

# INA310x -4V~110V、1.3MHz、超高精度電流センス・アンプ、オープン・ドレイン・コンパレータおよび基準電圧付き

## 1 特長

- 広いコモン・モード電圧範囲:
  - 動作電圧: -4V~+110V
  - 残存電圧: -20V~+120V
- 高い信号帯域幅: 1.3MHz
- スルーレート: 2.5V/μs
- 非常に優れた CMRR: 160dB
- 精度
  - ゲイン誤差 (最大値)
    - バージョン A: 0.15%、10ppm/°C のドリフト
    - バージョン B: 0.5%、20ppm/°C のドリフト
  - オフセット電圧 (最大値)
    - バージョン A: ±20μV、±0.25μV/°C のドリフト
    - バージョン B: ±150μV、±1μV/°C のドリフト
- オンボードのオープン・ドレイン・コンパレータ
- 内部のコンパレータ基準電圧: 0.6V
- 伝搬遅延時間: 1μs
- コンパレータのラッチ機能
- 利用可能なゲイン:
  - INA310A1, INA310B1: 20V/V
  - INA310A2, INA310B2: 50V/V
  - INA310A3, INA310B3: 100V/V
  - INA310A4, INA310B4: 200V/V
  - INA310A5, INA310B5: 500V/V
- パッケージ・オプション: VSSOP-8

## 2 アプリケーション

- 48V DC/DC コンバータ
- 48V バッテリ管理システム (BMS)
- 試験および測定機器
- マクロ・リモート無線ユニット (RRU)
- 48V ラック・サーバー
- 48V 商用ネットワーク / サーバー電源 (PSU)
- ソレノイドとアクチュエータ

## 3 概要

INA310x は、電源電圧に関係なく内蔵のコンパレータにより、-4V~110V の広い同相電圧範囲にわたってシャント抵抗両端での電圧降下を測定できる超高精度の電流センス・アンプです。低いオフセット電圧 (最大値 20μV)、小さいゲイン誤差 (最大値 0.15%)、高い DC CMRR (代表値 160dB) の組み合わせにより、高精度の電流測定が可能です。INA310x は、高電圧 DC 電流測定や、高速過電流保護などの高速アプリケーション向けに設計された、1.3MHz の高い信号帯域幅を備えています。

また、INA310x にはオープン・ドレインのコンパレータと内部基準電圧が組み込まれており、0.6V のスレッシュホールドを実現します。外付けの抵抗分圧器により、電流トリップ・ポイントが設定されます。コンパレータにはラッチ機能があり、RESET ピンをグランドに接続 (またはオープンに保持) することで透過的にできます。

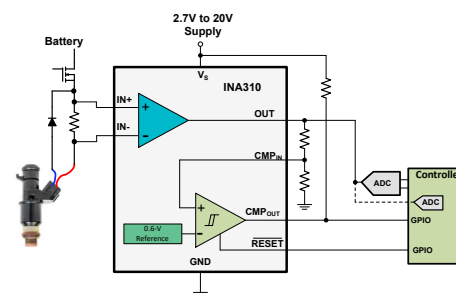
INA310x は 2.7V~20V 単電源で動作し、消費電流は 1.6mA です。INA310x には次の 5 種類のゲイン・オプションが提供されています: 20V/V、50V/V、100V/V、200V/V、500V/V。これらのゲインを選択できるため、ダイナミック・レンジの広い電流センシング・アプリケーションに対応できます。

INA310x は、-40°C~+125°C の動作温度範囲が規定されており、省スペースの 8 ピン VSSOP パッケージで供給されます。

### パッケージ情報<sup>(1)</sup>

| 部品番号    | パッケージ     | 本体サイズ (公称)      |
|---------|-----------|-----------------|
| INA310A | VSSOP (8) | 3.00mm × 3.00mm |
| INA310B |           |                 |

- (1) 利用可能なパッケージについては、データシートの末尾にあるパッケージ・オプションについての付録を参照してください。



代表的なアプリケーション



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## 4 Revision History

| DATE       | REVISION | NOTES           |
|------------|----------|-----------------|
| March 2023 | *        | Initial release |

## 5 Pin Configuration and Functions

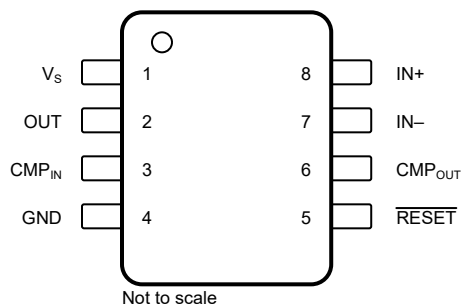


図 5-1. INA310x: DGK Package 8-Pin VSSOP Top View

表 5-1. Pin Functions

| PIN                |    | TYPE   | DESCRIPTION  |
|--------------------|----|--------|--|
| NAME               | NO |        |  |
| V <sub>S</sub>     | 1  | Power  | Power supply, 2.7 V to 20 V  |
| OUT                | 2  | Output | Output voltage   |
| CMP <sub>IN</sub>  | 3  | Input  | Comparator input   |
| GND                | 4  | Ground | Ground   |
| RESET              | 5  | Input  | Comparator reset pin, active low (Low: Transparent Mode, High: Latch Mode)   |
| CMP <sub>OUT</sub> | 6  | Output | Comparator output (latch high when $\overline{\text{RESET}}$ = High)   |
| IN <sub>-</sub>    | 7  | Input  | Shunt resistor negative sense input. For high-side applications, connect to load side of sense resistor. For low-side applications, connect to ground side of sense resistor.      |
| IN <sub>+</sub>    | 8  | Input  | Shunt resistor positive sense input. For high-side applications, connect to bus-voltage side of sense resistor. For low-side applications, connect to load side of sense resistor. |

## 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    |
| V <sub>IN+</sub> , V <sub>IN−</sub> | Analog inputs              | Differential (V <sub>IN+</sub> ) − (V <sub>IN−</sub> ) <sup>(2)</sup>    | −12       | 12                           | V    |
|                                     |                            | V <sub>IN+</sub> , V <sub>IN−</sub> , with respect to GND <sup>(2)</sup> | −20       | 120                          | V    |
| V <sub>OUT</sub>                    | Analog output              |  | GND − 0.3 | (V <sub>S</sub> ) + 0.3      | V    |
|                                     | Comparator reset pin       |  | GND − 0.3 | (V <sub>S</sub> ) + 0.3      | V    |
|                                     | Comparator analog input    |  | GND − 0.3 | MIN of 5.5 or V <sub>S</sub> | V    |
|                                     | Comparator Output          |  | GND − 0.3 | 22                           | V    |
|                                     | Input current into any pin |  |           | 5                            | mA   |
| T <sub>A</sub>                      | Operating temperature      |  | −55       | 150                          | °C   |
| T <sub>J</sub>                      | Junction temperature       |  | −65       | 150                          | °C   |
| T <sub>stg</sub>                    | Storage temperature        |  | −65       | 150                          | °C   |

- (1) Operation outside the Absolute Maximum Ratings may cause permanent device damage. Absolute Maximum Ratings do not imply functional operation of the device at these or any other conditions beyond those listed under Recommended Operating Conditions. If used outside the Recommended Operating Conditions but within the Absolute Maximum Ratings, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.
- (2) V<sub>IN+</sub> and V<sub>IN−</sub> are the voltages at the IN+ and IN− 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 ANSI/ESDA/JEDEC JS-002, 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        | −4  | 48  | 110                | V    |
| V <sub>S</sub>     | Operating supply voltage       | 2.7 | 5   | 20                 | V    |
| V <sub>SENSE</sub> | Differential sense input range | 0   |     | V <sub>S</sub> / G | V    |
| T <sub>A</sub>     | Operating free-air temperature | −40 |     | 125                | °C   |

### 6.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |  | INA310x     | UNIT |
|-------------------------------|--|-------------|------|
|                               |  | DGK (VSSOP) |      |
|                               |  | 8 PINS      |      |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance       | 172.2       | °C/W |
| R <sub>θJC(top)</sub>         | Junction-to-case (top) thermal resistance    | 63.5        | °C/W |
| R <sub>θJB</sub>              | Junction-to-board thermal resistance         | 93.8        | °C/W |
| Ψ <sub>JT</sub>               | Junction-to-top characterization parameter   | 9.8         | °C/W |
| Ψ <sub>JB</sub>               | Junction-to-board characterization parameter | 92.2        | °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  $T_A = 25^\circ\text{C}$ ,  $V_{\text{SENSE}} = V_{\text{IN}+} - V_{\text{IN}-} = 0.5\text{ V}$  / Gain,  $V_S = 5.0\text{ V}$ ,  $V_{\text{CM}} = V_{\text{IN}-} = 48\text{ V}$ , and  $R_{\text{PULLUP}} = 5.1\text{ k}\Omega$  connected from  $\text{CMP}_{\text{out}}$  to  $V_S$ , (unless otherwise noted)

| PARAMETER                |                                    | CONDITIONS   | MIN | TYP                    | MAX                     | UNIT                         |
|--------------------------|------------------------------------|--|-----|------------------------|-------------------------|------------------------------|
| <b>INPUT</b>             |                                    |  |     |                        |                         |                              |
| $V_{\text{CM}}$          | Common-mode input range            | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$  | –4  |                        | 110                     | V                            |
| CMRR                     | Common-mode rejection ratio        | INA310Ax, $V_{\text{IN}+} = -4\text{ V}$ to $110\text{ V}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                               | 140 | 160                    |                         | dB                           |
|                          |                                    | INA310Ax, $f = 50\text{ kHz}$  |     | 85                     |                         |                              |
|                          |                                    | INA310Bx, $V_{\text{IN}+} = -4\text{ V}$ to $110\text{ V}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                               | 120 | 140                    |                         |                              |
|                          |                                    | INA310Bx, $f = 50\text{ kHz}$  |     | 65                     |                         |                              |
| $V_{\text{OS}}$          | Offset voltage, RTI <sup>(1)</sup> | INA310A1   |     | $\pm 30$               | $\pm 150$               | $\mu\text{V}$                |
|                          |                                    | INA310B1   |     | $\pm 100$              | $\pm 500$               |                              |
|                          |                                    | INA310A2   |     | $\pm 15$               | $\pm 80$                |                              |
|                          |                                    | INA310B2   |     | $\pm 55$               | $\pm 300$               |                              |
|                          |                                    | INA310A3   |     | $\pm 10$               | $\pm 50$                |                              |
|                          |                                    | INA310B3   |     | $\pm 30$               | $\pm 250$               |                              |
|                          |                                    | INA310A4   |     | $\pm 5$                | $\pm 30$                |                              |
|                          |                                    | INA310B4   |     | $\pm 30$               | $\pm 200$               |                              |
|                          |                                    | INA310A5   |     | $\pm 2$                | $\pm 20$                |                              |
| $dV_{\text{OS}}/dT$      | Offset drift, RTI                  | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ , INA310A1, INA310A2, INA310A3   |     | $\pm 0.05$             | $\pm 0.5$               | $\mu\text{V}/^\circ\text{C}$ |
|                          |                                    | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ , INA310A4, INA310A5   |     | $\pm 0.025$            | $\pm 0.25$              |                              |
|                          |                                    | $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ , INA310Bx   |     | $\pm 0.1$              | $\pm 1$                 |                              |
| PSRR                     | Power-supply rejection ratio, RTI  | INA310A1, $2.7\text{ V} \leq V_S \leq 20\text{ V}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                                       |     | $\pm 1$                | $\pm 8$                 | $\mu\text{V}/\text{V}$       |
|                          |                                    | INA310A2, INA310A3, $2.7\text{ V} \leq V_S \leq 20\text{ V}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                             |     | $\pm 0.3$              | $\pm 3$                 |                              |
|                          |                                    | INA310A4, INA310A5, $2.7\text{ V} \leq V_S \leq 20\text{ V}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                             |     | $\pm 0.1$              | $\pm 1$                 |                              |
|                          |                                    | INA310Bx $2.7\text{ V} \leq V_S \leq 20\text{ V}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$  |     | $\pm 1.5$              | $\pm 10$                |                              |
| $I_B$                    | Input bias current                 | $I_{B+}$ , $I_{B-}$ , $V_{\text{SENSE}} = 0\text{ mV}$   | 10  | 20                     | 30                      | $\mu\text{A}$                |
| <b>OUTPUT</b>            |                                    |  |     |                        |                         |                              |
| G                        | Gain                               | INA310A1, INA310B1   |     | 20                     |                         | V/V                          |
|                          |                                    | INA310A2, INA310B2   |     | 50                     |                         |                              |
|                          |                                    | INA310A3, INA310B3   |     | 100                    |                         |                              |
|                          |                                    | INA310A4, INA310B4   |     | 200                    |                         |                              |
|                          |                                    | INA310A5, INA310B5   |     | 500                    |                         |                              |
| $G_{\text{ERR}}$         | Gain error                         | INA310Ax, $\text{GND} + 50\text{ mV} \leq V_{\text{OUT}} \leq V_S - 200\text{ mV}$   |     | $\pm 0.02\%$           | $\pm 0.15\%$            | $\text{ppm}/^\circ\text{C}$  |
|                          |                                    | INA310Bx, $\text{GND} + 50\text{ mV} \leq V_{\text{OUT}} \leq V_S - 200\text{ mV}$   |     | $\pm 0.07\%$           | $\pm 0.5\%$             |                              |
|                          |                                    | INA310Ax, $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$  |     | 1                      | 10                      |                              |
|                          |                                    | INA310Bx, $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$  |     | 2                      | 20                      |                              |
| $\text{NL}_{\text{ERR}}$ | Nonlinearity error                 | $\text{GND} + 50\text{ mV} \leq V_{\text{OUT}} \leq V_S - 200\text{ mV}$   |     | $\pm 0.01$             |                         | %                            |
|                          | Maximum capacitive load            | No sustained oscillation, no isolation resistor  |     | 500                    |                         | pF                           |
| <b>VOLTAGE OUTPUT</b>    |                                    |  |     |                        |                         |                              |
| $V_{\text{SP}}$          | Swing to $V_S$ (Power-supply rail) | $R_{\text{LOAD}} = 10\text{ k}\Omega$ to $\text{GND}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$                                    |     | $(V_S) - 70$           | $(V_S) - 150$           | mV                           |
| $V_{\text{SN}}$          | Swing to $\text{GND}$              | $R_{\text{LOAD}} = 10\text{ k}\Omega$ to $\text{GND}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ , $V_{\text{SENSE}} = 0\text{ mV}$ |     | $(V_{\text{GND}}) + 5$ | $(V_{\text{GND}}) + 20$ | mV                           |

