

# INA280 采用小型 (SC-70) 封装、的 2.7V 至 120V、1.1MHz、高精度电流检测放大器

## 1 特性

- 宽共模电压：
  - 工作电压：2.7V 至 120V
  - 可承受电压：-20V 至 +122V
- 出色的共模抑制比 (CMRR)：
  - 120dB 直流 (最小值)
  - 85dB 交流 (50kHz 时)
- 精度
  - 增益：
    - 增益误差：±0.5% (最大值)
    - 增益漂移：±20ppm/°C (最大值)
  - 失调电压：
    - 失调电压：±150μV (最大值)
    - 温漂：±1μV/°C (最大值)
- 可用增益：
  - INA280A1：20V/V
  - INA280A2：50V/V
  - INA280A3：100V/V
  - INA280A4：200V/V
  - INA280A5：500V/V
- 高带宽：1.1MHz
- 压摆率：2V/μs
- 静态电流：370μA

## 2 应用

- 有源天线系统 mMIMO (AAS)
- 宏远程无线电单元 (RRU)
- 48V 机架式服务器
- 48V 商用网络和服务器电源
- 测试和测量

## 3 说明

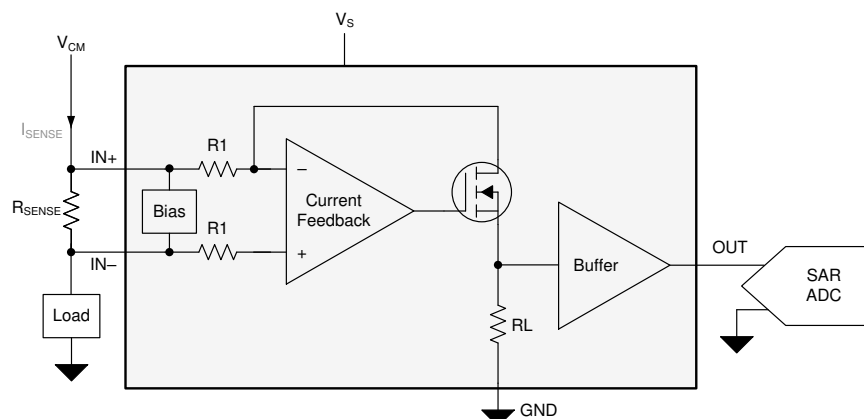
INA280 是一款电流检测放大器，可在 2.7V 至 120V 的宽共模范围内测量分流电阻器上的压降。它采用节省空间的 SC-70 封装，PCB 的空间占用仅为 2.0mm × 2.1mm。该器件在 ±150μV (最大值) 的超低失调电压、±0.5% (最大值) 的小增益误差和 140dB (典型值) 的高直流 CMRR 等特性的综合作用下，可实现精确的电流测量。INA280 凭借 1.1MHz (增益为 20V/V) 的高带宽和 85dB (50kHz 时) 的交流 CMRR，不仅适用于直流电流测量，还适用于高速应用 (例如，快速过流保护)。

INA280 由 2.7V 至 20V 单电源供电，消耗电源电流为 370μA (典型值)。INA280 器件具有五种增益选项：20V/V、50V/V、100V/V、200V/V 和 500V/V。INA280 的低失调电压和低温漂可在工作温度范围 (-40°C 至 +125°C) 内实现精确电流检测。

器件信息

| 器件型号   | 封装 <sup>(1)</sup> | 封装尺寸 (标称值)      |
|--------|-------------------|-----------------|
| INA280 | SC-70 (5)         | 2.00mm × 1.25mm |

(1) 如需了解所有可用封装，请参阅数据表末尾的封装选项附录。



典型应用



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## 4 Revision History

注：以前版本的页码可能与当前版本的页码不同

| DATE         | REVISION | NOTES           |
|--------------|----------|-----------------|
| October 2020 | *        | Initial Release |

## 5 Pin Configuration and Functions

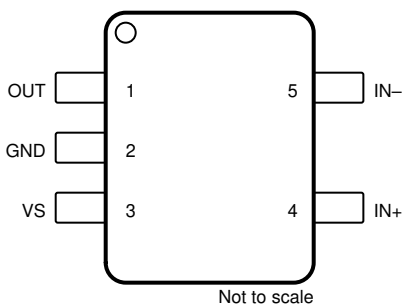


图 5-1. DCK Package 5-Pin SC-70 Top View

### Pin Functions

| PIN  |     | TYPE   | DESCRIPTION                              |
|------|-----|--------|------------------------------------------|
| NAME | NO. |        |                                          |
| GND  | 2   | Ground | Ground                                   |
| IN - | 5   | Input  | Connect to load side of shunt resistor   |
| IN+  | 4   | Input  | Connect to supply side of shunt resistor |
| OUT  | 1   | Output | Output voltage                           |
| VS   | 3   | Power  | Power supply                             |

## 6 Specifications

### 6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

|                                                                      |                                                        | MIN       | MAX                  | UNIT |
|----------------------------------------------------------------------|--------------------------------------------------------|-----------|----------------------|------|
| V <sub>S</sub>                                                       | Supply Voltage                                         | – 0.3     | 22                   | V    |
| Analog Inputs,<br>V <sub>IN+</sub> , V <sub>IN–</sub> <sup>(2)</sup> | Differential (V <sub>IN+</sub> ) – (V <sub>IN–</sub> ) | – 30      | 30                   | V    |
|                                                                      | Common - mode                                          | – 20      | 122                  | V    |
| Output                                                               |                                                        | GND – 0.3 | V <sub>S</sub> + 0.3 | V    |
| T <sub>A</sub>                                                       | Operating Temperature                                  | – 55      | 150                  | °C   |
| T <sub>J</sub>                                                       | Junction temperature                                   |           | 150                  | °C   |
| T <sub>stg</sub>                                                     | Storage temperature                                    | – 65      | 150                  | °C   |

(1) Stresses beyond those listed under *Absolute Maximum Rating* 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 Condition*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) V<sub>IN+</sub> and V<sub>IN–</sub> are the voltages at the VIN+ and VIN– pins, respectively.

### 6.2 ESD Ratings

|                    |                         |                                                                                          | VALUE | UNIT |
|--------------------|-------------------------|------------------------------------------------------------------------------------------|-------|------|
| V <sub>(ESD)</sub> | Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins <sup>(1)</sup>              | ±2000 | V    |
|                    |                         | Charged device model (CDM), per JEDEC specification JESD22-C101, all pins <sup>(2)</sup> | ±1000 |      |

(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.

### 6.3 Recommended Operating Conditions

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

|                 |                                        | MIN            | NOM | MAX | UNIT |
|-----------------|----------------------------------------|----------------|-----|-----|------|
| V <sub>CM</sub> | Common-mode input range <sup>(1)</sup> | V <sub>S</sub> | 48  | 120 | V    |
| V <sub>S</sub>  | Operating supply range                 | 2.7            | 5   | 20  | V    |
| T <sub>A</sub>  | Ambient temperature                    | – 40           |     | 125 | °C   |

(1) Common-mode voltage can go below V<sub>S</sub> under certain conditions. See [Figure 7-1](#) for additional information on operating range.

### 6.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |                                              | INA280      | UNIT |
|-------------------------------|----------------------------------------------|-------------|------|
|                               |                                              | DCK (SC-70) |      |
|                               |                                              | 5 PINS      |      |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance       | 191.6       | °C/W |
| R <sub>θJC(top)</sub>         | Junction-to-case (top) thermal resistance    | 144.4       | °C/W |
| R <sub>θJB</sub>              | Junction-to-board thermal resistance         | 69.2        | °C/W |
| Ψ <sub>JT</sub>               | Junction-to-top characterization parameter   | 46.2        | °C/W |
| Ψ <sub>JB</sub>               | Junction-to-board characterization parameter | 69.0        | °C/W |
| R <sub>θJC(bot)</sub>         | Junction-to-case (bottom) thermal resistance | N/A         | °C/W |

(1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

## 6.5 Electrical Characteristics

at  $T_A = 25\text{ }^{\circ}\text{C}$ ,  $V_S = 5\text{ V}$ ,  $V_{\text{SENSE}} = V_{\text{IN}+} - V_{\text{IN}-} = 0.5\text{ V}$  / Gain,  $V_{\text{CM}} = V_{\text{IN}-} = 48\text{ V}$  (unless otherwise noted)

