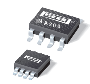


# INA200
# INA201
# INA202

SBOS374B − NOVEMBER 2006 − REVISED OCTOBER 2007

# High-Side Measurement Current-Shunt Monitor with Comparator and Reference

## FEATURES

- **COMPLETE CURRENT SENSE SOLUTION**
- **0.6V INTERNAL VOLTAGE REFERENCE**
- **INTERNAL OPEN-DRAIN COMPARATOR**
- **LATCHING CAPABILITY ON COMPARATOR**
- **COMMON-MODE RANGE: −16V to +80V**
- **HIGH ACCURACY: 3.5% MAX ERROR OVER TEMPERATURE**
- **BANDWIDTH: 500kHz (INA200)**
- **QUIESCENT CURRENT: 1800μA (max)**
- **PACKAGES: SO-8, MSOP-8**

## APPLICATIONS

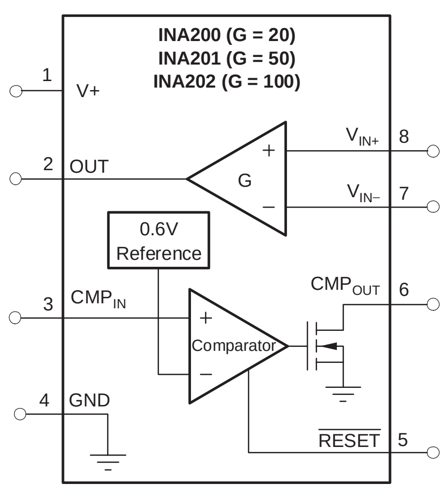
- **NOTEBOOK COMPUTERS**
- **CELL PHONES**
- **TELECOM EQUIPMENT**
- **AUTOMOTIVE**
- **POWER MANAGEMENT**
- **BATTERY CHARGERS**
- **WELDING EQUIPMENT**

## DESCRIPTION

The INA200, INA201, and INA202 are high-side current-shunt monitors with voltage output. The INA200−INA202 can sense drops across shunts at common-mode voltages from −16V to 80V. The INA200−INA202 are available with three output voltage scales: 20V/V, 50V/V, and 100V/V, with up to 500kHz bandwidth.

The INA200, INA201, and INA202 also incorporate an open-drain comparator and internal reference providing a 0.6V threshold. External dividers are used to set the current trip point. The comparator includes a latching capability, which can be made transparent by grounding (or leaving open) the $\overline{\text{RESET}}$ pin.

The INA200, INA201, and INA202 operate from a single +2.7V to +18V supply, drawing a maximum of 1800μA of supply current. Package options include the very small MSOP-8 and the SO-8. All versions are specified over the extended operating temperature range of −40°C to +125°C.



## ABSOLUTE MAXIMUM RATINGS(1)

| | |
|---|---|
| Supply Voltage, V+ | 18V |
| Current-Shunt Monitor Analog Inputs, $V_{IN+}$, $V_{IN-}$ | |
| Differential ($V_{IN+}$) − ($V_{IN-}$) | −18V to +18V |
| Common Mode(2) | −16V to +80V |
| Comparator Analog Input and Reset Pins(2) | GND − 0.3V to (V+) + 0.3V |
| Analog Output, Out(2) | GND − 0.3V to (V+) + 0.3V |
| Comparator Output, Out Pin(2) | GND − 0.3V to 18V |
| Input Current Into Any Pin(2) | 5mA |
| Operating Temperature | −55°C to +150°C |
| Storage Temperature | −65°C to +150°C |
| Junction Temperature | +150°C |
| ESD Ratings: | |
| Human Body Model (HBM) | 4000V |
| Charged Device Model (CDM) | 1000V |

(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not supported.

(2) This voltage may exceed the ratings shown if the current at that pin is limited to 5mA.

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.

## ORDERING INFORMATION(1)

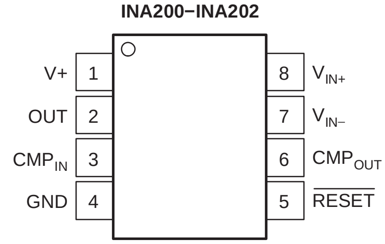
| PRODUCT | GAIN | PACKAGE-LEAD | PACKAGE DESIGNATOR | PACKAGE MARKING |
|---|---|---|---|---|
| INA200 | 20V/V | MSOP-8 | DGK | BQH |
| | | SO-8 | D | INA200A |
| INA201 | 50V/V | MSOP-8 | DGK | BQJ |
| | | SO-8 | D | INA201A |
| INA202 | 100V/V | MSOP-8 | DGK | BQL |
| | | SO-8 | D | INA202A |

(1) For the most current package and ordering information see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.

## PIN CONFIGURATIONS

**TOP VIEW**

**INA200−INA202**




MSOP−8 (DGK)
SO−8 (D)

## ELECTRICAL CHARACTERISTICS: CURRENT-SHUNT MONITOR

**Boldface** limits apply over the specified temperature range: **$T_A$ = −40°C to +125°C.**

At $T_A$ = +25°C, $V_S$ = +12V, $V_{CM}$ = +12V, $V_{SENSE}$ = 100mV, $R_L$ = 10kΩ to GND, $R_{PULL-UP}$ = 5.1kΩ connected from $CMP_{OUT}$ to $V_S$, and $CMP_{IN}$ = GND, unless otherwise noted.

| CURRENT-SHUNT MONITOR PARAMETERS | CONDITIONS | INA200, INA201, INA202 MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|
| **INPUT** | | | | | |
| Full-Scale Sense Input Voltage $V_{SENSE}$ | $V_{SENSE} = V_{IN+} - V_{IN-}$ | | 0.15 | ($V_S$ − 0.25)/Gain | V |
| **Common-Mode Input Range $V_{CM}$** | | **−16** | | **80** | **V** |
| Common-Mode Rejection CMR | $V_{IN+}$ = −16V to +80V | 80 | 100 | | dB |
| **Over Temperature** | **$V_{IN+}$ = +12V to +80V** | **100** | **123** | | **dB** |
| Offset Voltage, RTI(1) $V_{OS}$ | | | ±0.5 | ±2.5 | mV |
| +25°C to +125°C | | | | ±3 | mV |
| −40°C to +25°C | | | | ±3.5 | mV |
| **vs Temperature $dV_{OS}/dT$** | **$T_{MIN}$ to $T_{MAX}$** | | **5** | | **μV/°C** |
| **vs Power Supply PSR** | **$V_{OUT}$ = 2V, $V_{IN+}$ = +18V, 2.7V** | | **2.5** | **100** | **μV/V** |
| **Input Bias Current, $V_{IN-}$ Pin $I_B$** | | | **±9** | **±16** | **μA** |
| **OUTPUT ($V_{SENSE}$ ≥ 20mV)** | | | | | |
| Gain: G | | | | | |
| INA200 | | | 20 | | V/V |
| INA201 | | | 50 | | V/V |
| INA202 | | | 100 | | V/V |
| Gain Error | $V_{SENSE}$ = 20mV to 100mV | | ±0.2 | ±1 | % |
| **Over Temperature** | **$V_{SENSE}$ = 20mV to 100mV** | | | **±2** | **%** |
| Total Output Error(2) | $V_{SENSE}$ = 120mV, $V_S$ = +16V | | ±0.75 | ±2.2 | % |
| **Over Temperature** | **$V_{SENSE}$ = 120mV, $V_S$ = +16V** | | | **±3.5** | **%** |
| Nonlinearity Error(3) | $V_{SENSE}$ = 20mV to 100mV | | ±0.002 | | % |
| Output Impedance $R_O$ | | | 1.5 | | Ω |
| Maximum Capacitive Load | No Sustained Oscillation | | 10 | | nF |
| **OUTPUT ($V_{SENSE}$ < 20mV)(4)** | | | | | |
| INA200, INA201, INA202 | $-16V \le V_{CM} < 0V$ | | 300 | | mV |
| INA200 | $0V \le V_{CM} \le V_S$, $V_S$ = 5V | | | 0.4 | V |
| INA201 | $0V \le V_{CM} \le V_S$, $V_S$ = 5V | | | 1 | V |
| INA202 | $0V \le V_{CM} \le V_S$, $V_S$ = 5V | | | 2 | V |
| INA200, INA201, INA202 | $V_S < V_{CM} \le 80V$ | | 300 | | mV |
| **VOLTAGE OUTPUT(5)** | | | | | |
| **Output Swing to the Positive Rail** | **$V_{IN-}$ = 11V, $V_{IN+}$ = 12V** | | **(V+) − 0.15** | **(V+) − 0.25** | **V** |
| **Output Swing to GND(6)** | **$V_{IN-}$ = 0V, $V_{IN+}$ = −0.5V** | | **($V_{GND}$) + 0.004** | **($V_{GND}$) + 0.05** | **V** |
| **FREQUENCY RESPONSE** | | | | | |
| Bandwidth: BW | | | | | |
| INA200 | $C_{LOAD}$ = 5pF | | 500 | | kHz |
| INA201 | $C_{LOAD}$ = 5pF | | 300 | | kHz |
| INA202 | $C_{LOAD}$ = 5pF | | 200 | | kHz |
| Phase Margin | $C_{LOAD}$ < 10nF | | 40 | | Degrees |
| Slew Rate SR | | | 1 | | V/μs |
| Settling Time (1%) | $V_{SENSE}$ = 10mV$_{PP}$ to 100mV$_{PP}$, $C_{LOAD}$ = 5pF | | 2 | | μs |
| **NOISE, RTI** | | | | | |
| Voltage Noise Density | | | 40 | | nV/√Hz |

(1) Offset is extrapolated from measurements of the output at 20mV and 100mV $V_{SENSE}$.
(2) Total output error includes effects of gain error and $V_{OS}$.
(3) Linearity is best fit to a straight line.
(4) For details on this region of operation, see the *Accuracy Variations as a Result of $V_{SENSE}$ and Common-Mode Voltage* section in the Applications Information.
(5) See Typical Characteristic curve *Output Swing vs Output Current*.
(6) Specified by design.

