# INA310x –4 V to 110 V, 1.3 MHz, Ultra-Precise Current Sense Amplifier With Open-Drain Comparator and Reference

## 1 Features

- Wide common-mode voltage:
  - Operational voltage: −4 V to +110 V
  - Survival voltage: −20 V to +120 V
- High signal bandwidth: 1.3 MHz
- Slew rate: 2.5 V/µs
- Excellent CMRR: 160 dB
- Accuracy
  - Gain error (maximum)
    - Version A: 0.15%, 10 ppm/°C drift
    - Version B: 0.5%, 20 ppm/°C drift
  - Offset voltage (maximum)
    - Version A: ±20 µV, ±0.25 µV/°C drift
    - Version B: ±150 µV, ±1 µV/°C drift
- On-board open-drain comparator
- Internal comparator voltage reference: 0.6 V
- Propagation delay time: 1 µs
- Latching capability on comparator
- Available gains:
  - INA310A1, INA310B1 : 20 V/V
  - INA310A2, INA310B2 : 50 V/V
  - INA310A3, INA310B3 : 100 V/V
  - INA310A4, INA310B4 : 200 V/V
  - INA310A5, INA310B5 : 500 V/V
- Package options: VSSOP-8

## 2 Applications

- 48 V DC/DC converter
- 48 V battery management systems (BMS)
- Test and measurement
- Macro remote radio unit (RRU)
- 48 V rack server
- 48 V merchant network & server power supply (PSU)
- Solenoids and actuators

## 3 Description

The INA310x is an ultra-precise current sense amplifier that can measure voltage drops across shunt resistors over a wide common-mode range from –4 V to 110 V, independent of supply voltage with an integrated comparator. The high precision current measurement accuracy is achieved through a combination of low offset voltage (20 µV, maximum), small gain error (0.15%, maximum) and a high DC CMRR (160 dB, typical). The INA310x has a high signal bandwidth of 1.3 MHz designed for high voltage DC current measurements and high-speed applications like fast overcurrent protection.

The INA310x incorporates an open-drain comparator and internal reference that provides a 0.6 V threshold. An external resistive 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.

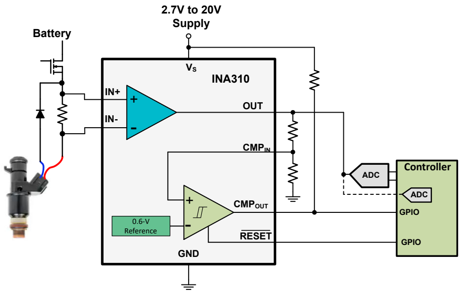
The INA310x operates from a single 2.7 V to 20 V supply and draws 1.6 mA of supply current. The INA310x is available in five gain options: 20 V/V, 50 V/V, 100 V/V, 200 V/V, and 500 V/V. These gain options address a wide dynamic range of current-sensing applications.

The INA310x is specified over an operating temperature range of −40°C to +125°C and is offered in a space-saving 8-pin VSSOP package.

**Package Information**(1)

| PART NUMBER | PACKAGE | BODY SIZE (NOM) |
|---|---|---|
| INA310A | VSSOP (8) | 3.00 mm × 3.00 mm |
| INA310B | | |

(1) For all available packages, see the package option addendum at the end of the data sheet.



**Typical Application**

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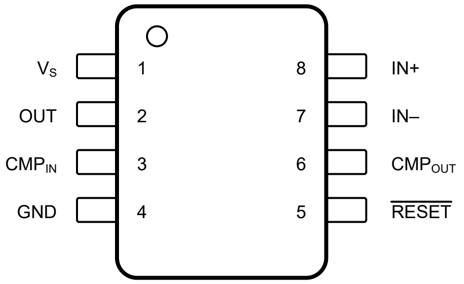
## 4 Revision History

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

# 5 Pin Configuration and Functions



Not to scale

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

**Table 5-1. Pin Functions**

| PIN | | TYPE | DESCRIPTION |
|---|---|---|---|
| NAME | NO | | |
| V$_S$ | 1 | Power | Power supply, 2.7 V to 20 V |
| OUT | 2 | Output | Output voltage |
| CMP$_{IN}$ | 3 | Input | Comparator input |
| GND | 4 | Ground | Ground |
| $\overline{\text{RESET}}$ | 5 | Input | Comparator reset pin, active low (Low: Transparent Mode, High: Latch Mode) |
| CMP$_{OUT}$ | 6 | Output | Comparator output (latch high when $\overline{\text{RESET}}$ = High) |
| IN– | 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+ | 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)(1)

| | | | MIN | MAX | UNIT |
|---|---|---|---|---|---|
| $V_S$ | Supply voltage | | –0.3 | 22 | V |
| $V_{IN+}$, $V_{IN–}$ | Analog inputs | Differential ($V_{IN+}$) – ($V_{IN–}$)(2) | –12 | 12 | V |
| | | $V_{IN+}$, $V_{IN–}$, with respect to GND(2) | –20 | 120 | |
| $V_{OUT}$ | Analog output | | GND – 0.3 | ($V_S$) + 0.3 | V |
| | Comparator reset pin | | GND – 0.3 | ($V_S$) + 0.3 | V |
| | Comparator analog input | | GND – 0.3 | MIN of 5.5 or $V_S$ | V |
| | Comparator Output | | GND – 0.3 | 22 | V |
| | Input current into any pin | | | 5 | mA |
| $T_A$ | Operating temperature | | –55 | 150 | °C |
| $T_J$ | Junction temperature | | –65 | 150 | °C |
| $T_{stg}$ | 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) $V_{IN+}$ and $V_{IN–}$ are the voltages at the IN+ and IN– pins, respectively.

## 6.2 ESD Ratings

| | | | VALUE | UNIT |
|---|---|---|---|---|
| $V_{(ESD)}$ | Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/ JEDEC JS-001, all pins(1) | ±2000 | V |
| | | Charged device model (CDM), per ANSI/ESDA/JEDEC JS-002, all pins(2) | ±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 |
|---|---|---|---|---|---|
| $V_{CM}$ | Common-mode input range | –4 | 48 | 110 | V |
| $V_S$ | Operating supply voltage | 2.7 | 5 | 20 | V |
| $V_{SENSE}$ | Differential sense input range | 0 | | $V_S$ / G | V |
| $T_A$ | Operating free-air temperature | –40 | | 125 | °C |

## 6.4 Thermal Information

| THERMAL METRIC(1) | | INA310x | UNIT |
|---|---|---|---|
| | | DGK (VSSOP) | |
| | | 8 PINS | |
| $R_{θJA}$ | Junction-to-ambient thermal resistance | 172.2 | °C/W |
| $R_{θJC(top)}$ | Junction-to-case (top) thermal resistance | 63.5 | °C/W |
| $R_{θJB}$ | Junction-to-board thermal resistance | 93.8 | °C/W |
| $Ψ_{JT}$ | Junction-to-top characterization parameter | 9.8 | °C/W |
| $Ψ_{JB}$ | 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°C, $V_{SENSE} = V_{IN+} – V_{IN–}$ = 0.5 V / Gain, $V_S$ = 5.0 V, $V_{CM} = V_{IN–}$ = 48 V, and $R_{PULLUP}$= 5.1 kΩ connected from $CMP_{out}$ to $V_s$, (unless otherwise noted)

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

at $T_A$ = 25°C, $V_{SENSE}$ = $V_{IN+}$ – $V_{IN–}$ = 0.5 V / Gain, $V_S$ = 5.0 V, $V_{CM}$ = $V_{IN–}$ = 48 V,  and $R_{PULLUP}$= 5.1 kΩ connected from $CMP_{out}$ to $V_s$, (unless otherwise noted)

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

(1) RTI = referred-to-input.
(2) The $\overline{\text{RESET}}$ input has an internal 2 MΩ (typical) pull-down. Leaving $\overline{\text{RESET}}$ open results in a LOW state, with transparent comparator operation.
(3) $V_{LIMIT}$ is $V_{OUT}$ at the overcurrent threshold set by external resistors.

