



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

 Check for Samples: [INA200](#), [INA201](#), [INA202](#)

### FEATURES

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

### APPLICATIONS

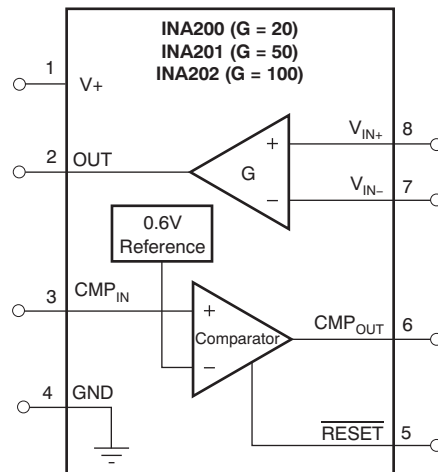
- NOTEBOOK COMPUTERS
- CELL PHONES
- TELECOM EQUIPMENT
- AUTOMOTIVE
- POWER MANAGEMENT
- BATTERY CHARGERS
- WELDING EQUIPMENT

### 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  $-16\text{V}$  to  $80\text{V}$ . 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  $+2.7\text{V}$  to  $+18\text{V}$  supply, drawing a maximum of 1800 $\mu\text{A}$  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  $-40^\circ\text{C}$  to  $+125^\circ\text{C}$ .



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.



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<sup>(1)</sup>

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

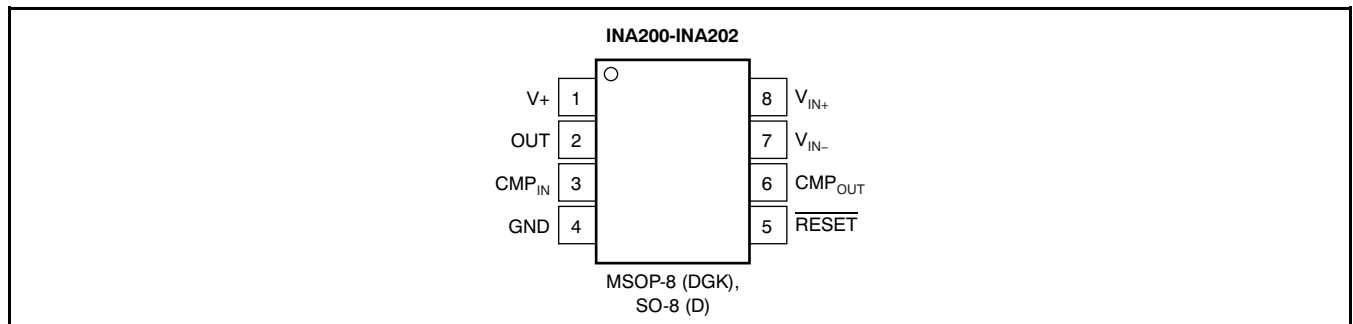
(1) For the most current package and ordering information see the Package Option Addendum at the end of this document, or see the device product folder at [www.ti.com](http://www.ti.com).

### ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>

	VALUE	UNIT
Supply Voltage, V+	18	V
Current-Shunt Monitor Analog Inputs, V <sub>IN+</sub> , V <sub>IN-</sub>		
Differential (V <sub>IN+</sub> ) – (V <sub>IN-</sub> )	–18 to +18	V
Common Mode <sup>(2)</sup>	–16 to +80	V
Comparator Analog Input and Reset Pins <sup>(2)</sup>	GND – 0.3 to (V+) + 0.3	V
Analog Output, Out <sup>(2)</sup>	GND – 0.3 to (V+) + 0.3	V
Comparator Output, Out Pin <sup>(2)</sup>	GND – 0.3 to 18	V
Input Current Into Any Pin <sup>(2)</sup>	5	mA
Operating Temperature	–55 to +150	°C
Storage Temperature	–65 to +150	°C
Junction Temperature	+150	°C
ESD Ratings	Human Body Model (HBM)	4000
	Charged Device Model (CDM)	1000

- (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.

### PIN CONFIGURATIONS



**ELECTRICAL CHARACTERISTICS: CURRENT-SHUNT MONITOR**
**Boldface** limits apply over the specified temperature range:  $T_A = -40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

At  $T_A = +25^{\circ}\text{C}$ ,  $V_S = +12\text{V}$ ,  $V_{\text{CM}} = +12\text{V}$ ,  $V_{\text{SENSE}} = 100\text{mV}$ ,  $R_L = 10\text{k}\Omega$  to GND,  $R_{\text{PULL-UP}} = 5.1\text{k}\Omega$  connected from  $\text{CMP}_{\text{OUT}}$  to  $V_S$ , and  $\text{CMP}_{\text{IN}} = \text{GND}$ , unless otherwise noted.