| PARAMETER           |                                              | TEST CONDITIONS                                                                                                                                        | MIN                   | TYP                  | MAX       | UNIT                           |
|---------------------|----------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|----------------------|-----------|--------------------------------|
| INPUT               |                                              |                                                                                                                                                        |                       |                      |           |                                |
| CMRR                | Common-mode rejection ratio                  | $V_{\text{CM}} = 2.7\text{ V to }120\text{ V}$ , $T_{\text{A}} = -40\text{ }^{\circ}\text{C to }+125\text{ }^{\circ}\text{C}$                          | 120                   | 140                  |           | dB                             |
|                     |                                              | $f = 50\text{ kHz}$                                                                                                                                    |                       | 85                   |           |                                |
| $V_{\text{os}}$     | Offset voltage, input referred               |                                                                                                                                                        |                       | 15                   | $\pm 150$ | $\mu\text{V}$                  |
| $dV_{\text{os}}/dT$ | Offset voltage drift                         | $T_{\text{A}} = -40\text{ }^{\circ}\text{C to }+125\text{ }^{\circ}\text{C}$                                                                           |                       |                      | 1         | $\mu\text{V}/^{\circ}\text{C}$ |
| PSRR                | Power supply rejection ratio, input referred | $V_{\text{S}} = 2.7\text{ V to }20\text{ V}$ , $T_{\text{A}} = -40\text{ }^{\circ}\text{C to }+125\text{ }^{\circ}\text{C}$                            |                       | 1                    | $\pm 10$  | $\mu\text{V/V}$                |
| $I_{\text{B}}$      | Input bias current                           | $I_{\text{B}+}$ , $V_{\text{SENSE}} = 0\text{ mV}$                                                                                                     | 10                    | 20                   | 30        | $\mu\text{A}$                  |
|                     |                                              | $I_{\text{B}-}$ , $V_{\text{SENSE}} = 0\text{ mV}$                                                                                                     | 10                    | 20                   | 30        |                                |
| OUTPUT              |                                              |                                                                                                                                                        |                       |                      |           |                                |
| G                   | Gain                                         | A1 devices                                                                                                                                             |                       | 20                   |           | V/V                            |
|                     |                                              | A2 devices                                                                                                                                             |                       | 50                   |           |                                |
|                     |                                              | A3 devices                                                                                                                                             |                       | 100                  |           |                                |
|                     |                                              | A4 devices                                                                                                                                             |                       | 200                  |           |                                |
|                     |                                              | A5 devices                                                                                                                                             |                       | 500                  |           |                                |
|                     | Gain error                                   | $\text{GND} + 50\text{ mV} \leq V_{\text{OUT}} \leq V_{\text{S}} - 200\text{ mV}$                                                                      |                       | 0.1                  | $\pm 0.5$ | %                              |
|                     | Gain error drift                             | $T_{\text{A}} = -40\text{ }^{\circ}\text{C to }+125\text{ }^{\circ}\text{C}$                                                                           |                       | 2.5                  | 20        | $\text{ppm}/^{\circ}\text{C}$  |
|                     | Nonlinearity error                           |                                                                                                                                                        |                       | 0.01                 |           | %                              |
|                     | Maximum capacitive load                      | No sustained oscillations, no isolation resistor                                                                                                       |                       | 500                  |           | pF                             |
| VOLTAGE OUTPUT      |                                              |                                                                                                                                                        |                       |                      |           |                                |
|                     | Swing to $V_{\text{S}}$ power supply rail    | $R_{\text{LOAD}} = 10\text{ k}\Omega$ , $T_{\text{A}} = -40\text{ }^{\circ}\text{C to }+125\text{ }^{\circ}\text{C}$                                   | $V_{\text{S}} - 0.07$ | $V_{\text{S}} - 0.2$ |           | V                              |
|                     | Swing to ground                              | $R_{\text{LOAD}} = 10\text{ k}\Omega$ , $V_{\text{SENSE}} = 0\text{ V}$ , $T_{\text{A}} = -40\text{ }^{\circ}\text{C to }+125\text{ }^{\circ}\text{C}$ | 0.005                 | 0.025                |           | V                              |
| FREQUENCY RESPONSE  |                                              |                                                                                                                                                        |                       |                      |           |                                |
| BW                  | Bandwidth                                    | A1 devices, $C_{\text{LOAD}} = 5\text{ pF}$ , $V_{\text{SENSE}} = 200\text{ mV}$                                                                       |                       | 1100                 |           | kHz                            |
|                     |                                              | A2 devices, $C_{\text{LOAD}} = 5\text{ pF}$ , $V_{\text{SENSE}} = 80\text{ mV}$                                                                        |                       | 1100                 |           |                                |
|                     |                                              | A3 devices, $C_{\text{LOAD}} = 5\text{ pF}$ , $V_{\text{SENSE}} = 40\text{ mV}$                                                                        |                       | 900                  |           |                                |
|                     |                                              | A4 devices, $C_{\text{LOAD}} = 5\text{ pF}$ , $V_{\text{SENSE}} = 20\text{ mV}$                                                                        |                       | 850                  |           |                                |
|                     |                                              | A5 devices, $C_{\text{LOAD}} = 5\text{ pF}$ , $V_{\text{SENSE}} = 8\text{ mV}$                                                                         |                       | 800                  |           |                                |
| SR                  | Slew rate                                    |                                                                                                                                                        |                       | 2                    |           | V/ $\mu\text{s}$               |
|                     | Settling time                                | $V_{\text{OUT}} = 4\text{ V} \pm 0.1\text{ V}$ step, output settles to 0.5%                                                                            |                       | 9                    |           | $\mu\text{s}$                  |
|                     |                                              | $V_{\text{OUT}} = 4\text{ V} \pm 0.1\text{ V}$ step, output settles to 1%                                                                              |                       | 5                    |           |                                |
| NOISE               |                                              |                                                                                                                                                        |                       |                      |           |                                |
| $V_{\text{e}_n}$    | Voltage noise density                        |                                                                                                                                                        |                       | 50                   |           | nV/ $\sqrt{\text{Hz}}$         |
| POWER SUPPLY        |                                              |                                                                                                                                                        |                       |                      |           |                                |
| $V_{\text{S}}$      | Supply voltage                               | $T_{\text{A}} = -40\text{ }^{\circ}\text{C to }+125\text{ }^{\circ}\text{C}$                                                                           | 2.7                   |                      | 20        | V                              |
| $I_{\text{Q}}$      | Quiescent current                            |                                                                                                                                                        |                       | 370                  | 500       | $\mu\text{A}$                  |
|                     |                                              | $T_{\text{A}} = -40\text{ }^{\circ}\text{C to }+125\text{ }^{\circ}\text{C}$                                                                           |                       |                      | 600       |                                |

## 6.6 Typical Characteristics

All specifications at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $V_{\text{SENSE}} = V_{\text{IN}+} - V_{\text{IN}-} = 0.5\text{ V} / \text{Gain}$ , and  $V_{\text{CM}} = V_{\text{IN}-} = 48\text{ V}$ , unless otherwise noted.