at  $T_A = 25^\circ\text{C}$ ,  $V_{\text{SENSE}} = V_{\text{IN}+} - V_{\text{IN}-} = 0.5\text{ V}$  / Gain,  $V_S = 5.0\text{ V}$ ,  $V_{\text{CM}} = V_{\text{IN}-} = 48\text{ V}$ , and  $R_{\text{PULLUP}} = 5.1\text{ k}\Omega$  connected from  $\text{CMP}_{\text{out}}$  to  $V_S$ , (unless otherwise noted)

| PARAMETER              |   | CONDITIONS  | MIN  | TYP | MAX | UNIT   |    |
|------------------------|---|---|------|-----|-----|--------|----|
| FREQUENCY RESPONSE     |   |   |      |     |     |        |    |
| BW                     | Bandwidth   | INA310A1, INA310B1, C <sub>LOAD</sub> = 5 pF, V <sub>SENSE</sub> = 200mV        | 1300 |     |     | kHz    |    |
|                        |   | INA310A2, INA310B2, C <sub>LOAD</sub> = 5 pF, V <sub>SENSE</sub> = 80mV         | 1300 |     |     |        |    |
|                        |   | INA310A3, INA310B3, C <sub>LOAD</sub> = 5 pF, V <sub>SENSE</sub> = 40mV         | 1000 |     |     |        |    |
|                        |   | INA310A4, INA310B4, C <sub>LOAD</sub> = 5 pF, V <sub>SENSE</sub> = 20mV         | 900  |     |     |        |    |
|                        |   | INA310A5, INA310B5, C <sub>LOAD</sub> = 5 pF, V <sub>SENSE</sub> = 8mV          | 900  |     |     |        |    |
| SR                     | Slew rate   | Rising edge   | 2.5  |     |     | V/μs   |    |
| t <sub>S</sub>         | Settling time   | V <sub>OUT</sub> = 4 V ± 0.1 V step, Output settles to 0.5%                     | 10   |     |     | μs     |    |
|                        |   | V <sub>OUT</sub> = 4 V ± 0.1 V step, Output settles to 1%                       | 5    |     |     | μs     |    |
|                        |   | V <sub>OUT</sub> = 4 V ± 0.1 V step, Output settles to 5%                       | 1    |     |     | μs     |    |
| NOISE                  |   |   |      |     |     |        |    |
| V <sub>en</sub>        | Voltage noise density                                   |   | 50   |     |     | nV/√Hz |    |
| COMPARATOR             |   |   |      |     |     |        |    |
| V <sub>THRESHOLD</sub> | Alert threshold   | T <sub>A</sub> = 25°C   | 585  | 600 | 615 | mV     |    |
|                        |   | T <sub>A</sub> = −40°C to +125°C  | 580  |     | 620 | mV     |    |
|                        | Hysteresis  | T <sub>A</sub> = 25°C   | 8    |     |     | mV     |    |
| t <sub>p</sub>         | Small-signal propagation delay                          | Comparator input overdrive = 20 mV  | 1    |     |     | μs     |    |
|                        | Slew-rate-limited propagation delay                     | V <sub>OUT</sub> step = 0.5 V to 4.5 V, V <sub>LIMIT</sub> <sup>(3)</sup> = 4 V | 1.6  |     |     | μs     |    |
| I <sub>BCMPIN</sub>    | Input bias current, CMP <sub>in</sub> PIN               | T <sub>A</sub> = 25°C, V <sub>CMPIN</sub> = 0.4 V to 1.2 V                      | −20  | 1   | 20  | nA     |    |
|                        |   | T <sub>A</sub> = −40°C to +125°C, V <sub>CMPIN</sub> = 0.4 V to 1.2 V           |      |     | 250 | nA     |    |
| I <sub>LKG</sub>       | High-level leakage current                              | V <sub>CMPout</sub> = V <sub>S</sub>  | 1    |     |     | μA     |    |
| V <sub>OL</sub>        | Low-level output voltage                                | I <sub>OL</sub> = 2.35 mA   | 300  |     |     | mV     |    |
|                        |   | T <sub>A</sub> = −40°C to +125°C, I <sub>OL</sub> = 2.35 mA                     | 350  |     |     | mV     |    |
| V <sub>IH</sub>        | RESET High-level input voltage threshold <sup>(2)</sup> | T <sub>A</sub> = −40°C to +125°C  | 1.2  |     |     | V      |    |
| V <sub>IL</sub>        | RESET Low-level input voltage threshold <sup>(2)</sup>  | T <sub>A</sub> = −40°C to +125°C  | 0.4  |     |     | V      |    |
|                        | Minimum RESET pulse width                               | T <sub>A</sub> = −40°C to +125°C  | 100  |     |     | 200    | ns |
|                        | RESET propagation delay                                 |   | 250  |     |     | ns     |    |
| POWER SUPPLY           |   |   |      |     |     |        |    |
| V <sub>S</sub>         | Supply voltage range                                    | T <sub>A</sub> = −40°C to +125°C  | 2.7  |     |     | 20     | V  |
| I <sub>Q</sub>         | Quiescent current                                       |   | 1.6  |     |     | 2      | mA |
|                        |   | T <sub>A</sub> = −40°C to +125°C  |      |     |     | 2.25   | mA |

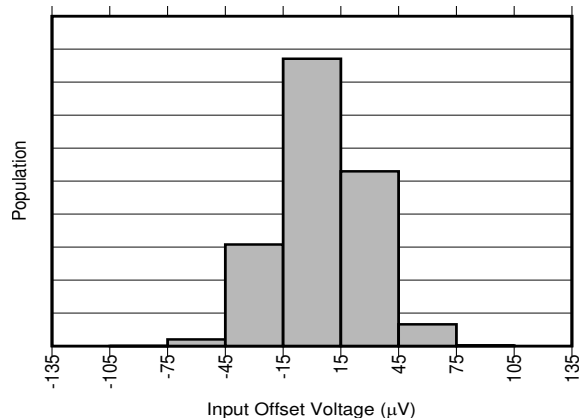
(1) RTI = referred-to-input.

(2) The RESET input has an internal 2 M $\Omega$  (typical) pull-down. Leaving RESET open results in a LOW state, with transparent comparator operation.

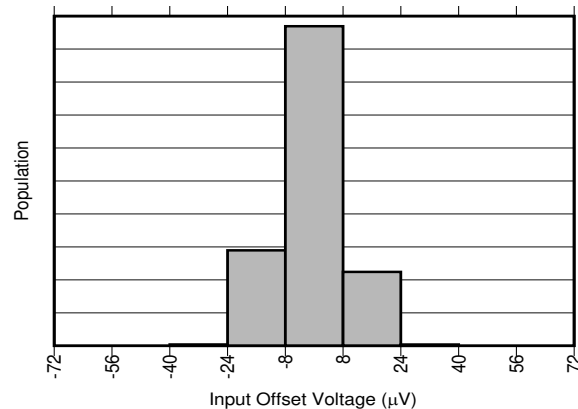
(3)  $V_{\text{LIMIT}}$  is  $V_{\text{OUT}}$  at the overcurrent threshold set by external resistors.

## 6.6 Typical Characteristics

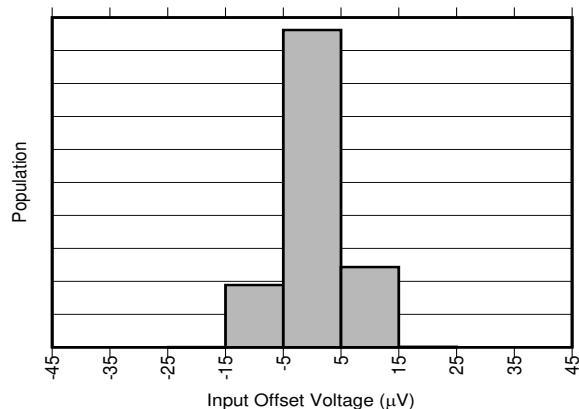
at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $V_{\text{SENSE}} = V_{\text{IN}+} - V_{\text{IN}-} = 0.5\text{ V} / \text{Gain}$ ,  $V_{\text{CM}} = V_{\text{IN}-} = 48\text{ V}$ , and  $R_{\text{PULLUP}} = 5.1\text{ k}\Omega$  (unless otherwise noted).



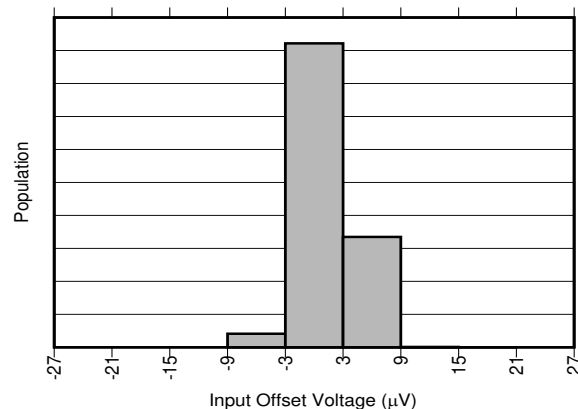
**FIG 6-1. INA310A1 Input Offset Production Distribution**



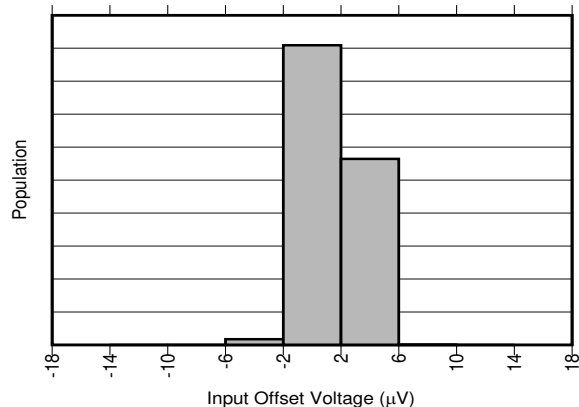
**FIG 6-2. INA310A2 Input Offset Production Distribution**



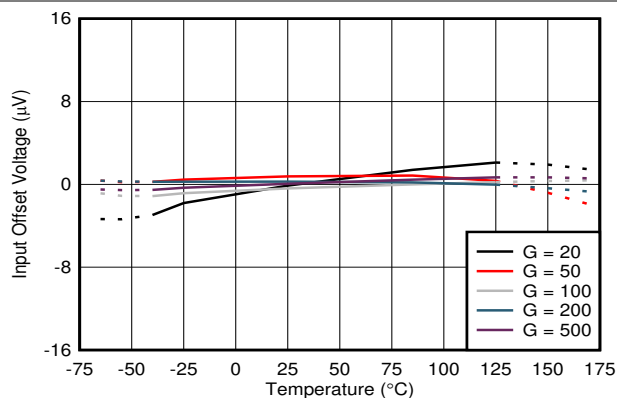
**FIG 6-3. INA310A3 Input Offset Production Distribution**



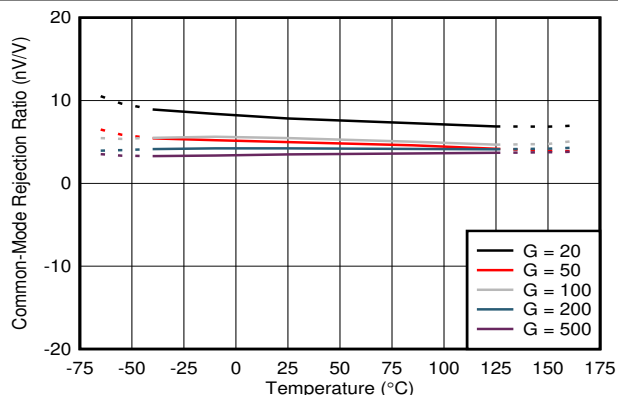
**FIG 6-4. INA310A4 Input Offset Production Distribution**



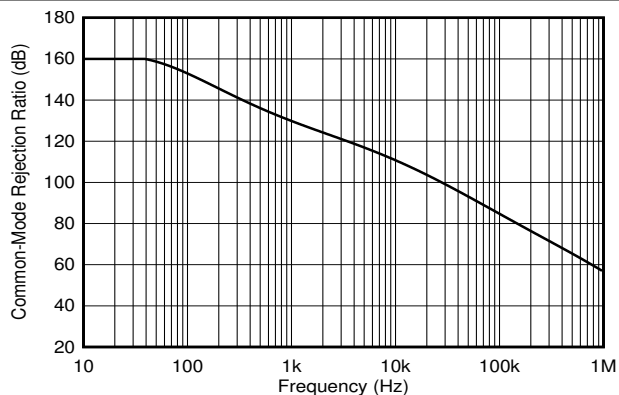
**FIG 6-5. INA310A5 Input Offset Production Distribution**