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

(1) Offset is extrapolated from measurements of the output at 20mV and 100mV  $V_{\text{SENSE}}$ .

(2) Total output error includes effects of gain error and  $V_{\text{OS}}$ .

(3) Linearity is best fit to a straight line.

(4) For details on this region of operation, see the [Accuracy Variations](#) 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:  $T_A = -40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

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

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

- (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 2M $\Omega$  (typical) pull-down. Leaving  $\overline{\text{RESET}}$  open results in a LOW state, with transparent comparator operation.

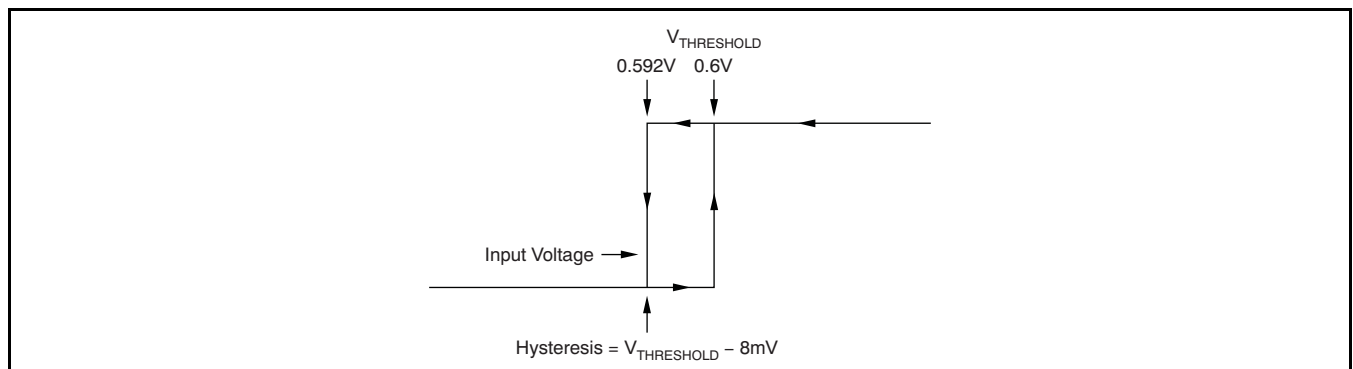


Figure 1. Typical Comparator Hysteresis

## ELECTRICAL CHARACTERISTICS: GENERAL

**Boldface** limits apply over the specified temperature range:  $T_A = -40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

At  $T_A = +25^{\circ}\text{C}$ ,  $V_S = +12\text{V}$ ,  $V_{CM} = +12\text{V}$ ,  $V_{SENSE} = 100\text{mV}$ ,  $R_L = 10\text{k}\Omega$  to GND,  $R_{PULL-UP} = 5.1\text{k}\Omega$  connected from  $\text{CMP}_{OUT}$  to  $V_S$ , and  $\text{CMP}_{IN} = 1\text{V}$ , unless otherwise noted.

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

- (1) The INA200, INA201, and INA202 are designed to power-up with the comparator in a defined reset state as long as  $\overline{\text{RESET}}$  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  $\overline{\text{RESET}}$  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  $T_A = +25^\circ\text{C}$ ,  $V_S = +12\text{V}$ ,  $V_{IN+} = 12\text{V}$ , and  $V_{SENSE} = 100\text{mV}$ , unless otherwise noted.

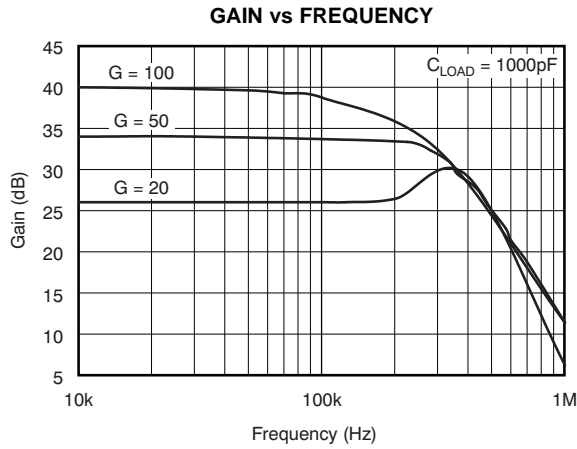


Figure 2.