## 6.6 Typical Characteristics

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

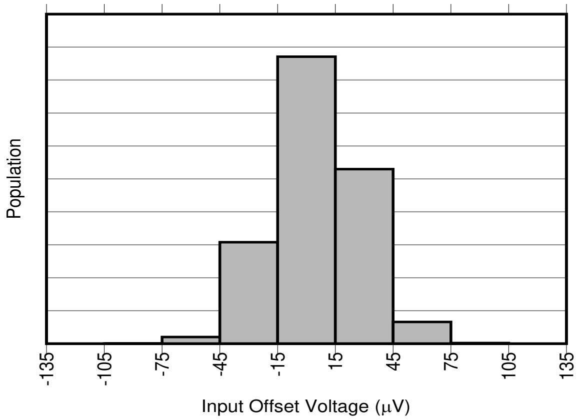


**Figure 6-1. INA310A1 Input Offset Production Distribution**

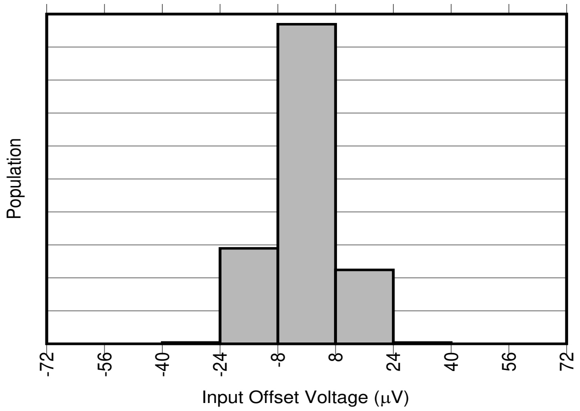


**Figure 6-2. INA310A2 Input Offset Production Distribution**

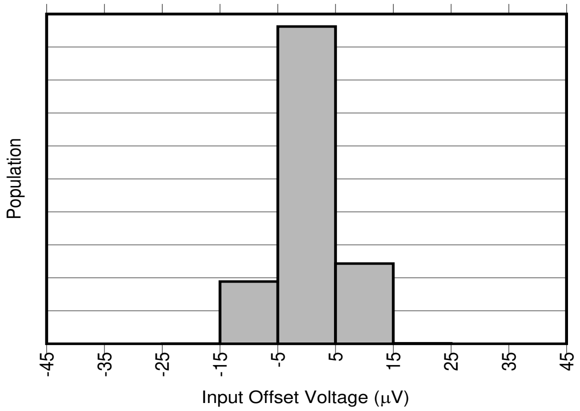


**Figure 6-3. INA310A3 Input Offset Production Distribution**

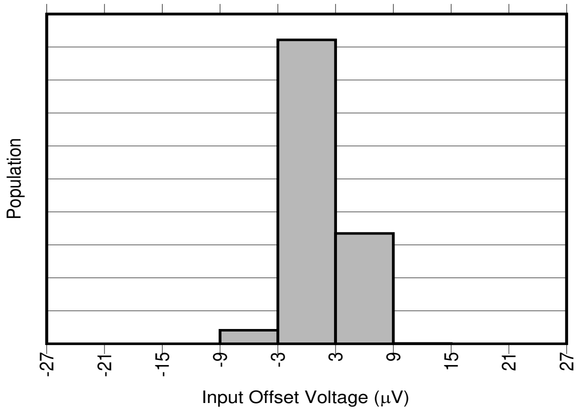


**Figure 6-4. INA310A4 Input Offset Production Distribution**

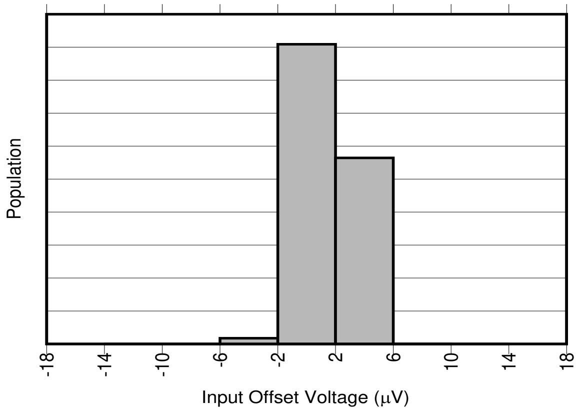


**Figure 6-5. INA310A5 Input Offset Production Distribution**

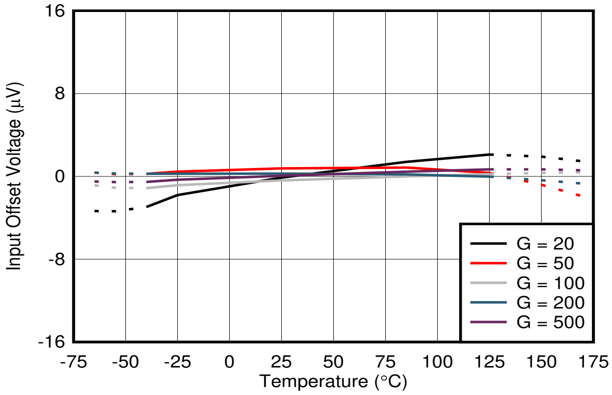


**Figure 6-6. Input Offset Voltage vs Temperature**

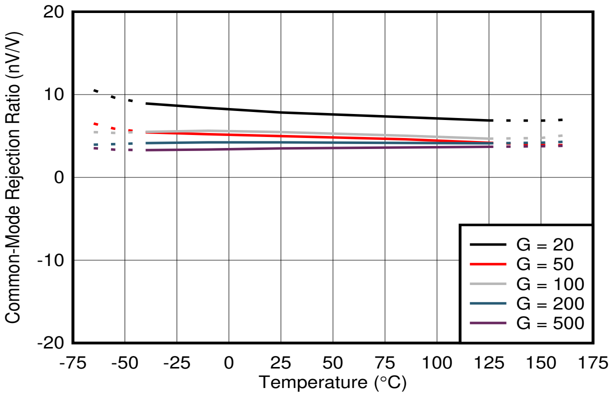


Figure 6-7. Common-Mode Rejection Ratio vs Temperature

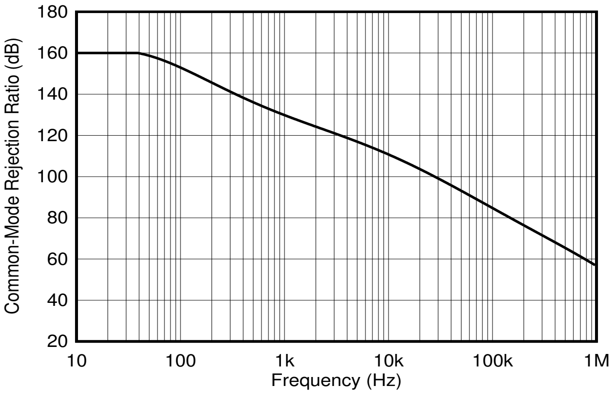


Figure 6-8. Common-Mode Rejection Ratio vs Frequency

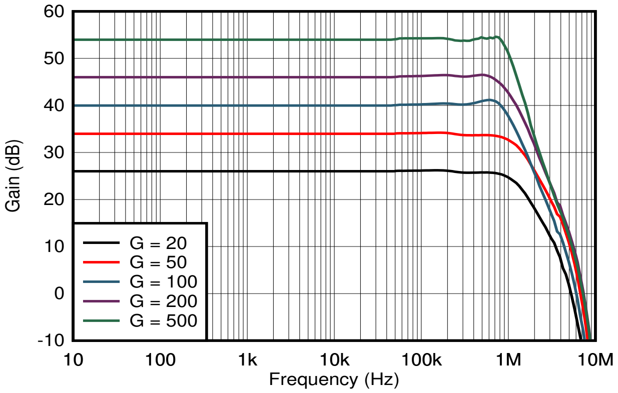


Figure 6-9. Gain vs Frequency

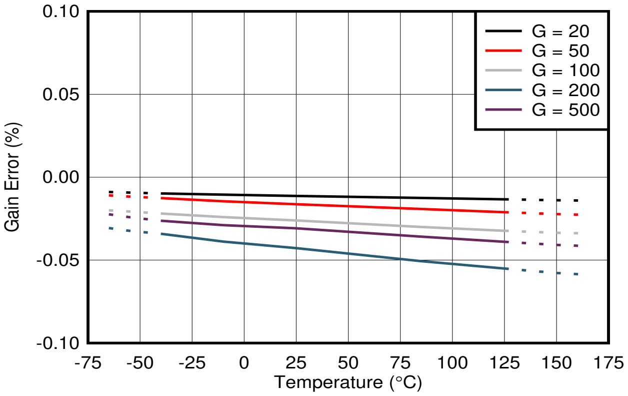


Figure 6-10. INA310A Gain Error vs Temperature

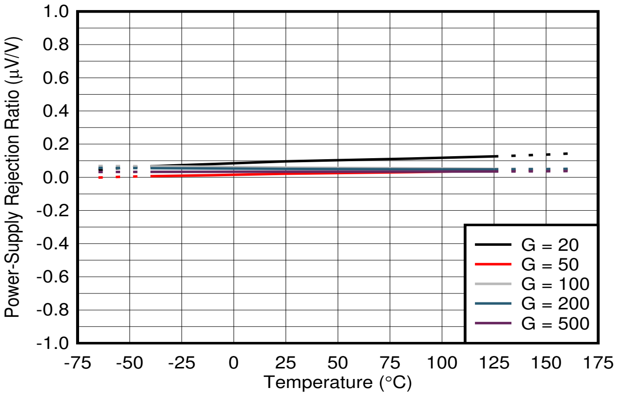


Figure 6-11. Power-Supply Rejection Ratio vs Temperature

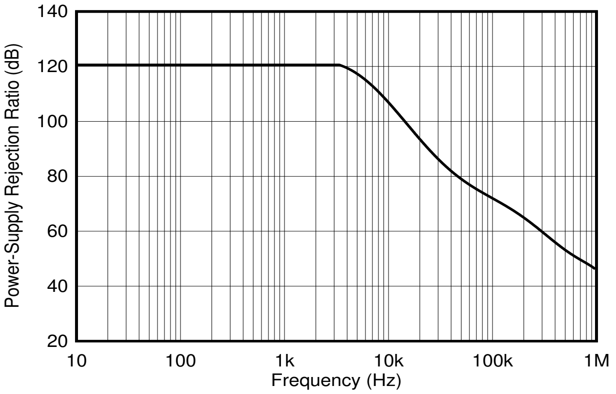
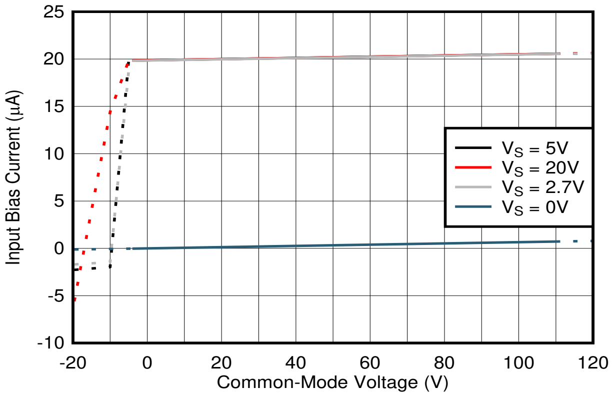