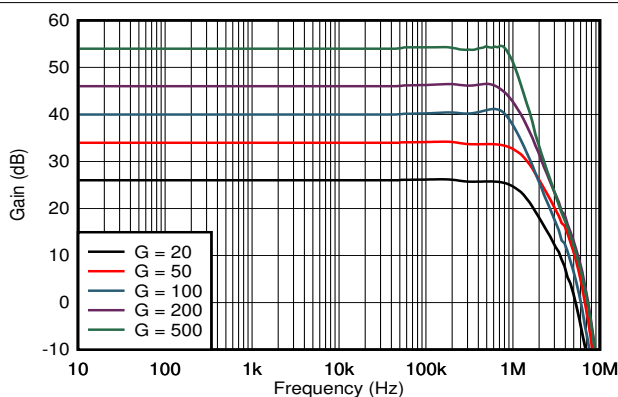
**FIG 6-6. Input Offset Voltage vs Temperature**



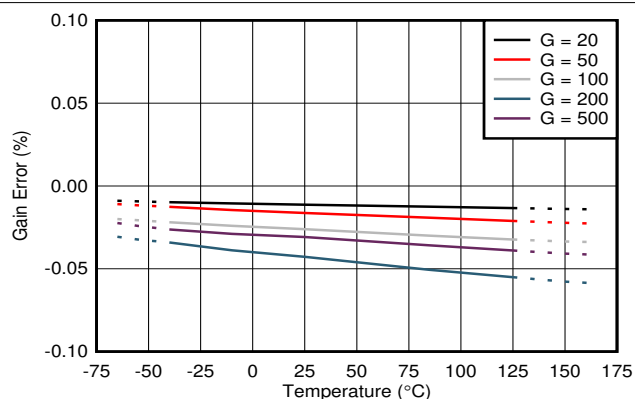
**Figure 6-7. Common-Mode Rejection Ratio vs Temperature**



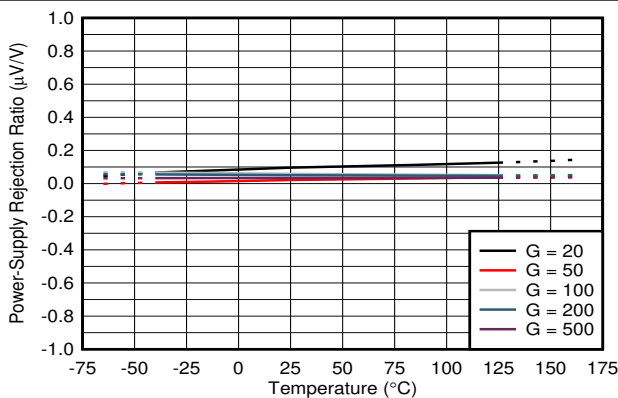
**Figure 6-8. Common-Mode Rejection Ratio vs Frequency**



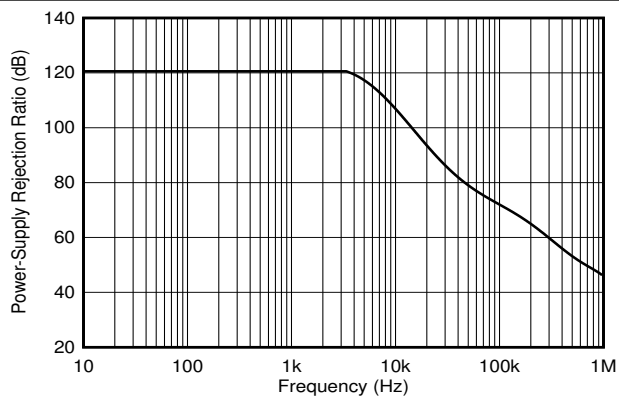
**Figure 6-9. Gain vs Frequency**



**Figure 6-10. INA310A Gain Error vs Temperature**

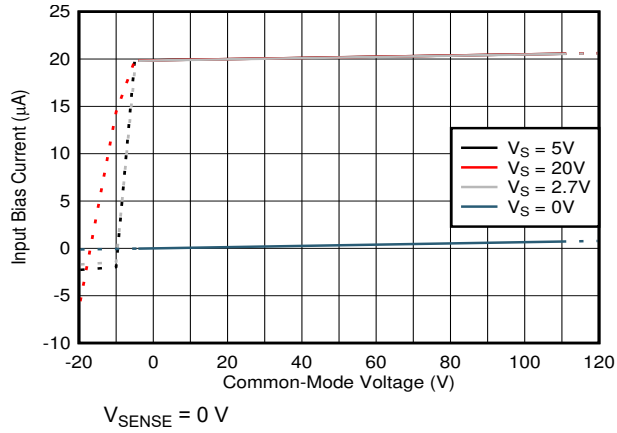


**Figure 6-11. Power-Supply Rejection Ratio vs Temperature**

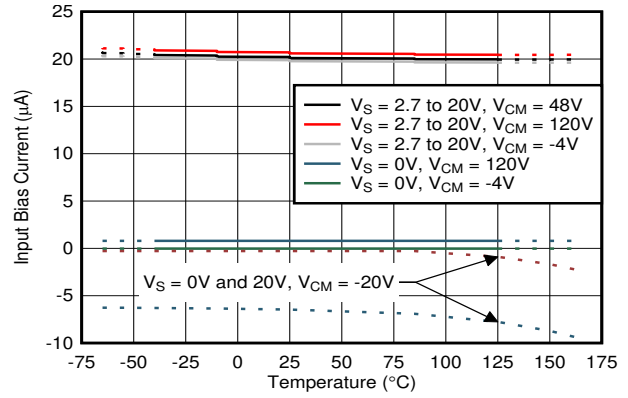


**Figure 6-12. Power-Supply Rejection Ratio vs Frequency**

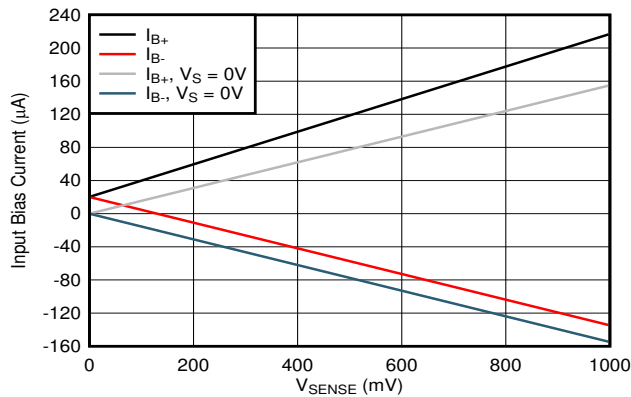




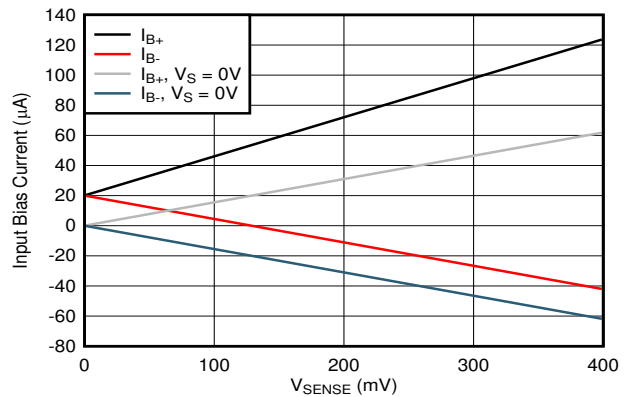
**6-13. Input Bias Current vs Common-Mode Voltage**



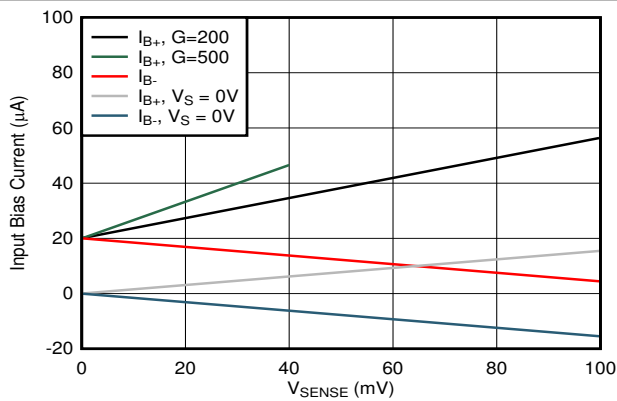
**6-14. Input Bias Current vs Temperature**



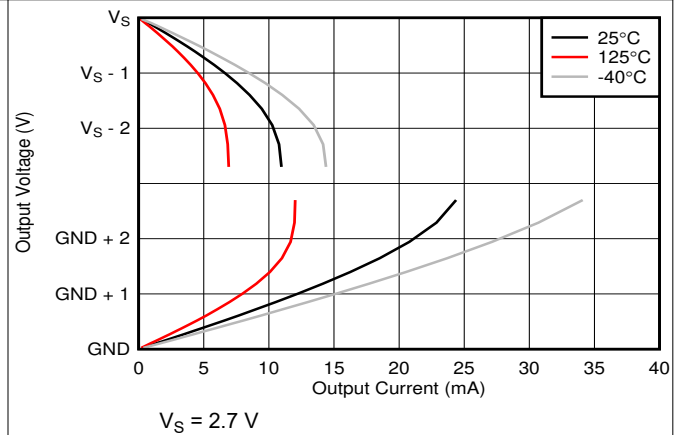
**6-15. INA310x1 Input Bias Current vs  $V_{SENSE}$**



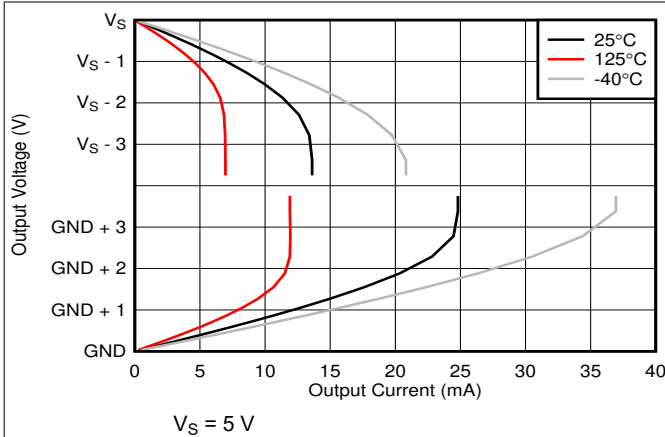
**6-16. INA310x2, INA310x3 Input Bias Current vs  $V_{SENSE}$**



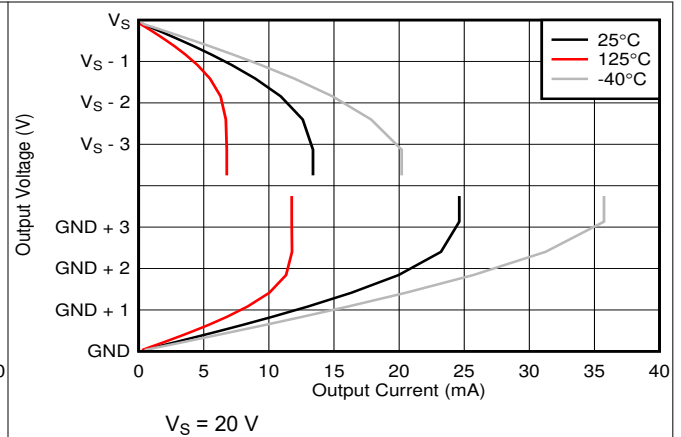
**6-17. INA310x4, INA310x5 Input Bias Current vs  $V_{SENSE}$**



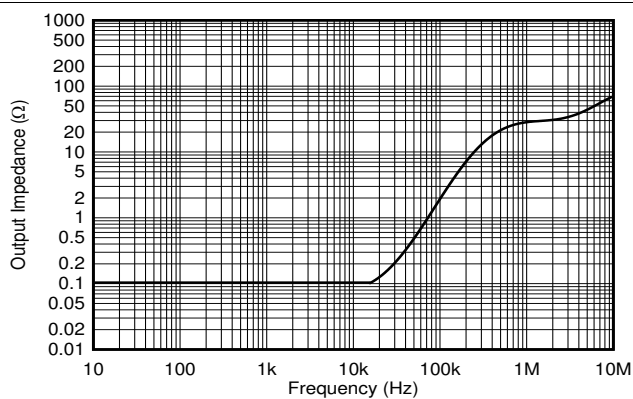
**6-18. Output Voltage vs Output Current**