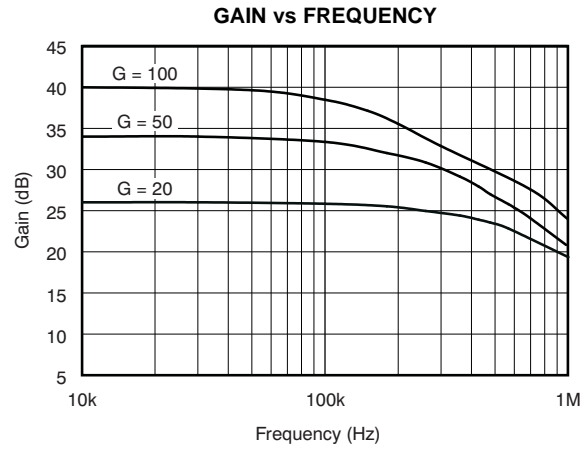


Figure 3.

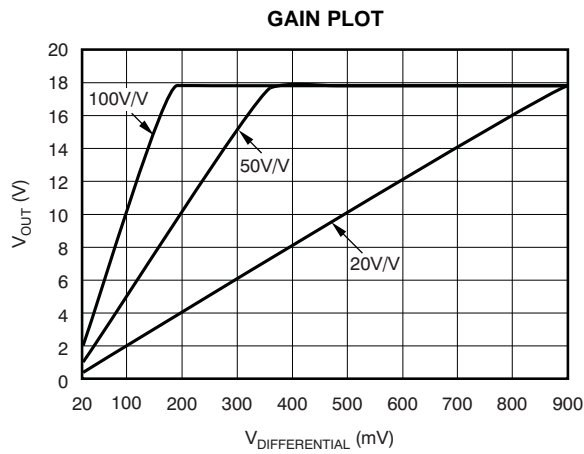


Figure 4.

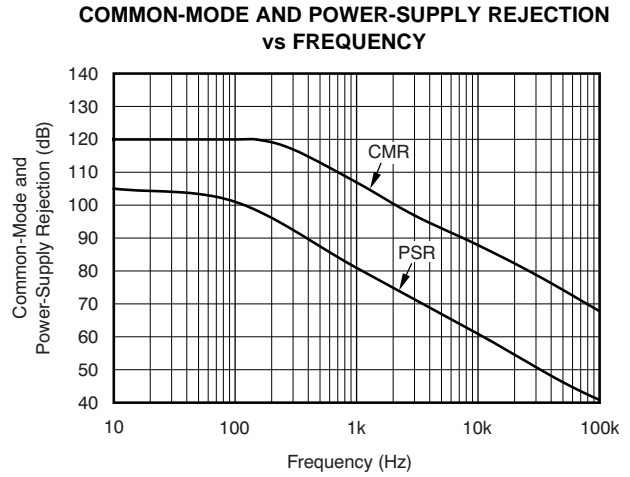


Figure 5.

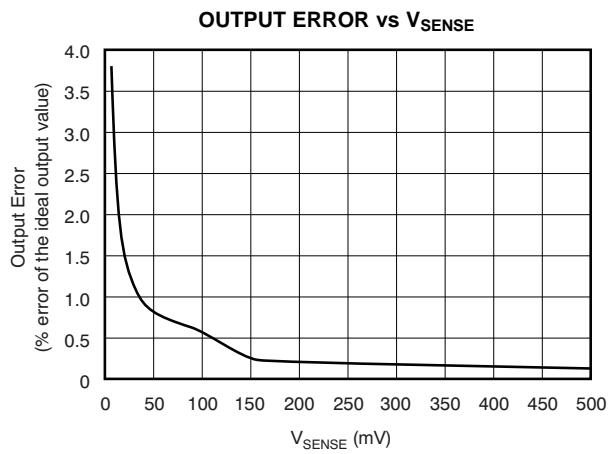


Figure 6.

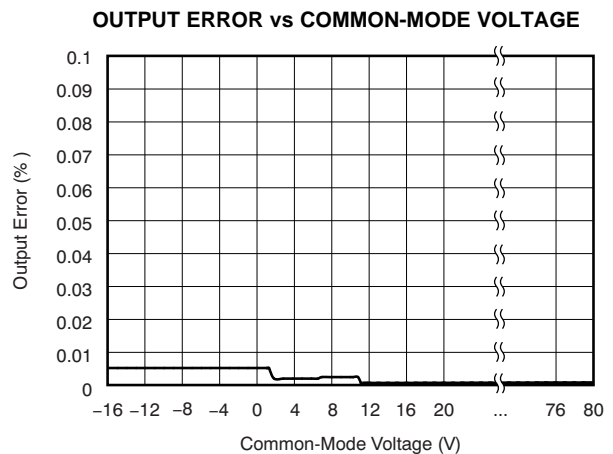


Figure 7.