## ELECTRICAL CHARACTERISTICS: COMPARATOR

**Boldface** limits apply over the specified temperature range: **$T_A$ = −40°C to +125°C.**

At $T_A$ = +25°C, $V_S$ = +12V, $V_{CM}$ = +12V, $V_{SENSE}$ = 100mV, $R_L$ = 10kΩ to GND, and $R_{PULL\text{-}UP}$ = 5.1kΩ connected from $CMP_{OUT}$ to $V_S$, unless otherwise noted.

| COMPARATOR PARAMETERS | | CONDITIONS | INA200, INA201, INA202 MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| **OFFSET VOLTAGE** | | | | | | |
| Threshold | | $T_A$ = +25°C | 590 | 608 | 620 | mV |
| **Over Temperature** | | | **586** | | **625** | **mV** |
| Hysteresis(1) | | $T_A$ = −40°C to +85°C | | −8 | | mV |
| **INPUT BIAS CURRENT(2)** | | | | | | |
| $CMP_{IN}$ Pin | | | | 0.005 | 10 | nA |
| **vs Temperature** | | | | | **15** | **nA** |
| **INPUT VOLTAGE RANGE** | | | | | | |
| $CMP_{IN}$ Pin | | | | 0V to $V_S$ − 1.5V | | V |
| **OUTPUT (OPEN-DRAIN)** | | | | | | |
| Large-Signal Differential Voltage Gain | | CMP $V_{OUT}$ 1V to 4V, $R_L$ ≥ 15kΩ Connected to 5V | | 200 | | V/mV |
| High-Level Leakage Current(3)(4) | $I_{LKG}$ | $V_{ID}$ = 0.4V, $V_{OH}$ = $V_S$ | | 0.0001 | 1 | µA |
| Low-Level Output Voltage(3) | $V_{OL}$ | $V_{ID}$ = −0.6V, $I_{OL}$ = 2.35mA | | 220 | 300 | mV |
| **RESPONSE TIME** | | | | | | |
| Response Time(5) | | $R_L$ to 5V, $C_L$ = 15pF, 100mV Input Step with 5mV Overdrive | | 1.3 | | µs |
| **$\overline{\text{RESET}}$** | | | | | | |
| $\overline{\text{RESET}}$ Threshold(6) | | | | 1.1 | | V |
| Logic Input Impedance | | | | 2 | | MΩ |
| Minimum $\overline{\text{RESET}}$ Pulse Width | | | | 1.5 | | µs |
| $\overline{\text{RESET}}$ Propagation Delay | | | | 3 | | µs |

(1) Hysteresis refers to the threshold (the threshold specification applies to a rising edge of a noninverting input) of a falling edge on the noninverting input of the comparator; refer to Figure 1.
(2) Specified by design.
(3) $V_{ID}$ refers to the differential voltage at the comparator inputs.
(4) Open-drain output can be pulled to the range of +2.7V to +18V, regardless of $V_S$.
(5) The comparator response time specified is the interval between the input step function and the instant when the output crosses 1.4V.
(6) The $\overline{\text{RESET}}$ input has an internal 2MΩ (typical) pull-down. Leaving $\overline{\text{RESET}}$ open results in a LOW state, with transparent comparator operation.

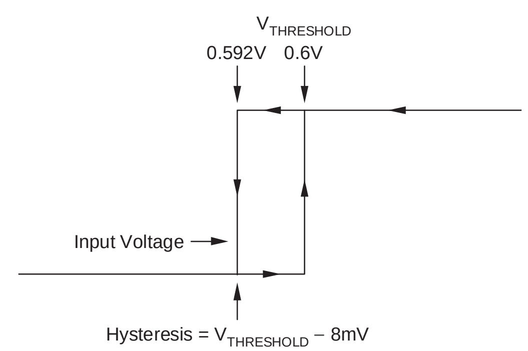



**Figure 1. Typical Comparator Hysteresis**

## ELECTRICAL CHARACTERISTICS: GENERAL

**Boldface** limits apply over the specified temperature range: **$T_A$ = −40°C to +125°C.**

At $T_A$ = +25°C, $V_S$ = +12V, $V_{CM}$ = +12V, $V_{SENSE}$ = 100mV, $R_L$ = 10kΩ to GND, $R_{PULL-UP}$ = 5.1kΩ connected from $CMP_{OUT}$ to $V_S$, and $CMP_{IN}$ = 1V, unless otherwise noted.

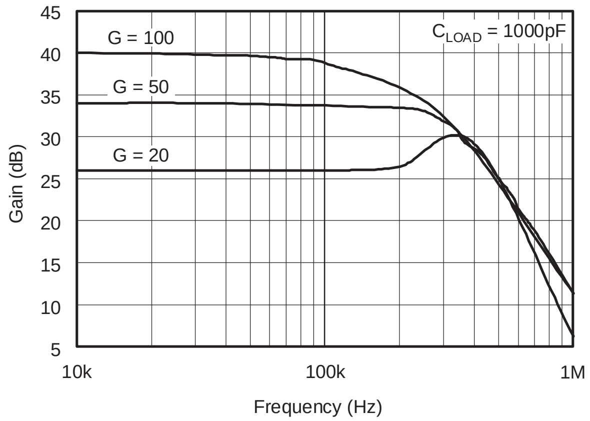
| GENERAL PARAMETERS | | CONDITIONS | INA200, INA201, INA202 MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| **POWER SUPPLY** | | | | | | |
| **Operating Power Supply** | **$V_S$** | | **+2.7** | | **+18** | **V** |
| Quiescent Current | $I_Q$ | $V_{OUT}$ = 2V | | 1350 | 1800 | μA |
| **Over Temperature** | | **$V_{SENSE}$ = 0mV** | | | **1850** | **μA** |
| Comparator Power-On Reset Threshold(1) | | | | 1.5 | | V |
| **TEMPERATURE** | | | | | | |
| Specified Temperature Range | | | −40 | | +125 | °C |
| Operating Temperature Range | | | −55 | | +150 | °C |
| Storage Temperature Range | | | −65 | | +150 | °C |
| Thermal Resistance | $\theta_{JA}$ | | | | | |
| MSOP-8 Surface-Mount | | | | 200 | | °C/W |
| SO-8 | | | | 150 | | °C/W |

(1) The INA200, INA201, and INA202 are designed to power-up with the comparator in a defined reset state as long as $\overline{RESET}$ is open or grounded. The comparator is in reset as long as the power supply is below the voltage shown here. The comparator assumes a state based on the comparator input above this supply voltage. If $\overline{RESET}$ is high at power-up, the comparator output comes up high and requires a reset to assume a low state, if appropriate.

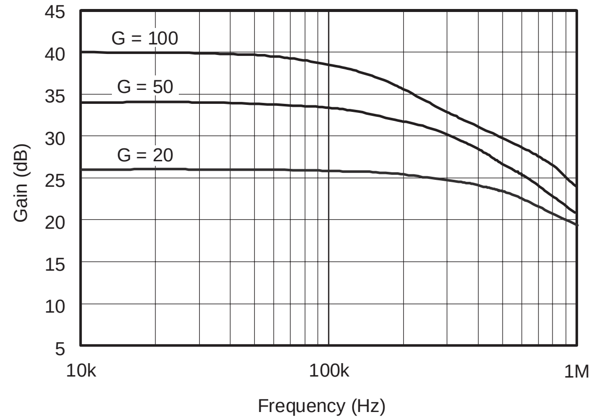
## TYPICAL CHARACTERISTICS

At $T_A$ = +25°C, $V_S$ = +12V, $V_{IN+}$ = 12V, and $V_{SENSE}$ = 100mV, unless otherwise noted.