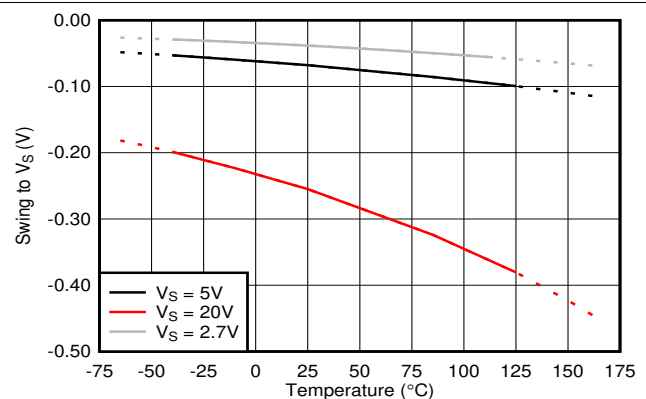
6-19. Output Voltage vs Output Current



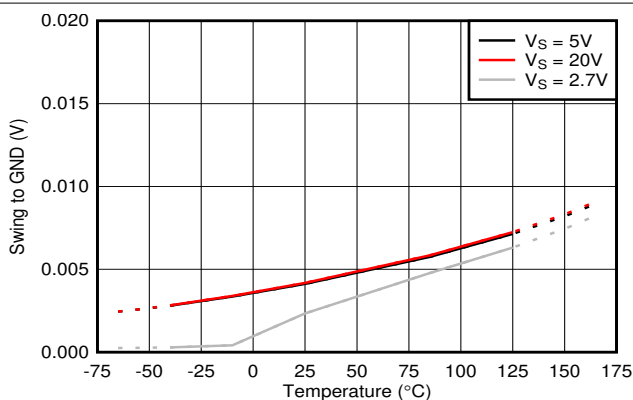
6-20. Output Voltage vs Output Current



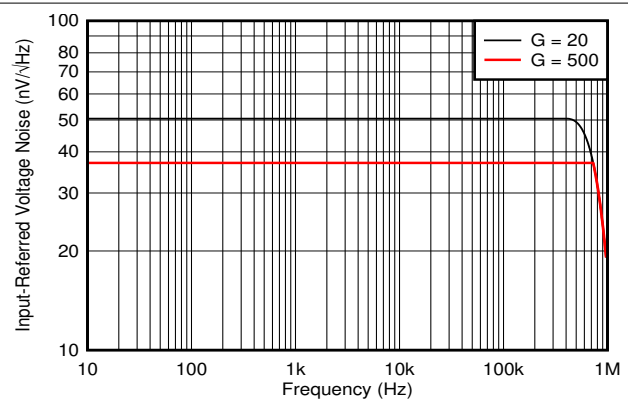
6-21. Output Impedance vs Frequency



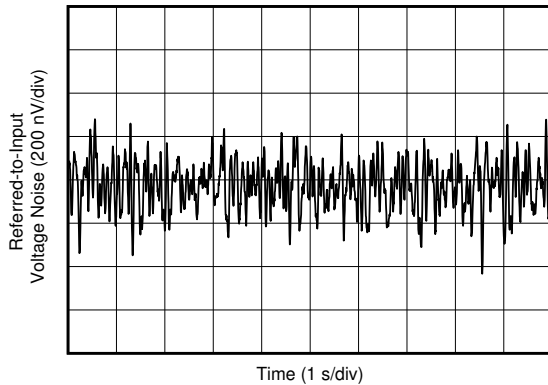
6-22. Swing to Supply vs Temperature



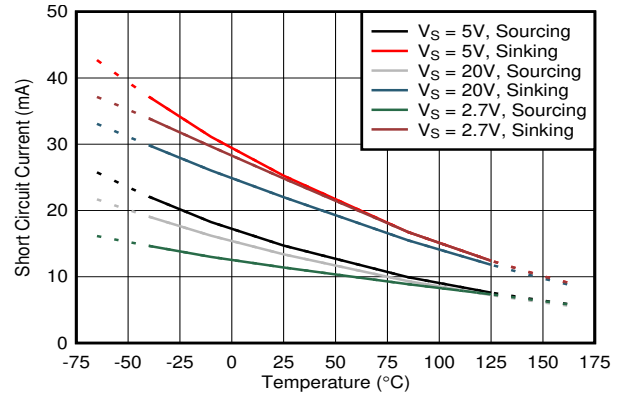
6-23. Swing to GND vs Temperature



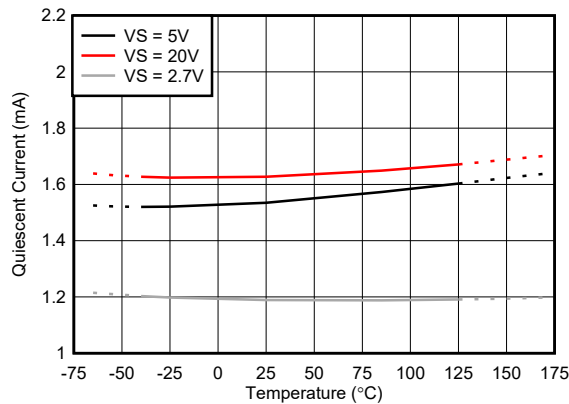
6-24. Input Referred Noise vs Frequency



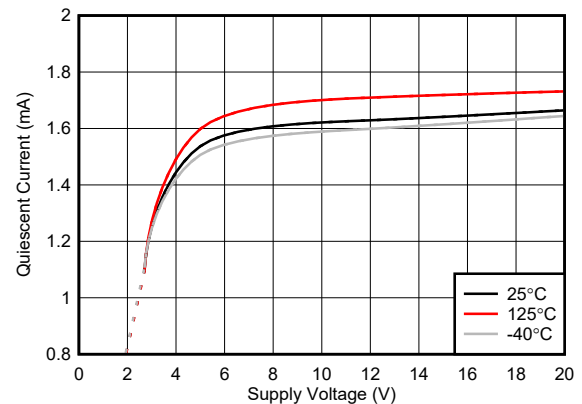
**6-25. Input Referred Noise**



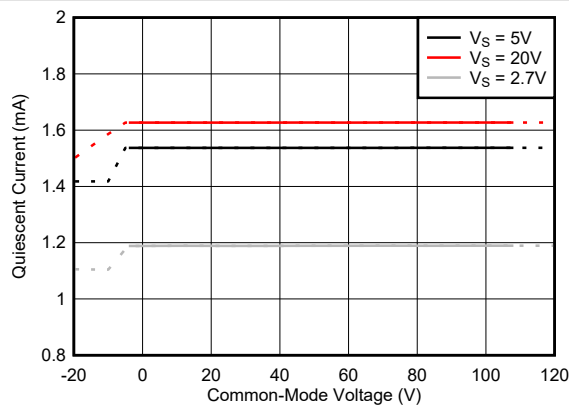
**6-26. Short-Circuit Current vs Temperature**



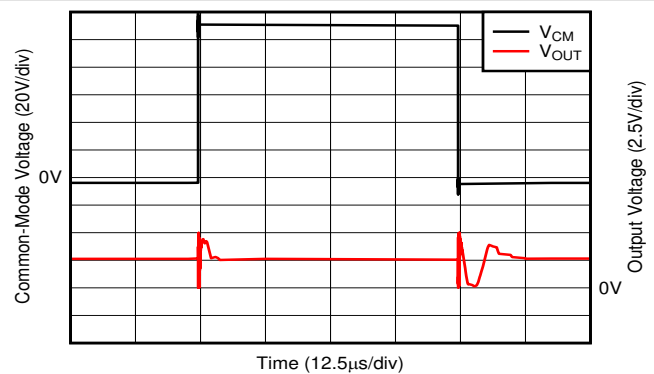
**6-27. Quiescent Current vs Temperature**



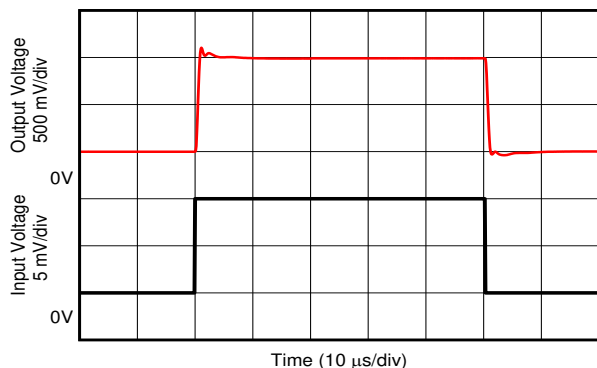
**6-28. Quiescent Current vs Supply Voltage**



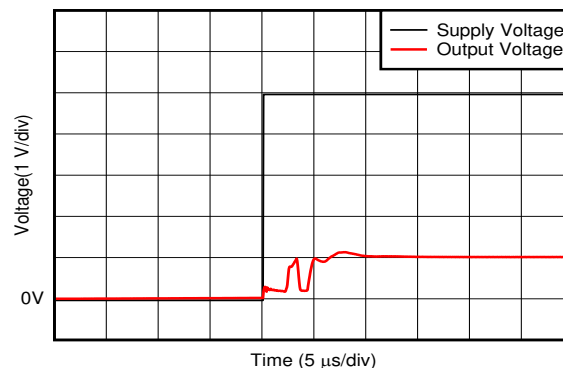
**6-29. Quiescent Current vs Common-Mode Voltage**



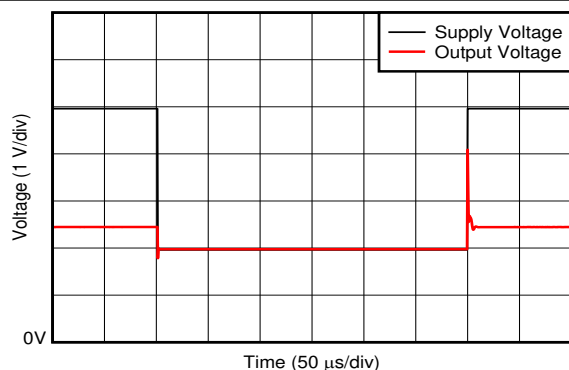
**6-30. Common-Mode Voltage Fast Transient Pulse**



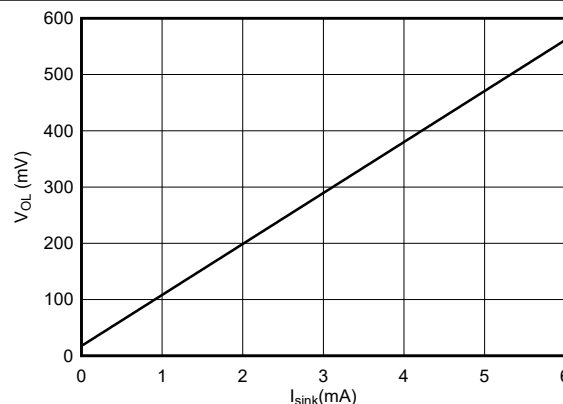
6-31. INA310x3 Step Response



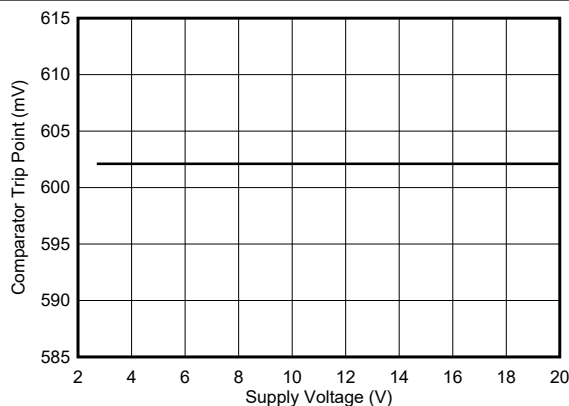
6-32. Start-Up Response



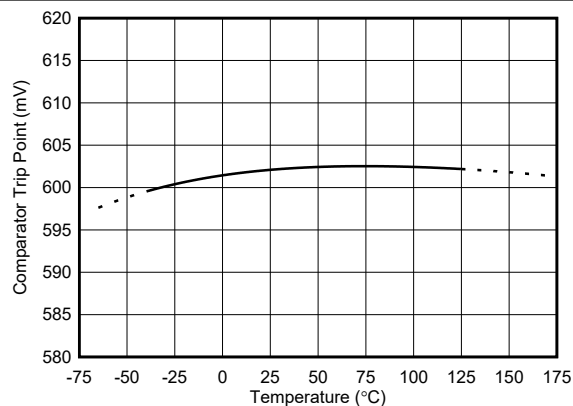
6-33. Supply Transient Response



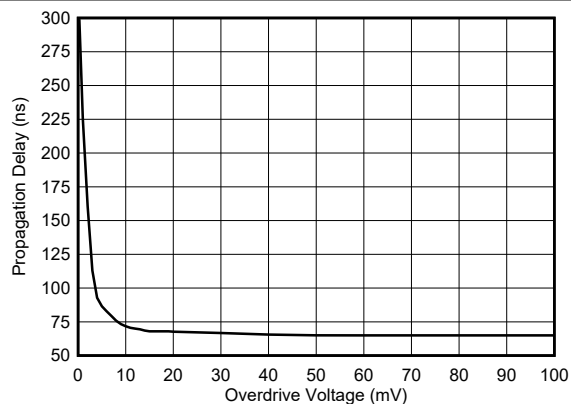
6-34. Comparator  $V_{OL}$  vs  $I_{SINK}$



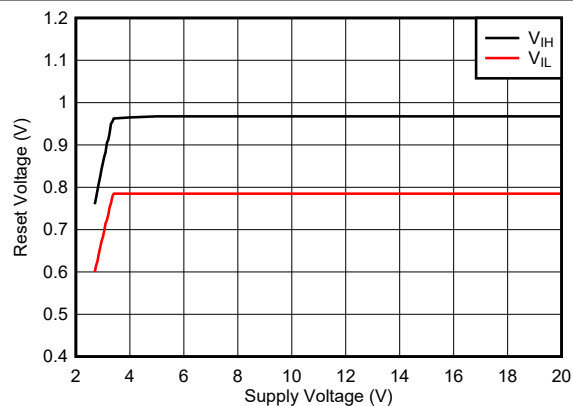
6-35. Comparator Trip Point vs Supply Voltage