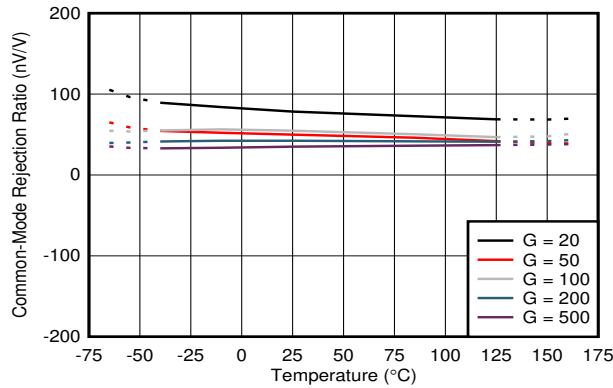


图 6-1. Common-Mode Rejection Ratio vs Temperature

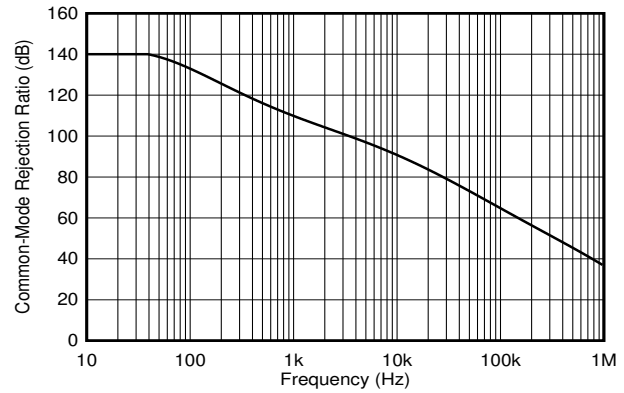


图 6-2. Common-Mode Rejection Ratio vs Frequency

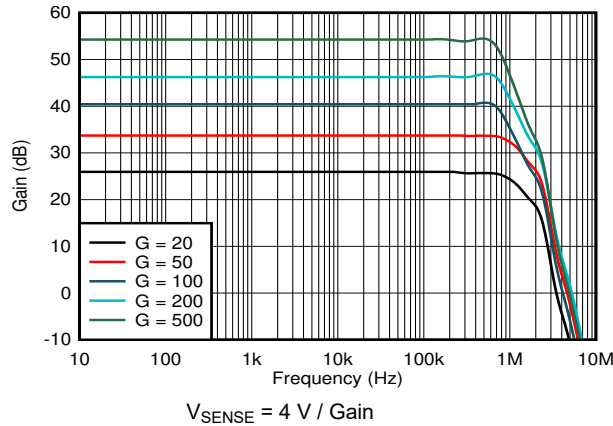


图 6-3. Gain vs Frequency

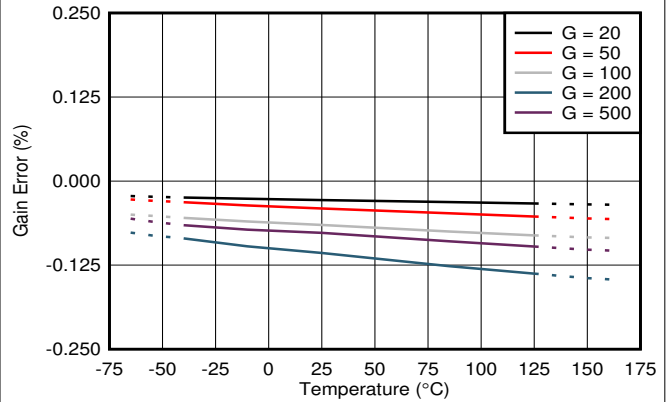


图 6-4. Gain Error vs Temperature

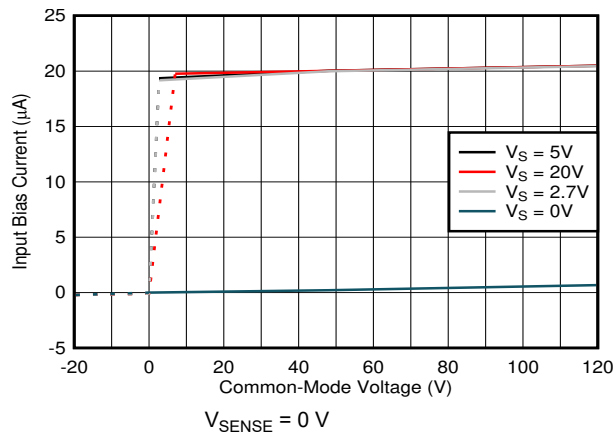


图 6-5. Input Bias Current vs Common-Mode Voltage

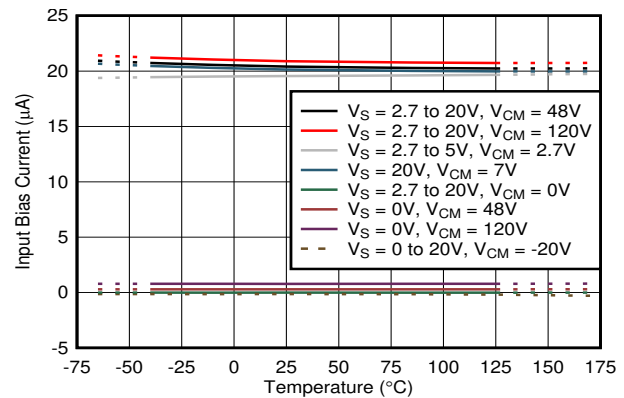


图 6-6. Input Bias Current vs Temperature

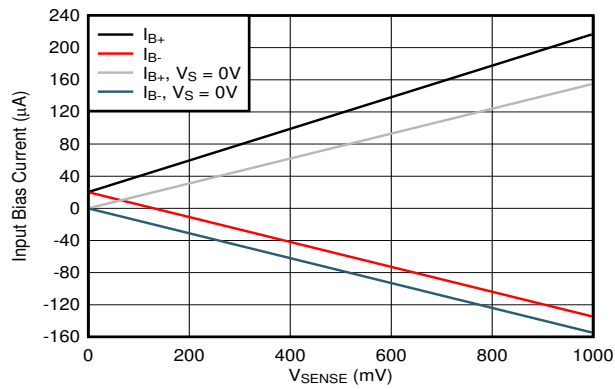


图 6-7. Input Bias Current vs  $V_{SENSE}$ , A1 devices

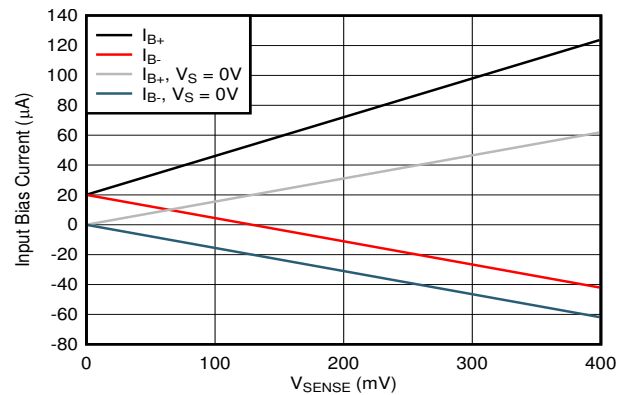


图 6-8. Input Bias Current vs  $V_{SENSE}$ , A2 and A3 devices

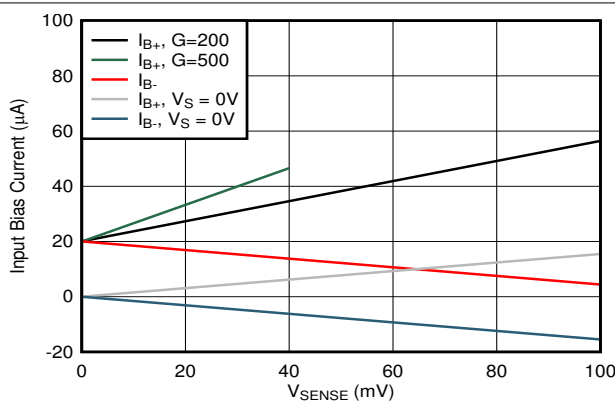


图 6-9. Input Bias Current vs  $V_{SENSE}$ , A4 and A5 devices

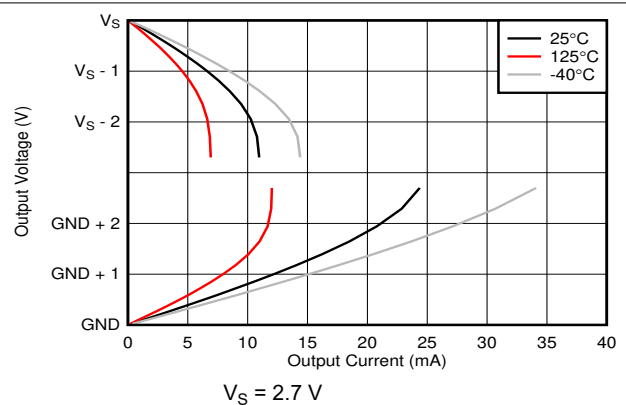


图 6-10. Output Voltage vs Output Current

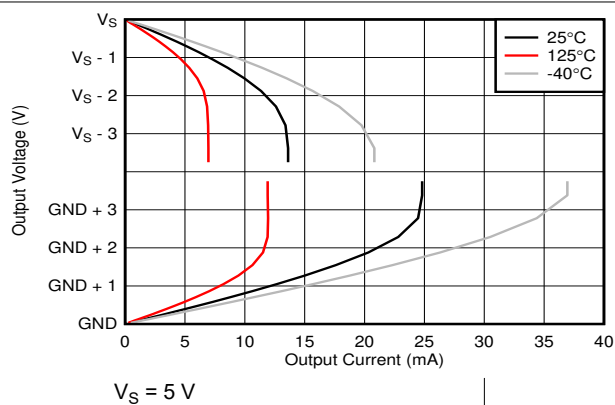


图 6-11. Output Voltage vs Output Current

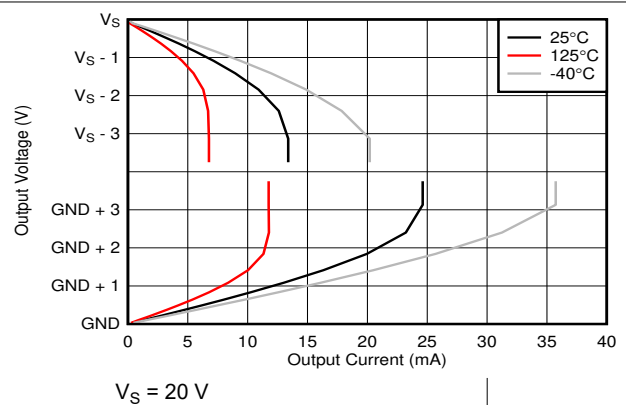


图 6-12. Output Voltage vs Output Current

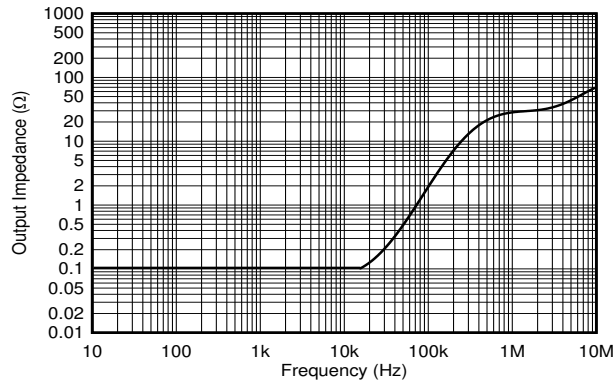


图 6-13. Output Impedance vs Frequency

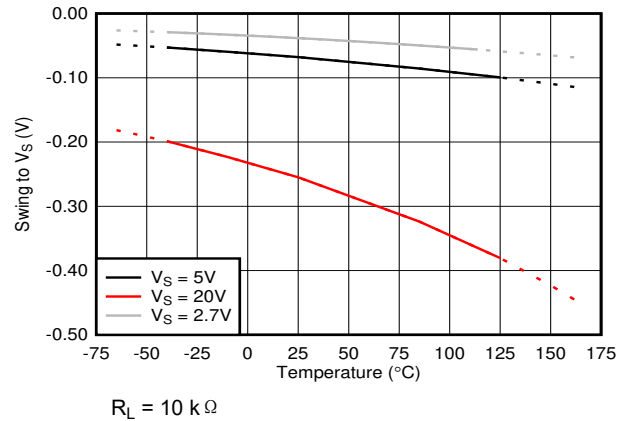


图 6-14. Swing to Supply vs Temperature

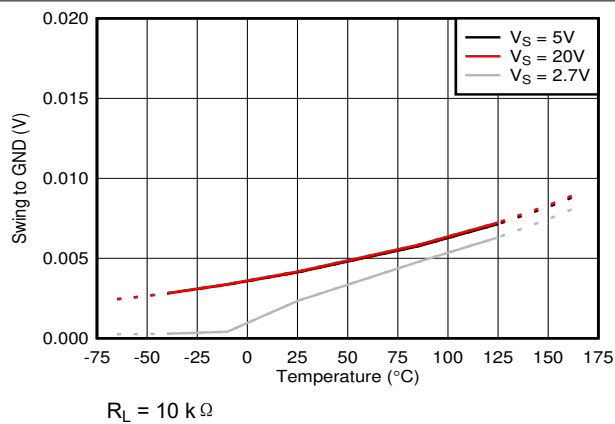


图 6-15. Swing to GND vs Temperature

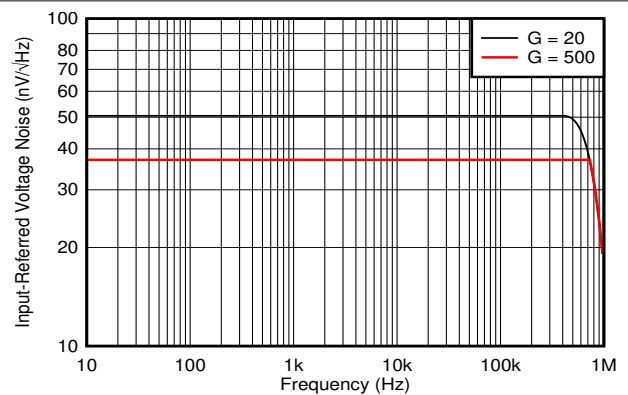


图 6-16. Input Referred Noise vs Frequency