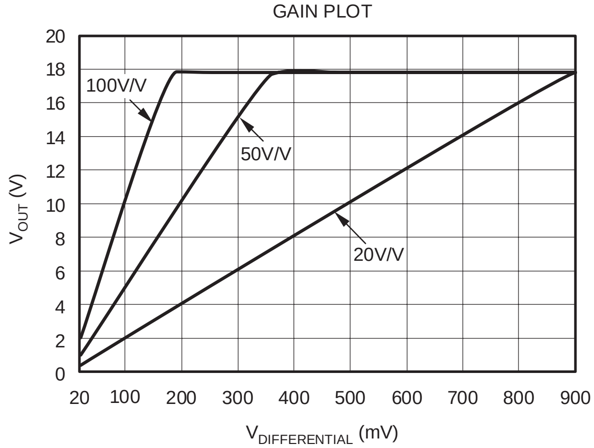
GAIN vs FREQUENCY



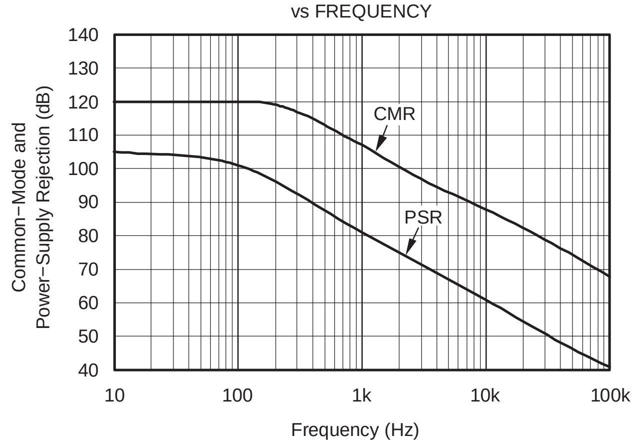

GAIN vs FREQUENCY



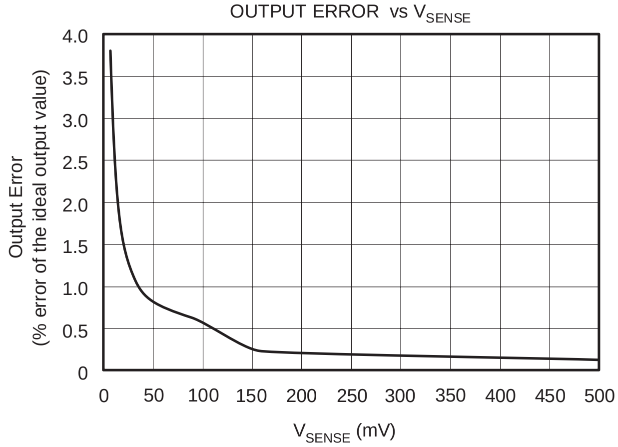

GAIN PLOT



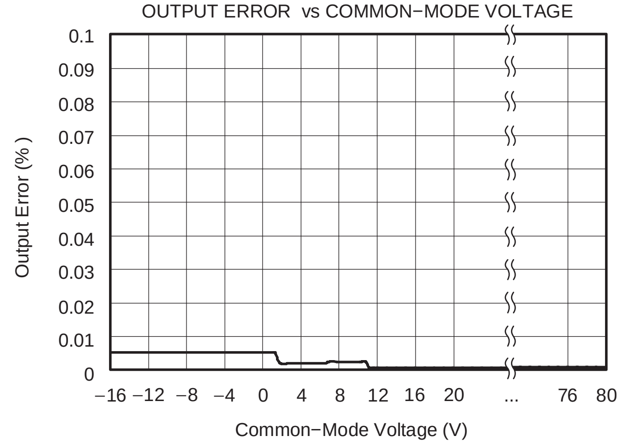

COMMON−MODE AND POWER−SUPPLY REJECTION vs FREQUENCY




OUTPUT ERROR vs $V_{SENSE}$



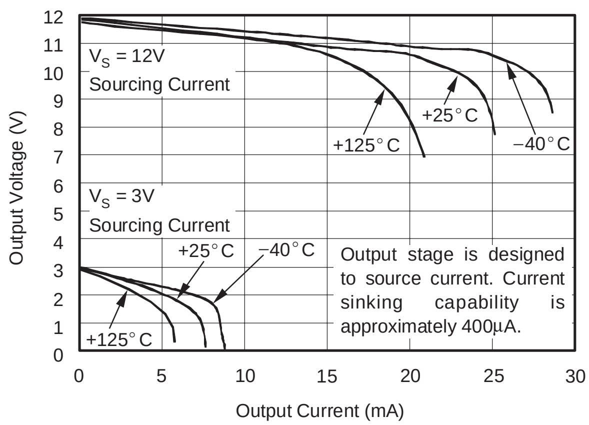

OUTPUT ERROR vs COMMON−MODE VOLTAGE



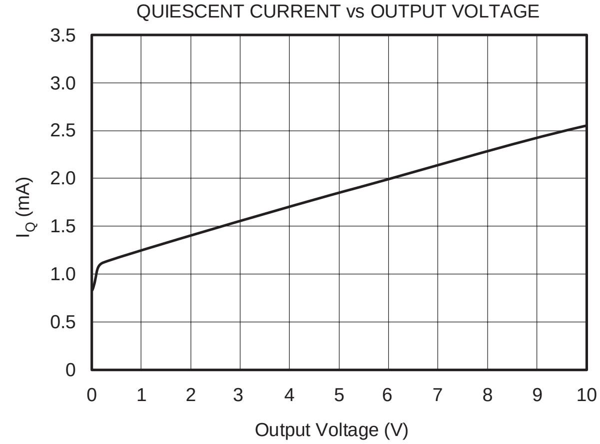
## TYPICAL CHARACTERISTICS (continued)

At $T_A$ = +25°C, $V_S$ = +12V, $V_{IN+}$ = 12V, and $V_{SENSE}$ = 100mV, unless otherwise noted.

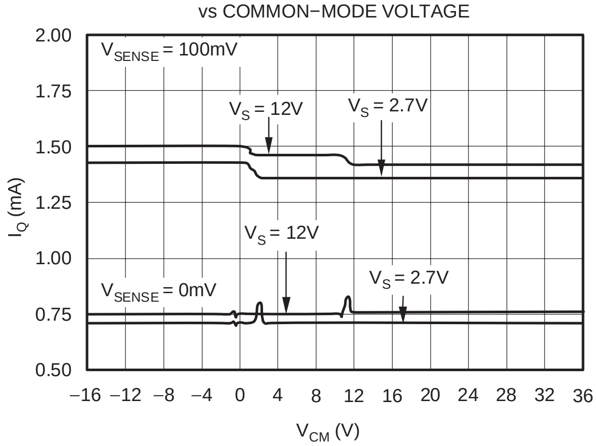
POSITIVE OUTPUT VOLTAGE SWING vs OUTPUT CURRENT



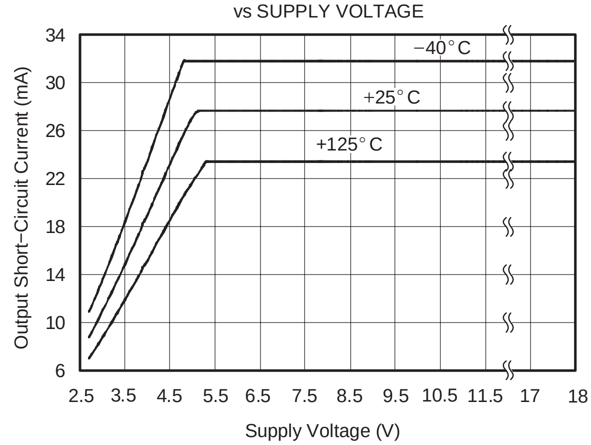

QUIESCENT CURRENT vs OUTPUT VOLTAGE



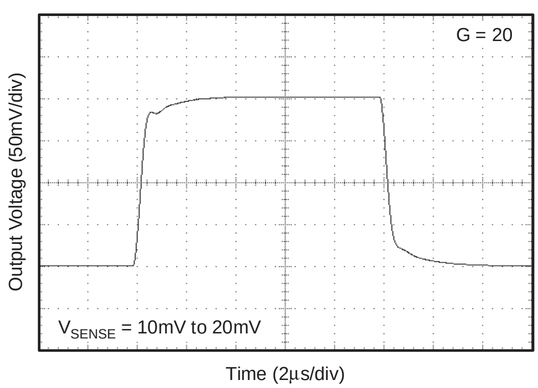

QUIESCENT CURRENT vs COMMON−MODE VOLTAGE



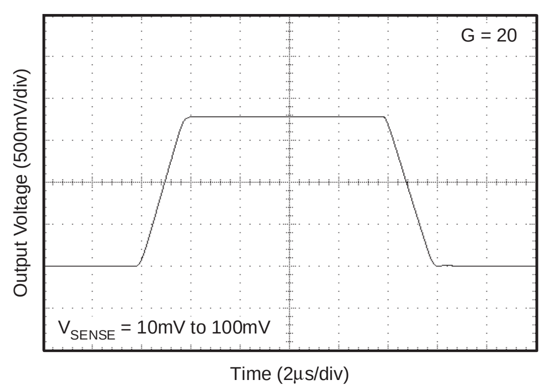

OUTPUT SHORT−CIRCUIT CURRENT vs SUPPLY VOLTAGE




STEP RESPONSE

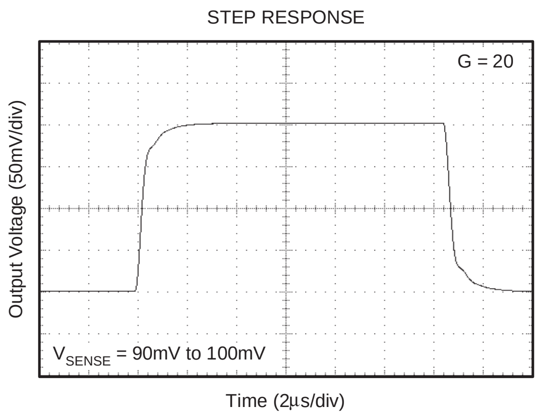


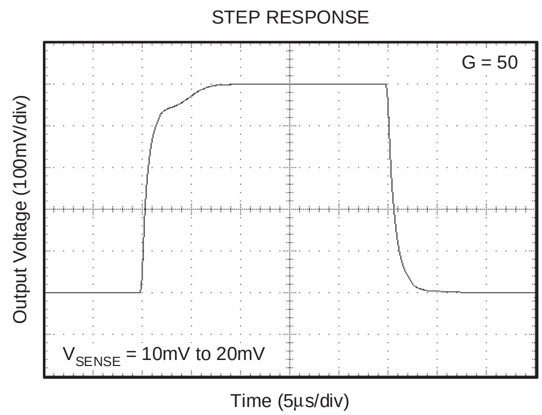

STEP RESPONSE

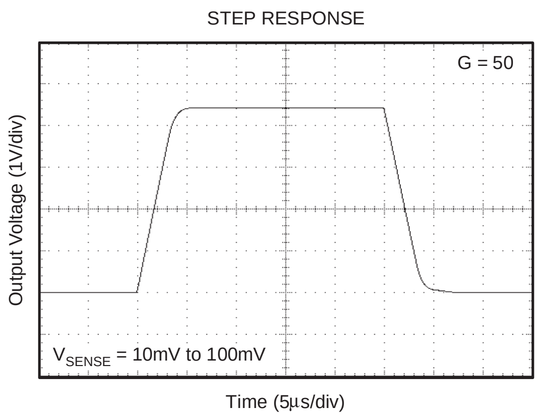


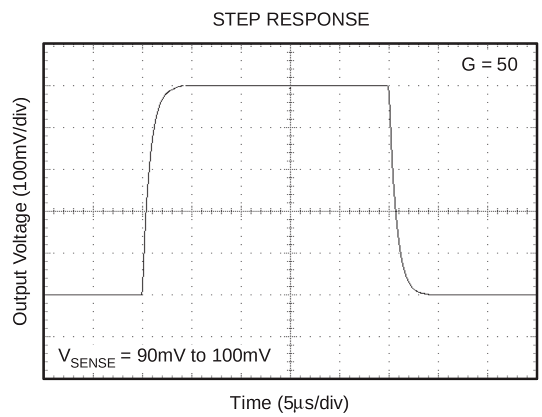
## TYPICAL CHARACTERISTICS (continued)

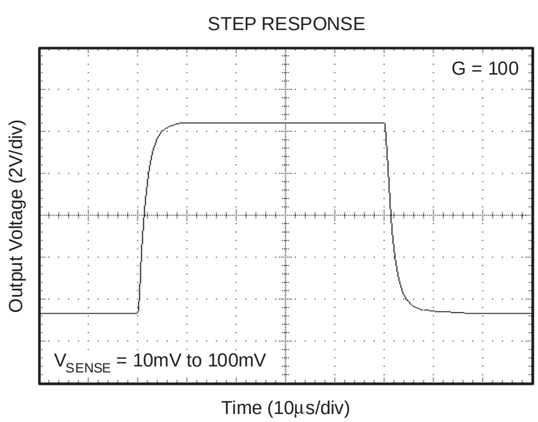
At $T_A = +25°C$, $V_S = +12V$, $V_{IN+} = 12V$, and $V_{SENSE} = 100mV$, unless otherwise noted.