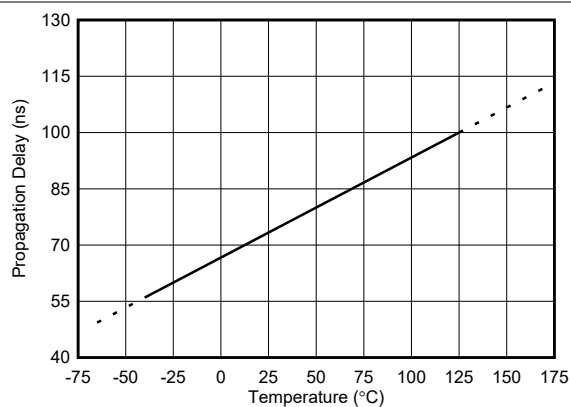
6-36. Comparator Trip Point vs Temperature



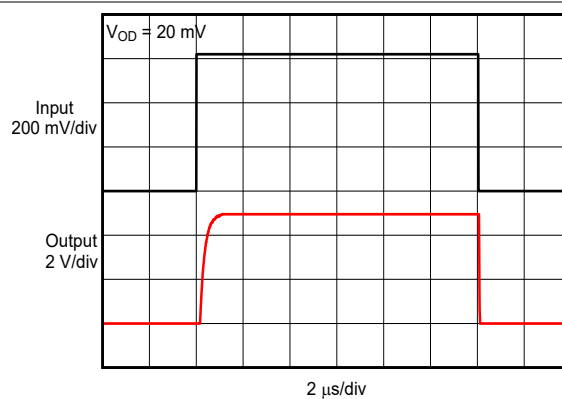
**6-37. Comparator Propagation Delay vs Overdrive Voltage**



**6-38. Comparator Reset Voltage vs Supply Voltage**



**6-39. Comparator Propagation Delay vs Temperature**



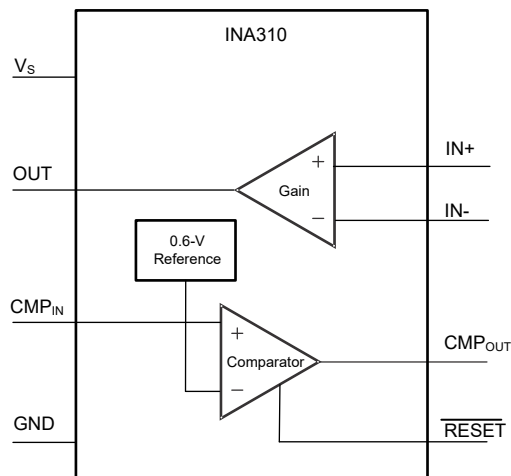
**6-40. Comparator Propagation Delay**

## 7 Detailed Description

### 7.1 Overview

The INA310x is a high or low-side high-speed current-sense amplifier that offers a wide common-mode range, precision zero-drift topology, excellent common-mode rejection ratio (CMRR) and fast slew rate. Different gain versions are available to optimize the output dynamic range based on the application. The INA310x is designed using an architecture that enables low input bias current of 20  $\mu$ A with a specified common-mode voltage range from  $-4$  V to 110 V with signal bandwidths up to 1.3 MHz. The INA310x incorporates an open-drain comparator and internal reference providing a 0.6-V threshold. An external resistor divider sets the current trip point. The comparator includes a latching capability, that can be made transparent by grounding (or leaving open) the  $\overline{\text{RESET}}$  pin (see the [RESET Function](#) section).

### 7.2 Functional Block Diagram



### 7.3 Feature Description

#### 7.3.1 Amplifier Input Common-Mode Signal

The INA310x supports large input common-mode voltages from  $-4$  V to  $+110$  V. The internal topology of the INA310x enables the common-mode range to not be restricted by the power-supply voltage ( $V_S$ ). Due to this feature, the INA310x can be used for both low-side and high-side current-sensing applications that extend beyond the supply range of 2.7 V to 20 V.

#### 7.3.2 Input-Signal Bandwidth

The INA310x is available with several gain options, including 20 V/V, 50 V/V, 100 V/V, 200 V/V, and 500 V/V. 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.

#### 7.3.3 Low Input Bias Current

The INA310x inputs draw a 20- $\mu$ A input bias current per pin at a common-mode voltage as high as 110 V, which enables precision current sensing on applications that require lower current leakage. Unlike many high voltage current sense amplifiers whose input bias currents are proportional to the common-mode voltage, the input bias current of the INA310x remains flat over the entire common-mode voltage range.

#### 7.3.4 Low $V_{\text{SENSE}}$ Operation

The INA310x features high performance operation across the entire valid  $V_{\text{SENSE}}$  range. The zero-drift input architecture of the INA310x provides the low offset voltage and low offset drift needed to measure low  $V_{\text{SENSE}}$  levels accurately across the wide operating temperature of  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ . Low  $V_{\text{SENSE}}$  operation is particularly beneficial when using low ohmic shunts for high current measurements, as power losses across the

shunt are significantly reduced.  $V_{SENSE}$  low level is only limited by the output swing to GND ( $V_{SN}$ ). The minimum  $V_{SENSE}$  is limited to  $V_{SN}$  divided by Gain.

### 7.3.5 Wide Fixed Gain Output

The INA310x maximum gain error is 0.15% at room temperature, with a maximum drift of 10 ppm/°C over the full temperature range of –40°C to +125°C. The INA310x 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, such as the dynamic current range and full-scale output voltage target.

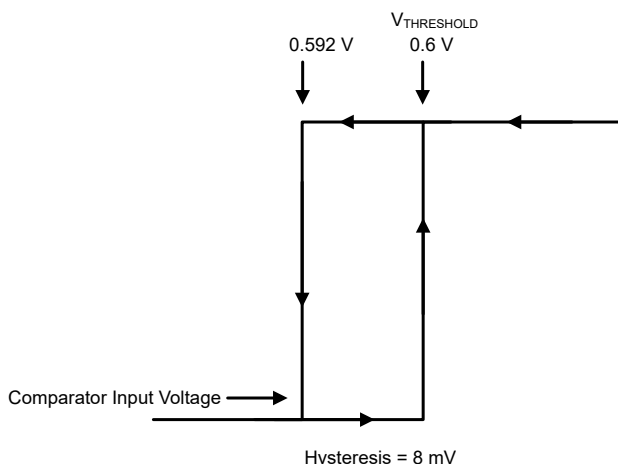
The INA310x closed-loop gain is set by a precision, low-drift internal resistor network. The ratio of these resistors are excellently matched, while the absolute values may vary significantly. TI does not recommend adding additional resistance around the INA310x to change the effective gain because of this variation.

### 7.3.6 Wide Supply Range

The INA310x operates with a wide supply range from 2.7 V to 20 V. While the input voltage range of the INA310x is independent of the supply voltage, the output voltage is bound by the supply voltage applied to the device. The output voltage can range from as low as 20 mV to as high as 200 mV below the supply voltage.

### 7.3.7 Integrated Comparator

The INA310x incorporates an open-drain comparator with an internal reference providing a 0.6-V threshold. The comparator input ( $CMP_{IN}$ ) can take voltage from 0 V up to 5.5 V or equal to power-supply voltage (if it is lower than 5.5 V). The comparator has a built-in hysteresis of 8 mV (typical). [Figure 7-1](#) shows the hysteresis, which is the difference between the rising-edge threshold and the falling-edge threshold. The hysteresis makes stable switching at the comparator output by providing noise immunity at comparator input.



**Figure 7-1. The Comparator Threshold and Hysteresis**

The open-drain output of the comparator can be tied to voltage range of 0 to 20 V (independent of power supply) through a pullup resistor. When the voltage at the comparator input ( $CMP_{IN}$ ) exceeds 0.6 V, the output of the comparator goes high. When the voltage at the comparator input falls below falling-threshold ( $0.6\text{ V} - \text{Hysteresis}$ ), the output of the comparator is pulled low by an internal open-drain transistor.

### 7.3.8 RESET Function

The  $\overline{\text{RESET}}$  function allows the comparator to work in transparent mode or latching mode. [Figure 7-2](#) shows the two modes of the  $\overline{\text{RESET}}$  function. When the  $\overline{\text{RESET}}$  pin is left open or connected to GND the comparator functions in a transparent mode. In transparent mode comparator output ( $CMP_{OUT}$ ) responds as a normal comparator. When the  $\overline{\text{RESET}}$  pin is connected to the supply voltage, the pin operates in latching mode. In the latching mode when the comparator is triggered by the comparator input going higher than 0.6 V, the output of the comparator stays high irrespective of comparator input after. To release the comparator from the latching mode, the  $\overline{\text{RESET}}$

pin must be pulled to GND or released to open. The  $\overline{\text{RESET}}$  pin can take a voltage range from 0 V to the power-supply voltage.

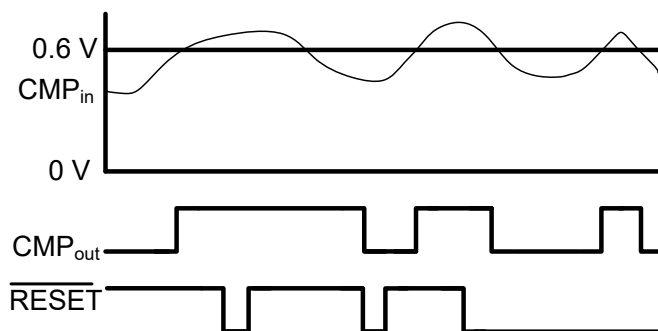


FIG 7-2. The Comparator  $\overline{\text{RESET}}$  Function

### 7.3.9 Short Propagation Delay

The combination of a high-speed current sense amplifier and a fast comparator provides a short total propagation delay of 1  $\mu\text{s}$ . The sense voltage (across the shunt resistor) propagates through the output where the output is divided down with the resistor divider to the comparator input and then to the comparator output. An external resistor divider at  $V_{\text{OUT}}$  sets overcurrent threshold. The total propagation delay is time taken from when the sense voltage (across the shunt resistor) exceeds the overcurrent threshold to when the comparator output drives high. The short propagation delay makes the INA310x well suited for overcurrent protection in systems sensitive to overcurrent events.

### 7.3.10 Comparator Input Bias Current

The INA310x comparator input has a built-in circuit to protect the input devices in case of large input differential voltage. This circuit results in the input bias current ( $I_{\text{BCMPIN}}$ ) curve against input voltage ( $V_{\text{CMPIN}}$ ) as shown in FIG 7-3. The  $I_{\text{BCMPIN}}$  reduces with  $V_{\text{CMPIN}}$  from 0 V to 0.4 V,  $I_{\text{BCMPIN}}$  is under 20 nA at 25°C for  $V_{\text{CMPIN}}$  range from 0.4 V to 1.2 V, and  $I_{\text{BCMPIN}}$  increases with  $V_{\text{CMPIN}}$  from 1.8 V to 5.5 V. The nature of  $I_{\text{BCMPIN}}$  does not contribute to the inaccuracy of the comparator alert threshold voltage ( $V_{\text{THRESHOLD}}$ ) significantly because the  $I_{\text{BCMPIN}}$  goes below 20 nA when the input voltage is close to the threshold voltage (0.6 V). Avoid using a high-value resistor for the divider network for better  $V_{\text{THRESHOLD}}$  accuracy. The sum of the two resistors in the divider network as shown in [Overcurrent Threshold Connection](#) is recommended to keep lower than 100 k $\Omega$ .