Figure 6-12. Power-Supply Rejection Ratio vs Frequency



$V_{SENSE}$ = 0 V

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

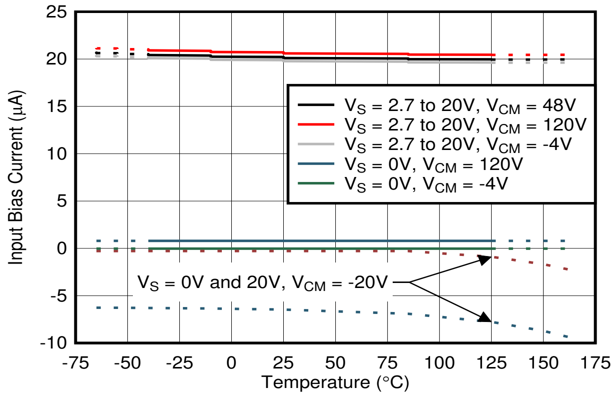


**Figure 6-14. Input Bias Current vs Temperature**

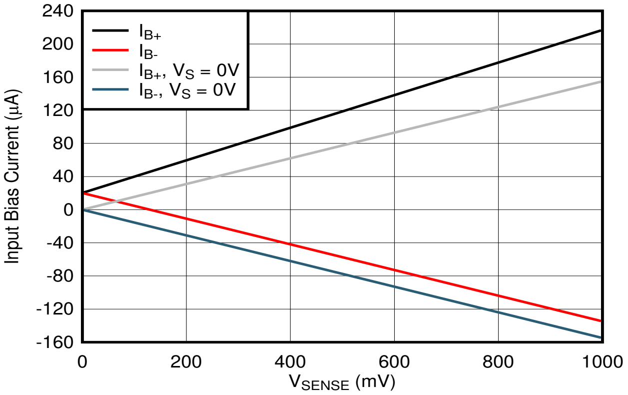


**Figure 6-15. INA310x1 Input Bias Current vs $V_{SENSE}$**

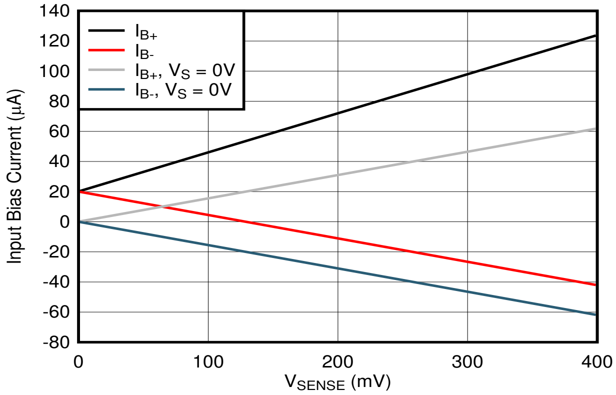


**Figure 6-16. INA310x2, INA310x3 Input Bias Current vs $V_{SENSE}$**

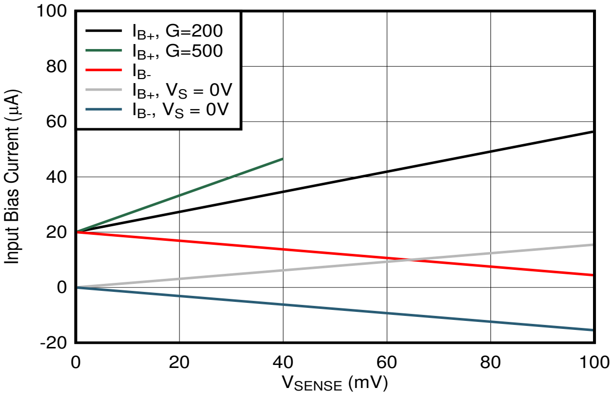
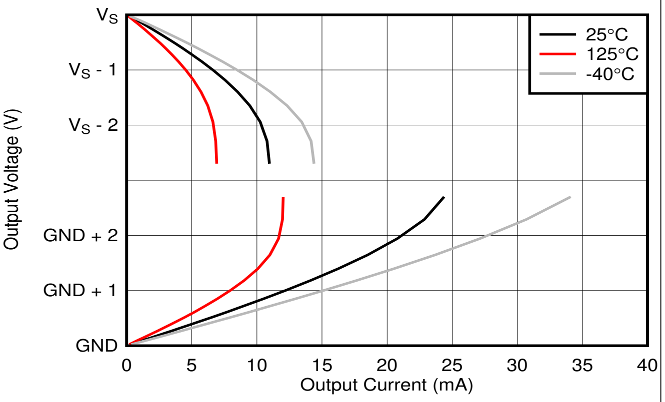
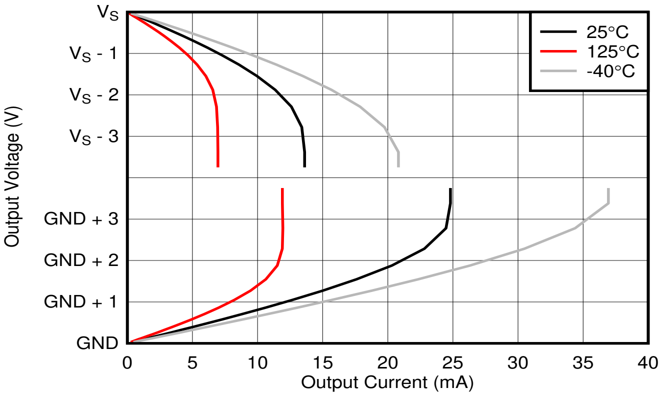