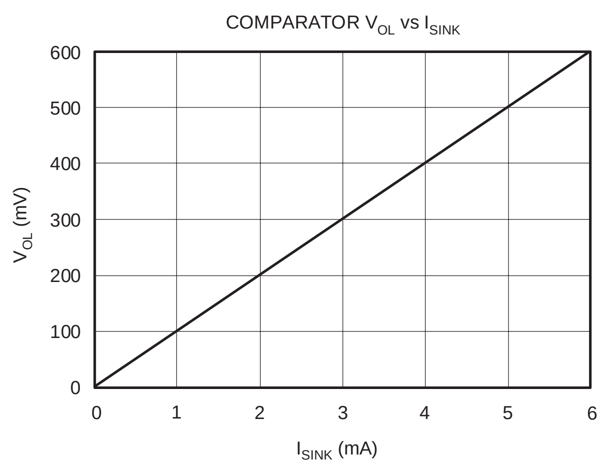


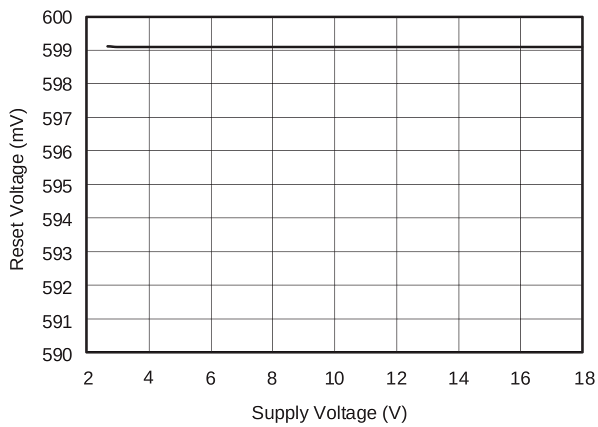



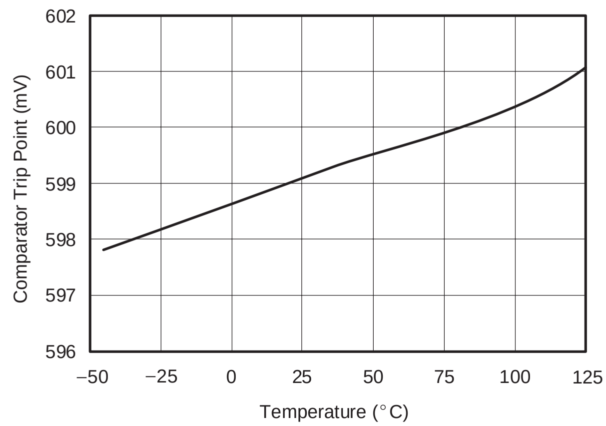
## TYPICAL CHARACTERISTICS (continued)

At $T_A$ = +25°C, $V_S$ = +12V, $V_{IN+}$ = 12V, and $V_{SENSE}$ = 100mV, unless otherwise noted.

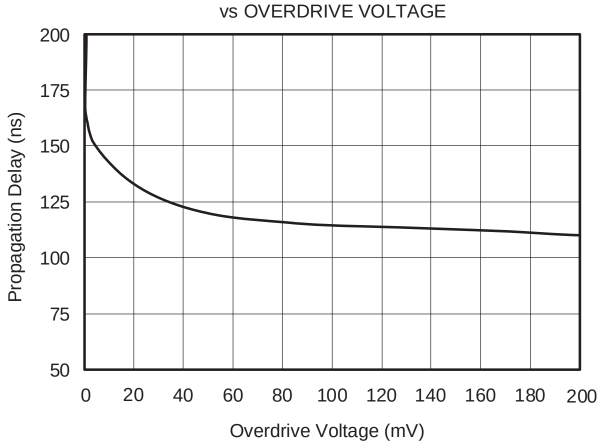
COMPARATOR TRIP POINT vs SUPPLY VOLTAGE



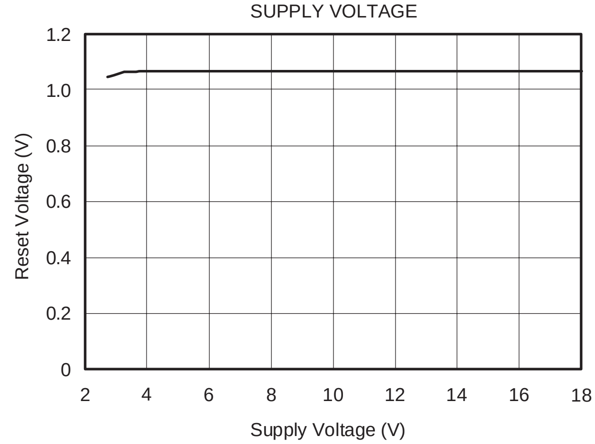

COMPARATOR TRIP POINT vs TEMPERATURE



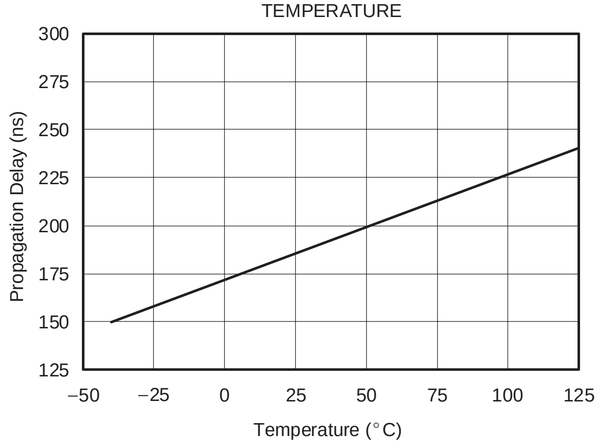

COMPARATOR PROPAGATION DELAY vs OVERDRIVE VOLTAGE



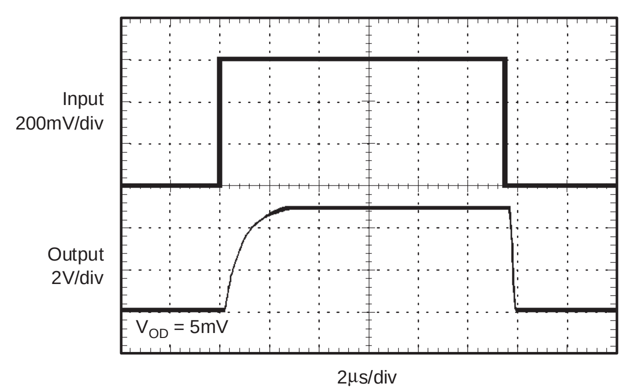

COMPARATOR RESET VOLTAGE vs SUPPLY VOLTAGE




COMPARATOR PROPAGATION DELAY vs TEMPERATURE




COMPARATOR PROPAGATION DELAY



# APPLICATIONS INFORMATION

## BASIC CONNECTIONS

Figure 2 shows the basic connections of the INA200, INA201, and INA202. The input pins, $V_{IN+}$ and $V_{IN-}$, should be connected as closely as possible to the shunt resistor to minimize any resistance in series with the shunt resistance.

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 pins.

## POWER SUPPLY

The input circuitry of the INA200, INA201, and INA202 can accurately measure beyond the power-supply voltage, V+. For example, the V+ power supply can be 5V, whereas the load power-supply voltage is up to +80V. The output voltage range of the OUT terminal, however, is limited by the voltages on the power-supply pin.

## ACCURACY VARIATIONS AS A RESULT OF $V_{SENSE}$ AND COMMON-MODE VOLTAGE

The accuracy of the INA200, INA201, and INA202 current shunt monitors is a function of two main variables: $V_{SENSE}$ ($V_{IN+} - V_{IN-}$) and common-mode voltage, $V_{CM}$, relative to the supply voltage, $V_S$. $V_{CM}$ is expressed as $(V_{IN+} + V_{IN-})/2$; however, in practice, $V_{CM}$ is seen as the voltage at $V_{IN+}$ because the voltage drop across $V_{SENSE}$ is usually small.

This section addresses the accuracy of these specific operating regions:

Normal Case 1: $V_{SENSE} \geq 20mV$, $V_{CM} \geq V_S$
Normal Case 2: $V_{SENSE} \geq 20mV$, $V_{CM} < V_S$
Low $V_{SENSE}$ Case 1: $V_{SENSE} < 20mV$, $-16V \leq V_{CM} < 0$
Low $V_{SENSE}$ Case 2: $V_{SENSE} < 20mV$, $0V \leq V_{CM} \leq V_S$
Low $V_{SENSE}$ Case 3: $V_{SENSE} < 20mV$, $V_S < V_{CM} \leq 80V$

### Normal Case 1: $V_{SENSE} \geq 20mV$, $V_{CM} \geq V_S$

This region of operation provides the highest accuracy. Here, the input offset voltage is characterized and measured using a two-step method. First, the gain is determined by Equation 1.

$$G = \frac{V_{OUT1} - V_{OUT2}}{100mV - 20mV} \qquad (1)$$

where:

$V_{OUT1}$ = Output Voltage with $V_{SENSE}$ = 100mV

$V_{OUT2}$ = Output Voltage with $V_{SENSE}$ = 20mV

Then the offset voltage is measured at $V_{SENSE}$ = 100mV and referred to the input (RTI) of the current shunt monitor, as shown in Equation 2.

$$V_{OS}\text{RTI (Referred−To−Input)} = \left(\frac{V_{OUT1}}{G}\right) - 100mV \qquad (2)$$