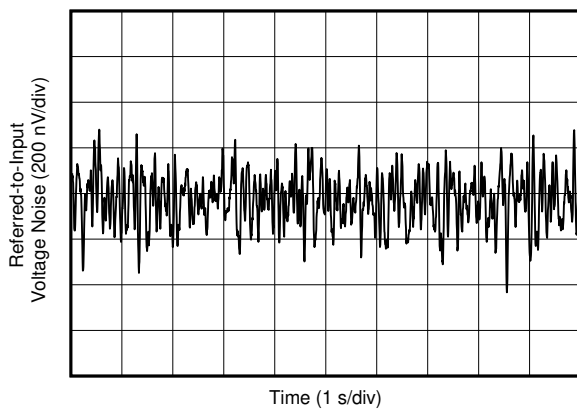


图 6-17. Input Referred Noise

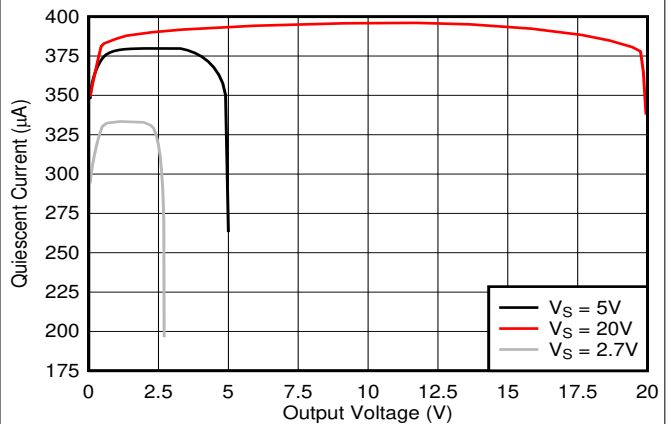


图 6-18. Quiescent Current vs Output Voltage

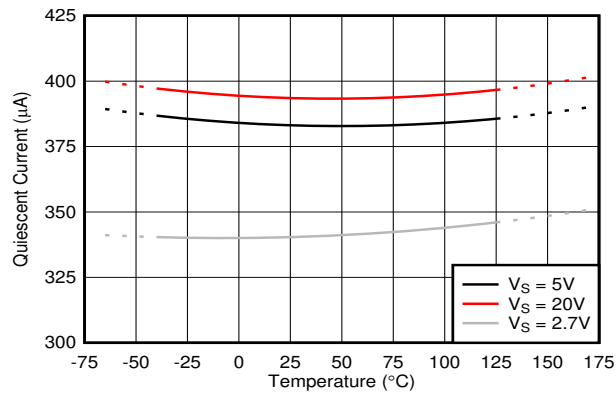


图 6-19. Quiescent Current vs Temperature

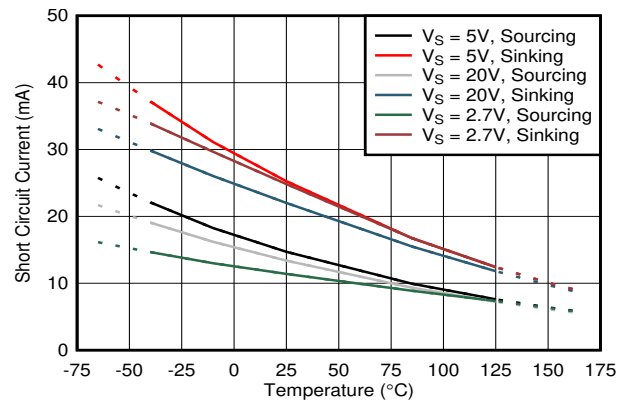


图 6-20. Short-Circuit Current vs Temperature

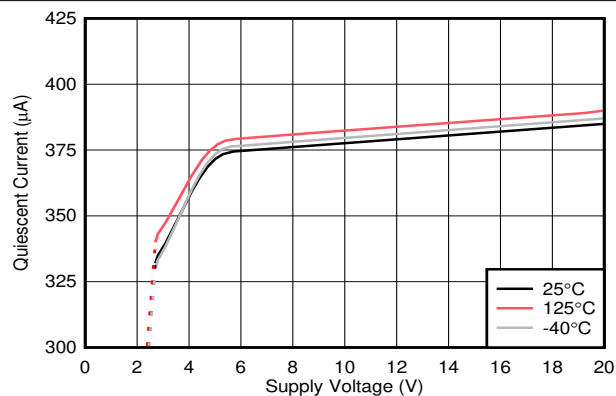


图 6-21. Quiescent Current vs Supply Voltage

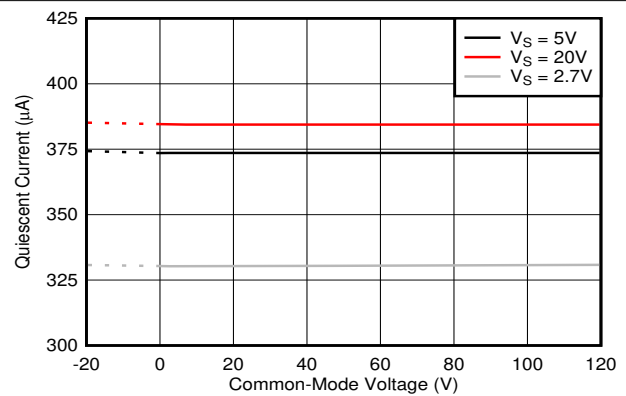


图 6-22. Quiescent Current vs Common-Mode Voltage

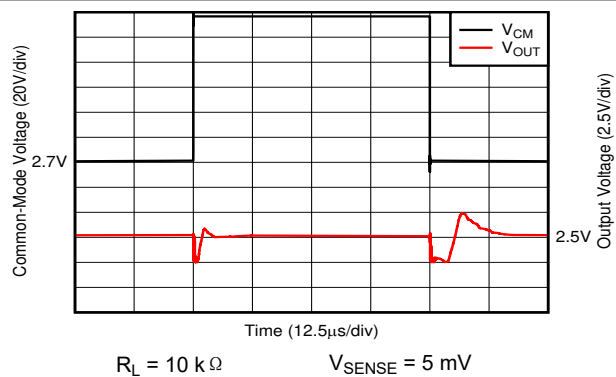


图 6-23. Common-Mode Voltage Fast Transient Pulse, A5 devices

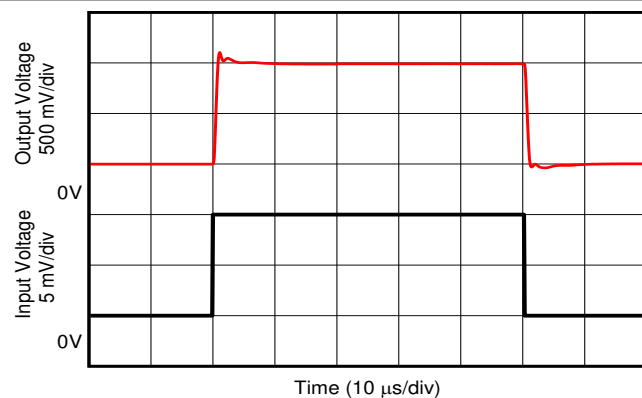


图 6-24. Step Response, A3 devices

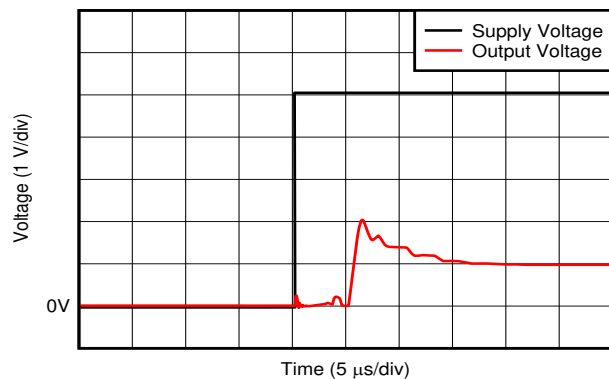


图 6-25. Start-Up Response

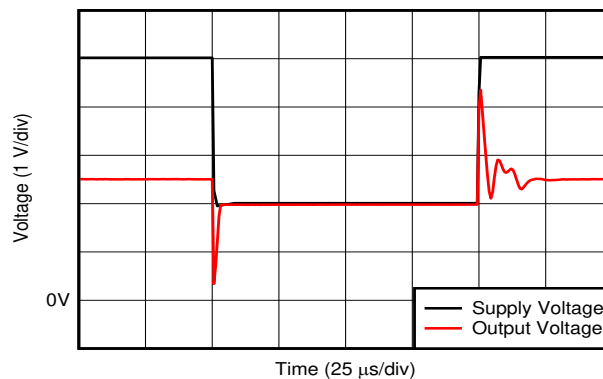


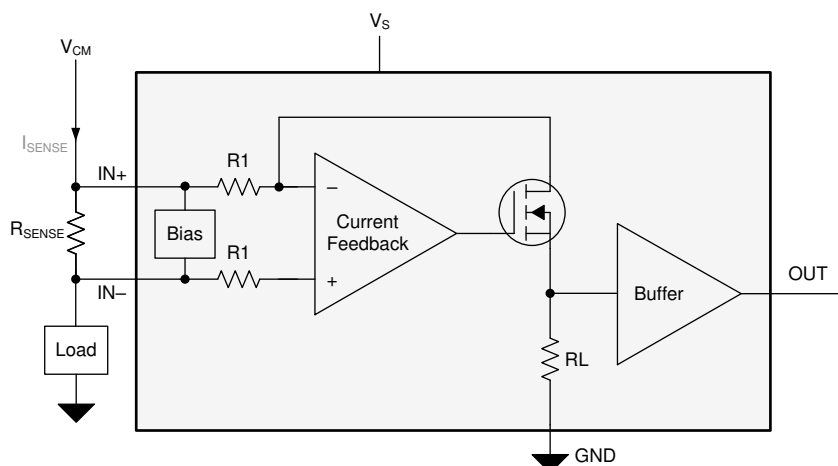
图 6-26. Supply Transient Response, A5 devices

## 7 Detailed Description

### 7.1 Overview

The INA280 is a high-side only current-sense amplifier that offers a wide common-mode range, excellent common-mode rejection ratio (CMRR), high bandwidth, and fast slew rate. Different gain versions are available to optimize the output dynamic range based on the application. The INA280 is designed using a transconductance architecture with a current-feedback amplifier that enables low bias currents of 20  $\mu\text{A}$  and a common-mode voltage of 120 V.