**Figure 6-17. INA310x4, INA310x5 Input Bias Current vs $V_{SENSE}$**



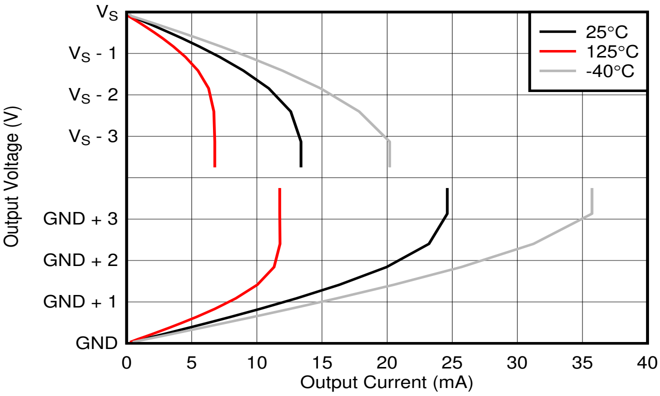
$V_S$ = 2.7 V

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



$V_S$ = 5 V

**Figure 6-19. Output Voltage vs Output Current**



$V_S$ = 20 V

**Figure 6-20. Output Voltage vs Output Current**

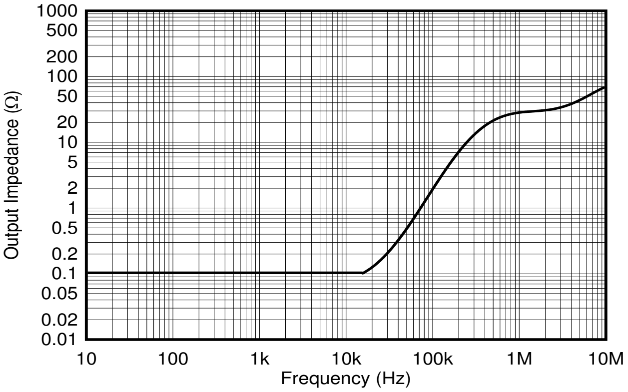


**Figure 6-21. Output Impedance vs Frequency**

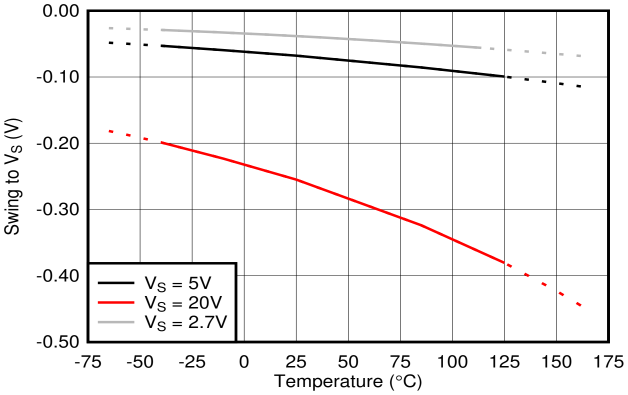


**Figure 6-22. Swing to Supply vs Temperature**

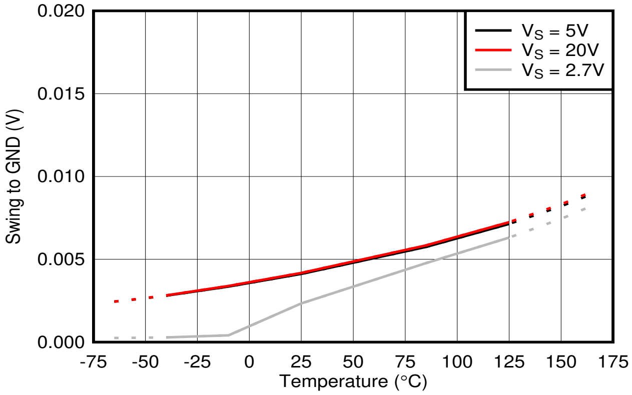


**Figure 6-23. Swing to GND vs Temperature**

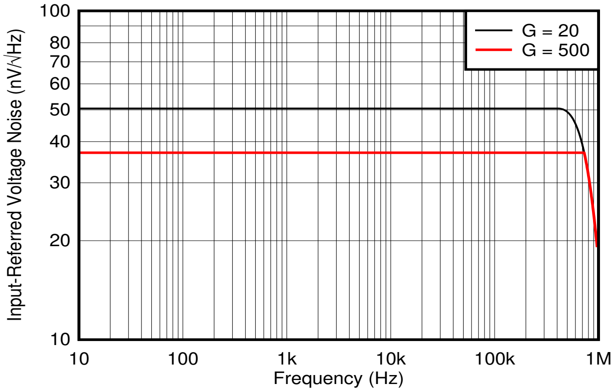


**Figure 6-24. Input Referred Noise vs Frequency**

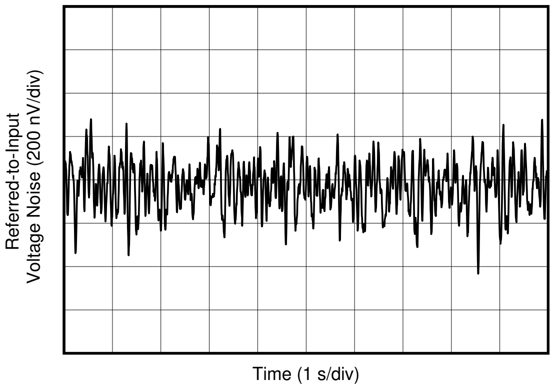


Figure 6-25. Input Referred Noise

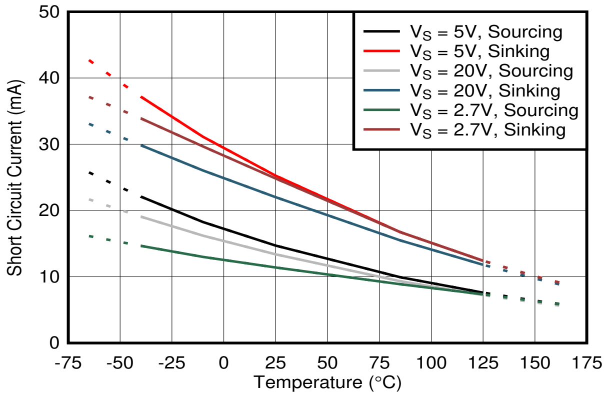


Figure 6-26. Short-Circuit Current vs Temperature

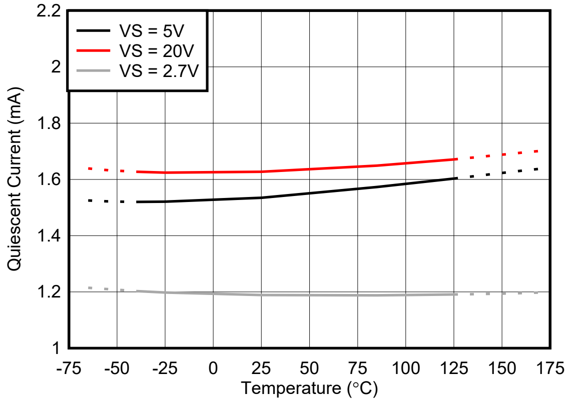


Figure 6-27. Quiescent Current vs Temperature

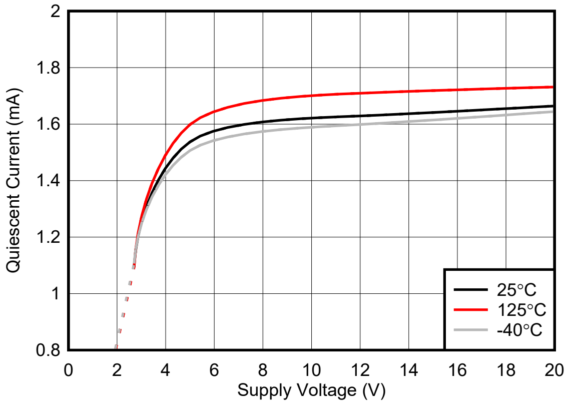


Figure 6-28. Quiescent Current vs Supply Voltage

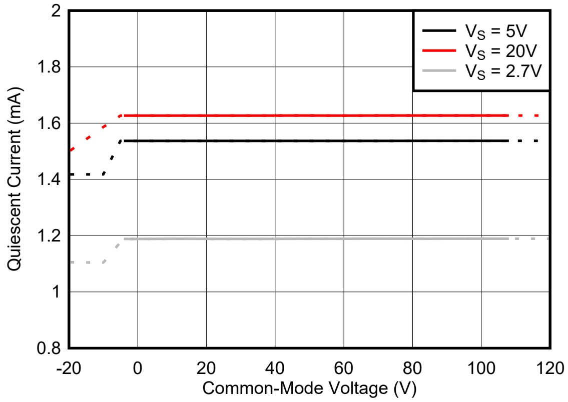


Figure 6-29. Quiescent Current vs Common-Mode Voltage

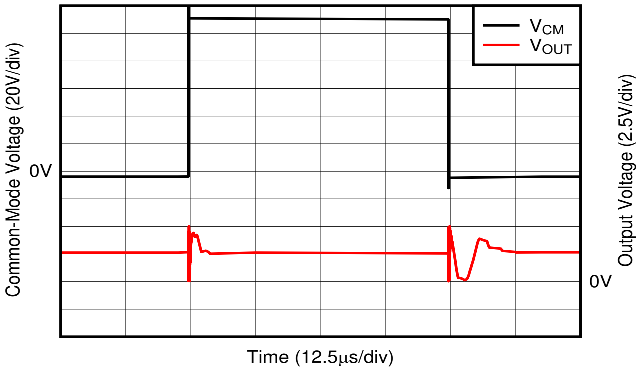


Figure 6-30. Common-Mode Voltage Fast Transient Pulse

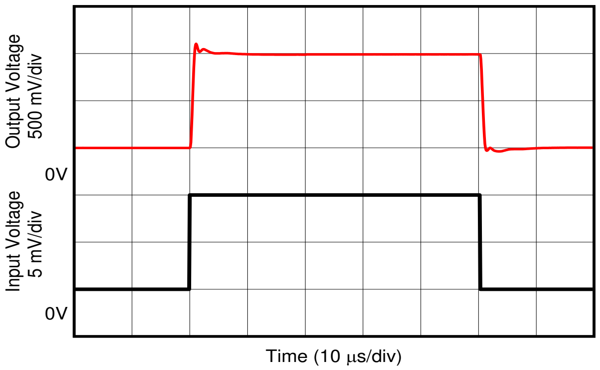


Figure 6-31. INA310x3 Step Response

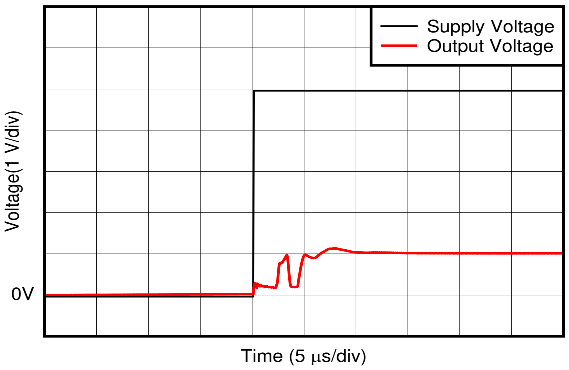


Figure 6-32. Start-Up Response

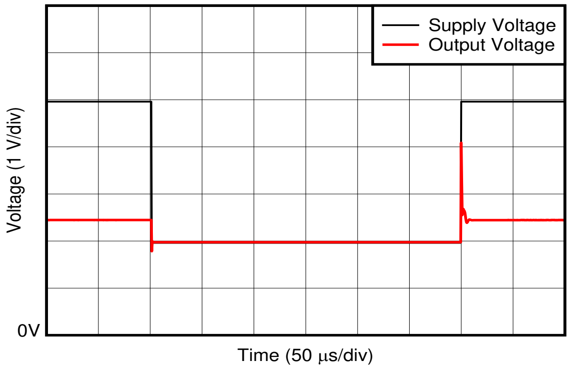


Figure 6-33. Supply Transient Response

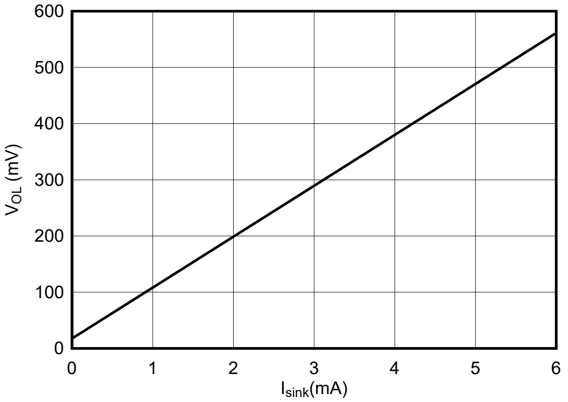


Figure 6-34. Comparator $V_{OL}$ vs $I_{SINK}$

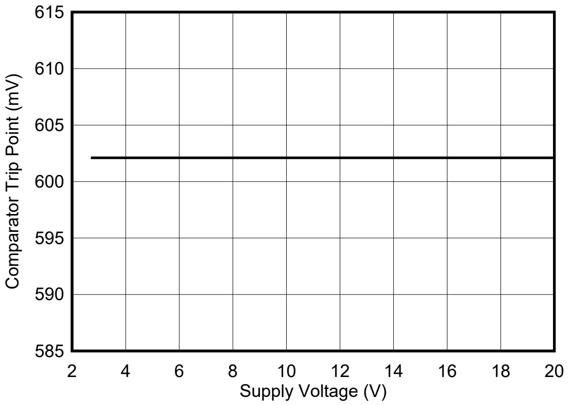


Figure 6-35. Comparator Trip Point vs Supply Voltage

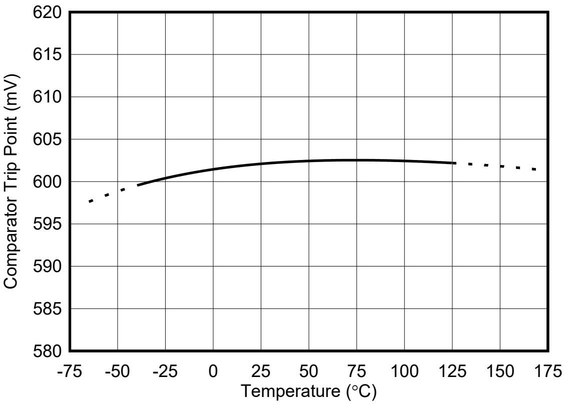


Figure 6-36. Comparator Trip Point vs Temperature

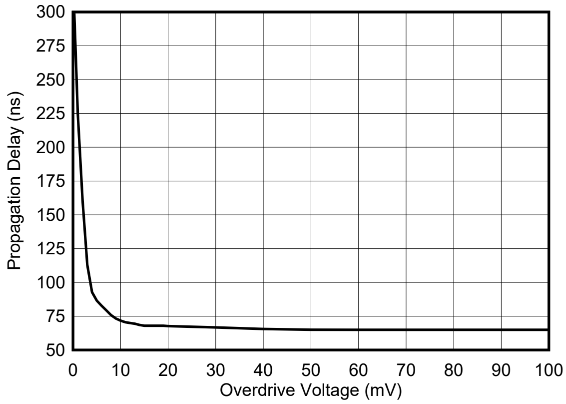


Figure 6-37. Comparator Propagation Delay vs Overdrive Voltage

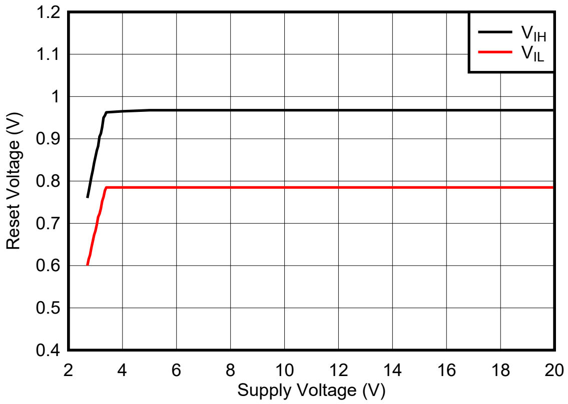


Figure 6-38. Comparator Reset Voltage vs Supply Voltage

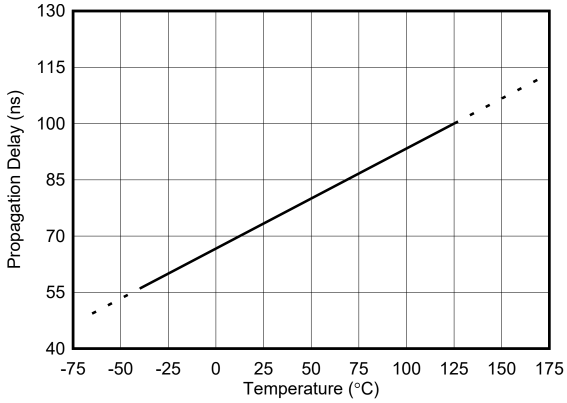


Figure 6-39. Comparator Propagation Delay vs Temperature

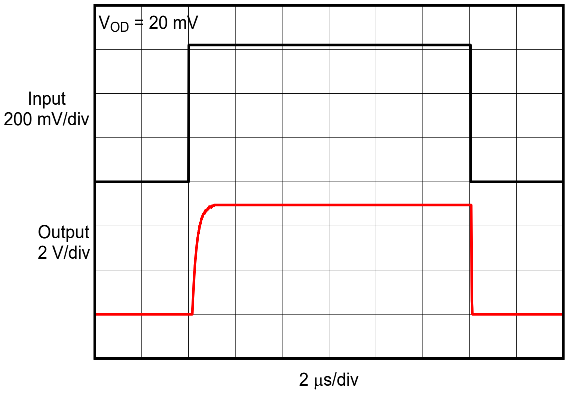


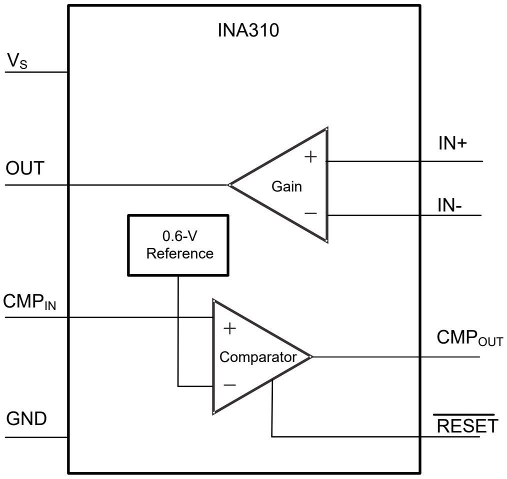
Figure 6-40. Comparator Propagation Delay

# 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 µA 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 *$\overline{\text{RESET}}$ 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-µA 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 $V_{SENSE}$ Operation

The INA310x features high performance operation across the entire valid $V_{SENSE}$ range. The zero-drift input architecture of the INA310x provides the low offset voltage and low offset drift needed to measure low $V_{SENSE}$ levels accurately across the wide operating temperature of –40°C to +125°C. Low $V_{SENSE}$ 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 grain 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.