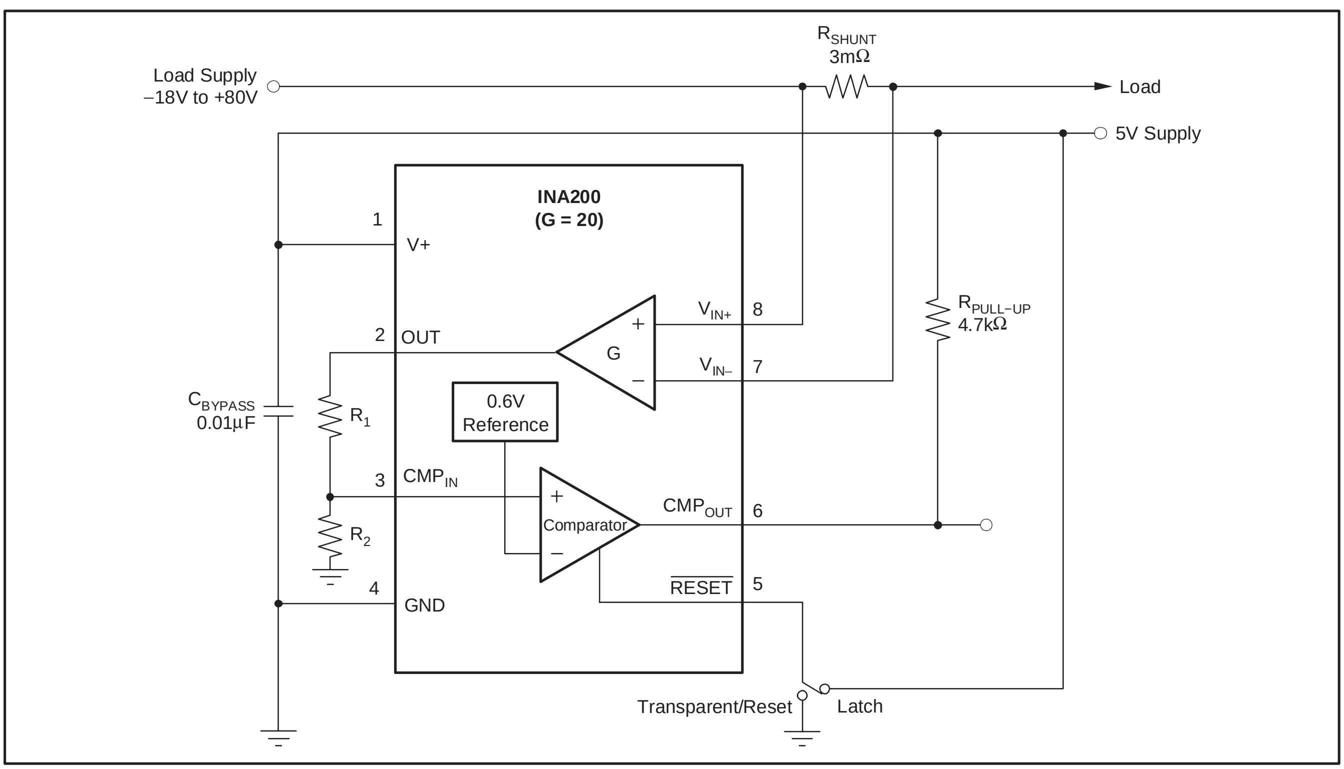



**Figure 2. INA200 Basic Connections**

In the Typical Characteristics, the *Output Error vs Common-Mode Voltage* curve shows the highest accuracy for the this region of operation. In this plot, $V_S$ = 12V; for $V_{CM} \geq$ 12V, the output error is at its minimum. This case is also used to create the $V_{SENSE} \geq$ 20mV output specifications in the Electrical Characteristics table.

### Normal Case 2: $V_{SENSE} \geq$ 20mV, $V_{CM} < V_S$

This region of operation has slightly less accuracy than Normal Case 1 as a result of the common-mode operating area in which the part functions, as seen in the *Output Error vs Common-Mode Voltage* curve. As noted, for this graph $V_S$ = 12V; for $V_{CM}$ < 12V, the Output Error increases as $V_{CM}$ becomes less than 12V, with a typical maximum error of 0.005% at the most negative $V_{CM}$ = −16V.

### Low $V_{SENSE}$ Case 1: $V_{SENSE}$ < 20mV, −16V ≤ $V_{CM}$ < 0; and Low $V_{SENSE}$ Case 3: $V_{SENSE}$ < 20mV, $V_S < V_{CM} \leq$ 80V

Although the INA200 family of devices are not designed for accurate operation in either of these regions, some applications are exposed to these conditions. For example, when monitoring power supplies that are switched on and off while $V_S$ is still applied to the INA200, INA201, or INA202, it is important to know what the behavior of the devices will be in these regions.

As $V_{SENSE}$ approaches 0mV, in these $V_{CM}$ regions, the device output accuracy degrades. A larger-than-normal offset can appear at the current shunt monitor output with a typical maximum value of $V_{OUT}$ = 300mV for $V_{SENSE}$ = 0mV. As $V_{SENSE}$ approaches 20mV, $V_{OUT}$ returns to the expected output value with accuracy as specified in the Electrical Characteristics. Figure 3 illustrates this effect using the INA202 (Gain = 100).

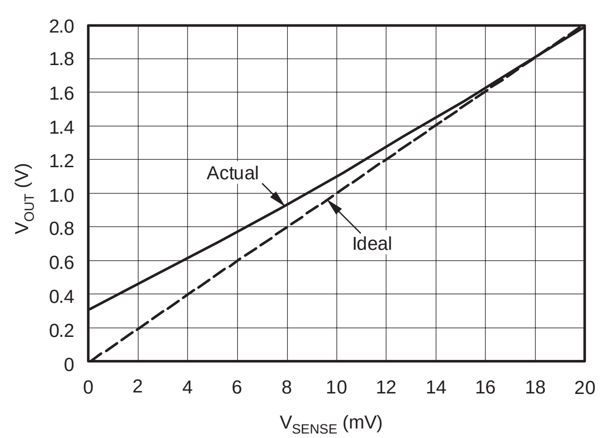
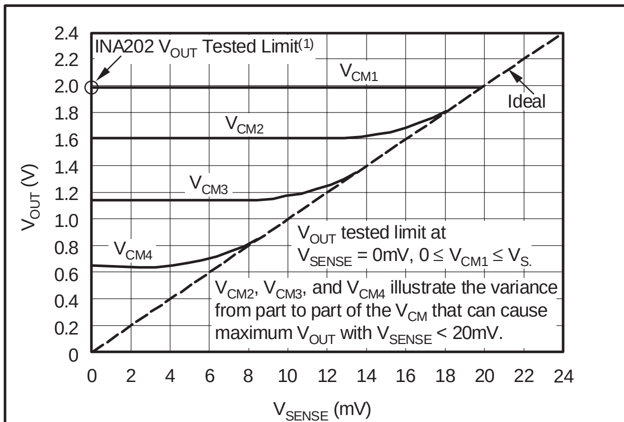



**Figure 3. Example for Low $V_{SENSE}$ Cases 1 and 3 (INA202, Gain = 100)**

### Low $V_{SENSE}$ Case 2: $V_{SENSE}$ < 20mV, 0V ≤ $V_{CM} \leq V_S$

This region of operation is the least accurate for the INA200 family. To achieve the wide input common-mode voltage range, these devices use two op amp front ends in parallel. One op amp front end operates in the positive input common-mode voltage range, and the other in the negative input region. For this case, neither of these two internal amplifiers dominates and overall loop gain is very low. Within this region, $V_{OUT}$ approaches voltages close to linear operation levels for Normal Case 2. This deviation from linear operation becomes greatest the closer $V_{SENSE}$ approaches 0V. Within this region, as $V_{SENSE}$ approaches 20mV, device operation is closer to that described by Normal Case 2. Figure 4 illustrates this behavior for the INA202. The $V_{OUT}$ maximum peak for this case is tested by maintaining a constant $V_S$, setting $V_{SENSE}$ = 0mV and sweeping $V_{CM}$ from 0V to $V_S$. The exact $V_{CM}$ at which $V_{OUT}$ peaks during this test varies from part to part, but the $V_{OUT}$ maximum peak is tested to be less than the specified $V_{OUT}$ tested limit.




NOTE: (1) INA200 $V_{OUT}$ Tested Limit = 0.4V. INA201 $V_{OUT}$ Tested Limit = 1V.

**Figure 4. Example for Low $V_{SENSE}$ Case 2 (INA202, Gain = 100)**

## SELECTING $R_S$

The value chosen for the shunt resistor, $R_S$, depends on the application and is a compromise between small-signal accuracy and maximum permissible voltage loss in the measurement line. High values of $R_S$ provide better accuracy at lower currents by minimizing the effects of offset, while low values of $R_S$ minimize voltage loss in the supply line. For most applications, best performance is attained with an $R_S$ value that provides a full-scale shunt voltage range of 50mV to 100mV. Maximum input voltage for accurate measurements is 500mV.

## TRANSIENT PROTECTION

The −16V to +80V common-mode range of the INA200, INA201, and INA202 is ideal for withstanding automotive fault conditions ranging from 12V battery reversal up to +80V transients, since no additional protective components are needed up to those levels. In the event that the INA200, INA201, and INA202 are exposed to transients on the inputs in excess of their ratings, then external transient absorption with semiconductor transient absorbers (such as zeners) will be necessary. Use of

MOVs or VDRs is not recommended except when they are used in addition to a semiconductor transient absorber. Select the transient absorber such that it will never allow the INA200, INA201, and INA202 to be exposed to transients greater than +80V (that is, allow for transient absorber tolerance, as well as additional voltage due to transient absorber dynamic impedance). Despite the use of internal zener-type ESD protection, the INA200, INA201, and INA202 do not lend themselves to using external resistors in series with the inputs since the internal gain resistors can vary up to ±30%. (If gain accuracy is not important, then resistors can be added in series with the INA200, INA201, and INA202 inputs with two equal resistors on each input.)

## OUTPUT VOLTAGE RANGE

The output of the INA200, INA201, and INA202 is accurate within the output voltage swing range set by the power supply pin, V+. This performance is best illustrated when using the INA202 (a gain of 100 version), where a 100mV full-scale input from the shunt resistor requires an output voltage swing of +10V, and a power-supply voltage sufficient to achieve +10V on the output.

## INPUT FILTERING

An obvious and straightforward location for filtering is at the output of the INA200, INA201, and INA202 series; however, this location negates the advantage of the low output impedance of the internal buffer. The only other option for filtering is at the input pins of the INA200, INA201, and INA202, which is complicated by the internal 5kΩ + 30% input impedance; this is shown in Figure 5. Using the lowest possible resistor values minimizes both the initial shift in gain and effects of tolerance. The effect on initial gain is given by Equation 3:

$$\text{Gain Error \%} = 100 - \left(100 \times \frac{5k\Omega}{5k\Omega + R_{FILT}}\right) \tag{3}$$

Total effect on gain error can be calculated by replacing the 5kΩ term with 5kΩ − 30%, (or 3.5kΩ) or 5kΩ + 30% (or 6.5kΩ). The tolerance extremes of $R_{FILT}$ can also be inserted into the equation. If a pair of 100. 1% resistors are used on the inputs, the initial gain error will be 1.96%. Worst-case tolerance conditions will always occur at the lower excursion of the internal 5kΩ resistor (3.5kΩ), and the higher excursion of $R_{FILT}$ − 3% in this case.