### 7.2 Functional Block Diagram



### 7.3 Feature Description

#### 7.3.1 Amplifier Input Common-Mode Range

The INA280 supports large input common-mode voltages from 2.7 V to 120 V and features a high DC CMRR of 140 dB (typical) and a 85-dB AC CMRR at 50 kHz. The minimum common-mode voltage is restricted by the supply voltage as shown in 图 7-1. The topology of the internal amplifiers INA280 restricts operation to high-side, current-sensing applications.

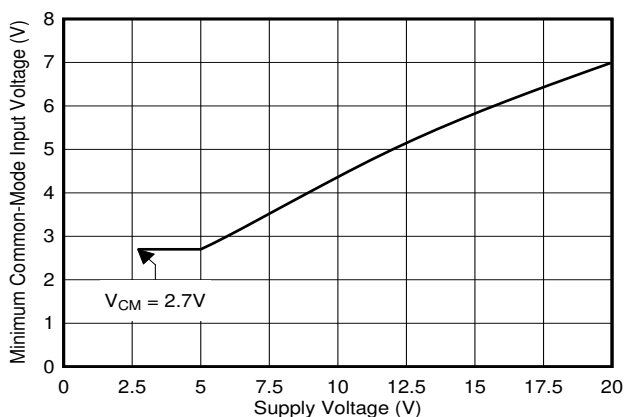


图 7-1. Minimum Common-Mode Voltage vs Supply

### 7.3.1.1 Input-Signal Bandwidth

The INA280 – 3-dB bandwidth is gain dependent with several gain options of 20 V/V, 50 V/V, 100 V/V, 200 V/V, and 500 V/V as shown in 图 6-2. The unique multistage design enables the amplifier to achieve high bandwidth at all gains. This high bandwidth provides the throughput and fast response that is required for the rapid detection and processing of overcurrent events.

The bandwidth of the device also depends on the applied  $V_{SENSE}$  voltage. 图 7-2 shows the bandwidth performance profile of the device over frequency as output voltage increases for each gain variation. As shown in 图 7-2, the device exhibits the highest bandwidth with higher  $V_{SENSE}$  voltages, and the bandwidth is higher with lower device gain options. Individual requirements determine the acceptable limits of error for high-frequency, current-sensing applications. Testing and evaluation in the end application or circuit is required to determine the acceptance criteria and validate whether or not the performance levels meet the system specifications.

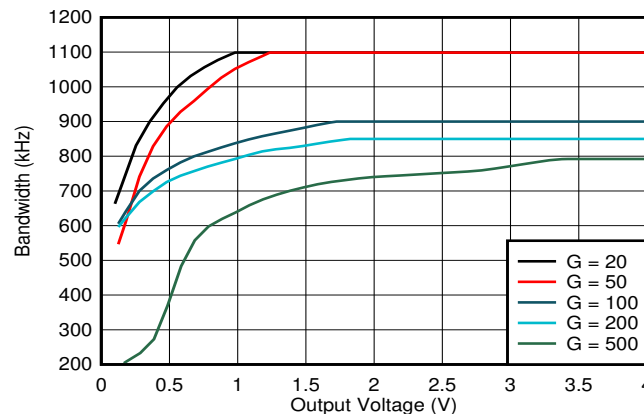


图 7-2. Bandwidth vs Output Voltage

### 7.3.1.2 Low Input Bias Current

The INA280 input bias current draws 20  $\mu$ A (typical) even with common-mode voltages as high as 120 V. This enables precision current sensing in applications where the sensed current is small or applications that require lower input leakage current.

### 7.3.1.3 Multiple Fixed Gain Outputs

The INA280 gain error is  $< 0.5\%$  at room temperature for all gain options, with a maximum drift of 20ppm/ $^{\circ}$ C over the full temperature range of  $-40^{\circ}$ C to  $+125^{\circ}$ C. The INA280 is available in multiple gain options of 20 V/V, 50 V/V, 100 V/V, 200 V/V, and 500 V/V, which the system designer should select based on their desired signal-to-noise ratio and other system requirements.

The INA280 closed-loop gain is set by a precision, low-drift internal resistor network. Even though the ratio of these resistors are well matched, the absolute value of these resistors may vary significantly. TI does not recommend adding additional resistance around the INA280 to change the effective gain because of this variation, however. The typical values of the gain resistors are described in 表 7-1.

表 7-1. Fixed Gain Resistor

| GAIN      | R1            | RL              |
|-----------|---------------|-----------------|
| 20 (V/V)  | 25 k $\Omega$ | 500 k $\Omega$  |
| 50 (V/V)  | 10 k $\Omega$ | 500 k $\Omega$  |
| 100 (V/V) | 10 k $\Omega$ | 1000 k $\Omega$ |
| 200 (V/V) | 5 k $\Omega$  | 1000 k $\Omega$ |
| 500 (V/V) | 2 k $\Omega$  | 1000 k $\Omega$ |

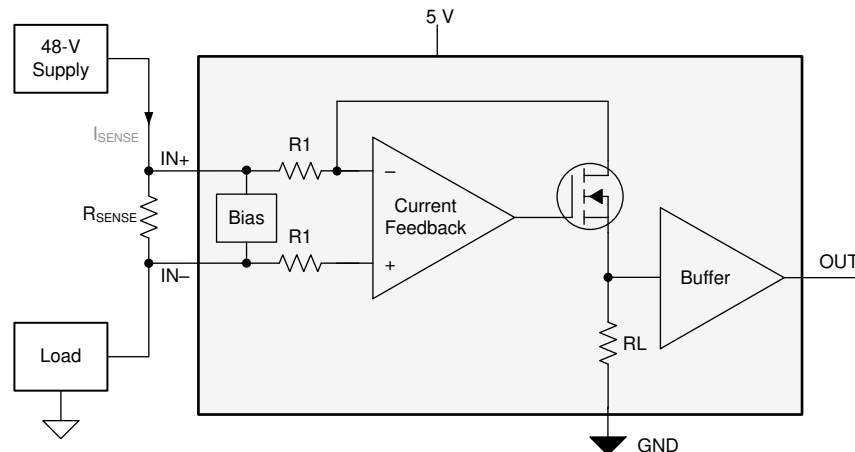
### 7.3.1.4 Wide Supply Range

The INA280 operates with a wide supply range from a 2.7 V to 20 V. The output stage supports a full-scale output voltage range of up to  $V_S$ . Wide output range can enable very-wide dynamic range current measurements. For a gain of 20 V/V, the maximum differential input acceptable is 1 V.

## 7.4 Device Functional Modes

### 7.4.1 Unidirectional Operation

The INA280 measures the differential voltage developed by current flowing through a resistor that is commonly referred to as a current-sensing resistor or a current-shunt resistor. The INA280 operates in unidirectional mode only, meaning it only senses current sourced from a power supply to a system load as shown in [图 7-3](#).



**图 7-3. Unidirectional Application**

The linear range of the output stage is limited to how close the output voltage can approach ground under zero-input conditions. The zero current output voltage of the INA280 is very small, with a maximum of GND + 25 mV. Make sure to apply a sense voltage of (25 mV / Gain) or greater to keep the INA280 output in the linear region of operation.

### 7.4.2 High Signal Throughput

With a bandwidth of 1.1 MHz at a gain of 20 V/V and a slew rate of 2 V/ $\mu$ s, the INA280 is specifically designed for detecting and protecting applications from fast inrush currents. As shown in [表 7-2](#), the INA280 responds in less than 2  $\mu$ s for a system measuring a 75-A threshold on a 2-m $\Omega$  shunt.

**表 7-2. Response Time**

| PARAMETER       |                                     | EQUATION                                           | INA280<br>AT $V_S = 5$ V |
|-----------------|-------------------------------------|----------------------------------------------------|--------------------------|
| G               | Gain                                |                                                    | 20 V/V                   |
| $I_{MAX}$       | Maximum current                     |                                                    | 100 A                    |
| $I_{Threshold}$ | Threshold current                   |                                                    | 75 A                     |
| $R_{SENSE}$     | Current sense resistor value        |                                                    | 2 m $\Omega$             |
| $V_{OUT\_MAX}$  | Output voltage at maximum current   | $V_{OUT} = I_{MAX} \times R_{SENSE} \times G$      | 4 V                      |
| $V_{OUT\_THR}$  | Output voltage at threshold current | $V_{OUT\_THR} = I_{THR} \times R_{SENSE} \times G$ | 3 V                      |
| SR              | Slew rate                           |                                                    | 2 V/ $\mu$ s             |
|                 | Output response time                | $T_{response} = V_{OUT\_THR} / SR$                 | < 2 $\mu$ s              |

## 8 Application and Implementation

### Note

以下应用部分的信息不属于 TI 组件规范，TI 不担保其准确性和完整性。客户应负责确定 TI 组件是否适用于其应用。客户应验证并测试其设计，以确保系统功能。

### 8.1 Application Information

The INA280 amplifies the voltage developed across a current-sensing resistor as current flows through the resistor to the load. The wide input common-mode voltage range and high common-mode rejection of the INA280 allows use over a wide range of voltage rails while still maintaining an accurate current measurement.