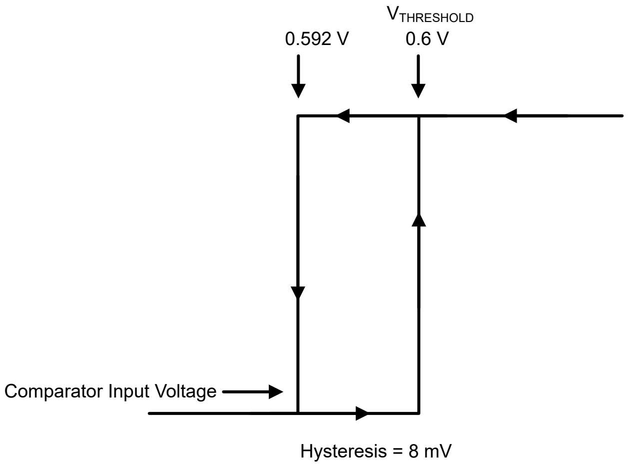


**Figure 7-1. The Comparator Threshold and Hysteresis**

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 V – Hysteresis), the output of the comparator is pulled low by an internal open-drain transistor.

### 7.3.8 $\overline{\text{RESET}}$ 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.

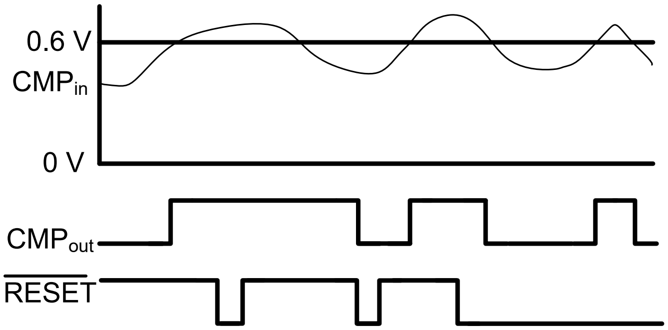


**Figure 7-2. The Comparator $\overline{\text{RESET}}$ Function**

### 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 µs. 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 $V_{OUT}$ 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 ($I_{BCMPIN}$) curve against input voltage ($V_{CMPIN}$) as shown in *Figure 7-3*. The $I_{BCMPIN}$ reduces with $V_{CMPIN}$ from 0 V to 0.4 V, $I_{BCMPIN}$ is under 20 nA at 25°C for $V_{CMPIN}$ range from 0.4 V to 1.2 V, and $I_{BCMPIN}$ increases with $V_{CMPIN}$ from 1.8 V to 5.5 V. The nature of $I_{BCMPIN}$ does not contribute to the inaccuracy of the comparator alert threshold voltage ($V_{THRESHOLD}$) significantly because the $I_{BCMPIN}$ 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 $V_{THRESHOLD}$ accuracy. The sum of the two resistors in the divider network as shown in *Overcurrent Threshold Connection* is recommended to keep lower than 100 kΩ.

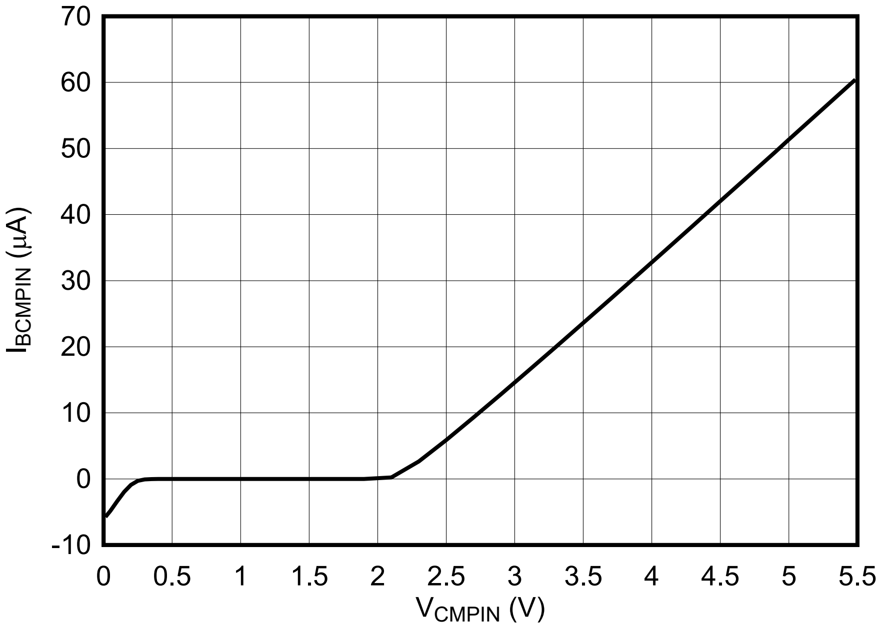


**Figure 7-3. Comparator $I_{BCMPIN}$ vs $V_{CMPIN}$**

## 7.4 Device Functional Modes

### 7.4.1 Basic Connections

Figure 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 $V_S$ pin. The recommended value of a bypass capacitor is 0.01 µF

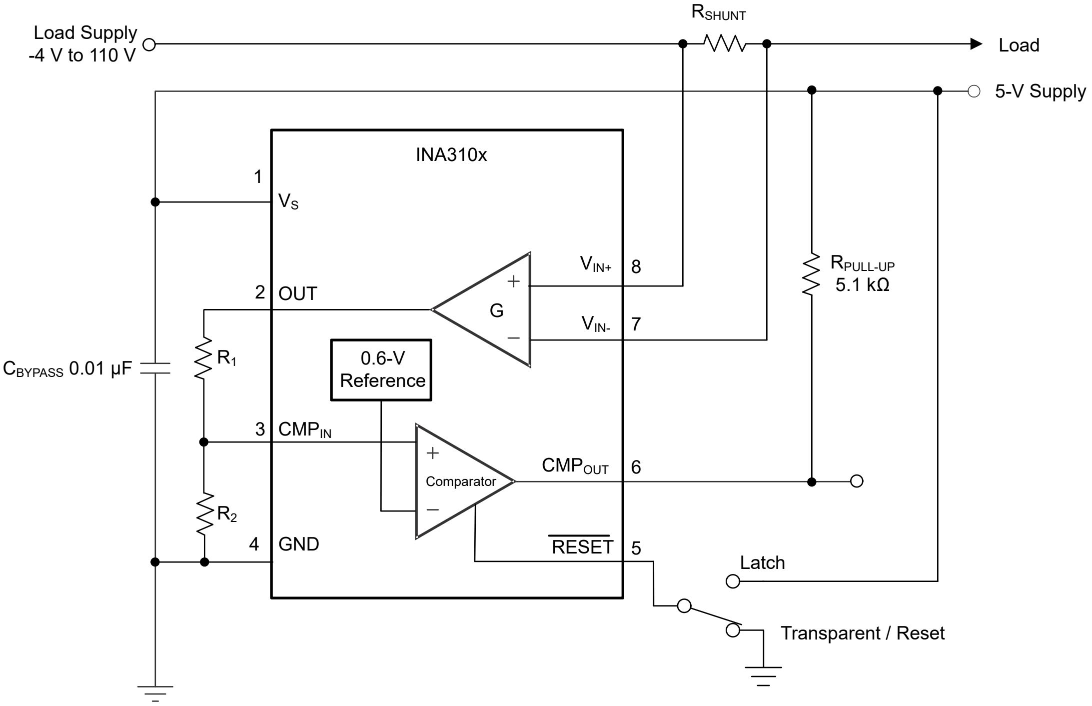


**Figure 7-4. INA310 Basic Connections**

#### *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 $R_2$.

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

$R_1$ and $R_2$ 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 ($CMP_{OUT}$) 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 $CMP_{OUT}$ 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.

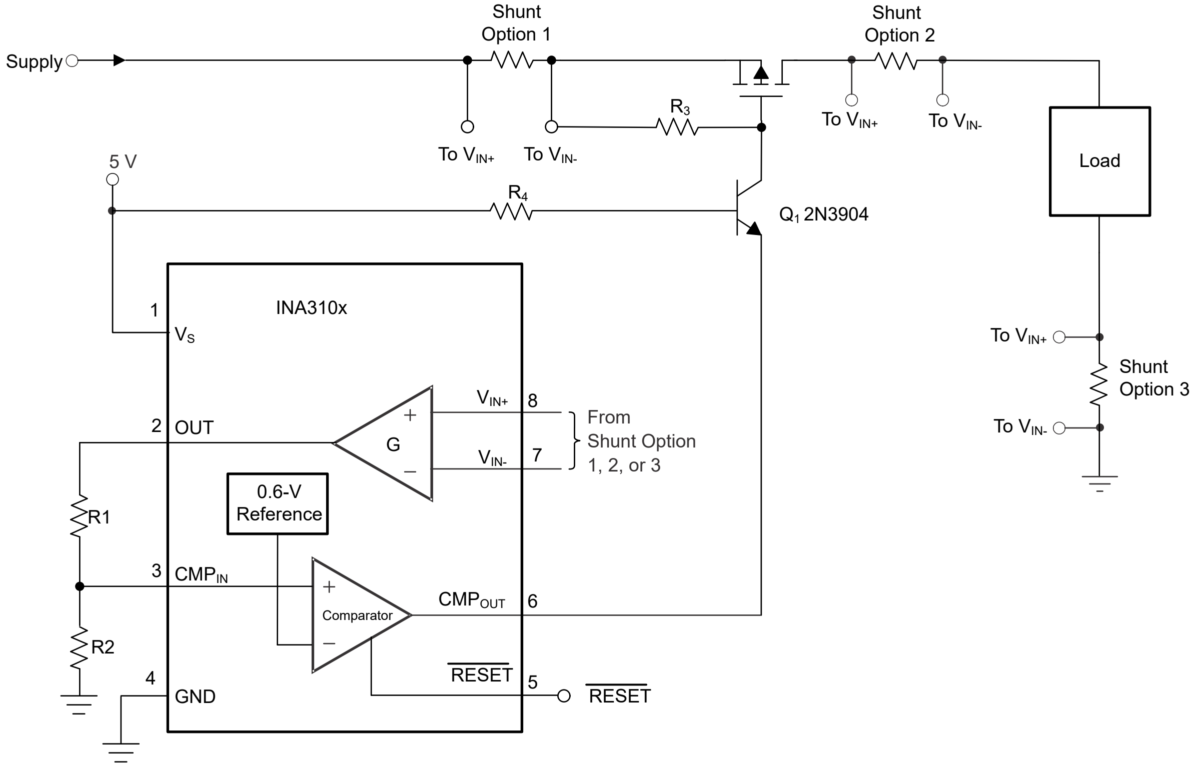


**Figure 7-5. High-Side Switch for Overcurrent Shutdown**

### 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 INA310x function to cover the opposite current directions, and therefore provide bidirectional overcurrent monitor function.