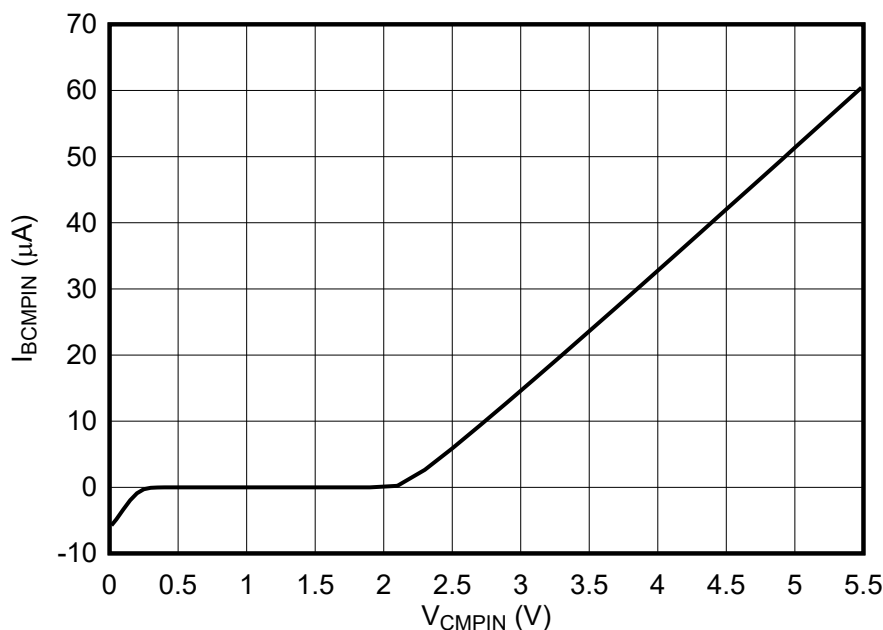


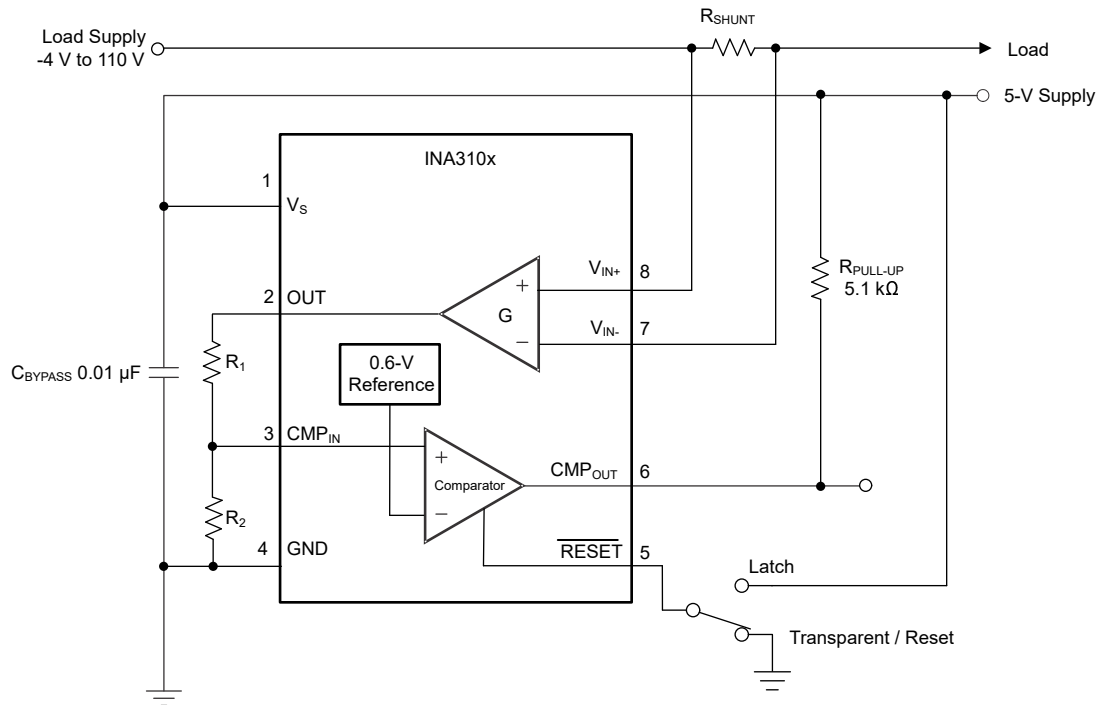
FIG 7-3. Comparator I<sub>BCMPIN</sub> vs V<sub>CMPIIN</sub>

## 7.4 Device Functional Modes

### 7.4.1 Basic Connections

FIG 7-4 shows a basic circuit connection for INA310x. The INA310x is configurable to allow for unidirectional high-side or low-side, current-sensing operation. The input pins (IN+ and IN–) must be connected as closely as possible with Kelvin connections to the shunt resistor to minimize any resistance in series with the shunt resistance. The [Layout](#) section provides the layout guidelines and a layout example.

Power-supply bypass capacitors are required for stability. Applications with noisy or high-impedance power supplies may require additional decoupling capacitors to reject power-supply noise. Connect bypass capacitors close to the device V<sub>S</sub> pin. The recommended value of a bypass capacitor is 0.01 μF.



### 7-4. INA310 Basic Connections

#### 7.4.1.1 Overcurrent Threshold Connection

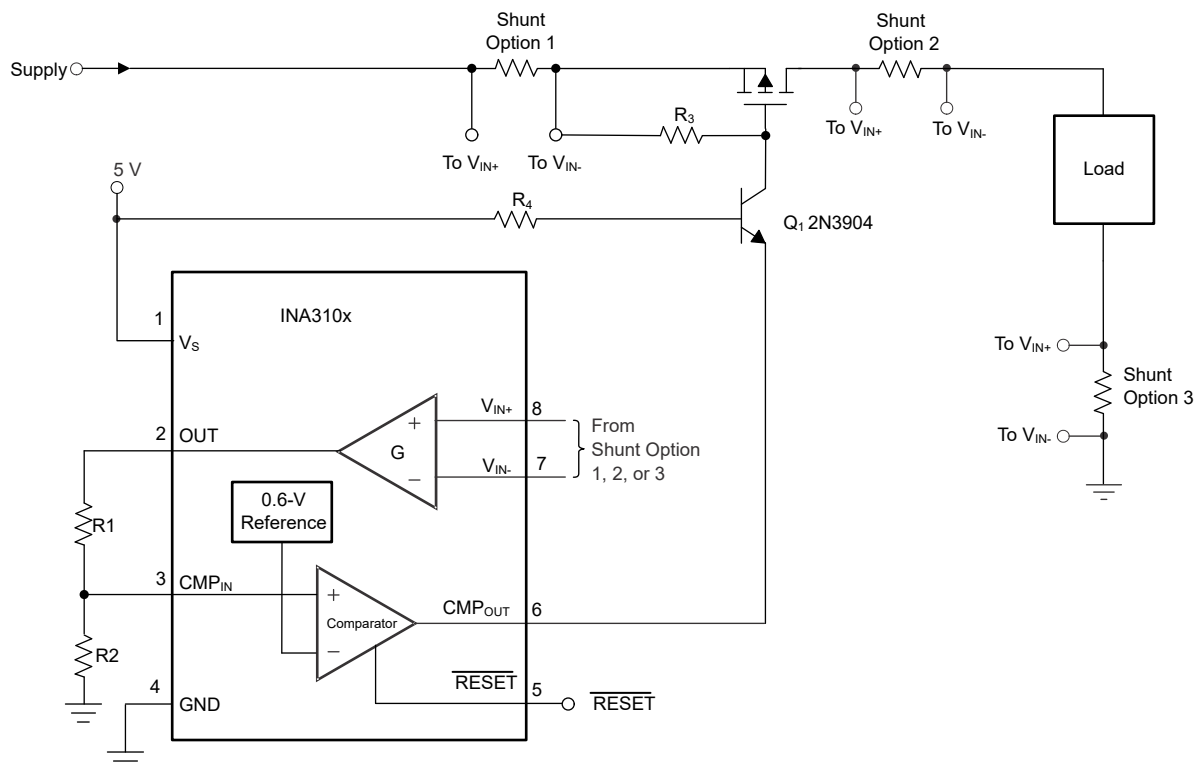
The INA310x comparator in [Figure 7-4](#) is configured to provide overcurrent alert signal when the current through  $R_{SHUNT}$  exceeds the overcurrent threshold. OUT voltage times  $R_2$  divided by  $R_1$  and  $R_2$  compared to the internal reference voltage (0.6 V) sets the overcurrent threshold. [Equation 1](#) shows the relation of the overcurrent threshold with gain,  $R_{SHUNT}$ ,  $R_1$  and  $R_2$ .

$$I_{Sense\_Alert\_Threshold} = \frac{0.6 \times (R_1 + R_2)}{R_2 \times G \times R_{shunt}} \quad (1)$$

R<sub>1</sub> and R<sub>2</sub> load OUT, therefore TI recommends to set the sum of these resistors higher than 10k. This helps keep the high swing range at the OUT and lower total supply current. The high value of these resistors will contribute to inaccuracy in comparator alert threshold voltage ( $V_{THRESHOLD}$ ) as mentioned in [Comparator Input Bias Current](#). The [Design Requirements](#) section shows an example of resistors values to set the overcurrent threshold.

### 7.4.2 High-Side Switch Overcurrent Shutdown

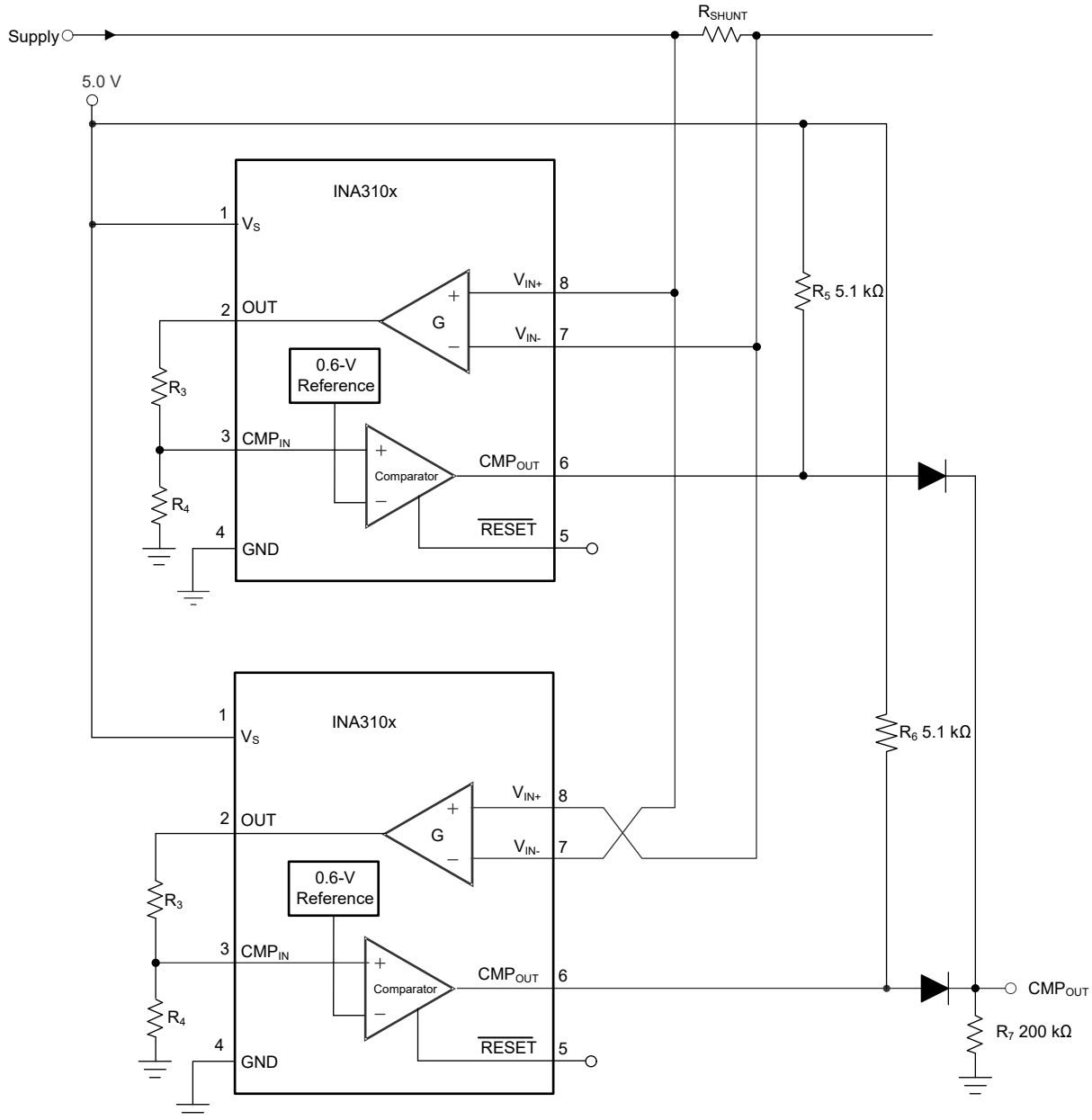
The INA310x measures differential voltage developed by current flowing through a current-shunt resistor. [Figure 7-5](#) shows the circuit with INA310x used for turning off the high-side switch in case of overcurrent. When the current exceeds overcurrent threshold, the comparator output (CMP<sub>OUT</sub>) signal goes high. This signal from the comparator drives through the Q1 transistor to the gate of the high-side switch, causing the switch to shut down. The Q1 transistor helps isolate CMP<sub>OUT</sub> from the high voltage of the Supply. There are three location options to have shunt resistor to measure unidirectional current. Option 1 and Option 2 are high-side current sensing, and Option 3 is low-side current sensing. Though both are high-side current sensing, Option 1 accounts for the current flowing through the Q1 transistor, and Option 2 does not. The advantages of high-side current sensing are that high-side sensing options do not contribute to ground disturbances and that high-side sensing can detect load shorts. In high-side current sensing, input common-mode is close to the power supply so a current-sensing amplifier with high CMRR and high common-mode is required for high-accuracy measurement. The low-side current sensing does not require a high-voltage, current-sensing amplifier as common mode remains very close to the ground. The disadvantages of low-side current sensing are that low-side sensing options contribute to ground disturbances and that low-side current sensing cannot detect load shorts.



**Figure 7-5. High-Side Switch for Overcurrent Shutdown**

### 7.4.3 Bidirectional Overcurrent Comparator

The INA310x can operate only in unidirectional mode, but [Figure 7-6](#) shows that two INA310xs can be configured to provide a bidirectional overcurrent alert signal. The polarity of the differential voltage measured across the shunt resistor is in reverse for one current sense amplifier. Two INA310xs function to cover the opposite current directions, and therefore provide bidirectional overcurrent monitor function.



**Figure 7-6. Ground Referenced Output**

## 8 Application and Implementation

### 注

以下のアプリケーション情報は、TI の製品仕様に含まれるものではなく、TI ではその正確性または完全性を保証いたしません。個々の目的に対する製品の適合性については、お客様の責任で判断していただくことになります。お客様は自身の設計実装を検証しテストすることで、システムの機能を確認する必要があります。

### 8.1 Application Information

The INA310x 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 INA310x make the device usable over a wide range of voltage rails while still maintaining accurate current measurement.