#### 8.1.1 R<sub>SENSE</sub> and Device Gain Selection

The accuracy of any current-sense amplifier is maximized by choosing the current-sense resistor to be as large as possible. A large sense resistor maximizes the differential input signal for a given amount of current flow and reduces the error contribution of the offset voltage. However, there are practical limits as to how large the current-sense resistor can be in a given application because of the resistor size and maximum allowable power dissipation. [方程式 1](#) gives the maximum value for the current-sense resistor for a given power dissipation budget:

$$R_{\text{SENSE}} < \frac{PD_{\text{MAX}}}{I_{\text{MAX}}^2} \quad (1)$$

where:

- $PD_{\text{MAX}}$  is the maximum allowable power dissipation in  $R_{\text{SENSE}}$ .
- $I_{\text{MAX}}$  is the maximum current that will flow through  $R_{\text{SENSE}}$ .

An additional limitation on the size of the current-sense resistor and device gain is due to the power-supply voltage,  $V_S$ , and device swing-to-rail limitations. To make sure that the current-sense signal is properly passed to the output, both positive and negative output swing limitations must be examined. [方程式 2](#) provides the maximum values of  $R_{\text{SENSE}}$  and GAIN to keep the device from exceeding the positive swing limitation.

$$I_{\text{MAX}} \times R_{\text{SENSE}} \times \text{GAIN} < V_{\text{SP}} \quad (2)$$

where:

- $I_{\text{MAX}}$  is the maximum current that will flow through  $R_{\text{SENSE}}$ .
- GAIN is the gain of the current-sense amplifier.
- $V_{\text{SP}}$  is the positive output swing as specified in the data sheet.

To avoid positive output swing limitations when selecting the value of  $R_{\text{SENSE}}$ , there is always a trade-off between the value of the sense resistor and the gain of the device under consideration. If the sense resistor selected for the maximum power dissipation is too large, then it is possible to select a lower-gain device in order to avoid positive swing limitations.

The negative swing limitation places a limit on how small the sense resistor value can be for a given application. [方程式 3](#) provides the limit on the minimum value of the sense resistor.

$$I_{\text{MIN}} \times R_{\text{SENSE}} \times \text{GAIN} > V_{\text{SN}} \quad (3)$$

where:

- $I_{\text{MIN}}$  is the minimum current that will flow through  $R_{\text{SENSE}}$ .
- GAIN is the gain of the current-sense amplifier.
- $V_{\text{SN}}$  is the negative output swing of the device.

表 8-1 shows an example of the different results obtained from using five different gain versions of the INA280. From the table data, the highest gain device allows a smaller current-shunt resistor and decreased power dissipation in the element.

表 8-1.  $R_{SENSE}$  Selection and Power Dissipation

| PARAMETER <sup>(1)</sup> |                                                                                         | EQUATION                          | RESULTS AT $V_S = 5\text{ V}$ |               |              |                |              |
|--------------------------|-----------------------------------------------------------------------------------------|-----------------------------------|-------------------------------|---------------|--------------|----------------|--------------|
|                          |                                                                                         |                                   | INA280A1                      | INA280A2      | INA280A3     | INA280A4       | INA280A5     |
| G                        | Gain                                                                                    |                                   | 20 V/V                        | 50 V/V        | 100 V/V      | 200 V/V        | 500 V/V      |
| $V_{SENSE}$              | Ideal differential input voltage (Ignores swing limitation and power supply variation.) | $V_{SENSE} = V_{OUT} / G$         | 250 mV                        | 100 mV        | 50 mV        | 25 mV          | 10 mV        |
| $R_{SENSE}$              | Current sense resistor value                                                            | $R_{SENSE} = V_{SENSE} / I_{MAX}$ | 25 m $\Omega$                 | 10 m $\Omega$ | 5 m $\Omega$ | 2.5 m $\Omega$ | 1 m $\Omega$ |
| $P_{SENSE}$              | Current-sense resistor power dissipation                                                | $R_{SENSE} \times I_{MAX}^2$      | 2.5 W                         | 1 W           | 0.5W         | 0.25 W         | 0.1 W        |

(1) Design example with 10-A full-scale current with maximum output voltage set to 5 V.

## 8.1.2 Input Filtering

### Note

Input filters are not required for accurate measurements using the INA280, and use of filters in this location is not recommended. If filter components are used on the input of the amplifier, follow the guidelines in this section to minimize the effects on performance.

Based strictly on user design requirements, external filtering of the current signal may be desired. The initial location that can be considered for the filter is at the output of the current-sense amplifier. Although placing the filter at the output satisfies the filtering requirements, this location changes the low output impedance measured by any circuitry connected to the output voltage pin. The other location for filter placement is at the current-sense amplifier input pins. This location also satisfies the filtering requirement, but the components must be carefully selected to minimally impact device performance. 图 8-1 shows a filter placed at the input pins.

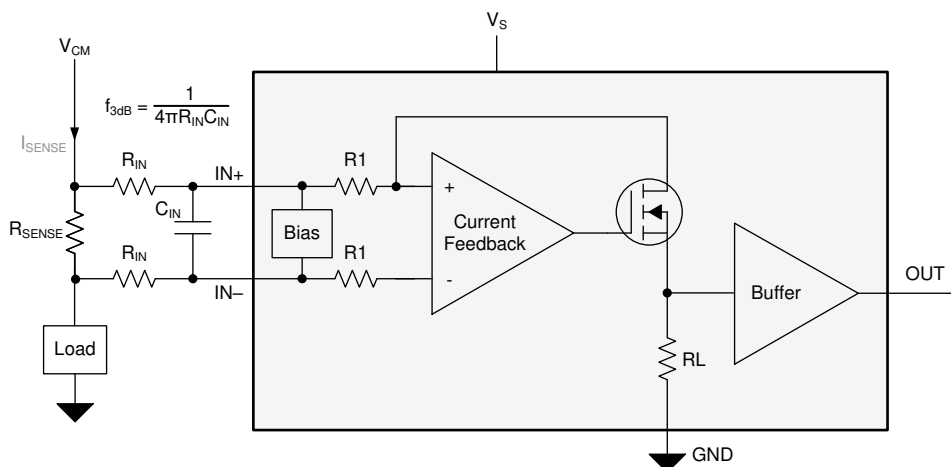


图 8-1. Filter at Input Pins

External series resistance provides a source of additional measurement error, so keep the value of these series resistors to 10  $\Omega$  or less to reduce loss of accuracy. The internal bias network shown in Figure 38 creates a mismatch in input bias currents (see 图 6-7, 图 6-8, and 图 6-9) when a differential voltage is applied between the input pins. If additional external series filter resistors are added to the circuit, a mismatch is created in the voltage drop across the filter resistors. This voltage is a differential error voltage in the shunt resistor voltage. In addition to the absolute resistor value, mismatch resulting from resistor tolerance can significantly impact the error because this value is calculated based on the actual measured resistance.

The measurement error expected from the additional external filter resistors can be calculated using 方程式 4, where the gain error factor is calculated using 方程式 5.

$$\text{Gain Error (\%)} = 100 \times (\text{Gain Error Factor} - 1) \quad (4)$$

The gain error factor, shown in 方程式 4, can be calculated to determine the gain error introduced by the additional external series resistance. 方程式 4 calculates the deviation of the shunt voltage, resulting from the attenuation and imbalance created by the added external filter resistance. 表 8-2 provides the gain error factor and gain error for several resistor values.

$$\text{Gain Error Factor} = \frac{R_B \times R_1}{(R_B \times R_1) + (R_B \times R_{IN}) + (2 \times R_{IN} \times R_1)} \quad (5)$$

Where:

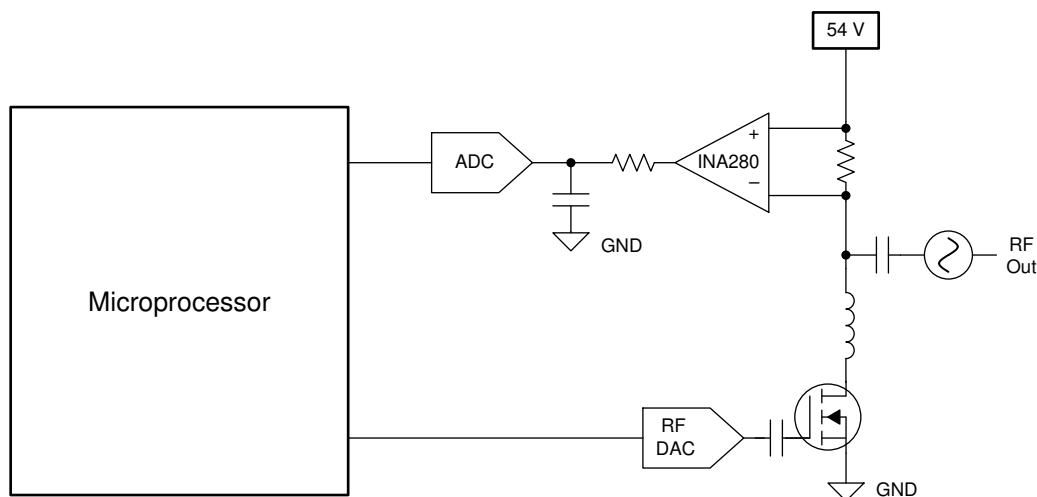
- $R_{IN}$  is the external filter resistance value.
- $R_1$  is the INA280 input resistance value specified in 表 7-1.
- $R_B$  is the internal bias resistance, which is  $6600 \, \Omega \pm 20\%$ .