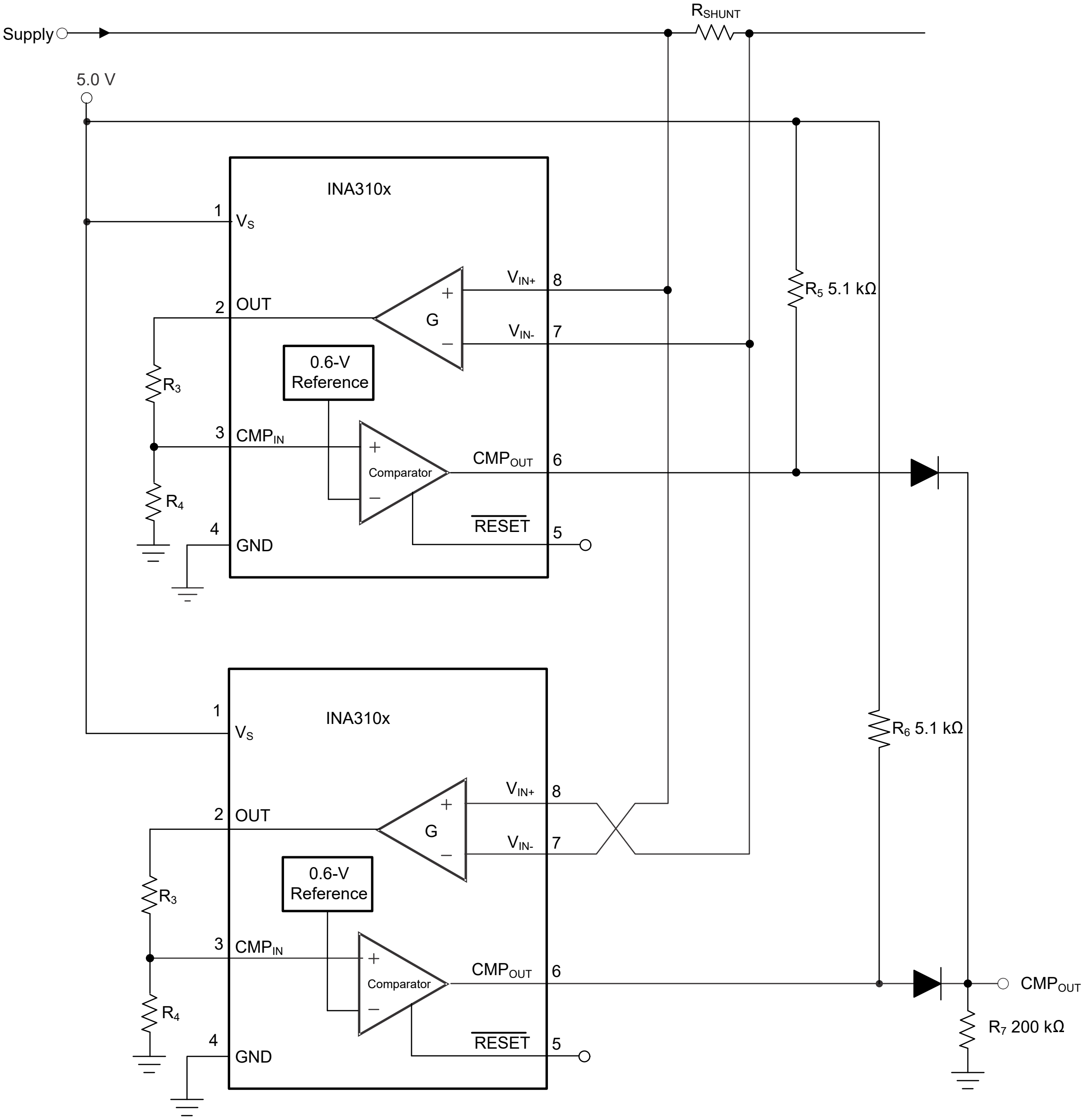


**Figure 7-6. Ground Referenced Output**

# 8 Application and Implementation

**Note**

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

## 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 $R_{SENSE}$ 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. Equation 2 gives the maximum value for the current-sense resistor for a given power dissipation budget:

$$R_{SENSE} < \frac{PD_{MAX}}{I_{MAX}^{2}} \tag{2}$$

where:

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

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. Equation 3 provides the maximum values of $R_{SENSE}$ and GAIN to keep the device from exceeding the positive swing limitation.

$$I_{MAX} \times R_{SENSE} \times GAIN < V_{SP} \tag{3}$$

where:

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

To avoid positive output swing limitations when selecting the value of $R_{SENSE}$, 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 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. Equation 4 provides the limit on the minimum value of the sense resistor.

$$I_{MIN} \times R_{SENSE} \times GAIN > V_{SN} \tag{4}$$

where:

- $I_{MIN}$ is the minimum current that will flow through $R_{SENSE}$.

- GAIN is the gain of the current-sense amplifier.
- $V_{SN}$ is the negative output swing of the device.

Table 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.

**Table 8-1. $R_{SENSE}$ Selection and Power Dissipation(1)**

| PARAMETER | | EQUATION | RESULTS AT $V_S$ = 5 V | | | | |
|---|---|---|---|---|---|---|---|
| | | | A1, B1 DEVICES | A2, B2 DEVICES | A3, B3 DEVICES | A4, B4 DEVICES | A5, B5 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 V to +110 V.

### 8.2.1 Current Sensing in a Solenoid Application

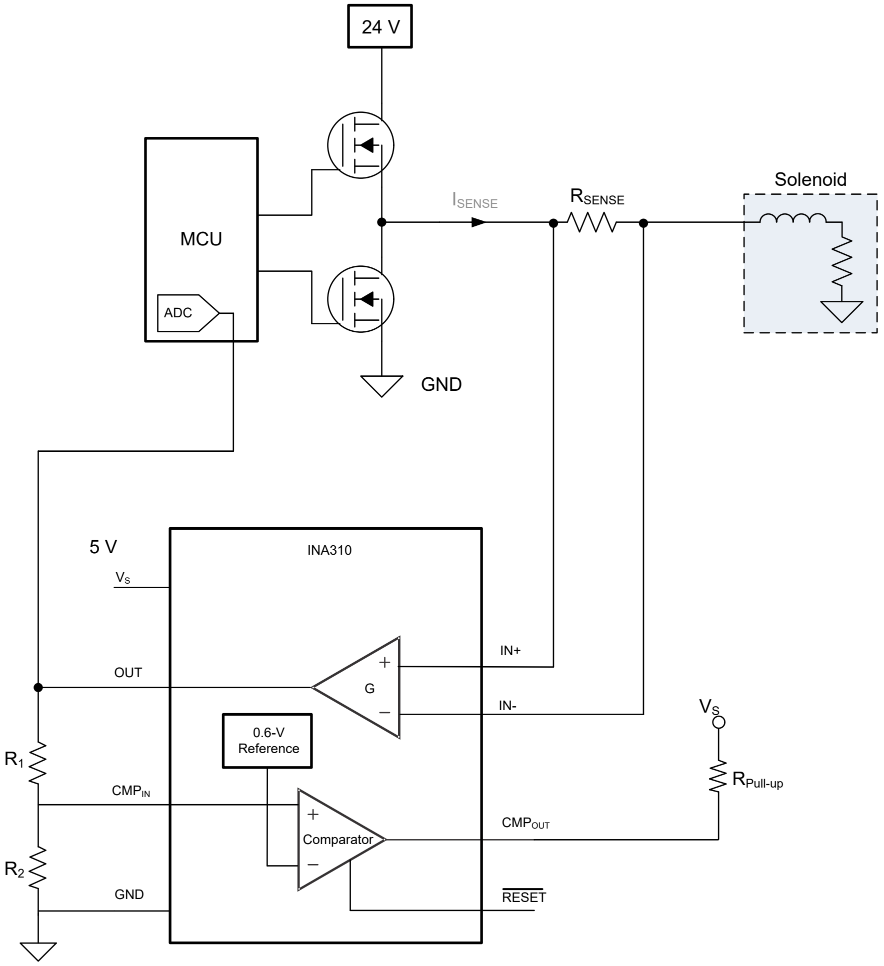


Figure 8-1. Current Sensing in a Solenoid Application

#### 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 *$R_{SENSE}$ and Device Gain Selection*, a $R_{SENSE}$ of 50 mΩ and a gain of 50 V/V are selected to provide good output dynamic range. Table 8-2 lists the design setup for this application.

**Table 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 |
| $R_{SENSE}$ resistor | 50 mΩ |
| Gain option | 50 V/V |
| Over-current Threshold | 1.9 A |
| $R_1$ | 69.15 kΩ |
| $R_2$ | 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.

$R_2$ is fixed as 10 kΩ to avoid loading of OUT as recommended in *Overcurrent Threshold Connection*. $R_1$ is calculated as 69.15 kΩ using Equation 1.

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

$R_1$ (69.15 kΩ) and $R_2$ (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 $V_{SENSE}$

The INA310x 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 or saturated condition and requires time to recover after $V_{SENSE}$ returns positive. The required overload recovery time increases with more negative $V_{SENSE}$.

### 8.2.1.3 Application Curve

Figure 8-2 shows the output response of a solenoid.