**TYPICAL CHARACTERISTICS (continued)**

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

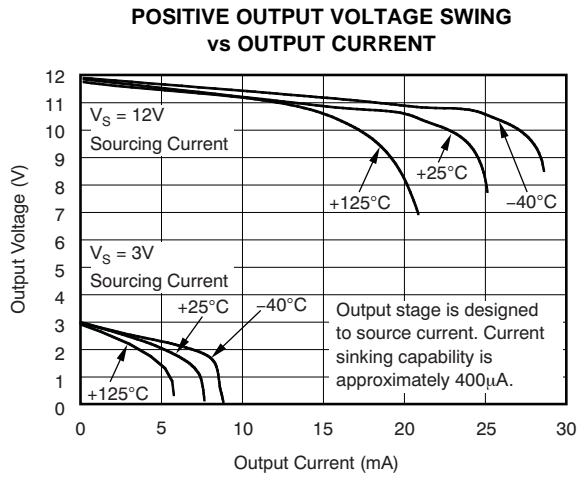


Figure 8.

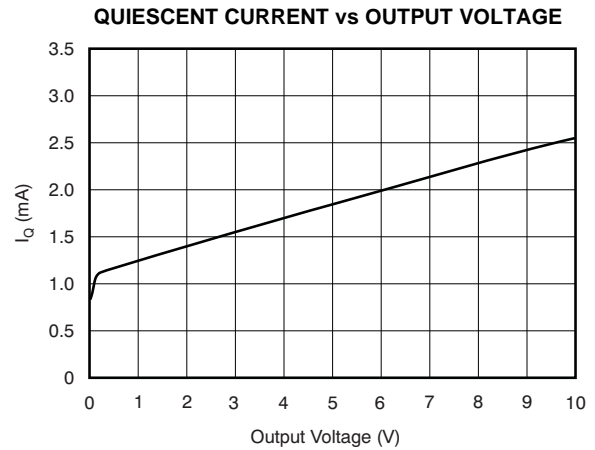


Figure 9.

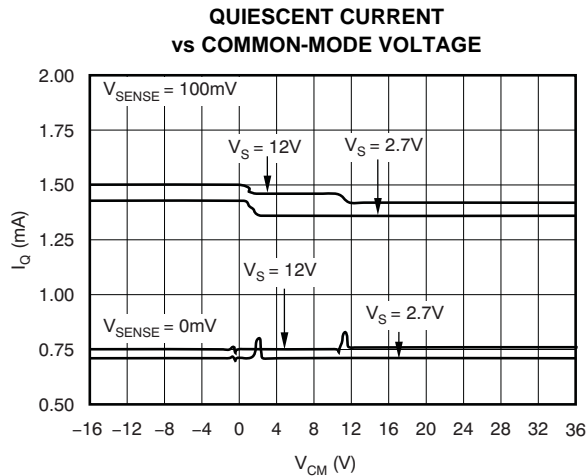


Figure 10.

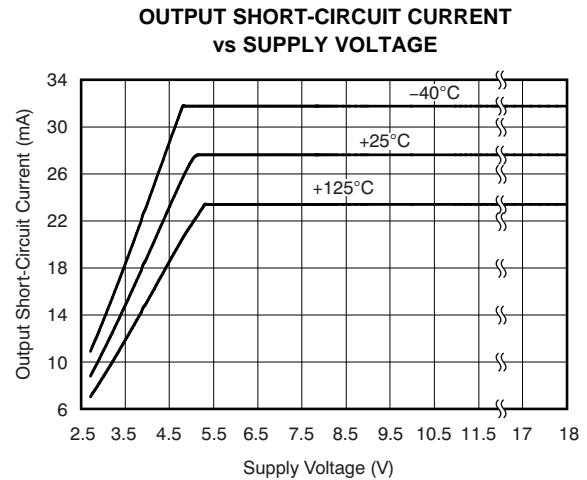


Figure 11.

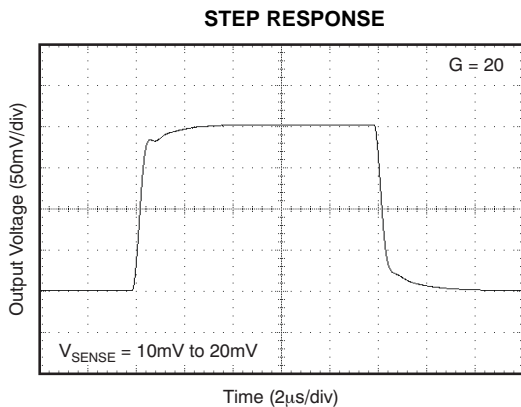


Figure 12.