**表 8-2. Example Gain Error Factor and Gain Error for 10- $\Omega$  External Filter Input Resistors**

| DEVICE (GAIN)    | GAIN ERROR FACTOR | GAIN ERROR (%) |
|------------------|-------------------|----------------|
| A1 devices (20)  | 0.99658           | - 0.34185      |
| A2 devices (50)  | 0.99598           | - 0.40141      |
| A3 devices (100) | 0.99598           | - 0.40141      |
| A4 devices (200) | 0.99499           | - 0.50051      |
| A5 devices (500) | 0.99203           | - 0.79663      |

## 8.2 Typical Application

The INA280 is a unidirectional, current-sense amplifier capable of measuring currents through a resistive shunt with shunt common-mode voltages from 2.7 V to 120 V. The circuit configuration for monitoring current in a high-side radio frequency (RF) power amplifier (PA) application is shown in 图 8-2.



**图 8-2. Current Sensing in a PA Application**

### 8.2.1 Design Requirements

$V_{SUPPLY}$  is set to 5 V, and the common-mode voltage set to 54 V. 表 8-3 lists the design setup for this application.

表 8-3. Design Parameters

| DESIGN PARAMETERS                   | EXAMPLE VALUE |
|-------------------------------------|---------------|
| INA280 supply voltage               | 5 V           |
| High-side supply voltage            | 5 V           |
| Maximum sense current ( $I_{MAX}$ ) | 5 A           |
| Gain option                         | 50 V/V        |

## 8.2.2 Detailed Design Procedure

The maximum value of the current-sense resistor is calculated based choice of gain, value of the maximum current the be sensed ( $I_{MAX}$ ), and the power-supply voltage ( $V_S$ ). When operating at the maximum current, the output voltage must not exceed the positive output swing specification,  $V_{SP}$ . Under the given design parameters, 方程式 6 calculates the maximum value for  $R_{SENSE}$  as 19.2 m $\Omega$ .

$$R_{SENSE} < \frac{V_{SP}}{I_{MAX} \times GAIN} \quad (6)$$

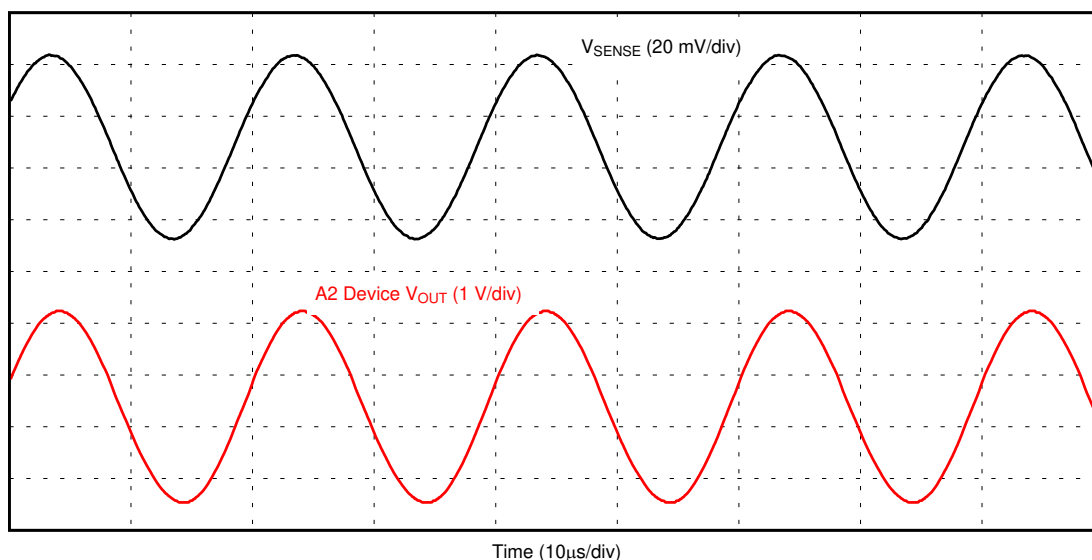
For this design example, a value of 15 m $\Omega$  is selected because, while the 15 m $\Omega$  is less than the maximum value calculated, 15 m $\Omega$  is still large enough to give adequate signal at the current-sense amplifier output.

### 8.2.2.1 Overload Recovery With Negative $V_{SENSE}$

The INA280 is a unidirectional current-sense amplifier that is meant to operate with a positive differential input voltage ( $V_{SENSE}$ ). If negative  $V_{SENSE}$  is applied, the device is placed in an overload condition and requires time to recover once  $V_{SENSE}$  returns positive. The required overload recovery time increases with more negative  $V_{SENSE}$ .

## 8.2.3 Application Curve

图 8-3 shows the output response of the device to a high frequency sinusoidal current.



INA2

图 8-3. INA280 Output Response

## 9 Power Supply Recommendations

The input circuitry of the INA280 device can accurately measure beyond the power-supply voltage. The power supply can be 20 V, whereas the load power-supply voltage at IN+ and IN- can go up to 120 V. The output voltage range of the OUT pin is limited by the voltage on the V<sub>S</sub> pin and the device swing to supply specification.

## 10 Layout

### 10.1 Layout Guidelines

TI always recommends to follow good layout practices:

- Connect the input pins to the sensing resistor using a Kelvin or 4-wire connection. This connection technique makes sure that only the current-sensing resistor impedance is detected between the input pins. Poor routing of the current-sensing resistor commonly results in additional resistance present between the input pins. Given the very low ohmic value of the current resistor, any additional high-current carrying impedance can cause significant measurement errors.
- Place the power-supply bypass capacitor as close to the device power supply and ground pins as possible. The recommended value of this bypass capacitor is 0.1  $\mu$ F. Additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies.
- When routing the connections from the current-sense resistor to the device, keep the trace lengths as short as possible.

### 10.2 Layout Example

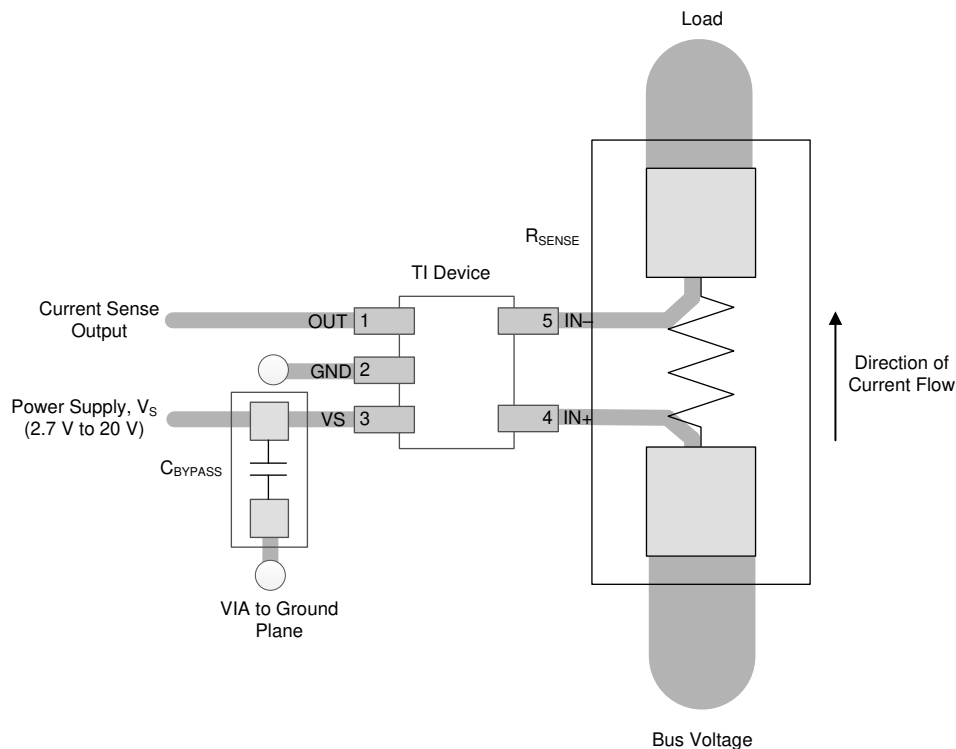


图 10-1. Recommended Layout for INA280

## 11 Device and Documentation Support

### 11.1 Documentation Support

#### 11.1.1 Related Documentation

For related documentation, see the following:

Texas Instruments, [INA280EVM User's Guide](#)

### 11.2 接收文档更新通知

要接收文档更新通知，请导航至 [ti.com](#) 上的器件产品文件夹。点击 [订阅更新](#) 进行注册，即可每周接收产品信息更改摘要。有关更改的详细信息，请查看任何已修订文档中包含的修订历史记录。

### 11.3 支持资源

[TI E2E™ 支持论坛](#) 是工程师的重要参考资料，可直接从专家获得快速、经过验证的解答和设计帮助。搜索现有解答或提出自己的问题可获得所需的快速设计帮助。

链接的内容由各个贡献者“按原样”提供。这些内容并不构成 TI 技术规范，并且不一定反映 TI 的观点；请参阅 TI 的《[使用条款](#)》。

### 11.4 Trademarks

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### 11.5 静电放电警告



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ESD 的损坏小至导致微小的性能降级，大至整个器件故障。精密的集成电路可能更容易受到损坏，这是因为非常细微的参数更改都可能会导致器件与其发布的规格不相符。