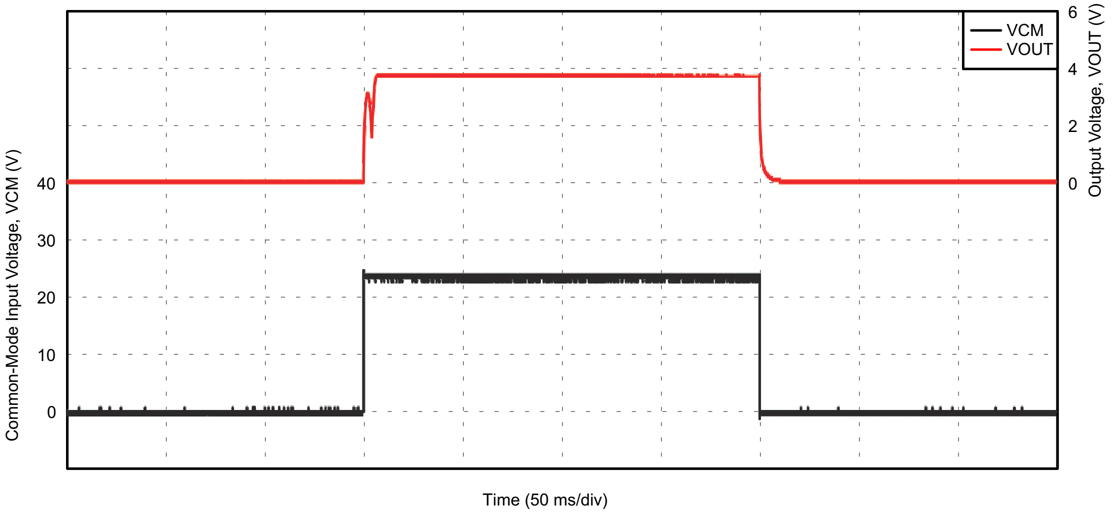


**Figure 8-2. Solenoid Control Current Response**

## 8.2.2 Low-Side Switch Overcurrent Shutdown

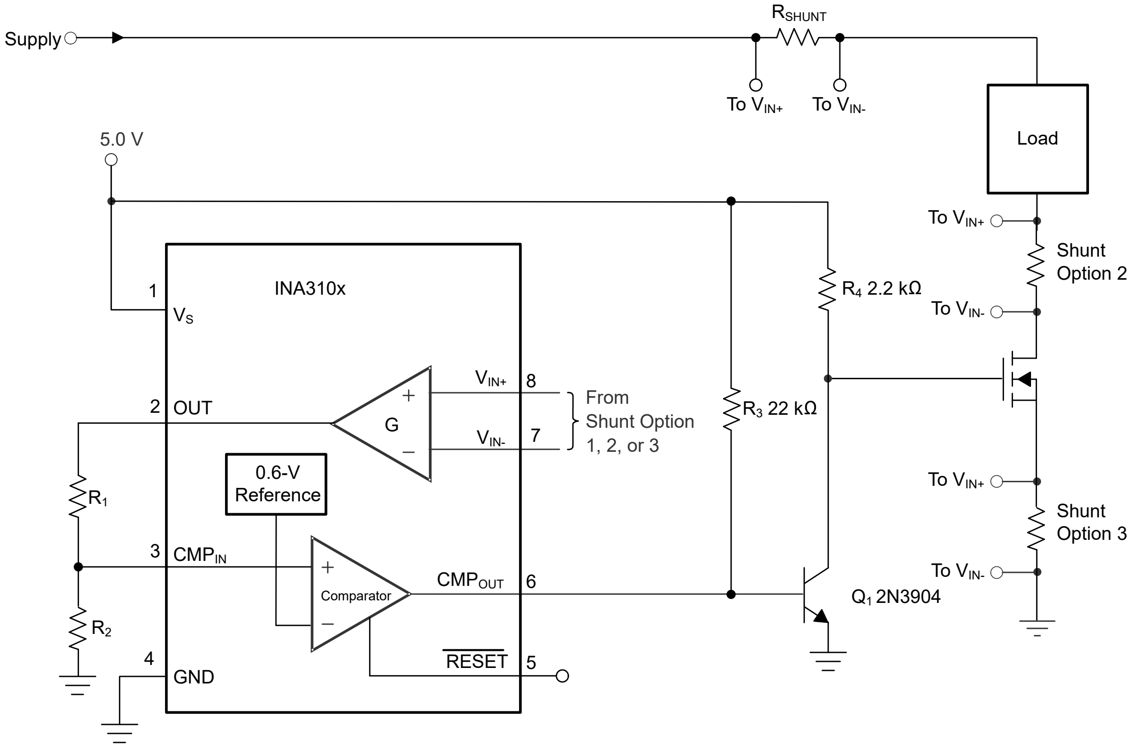


**Figure 8-3. Low-Side Switch Overcurrent Shutdown**

### 8.2.2.1 Design Requirements

The INA310x measures current through a resistive shunt with current flowing in one direction that enables detection of an overcurrent event only when the differential input voltage exceeds the threshold limit. When the current reaches the set limit of the divider of $R_1$ and $R_2$, the output of comparator ($CMP_{OUT}$) transitions high, which turns on $Q_1$, pulls the gate of the pass-FET low, and turns off the flow of the current. In this example 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 *$R_{SENSE}$ and Device Gain Selection*, a $R_{SHUNT}$ of 100 mΩ and a gain of 20 V/V are selected to provide a good output dynamic range. Table 8-3 lists the design setup for this application.

**Table 8-3. Design Parameters**

| DESIGN PARAMETERS | EXAMPLE VALUE |
|---|---|
| Power supply voltage | 5 V |
| Common mode voltage range | 5 V |
| Maximum sense current | 1 A |
| $R_{SENSE}$ resistor | 100 mΩ |
| Gain option | 20 V/V |
| Over-current Threshold | 1.2 A |
| $R_1$ | 10.2 kΩ |
| $R_2$ | 3.4 kΩ |

### 8.2.2.2 Detailed Design Procedure

Figure 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.

$R_1$ is fixed as 10.2 kΩ to avoid loading of OUT as recommended in *Overcurrent Threshold Connection*. $R_2$ is calculated as 3.4 kΩ using Equation 1. $R_1$ (10.2 kΩ) and $R_2$ (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

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

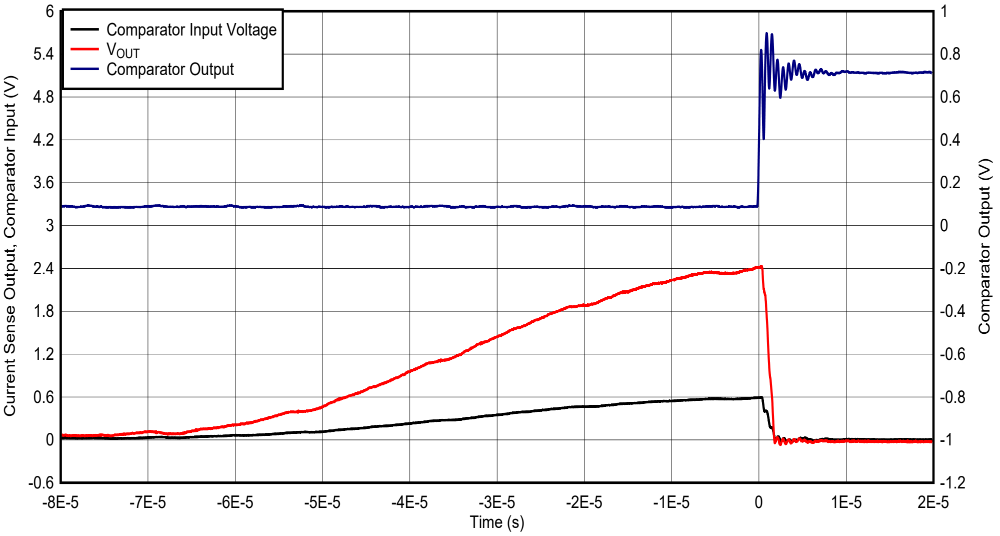


**Figure 8-4. Low-Side Switch Overcurrent Shutdown Response**

## 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 µF. 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 µF. Additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies.

### 8.4.2 Layout Example

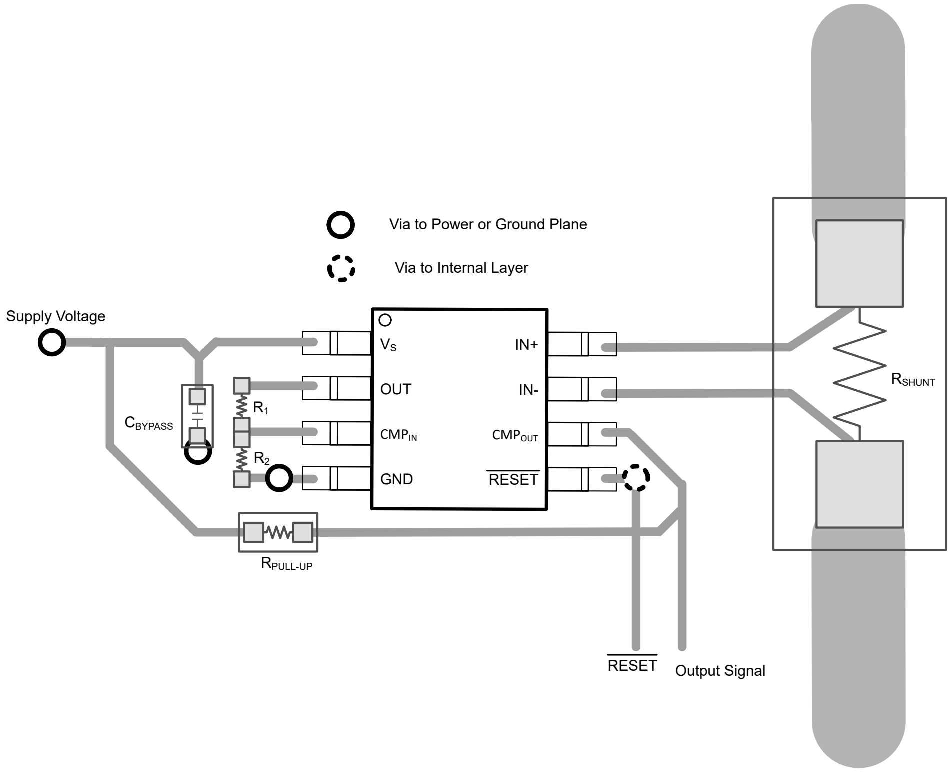


Figure 8-5. INA310xx Recommended Layout

# 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.

## 9.2 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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## 9.3 Trademarks

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## 9.4 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

## 9.5 Glossary

| | |
|---|---|
| TI Glossary | This glossary lists and explains terms, acronyms, and definitions. |

# 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 Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| INA310A1IDGKR | ACTIVE | VSSOP | DGK | 8 | 2500 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 2OZB | Samples |
| INA310A2IDGKR | ACTIVE | VSSOP | DGK | 8 | 2500 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 2P1B | Samples |
| INA310A3IDGKR | ACTIVE | VSSOP | DGK | 8 | 2500 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 2P2B | Samples |
| INA310A4IDGKR | ACTIVE | VSSOP | DGK | 8 | 2500 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 2P3B | Samples |
| INA310A5IDGKR | ACTIVE | VSSOP | DGK | 8 | 2500 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 2P4B | Samples |
| INA310B1IDGKR | ACTIVE | VSSOP | DGK | 8 | 2500 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 2P5B | Samples |
| INA310B2IDGKR | ACTIVE | VSSOP | DGK | 8 | 2500 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 2P6B | Samples |
| INA310B3IDGKR | ACTIVE | VSSOP | DGK | 8 | 2500 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 2P7B | Samples |
| INA310B4IDGKR | ACTIVE | VSSOP | DGK | 8 | 2500 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 2P8B | Samples |
| INA310B5IDGKR | ACTIVE | VSSOP | DGK | 8 | 2500 | RoHS & Green | NIPDAU | Level-2-260C-1 YEAR | -40 to 125 | 2P9B | Samples |

(1) 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.

(2) **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.

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

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

[5] 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.

[6] 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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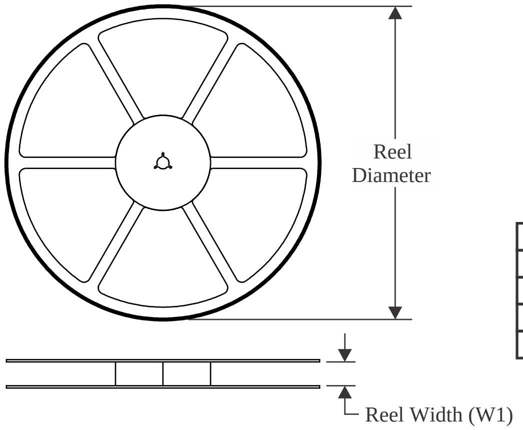
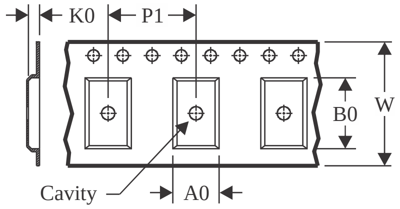
## TAPE AND REEL INFORMATION

REEL DIMENSIONS

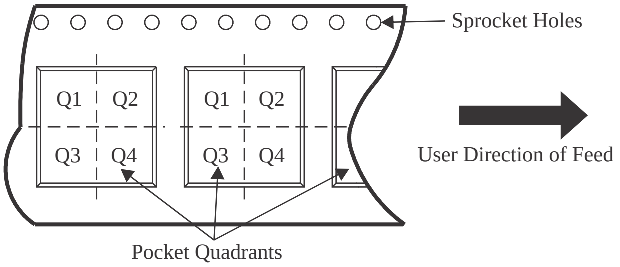


TAPE DIMENSIONS



| | |
|---|---|
| A0 | Dimension designed to accommodate the component width |
| B0 | Dimension designed to accommodate the component length |
| K0 | Dimension designed to accommodate the component thickness |
| W | Overall width of the carrier tape |
| P1 | Pitch between successive cavity centers |