Note that the specified accuracy of the INA200, INA201, and INA202 must then be combined in addition to these tolerances. While this discussion treated accuracy worst-case conditions by combining the extremes of the resistor values, it is appropriate to use geometric mean or root sum square calculations to total the effects of accuracy variations.

## COMPARATOR

The INA200, INA201, and INA202 devices incorporate an open-drain comparator. This comparator typically has 2mV of offset and a 1.3µs (typical) response time. The output of the comparator latches and is reset through the $\overline{\text{RESET}}$ pin, see Figure 6.

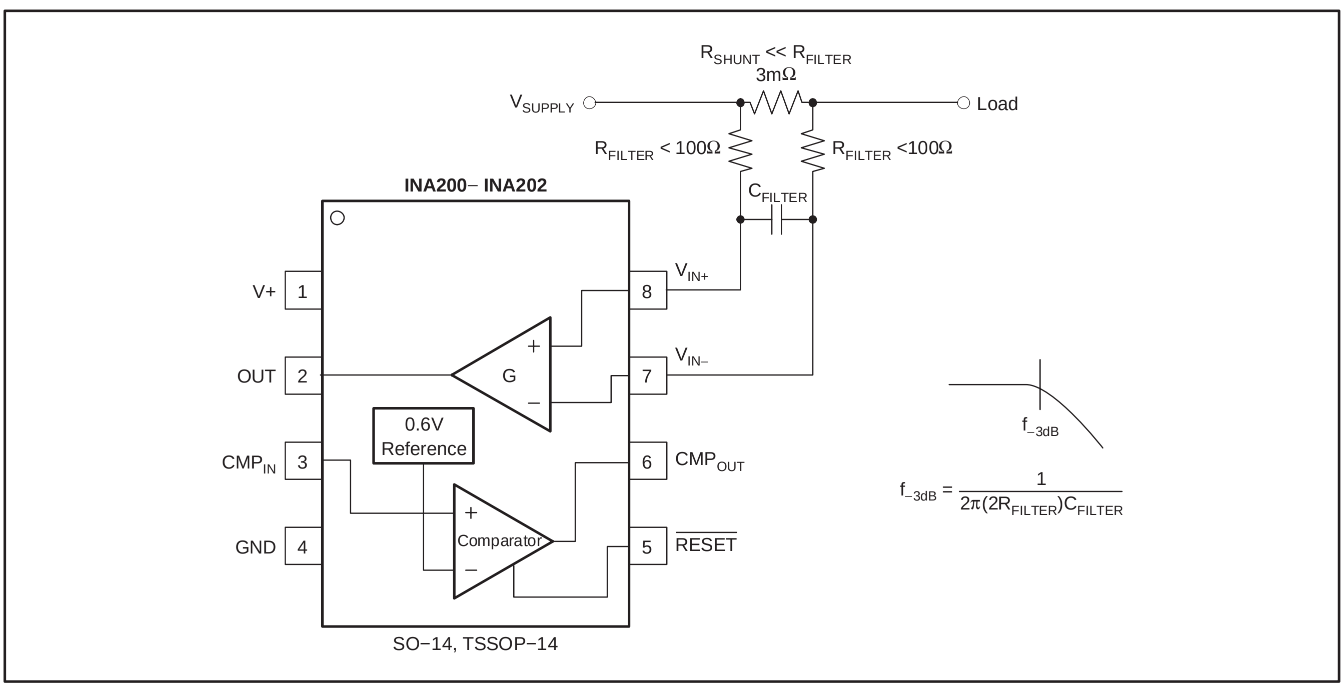



**Figure 5. Input Filter (Gain Error — 1.5% to −2.2%)**

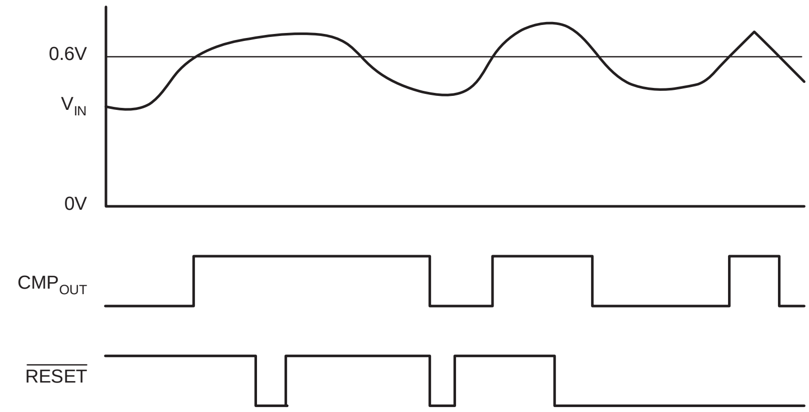
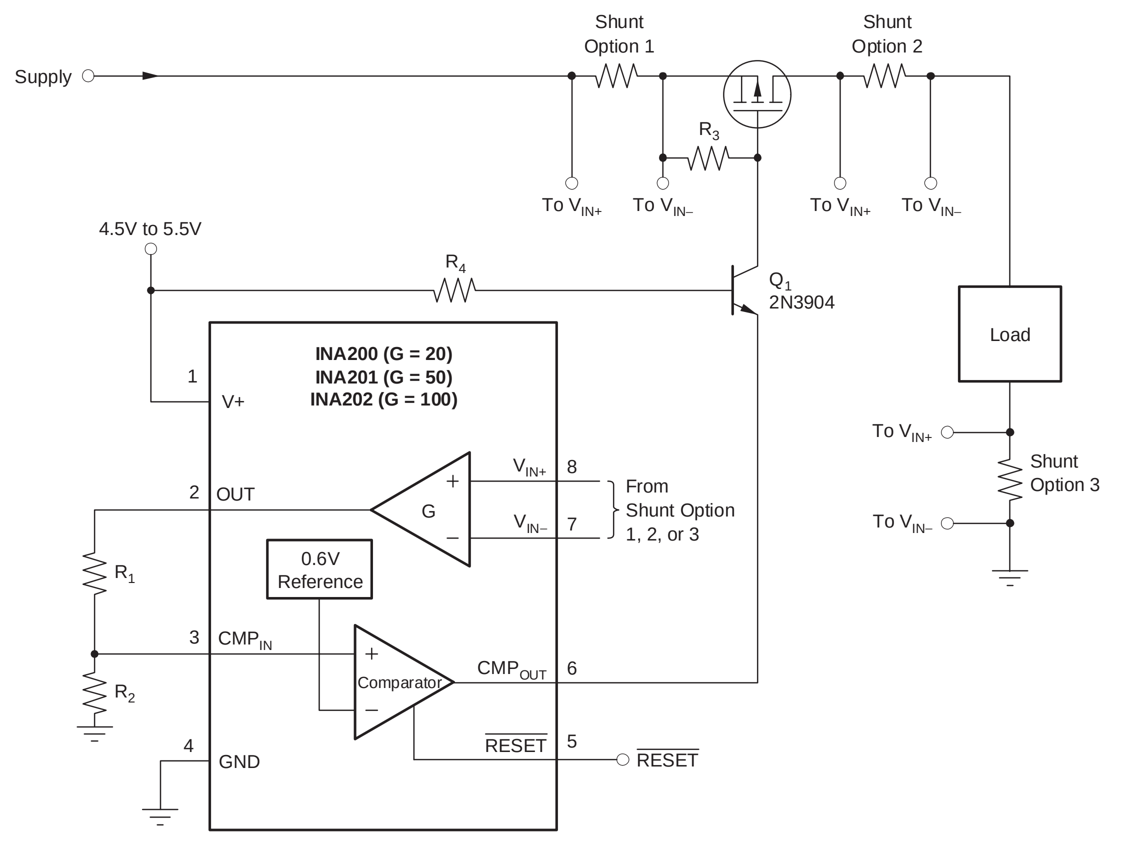



**Figure 6. Comparator Latching Capability**




NOTE: $Q_1$ cascodes the comparator output to drive a high-side FET (the 2N3904 shown is good up to 60V). The shunt could be located in any one of the three locations shown. The latching capability should be used in shutdown applications to prevent oscillation at the trip point.