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

To maximize the accuracy of a current sense amplifier, TI recommends to choose the largest current sense resistor value possible in an application. A larger value 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 value can be in a given application because of the physical dimensions of the resistor, package construction and maximum power dissipation. 式 2 gives the maximum value for the current-sense resistor for a given power dissipation budget:

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

where:

- PD<sub>MAX</sub> is the maximum allowable power dissipation in R<sub>SENSE</sub>.
- I<sub>MAX</sub> is the maximum current that will flow through R<sub>SENSE</sub>.

An additional limitation on the size of the current sense resistor and device gain is due to the power-supply voltage, V<sub>S</sub>, 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. 式 3 provides the maximum values of R<sub>SENSE</sub> and GAIN to keep the device from exceeding the positive swing limitation.

$$I_{\text{MAX}} \times R_{\text{SENSE}} \times \text{GAIN} < V_{\text{SP}} \quad (3)$$

where:

- I<sub>MAX</sub> is the maximum current that will flow through R<sub>SENSE</sub>.
- GAIN is the gain of the current-sense amplifier.
- V<sub>SP</sub> is the positive output swing as specified in the data sheet.

To avoid positive output swing limitations when selecting the value of R<sub>SENSE</sub>, 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 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. 式 4 provides the limit on the minimum value of the sense resistor.

$$I_{\text{MIN}} \times R_{\text{SENSE}} \times \text{GAIN} > V_{\text{SN}} \quad (4)$$

where:

- I<sub>MIN</sub> is the minimum current that will flow through R<sub>SENSE</sub>.

- GAIN is the gain of the current-sense amplifier.
- $V_{SN}$  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 INA310x. 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<sup>(1)</sup>

| PARAMETER   |  | EQUATION                         | RESULTS AT $V_S = 5\text{ V}$ |                   |                   |                   |                   |
|-------------|--|----------------------------------|-------------------------------|-------------------|-------------------|-------------------|-------------------|
|             |  |                                  | A1, B1<br>DEVICES             | A2, B2<br>DEVICES | A3, B3<br>DEVICES | A4, B4<br>DEVICES | A5, B5<br>DEVICES |
| G           | Gain                                     |                                  | 20 V/V                        | 50 V/V            | 100 V/V           | 200 V/V           | 500 V/V           |
| $V_{DIFF}$  | Ideal differential input voltage         | $V_{DIFF} = V_{OUT} / G$         | 250 mV                        | 100 mV            | 50 mV             | 25 mV             | 10mV              |
| $R_{SENSE}$ | Current sense resistor value             | $R_{SENSE} = V_{DIFF} / I_{MAX}$ | 25 mΩ                         | 10 mΩ             | 5 mΩ              | 2.5 mΩ            | 1 mΩ              |
| $P_{SENSE}$ | Current-sense resistor power dissipation | $R_{SENSE} \times I_{MAX}^2$     | 2.5 W                         | 1 W               | 0.5 W             | 0.25 W            | 0.1 W             |

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

## 8.2 Typical Application

The INA310x is a unidirectional, current-sense amplifier capable of measuring currents through a resistive shunt with shunt common-mode voltages from  $-4\text{ V}$  to  $+110\text{ V}$ .

### 8.2.1 Current Sensing in a Solenoid Application

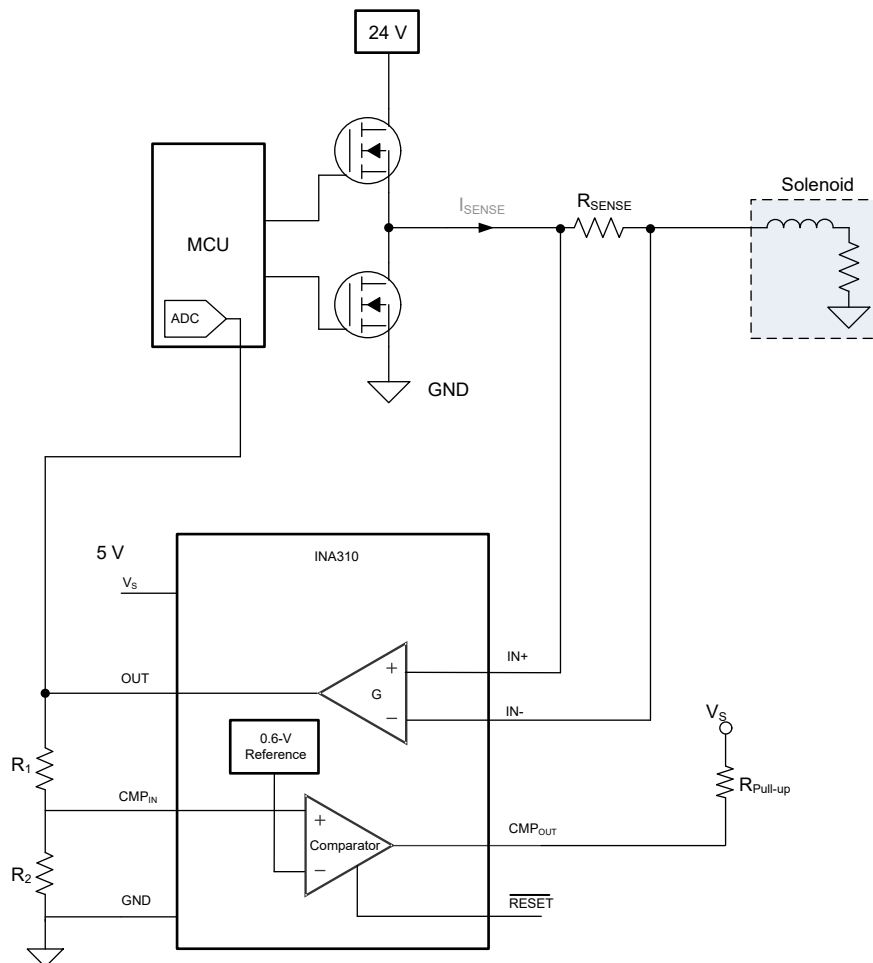


图 8-1. Current Sensing in a Solenoid Application

### 8.2.1.1 Design Requirements

In this example application, the common-mode voltage ranges from 0 V to 24 V. The maximum sense current is 1.5 A, an alert must be indicated if the current exceeds 1.9 A, and a 5 V supply is available for the INA310x. Following the design guidelines from [R<sub>SENSE</sub> and Device Gain Selection](#), a R<sub>SENSE</sub> of 50 mΩ and a gain of 50 V/V are selected to provide good output dynamic range. 表 8-2 lists the design setup for this application.

**表 8-2. Design Parameters**

| DESIGN PARAMETERS           | EXAMPLE VALUE |
|-----------------------------|---------------|
| Power supply voltage        | 5 V           |
| Common mode voltage range   | 0 V to 24 V   |
| Maximum sense current       | 1.5 A         |
| R <sub>SENSE</sub> resistor | 50 mΩ         |
| Gain option                 | 50 V/V        |
| Over-current Threshold      | 1.9 A         |
| R <sub>1</sub>              | 69.15 kΩ      |
| R <sub>2</sub>              | 10 kΩ         |

### 8.2.1.2 Detailed Design Procedure

The INA310x is designed to measure current in a typical solenoid application. The INA310x measures current across the 50-mΩ shunt that is placed at the output of the half-bridge. The INA310x measures the differential voltage across the shunt resistor, and the signal is internally amplified with a gain of 50 V/V. The output of the INA310x is connected to the analog-to-digital converter (ADC) of an MCU to digitize the current measurements.

R<sub>2</sub> is fixed as 10 kΩ to avoid loading of OUT as recommended in [Overcurrent Threshold Connection](#). R<sub>1</sub> is calculated as 69.15 kΩ using 式 1.

$$1.9 \text{ A} = \frac{0.6 \text{ V} \times (R_1 + 10 \text{ k}\Omega)}{10 \text{ k}\Omega \times 50 \times 50 \text{ m}\Omega}$$

R<sub>1</sub> (69.15 kΩ) and R<sub>2</sub> (10 kΩ) divides down the output which is an input to the comparator. This sets the overcurrent alert threshold of 1.9 A.

Solenoid loads are highly inductive and are often prone to failure. Solenoids are often used for position control, precise fluid control, and fluid regulation. Measuring real-time current on the solenoid continuously can indicate premature failure of the solenoid, which can lead to a faulty control loop in the system. Measuring high-side current also indicates if there are any ground faults on the solenoid or the FETs that can be damaged in an application. The INA310x, with high bandwidth and slew rate, can be used to detect fast overcurrent conditions to prevent the solenoid damage from short-to-ground faults.

#### 8.2.1.2.1 Overload Recovery With Negative V<sub>SENSE</sub>

The INA310x is a unidirectional current sense amplifier that is meant to operate with a positive differential input voltage (V<sub>SENSE</sub>). If negative V<sub>SENSE</sub> is applied, the device is placed in an overload or saturated condition and requires time to recover after V<sub>SENSE</sub> returns positive. The required overload recovery time increases with more negative V<sub>SENSE</sub>.





application, the common-mode voltage is set at 5 V. The maximum sense current is 1 A, an alert must be indicated if the current exceeds 1.2 A, and a 5 V supply is available for the INA310x. Following the design guidelines from [R<sub>SENSE</sub> and Device Gain Selection](#), a R<sub>SHUNT</sub> of 100 mΩ and a gain of 20 V/V are selected to provide a good output dynamic range. 表 8-3 lists the design setup for this application.

**表 8-3. Design Parameters**

| DESIGN PARAMETERS           | EXAMPLE VALUE |
|-----------------------------|---------------|
| Power supply voltage        | 5 V           |
| Common mode voltage range   | 5 V           |
| Maximum sense current       | 1 A           |
| R <sub>SENSE</sub> resistor | 100 mΩ        |
| Gain option                 | 20 V/V        |
| Over-current Threshold      | 1.2 A         |
| R <sub>1</sub>              | 10.2 kΩ       |
| R <sub>2</sub>              | 3.4 kΩ        |

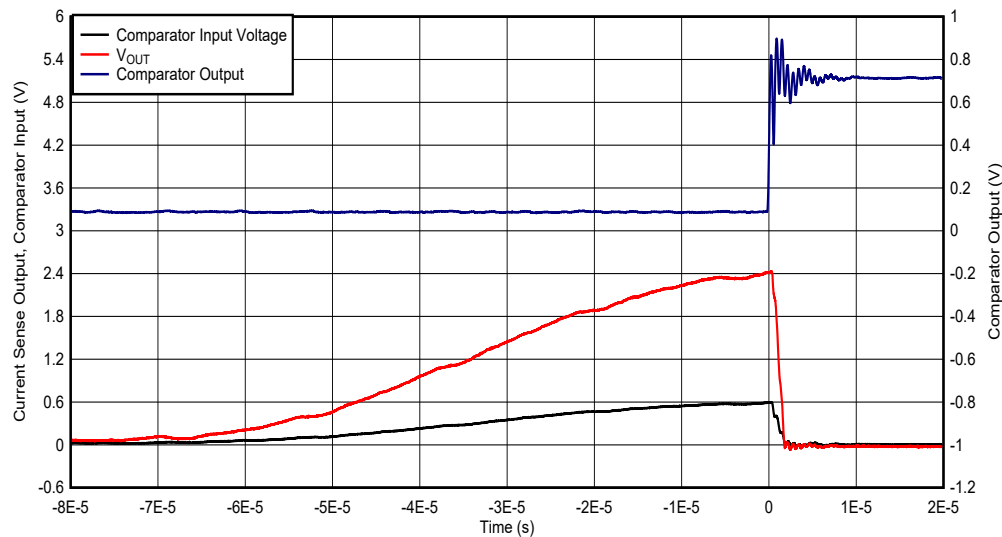
### 8.2.2.2 Detailed Design Procedure

図 8-3 shows the basic connections to the INA310x. The inputs terminals (IN+ and IN–) must be connected to the current sense resistor as close as possible to minimize any resistance in series with the shunt resistor. The INA310x measures current across the 100-mΩ shunt that is placed in series with load. The INA310x measures the differential voltage across the shunt resistor, and the signal is internally amplified with a gain of 20 V/V.

R<sub>1</sub> is fixed as 10.2 kΩ to avoid loading of OUT as recommended in [Overcurrent Threshold Connection](#). R<sub>2</sub> is calculated as 3.4 kΩ using 式 1. R<sub>1</sub> (10.2 kΩ) and R<sub>2</sub> (3.4 kΩ) divides down the output which is an input to the comparator. This sets the overcurrent alert threshold of 1.2 A.

### 8.2.2.3 Application Curve

図 8-4 shows the output response the current sense amplifier and the comparator in event of overcurrent.



**図 8-4. Low-Side Switch Overcurrent Shutdown Response**

## 8.3 Power Supply Recommendations

The INA310x makes accurate measurements beyond the connected power-supply voltage ( $V_S$ ) because the inputs (IN+ and IN–) can operate anywhere between –4 V and 110 V independent of  $V_S$ . For example, with the  $V_S$  power supply equal to 5 V, the common-mode voltage of the measured shunt can be as high as 110 V.

### 8.3.1 Power Supply Decoupling

Place the power-supply bypass capacitor as close to the power-supply and ground pins as possible. TI recommends a bypass capacitor value of 0.1  $\mu\text{F}$ . Additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies.