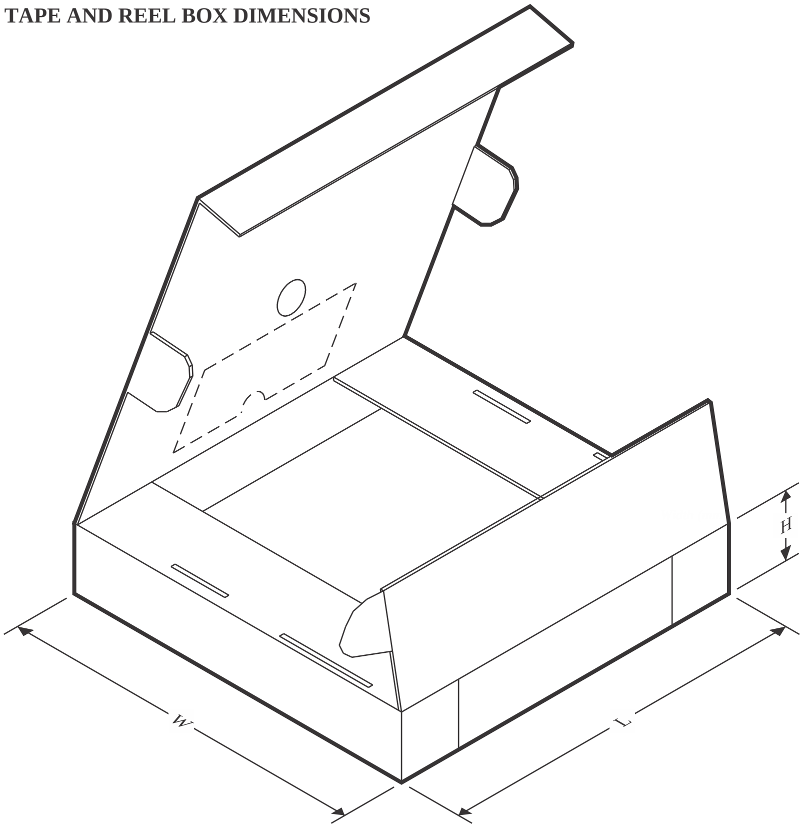
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

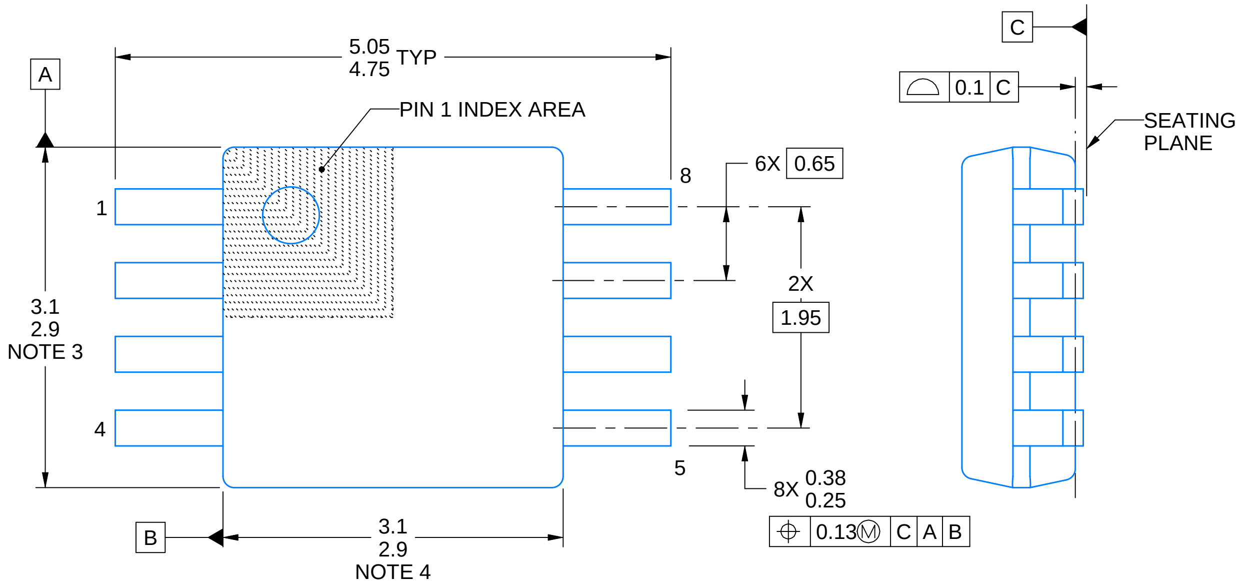
| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INA310A1IDGKR | VSSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| INA310A2IDGKR | VSSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| INA310A3IDGKR | VSSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| INA310A4IDGKR | VSSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| INA310A5IDGKR | VSSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| INA310B1IDGKR | VSSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| INA310B4IDGKR | VSSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| INA310B5IDGKR | VSSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |

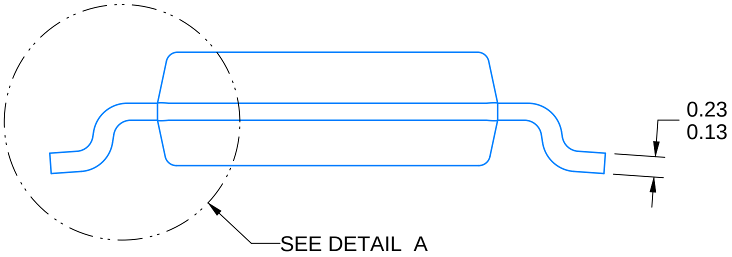
## TAPE AND REEL BOX DIMENSIONS

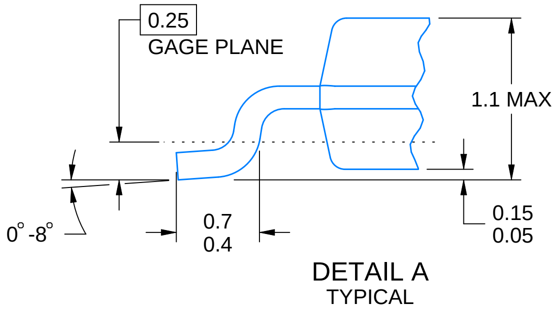


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| INA310A1IDGKR | VSSOP | DGK | 8 | 2500 | 356.0 | 356.0 | 35.0 |
| INA310A2IDGKR | VSSOP | DGK | 8 | 2500 | 356.0 | 356.0 | 35.0 |
| INA310A3IDGKR | VSSOP | DGK | 8 | 2500 | 356.0 | 356.0 | 35.0 |
| INA310A4IDGKR | VSSOP | DGK | 8 | 2500 | 356.0 | 356.0 | 35.0 |
| INA310A5IDGKR | VSSOP | DGK | 8 | 2500 | 356.0 | 356.0 | 35.0 |
| INA310B1IDGKR | VSSOP | DGK | 8 | 2500 | 356.0 | 356.0 | 35.0 |
| INA310B4IDGKR | VSSOP | DGK | 8 | 2500 | 356.0 | 356.0 | 35.0 |
| INA310B5IDGKR | VSSOP | DGK | 8 | 2500 | 356.0 | 356.0 | 35.0 |







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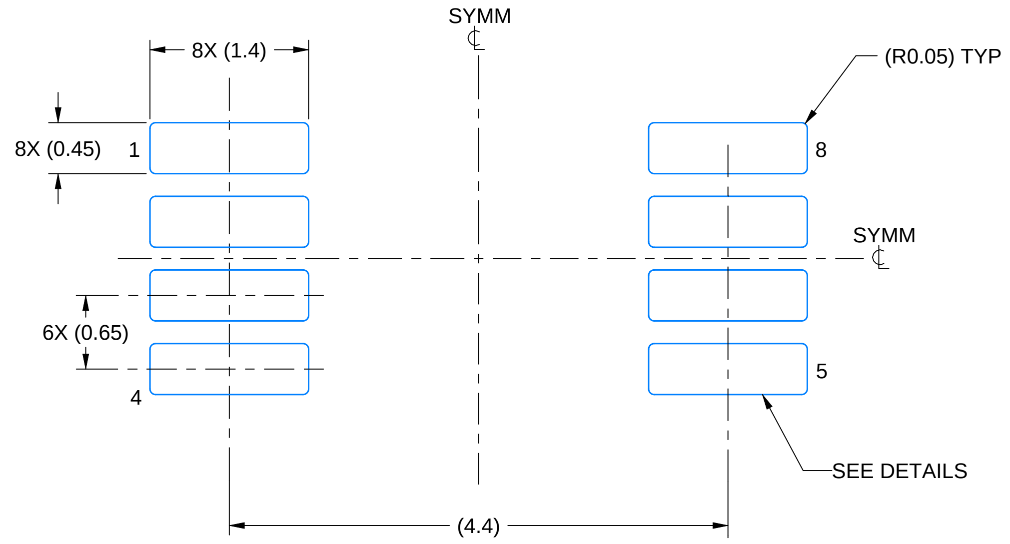
NOTES:

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. 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.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 15X

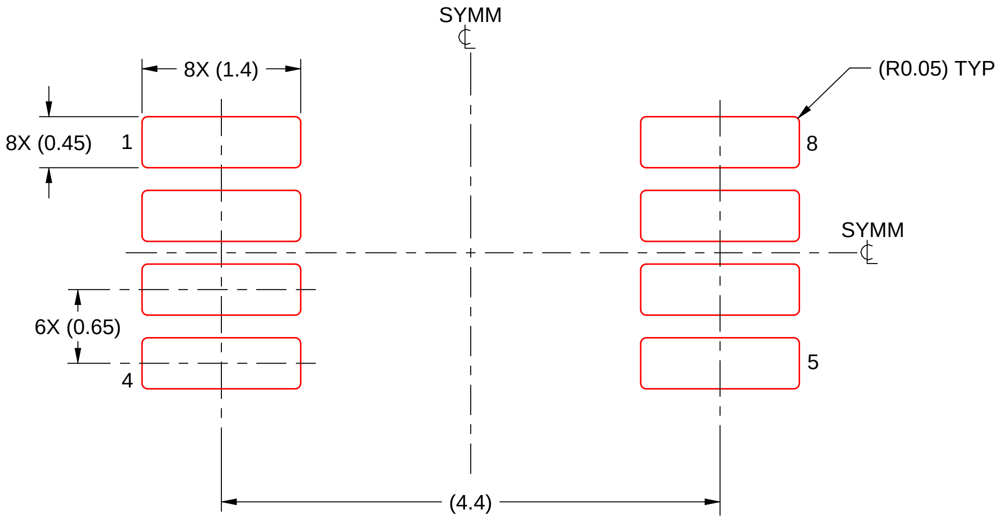
NON-SOLDER MASK
DEFINED
(PREFERRED)

SOLDER MASK
DEFINED

SOLDER MASK DETAILS

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.



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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