### 11.6 术语表

[TI 术语表](#) 本术语表列出并解释了术语、首字母缩略词和定义。

## 12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

## PACKAGING INFORMATION

| Orderable Device | Status<br>(1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan<br>(2) | Lead finish/<br>Ball material<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|-----------------|------|-------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| INA280A1IDCKR    | ACTIVE        | SC70         | DCK             | 5    | 3000        | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 125   | 1HP                     | <a href="#">Samples</a> |
| INA280A2IDCKR    | ACTIVE        | SC70         | DCK             | 5    | 3000        | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 125   | 1HQ                     | <a href="#">Samples</a> |
| INA280A2IDCKT    | ACTIVE        | SC70         | DCK             | 5    | 250         | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 125   | 1HQ                     | <a href="#">Samples</a> |
| INA280A3IDCKR    | ACTIVE        | SC70         | DCK             | 5    | 3000        | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 125   | 1HR                     | <a href="#">Samples</a> |
| INA280A3IDCKT    | ACTIVE        | SC70         | DCK             | 5    | 250         | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 125   | 1HR                     | <a href="#">Samples</a> |
| INA280A4IDCKR    | ACTIVE        | SC70         | DCK             | 5    | 3000        | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 125   | 1HS                     | <a href="#">Samples</a> |
| INA280A5IDCKR    | ACTIVE        | SC70         | DCK             | 5    | 3000        | RoHS & Green    | NIPDAU                               | Level-1-260C-UNLIM   | -40 to 125   | 1HT                     | <a href="#">Samples</a> |

<sup>(1)</sup> The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

<sup>(2)</sup> **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

<sup>(4)</sup> There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

<sup>(5)</sup> Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

<sup>(6)</sup> Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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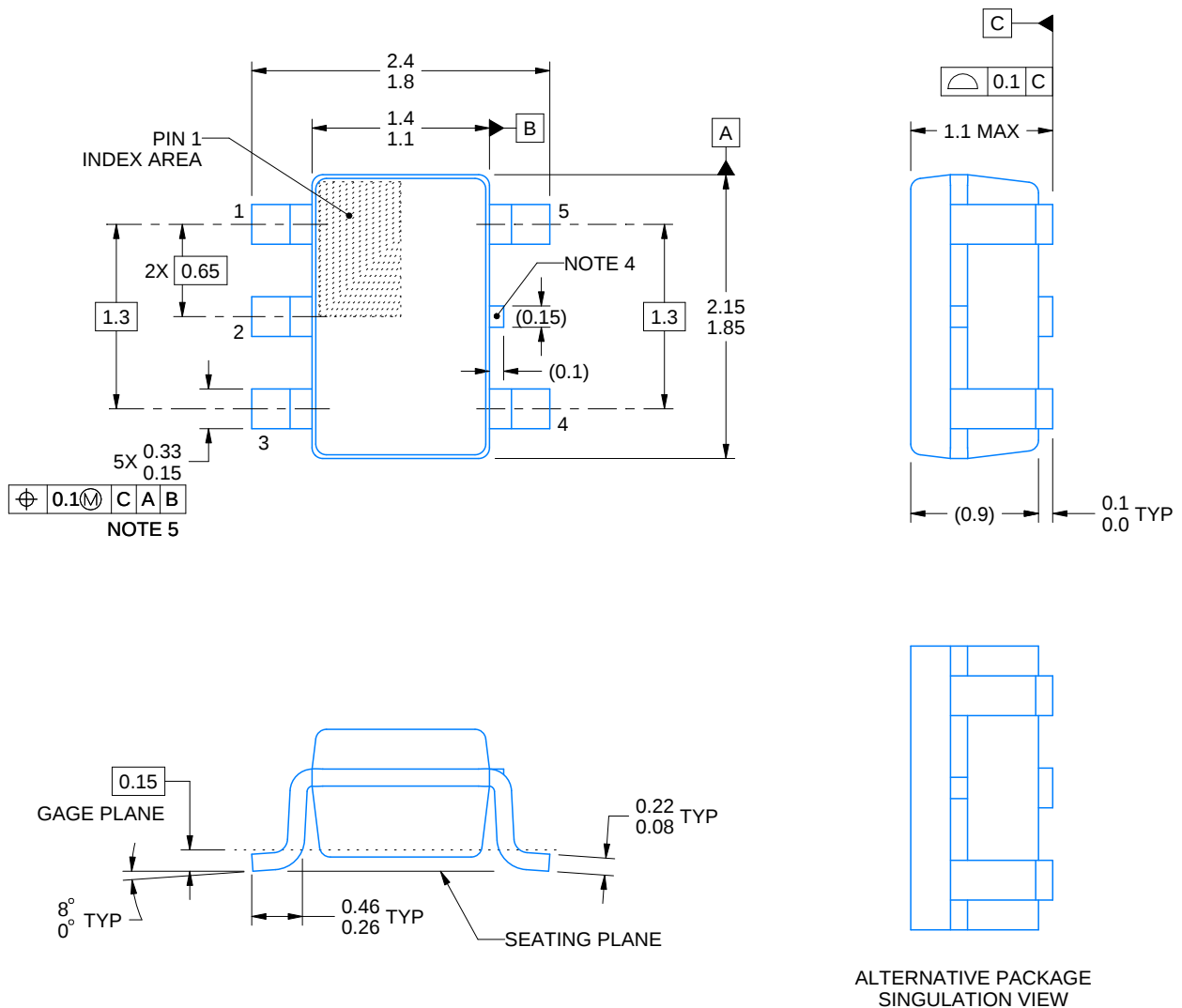
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

**OTHER QUALIFIED VERSIONS OF INA280 :**

- Automotive : [INA280-Q1](#)

NOTE: Qualified Version Definitions:

- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects



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## NOTES:

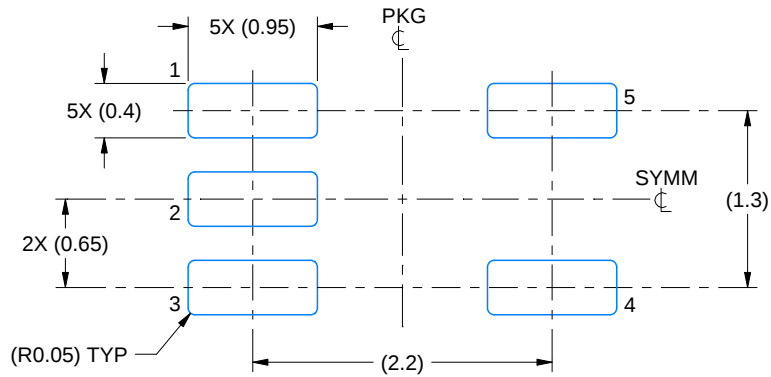
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC MO-203.
4. Support pin may differ or may not be present.
5. Lead width does not comply with JEDEC.
6. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25mm per side

# EXAMPLE BOARD LAYOUT

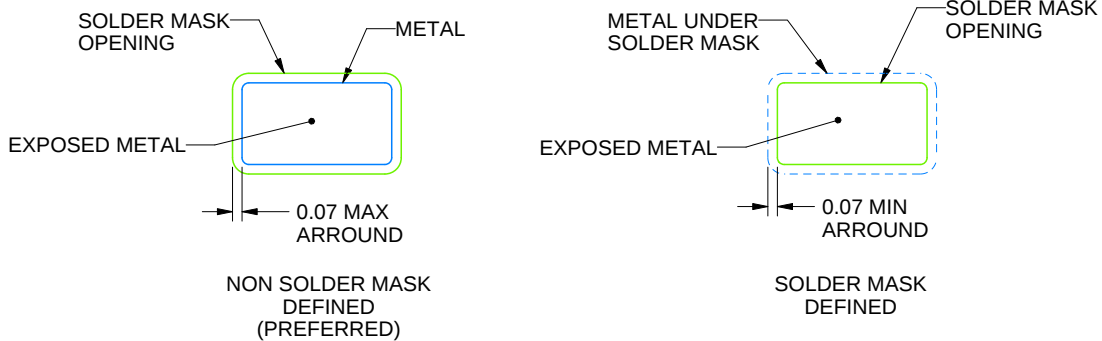
DCK0005A

SOT - 1.1 max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:18X



SOLDER MASK DETAILS

4214834/E 06/2024

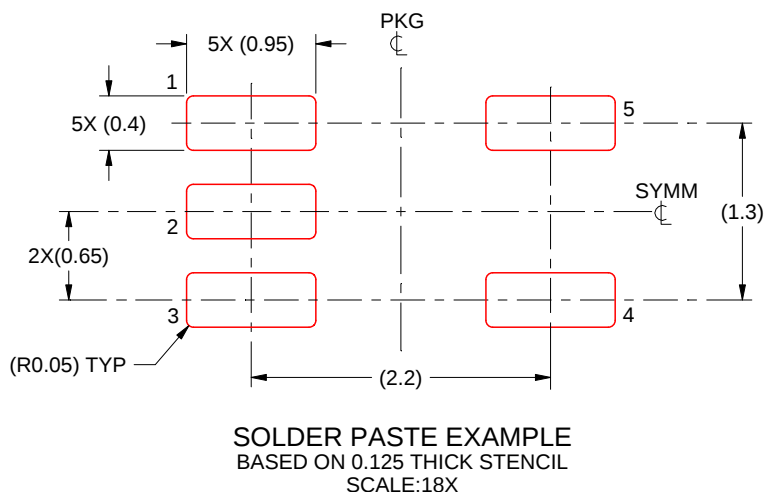
NOTES: (continued)

7. Publication IPC-7351 may have alternate designs.
8. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

**DCK0005A**

### SOT - 1.1 max height

## SMALL OUTLINE TRANSISTOR



4214834/E 06/2024

NOTES: (continued)

9. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
10. Board assembly site may have different recommendations for stencil design.

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