**Figure 7. High-Side Switch Over-Current Shutdown**

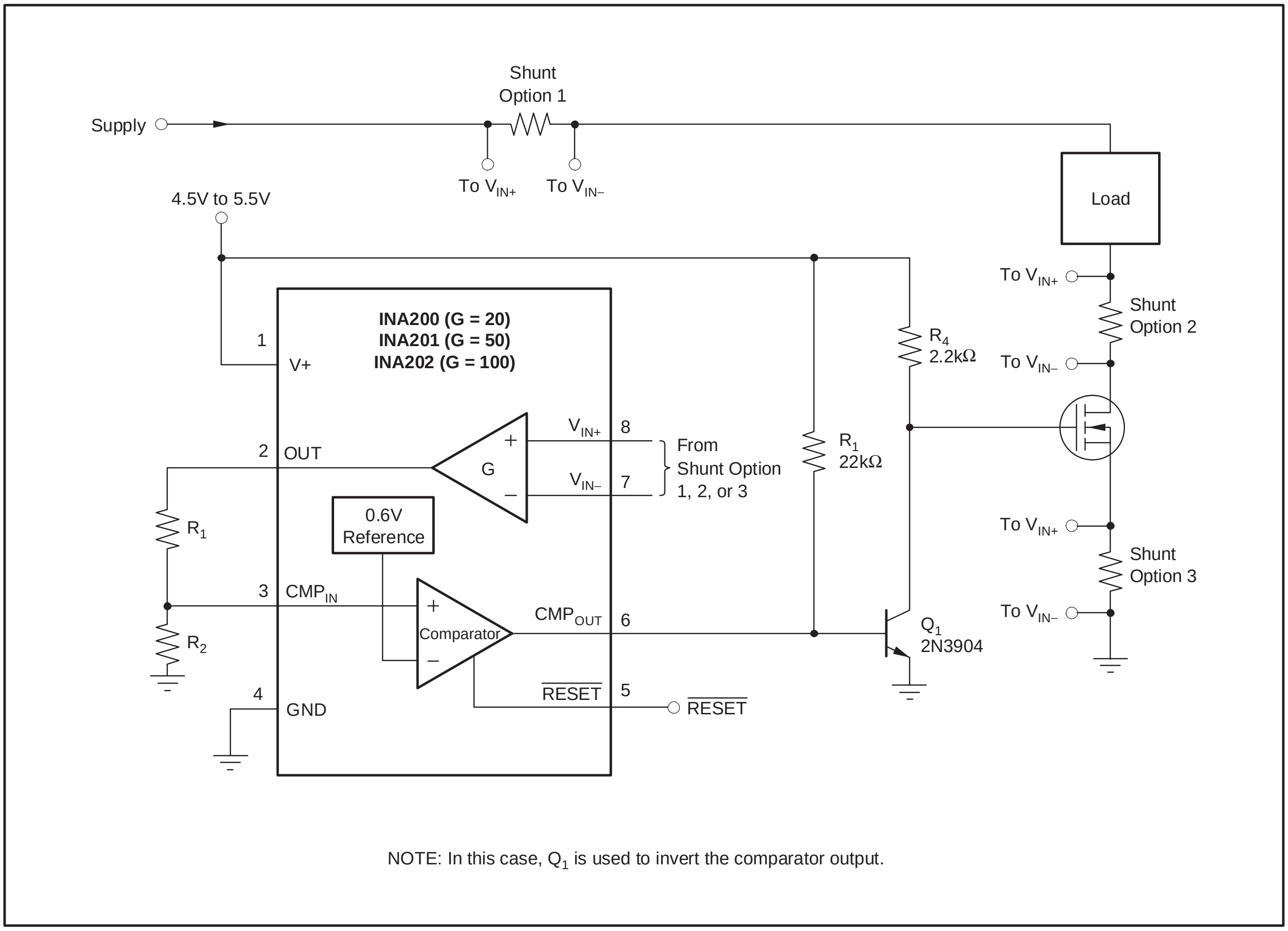



**Figure 8. Low-Side Switch Over-Current Shutdown**

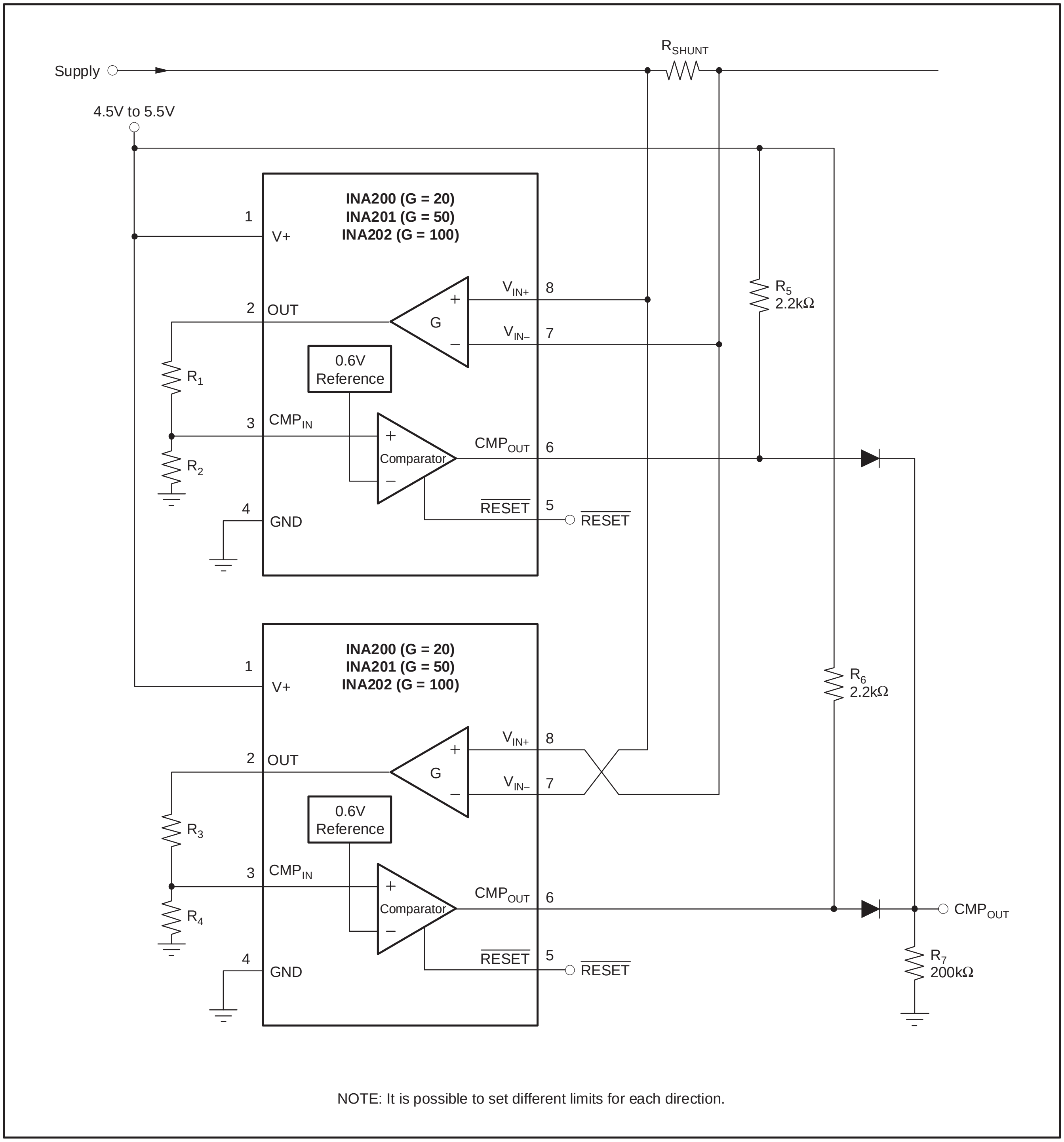



**Figure 9. Bidirectional Over-Current Comparator**

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish | MSL Peak Temp (3) |
|---|---|---|---|---|---|---|---|---|
| INA200AID | ACTIVE | SOIC | D | 8 | 50 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| INA200AIDGKR | ACTIVE | MSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| INA200AIDGKRG4 | ACTIVE | MSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| INA200AIDGKT | ACTIVE | MSOP | DGK | 8 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| INA200AIDGKTG4 | ACTIVE | MSOP | DGK | 8 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| INA200AIDR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| INA201AID | ACTIVE | SOIC | D | 8 | 50 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| INA201AIDGKR | ACTIVE | MSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| INA201AIDGKRG4 | ACTIVE | MSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| INA201AIDGKT | ACTIVE | MSOP | DGK | 8 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| INA201AIDGKTG4 | ACTIVE | MSOP | DGK | 8 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| INA201AIDR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| INA202AID | ACTIVE | SOIC | D | 8 | 50 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| INA202AIDGKR | ACTIVE | MSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| INA202AIDGKRG4 | ACTIVE | MSOP | DGK | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| INA202AIDGKT | ACTIVE | MSOP | DGK | 8 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| INA202AIDGKTG4 | ACTIVE | MSOP | DGK | 8 | 250 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |
| INA202AIDR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-2-260C-1 YEAR |

(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) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
**TBD:** The Pb-Free/Green conversion plan has not been defined.
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**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and

package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

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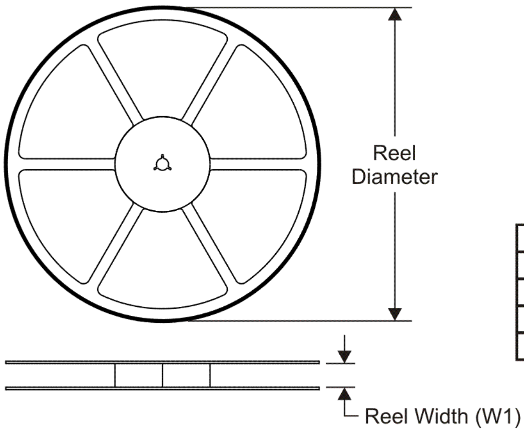
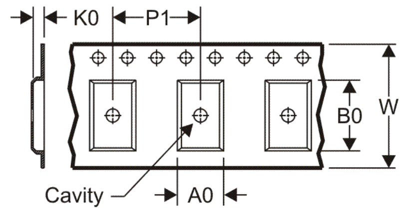
## TAPE AND REEL INFORMATION

### REEL DIMENSIONS

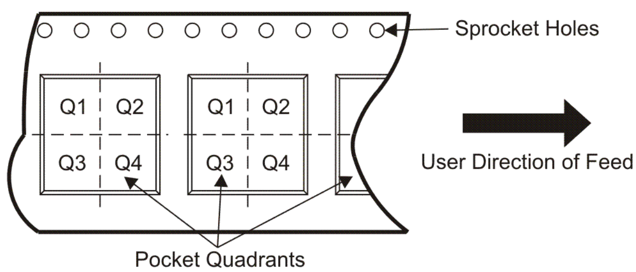



### TAPE DIMENSIONS




| | |
|---|---|
| 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 |

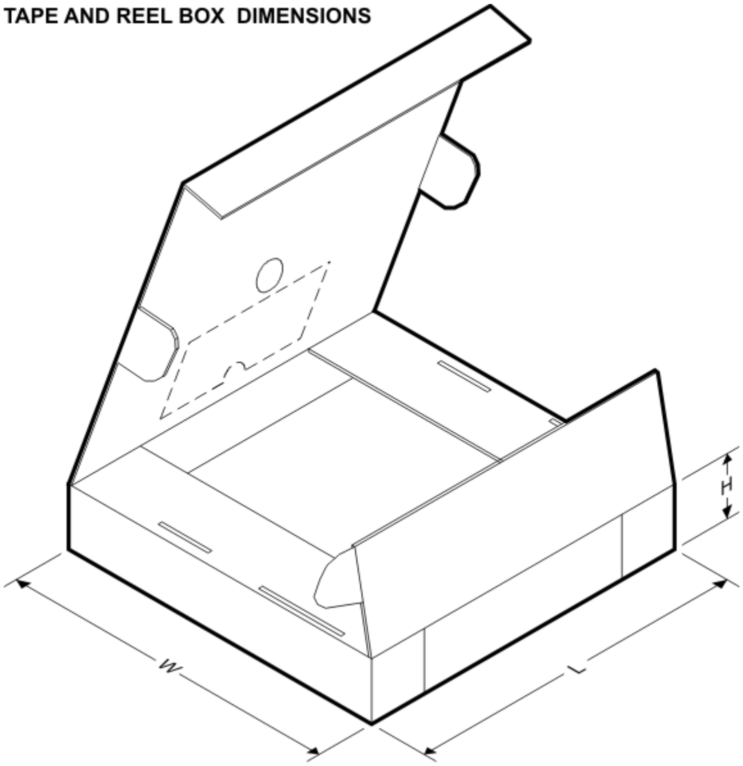
### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE




*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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INA200AIDGKR | MSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| INA200AIDGKT | MSOP | DGK | 8 | 250 | 180.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| INA201AIDGKR | MSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| INA201AIDGKT | MSOP | DGK | 8 | 250 | 180.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| INA202AIDGKR | MSOP | DGK | 8 | 2500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| INA202AIDGKT | MSOP | DGK | 8 | 250 | 180.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |

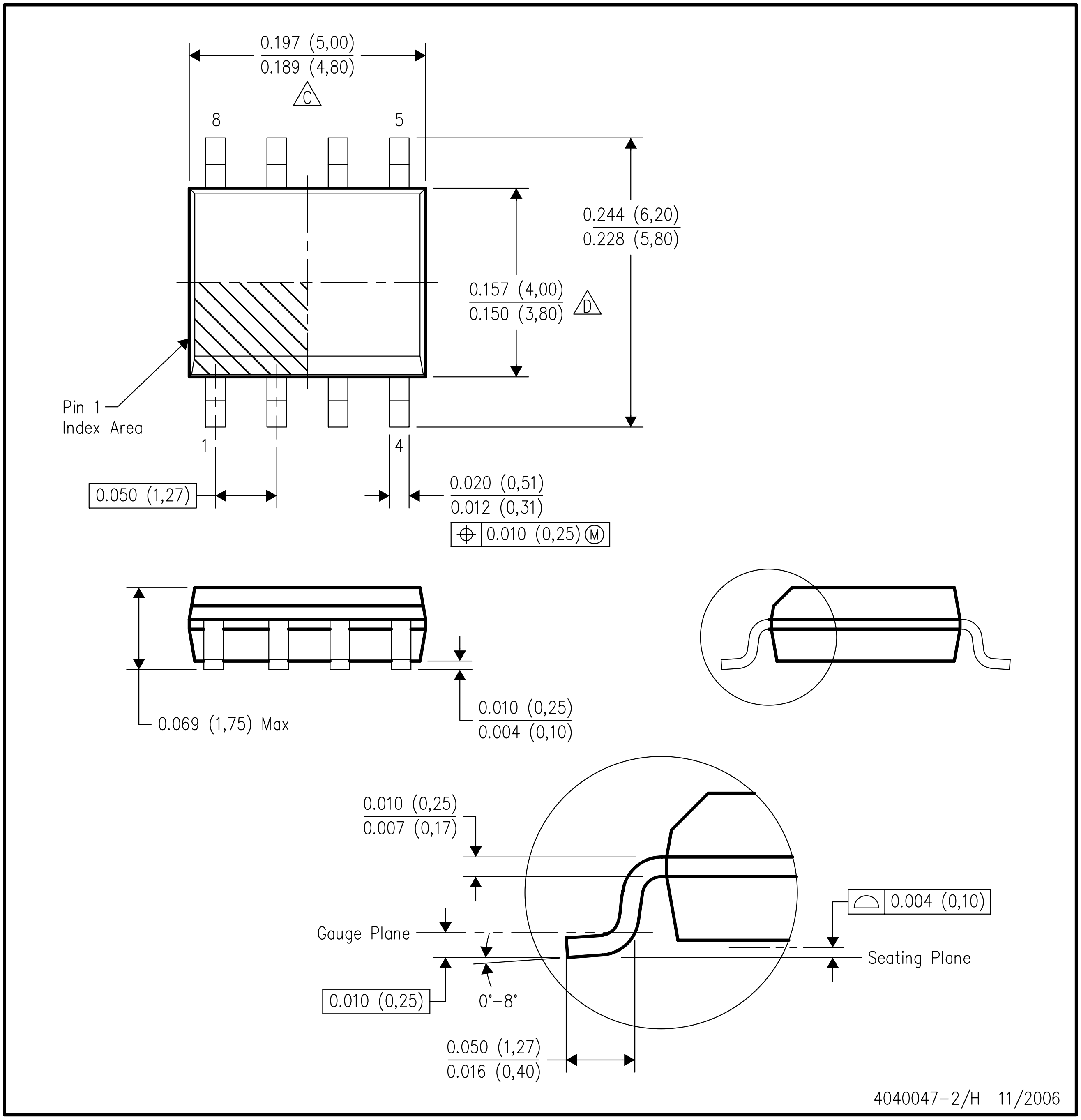
## TAPE AND REEL BOX DIMENSIONS




*All dimensions are nominal

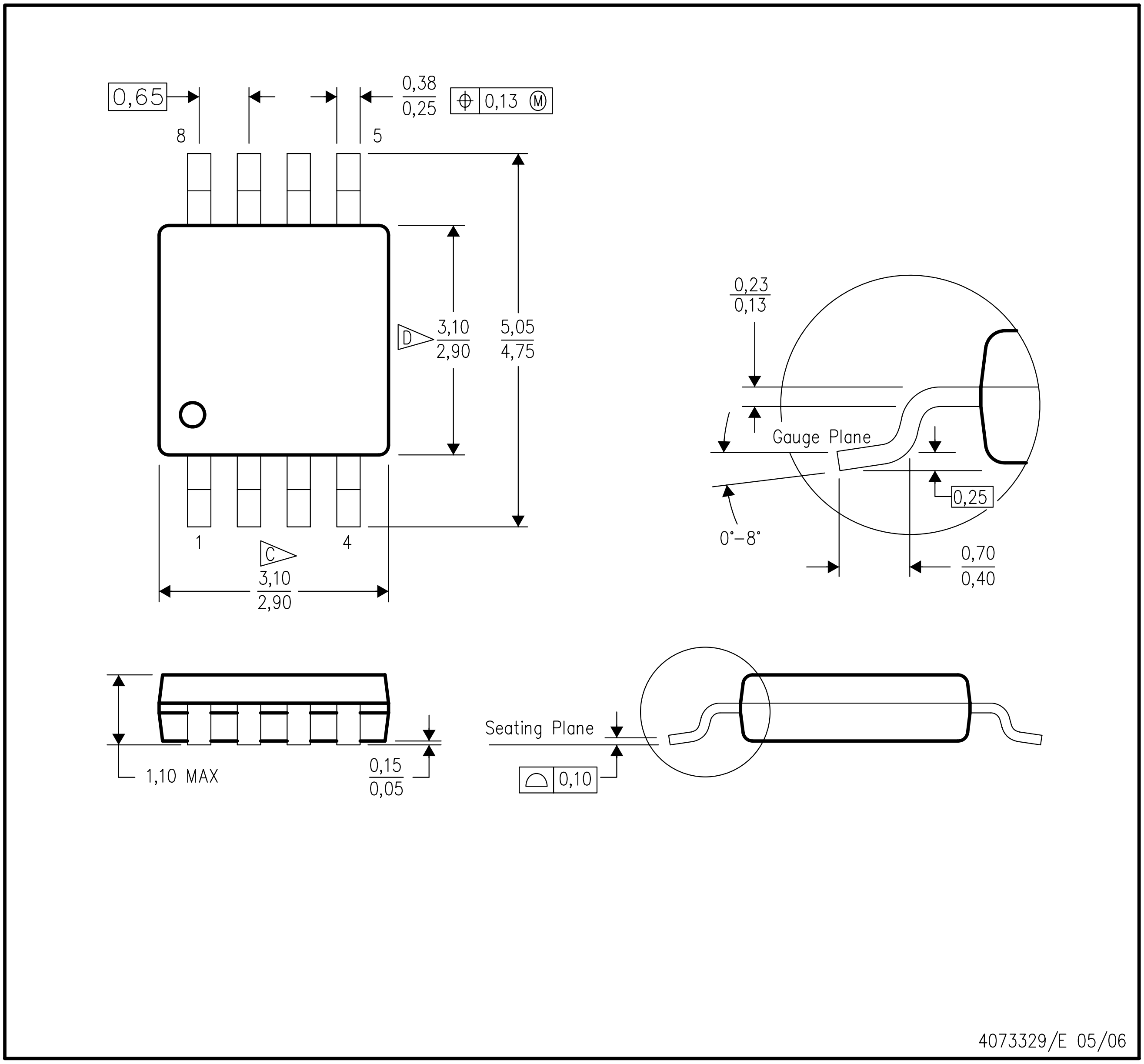
| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| INA200AIDGKR | MSOP | DGK | 8 | 2500 | 346.0 | 346.0 | 29.0 |
| INA200AIDGKT | MSOP | DGK | 8 | 250 | 190.5 | 212.7 | 31.8 |
| INA201AIDGKR | MSOP | DGK | 8 | 2500 | 346.0 | 346.0 | 29.0 |
| INA201AIDGKT | MSOP | DGK | 8 | 250 | 190.5 | 212.7 | 50.0 |
| INA202AIDGKR | MSOP | DGK | 8 | 2500 | 346.0 | 346.0 | 29.0 |
| INA202AIDGKT | MSOP | DGK | 8 | 250 | 190.5 | 212.7 | 31.8 |

D (R–PDSO–G8) PLASTIC SMALL–OUTLINE PACKAGE




NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 (0,15) per end.
- D. Body width does not include interlead flash. Interlead flash shall not exceed .017 (0,43) per side.
- E. Reference JEDEC MS–012 variation AA.

DGK (S-PDSO-G8) PLASTIC SMALL-OUTLINE PACKAGE




NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
- D. Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
- E. Falls within JEDEC MO-187 variation AA, except interlead flash.

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