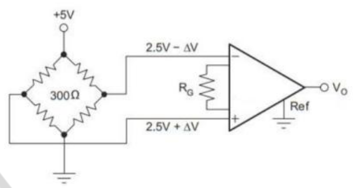

Optional Trimming of Output Offset Voltage

### Input Bias Current Return Path

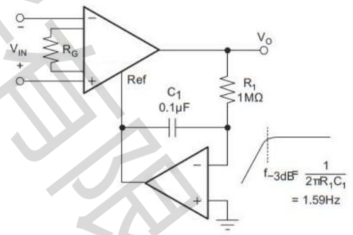
The devices possess an exceptionally high input impedance, approximately 10 GΩ. However, it is crucial to establish a path for the input bias current of both inputs, which stands at approximately ±2 nA. Due to the high input impedance, this bias current remains relatively stable even with varying input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

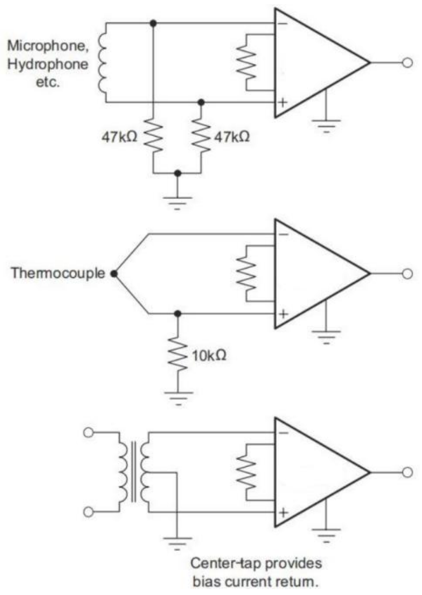
In cases where the differential source resistance is relatively low, connecting the bias current return path to one input is sufficient (as demonstrated in the thermocouple example in the figure). However, with higher source impedance, it is advisable to employ two equal resistors to create a balanced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



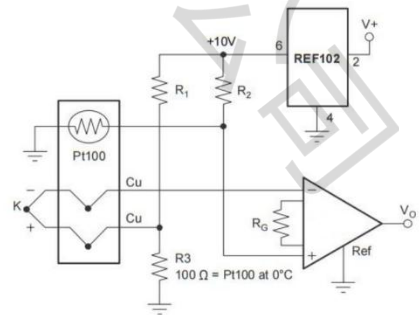

Bridge Amplifier




AC-Coupled Instrumentation Amplifier



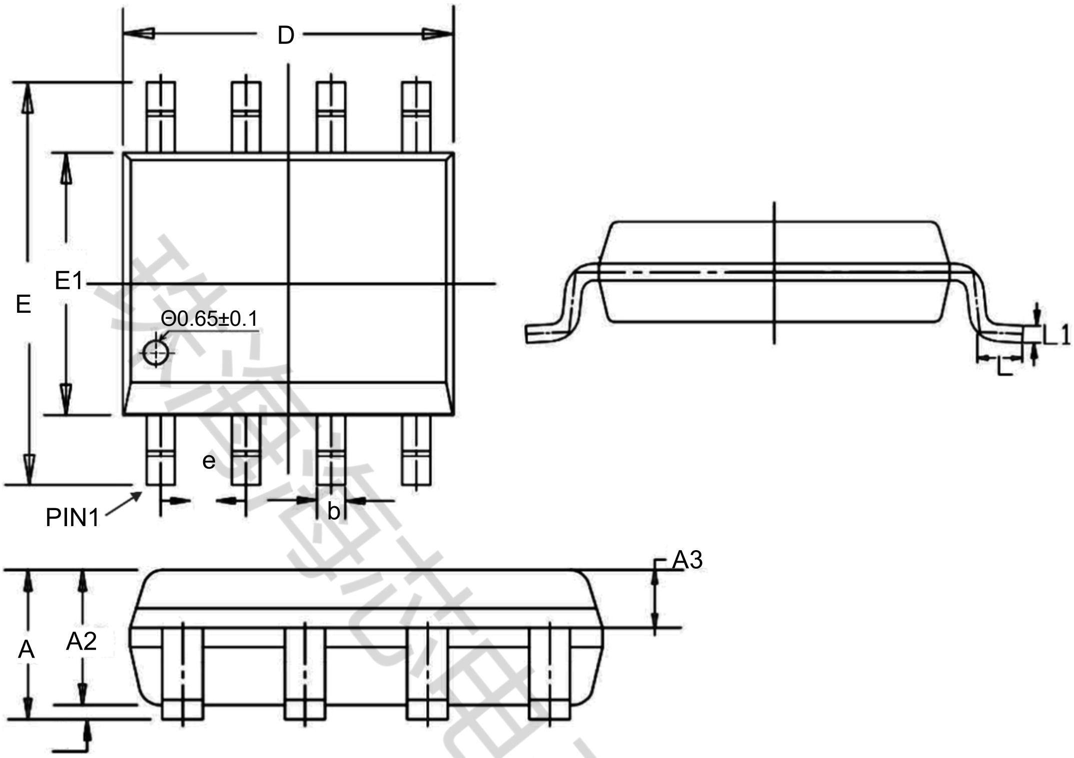

Providing an Input Common-Mode Current Path




| ISA TYPE | MATERIAL | SEEBECK COEFICIENT (µV/°C) | R1, R2 |
|---|---|---|---|
| E | + Chromel<br>− Constantan | 58.5 | 66.5 kΩ |
| J | + Iron<br>− Constantan | 50.2 | 76.8 kΩ |
| K | + Chromel<br>− Alumel | 39.4 | 97.6 kΩ |
| T | + Copper<br>− 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 |
|---|---|---|---|
| INA128UA/2K5-HX | SOP-8 | Taping | 2500 |