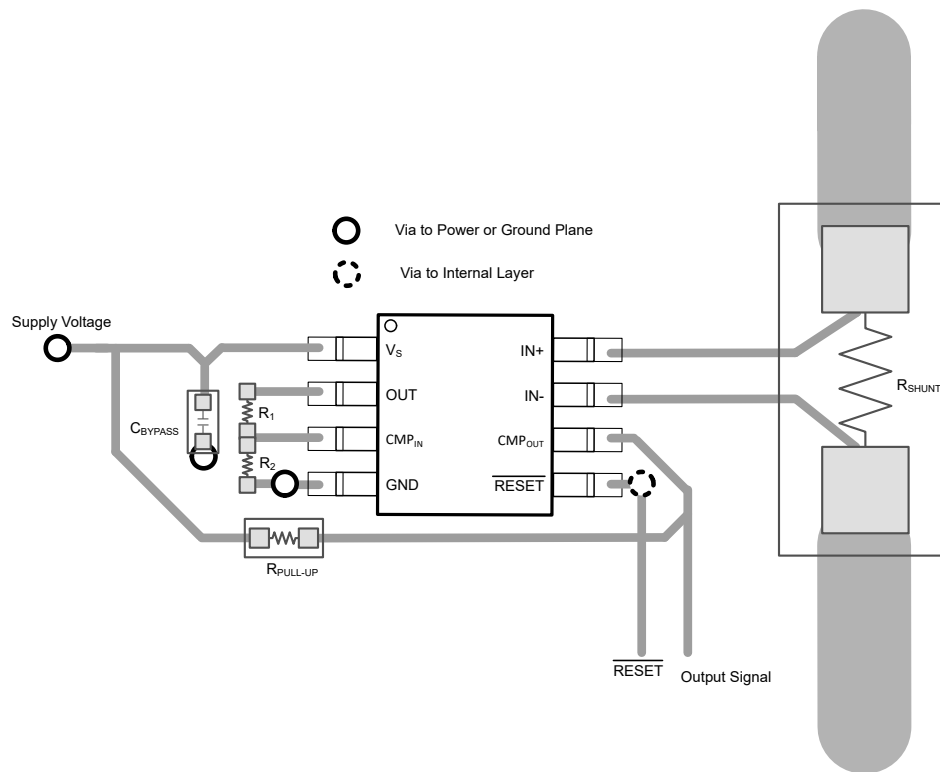
## 8.4 Layout

### 8.4.1 Layout Guidelines

Attention to good layout practices is always recommended.

- 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  $\mu\text{F}$ . Additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies.

### 8.4.2 Layout Example



 **8-5. INA310xx Recommended Layout**

## 9 Device and Documentation Support

### 9.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

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### 9.5 用語集

[テキサス・インスツルメンツ用語集](#) この用語集には、用語や略語の一覧および定義が記載されています。

## 10 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 part number         | Status<br>(1) | Material type<br>(2) | Package   Pins  | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|-------------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">INA310A1IDGKR</a> | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2OZB                |
| INA310A1IDGKR.B               | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2OZB                |
| <a href="#">INA310A2IDGKR</a> | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2P1B                |
| INA310A2IDGKR.B               | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2P1B                |
| <a href="#">INA310A3IDGKR</a> | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2P2B                |
| INA310A3IDGKR.B               | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2P2B                |
| <a href="#">INA310A4IDGKR</a> | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2P3B                |
| INA310A4IDGKR.B               | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2P3B                |
| <a href="#">INA310A5IDGKR</a> | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2P4B                |
| INA310A5IDGKR.B               | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2P4B                |
| <a href="#">INA310B1IDGKR</a> | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2P5B                |
| INA310B1IDGKR.B               | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2P5B                |
| <a href="#">INA310B2IDGKR</a> | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2P6B                |
| INA310B2IDGKR.B               | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2P6B                |
| <a href="#">INA310B3IDGKR</a> | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2P7B                |
| INA310B3IDGKR.B               | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2P7B                |
| <a href="#">INA310B4IDGKR</a> | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2P8B                |
| INA310B4IDGKR.B               | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2P8B                |
| <a href="#">INA310B5IDGKR</a> | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2P9B                |
| INA310B5IDGKR.B               | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-2-260C-1 YEAR               | -40 to 125   | 2P9B                |

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

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(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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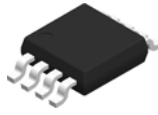
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

**OTHER QUALIFIED VERSIONS OF INA310A, INA310B :**

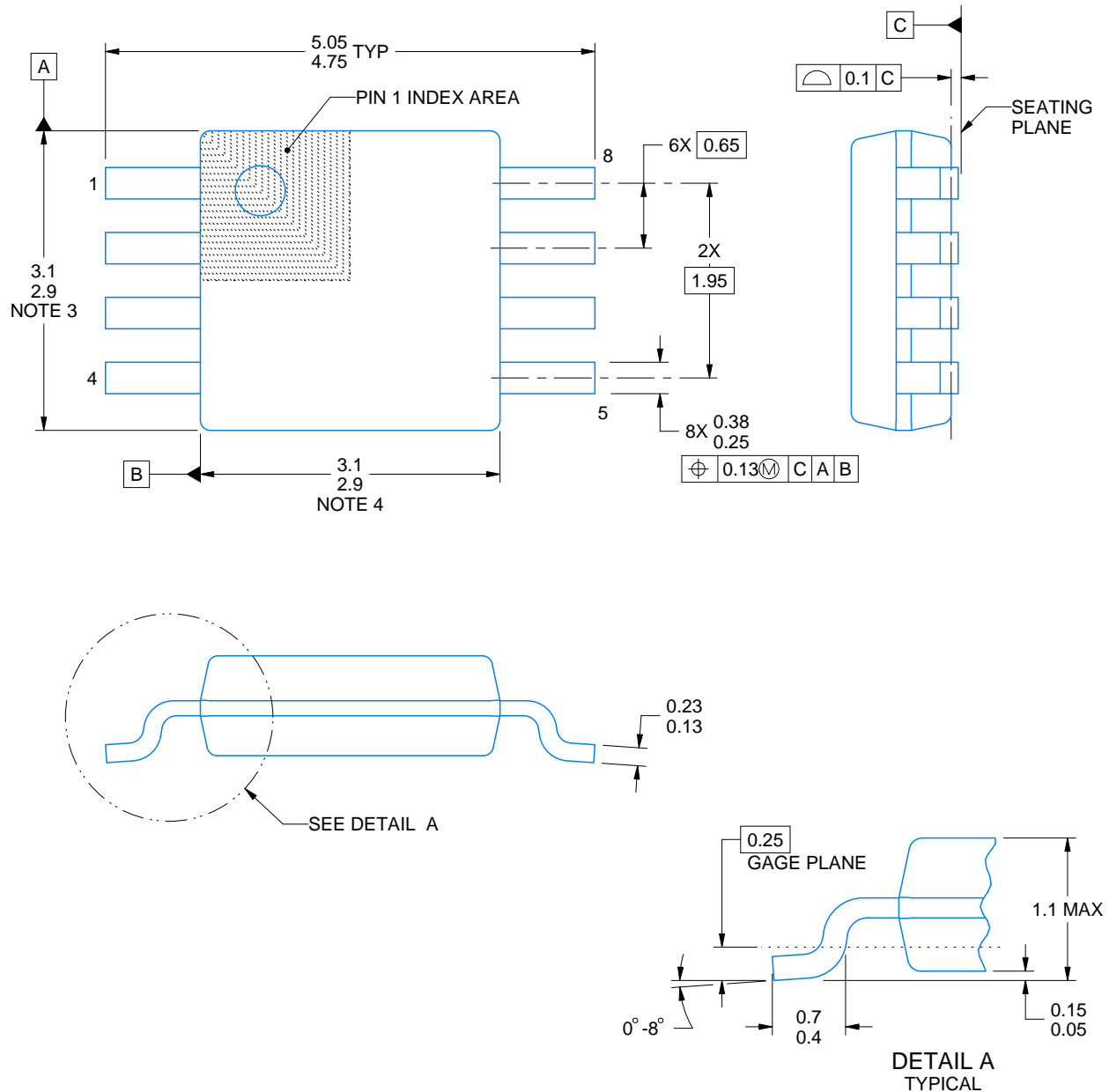
- Automotive : [INA310A-Q1](#), [INA310B-Q1](#)

NOTE: Qualified Version Definitions:

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

**DGK0008A****PACKAGE OUTLINE****VSSOP - 1.1 mm max height**

SMALL OUTLINE PACKAGE



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**NOTES:**

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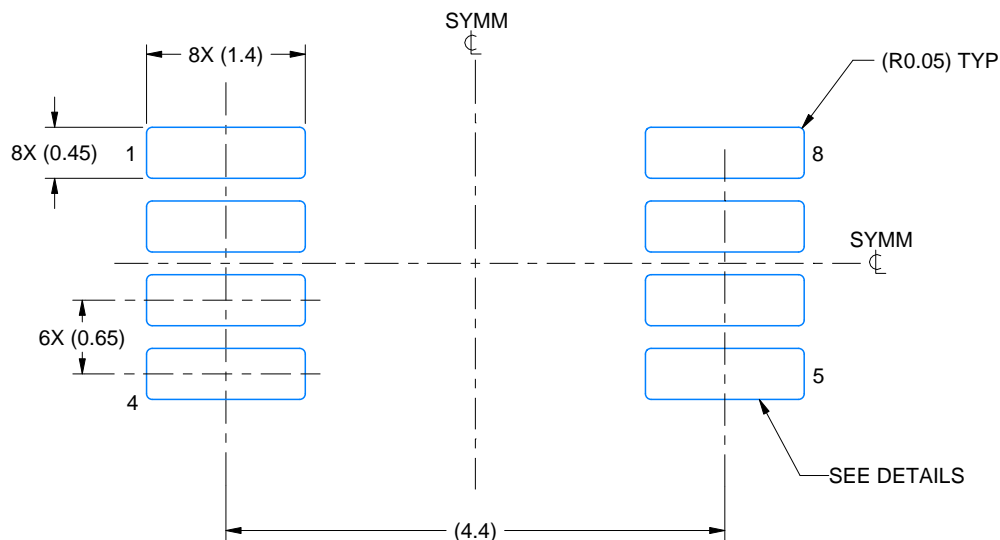
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-187.

# EXAMPLE BOARD LAYOUT

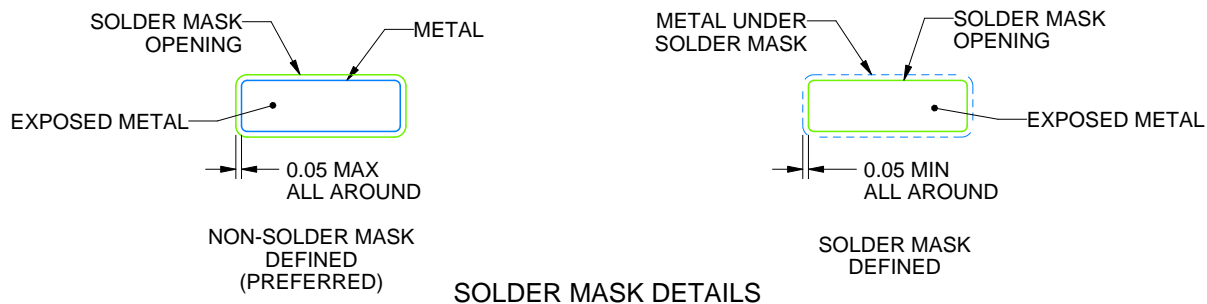
DGK0008A

™ VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 15X



SOLDER MASK DETAILS

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NOTES: (continued)

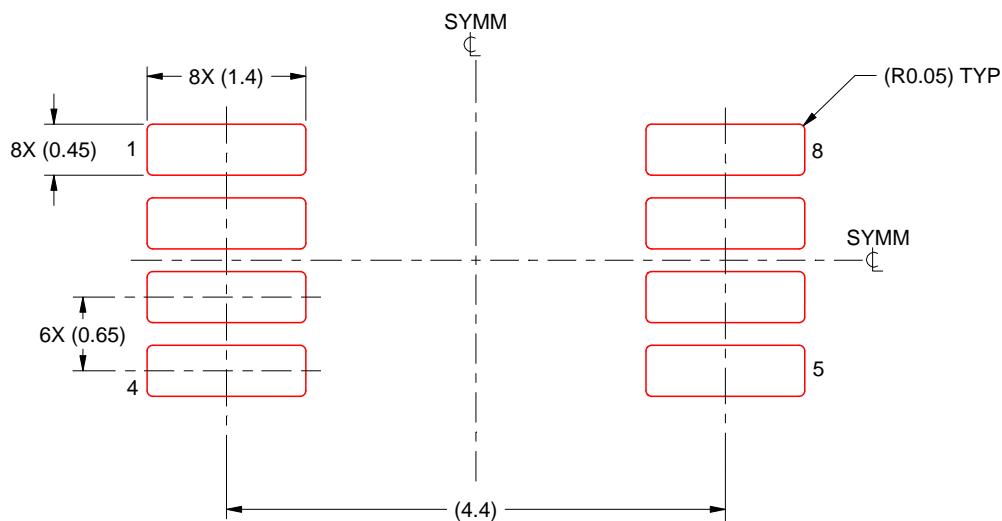
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.
9. Size of metal pad may vary due to creepage requirement.

## EXAMPLE STENCIL DESIGN

DGK0008A

<sup>TM</sup> VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE  
SCALE: 15X

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NOTES: (continued)

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



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