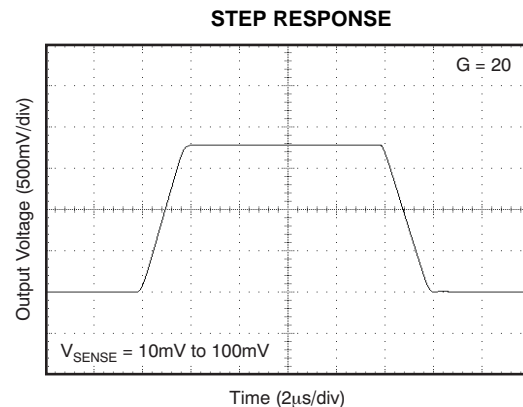
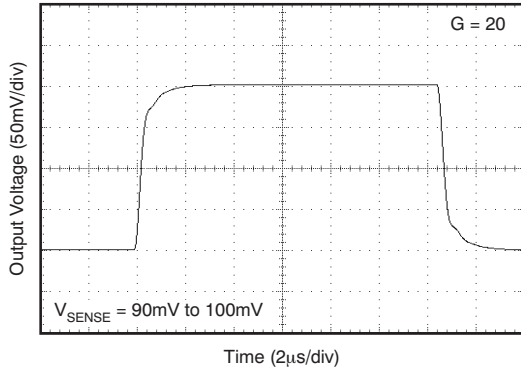


Figure 13.

**TYPICAL CHARACTERISTICS (continued)**

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

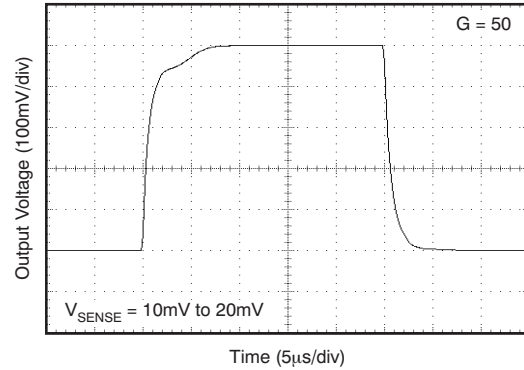
**STEP RESPONSE**



Time (2µs/div)

**Figure 14.**

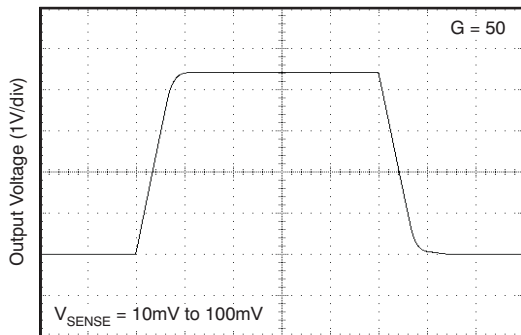
**STEP RESPONSE**



Time (5µs/div)

**Figure 15.**

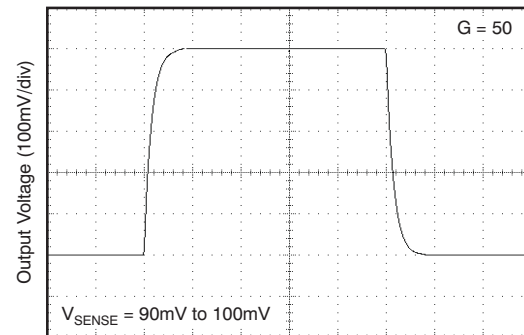
**STEP RESPONSE**



Time (5µs/div)

**Figure 16.**

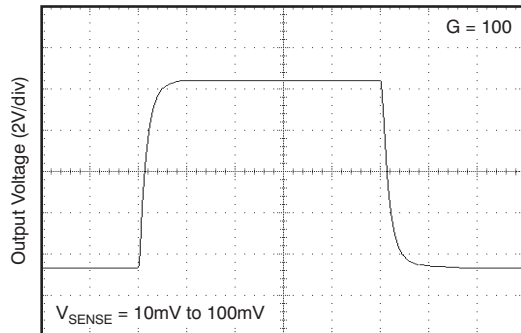
**STEP RESPONSE**



Time (5µs/div)

**Figure 17.**

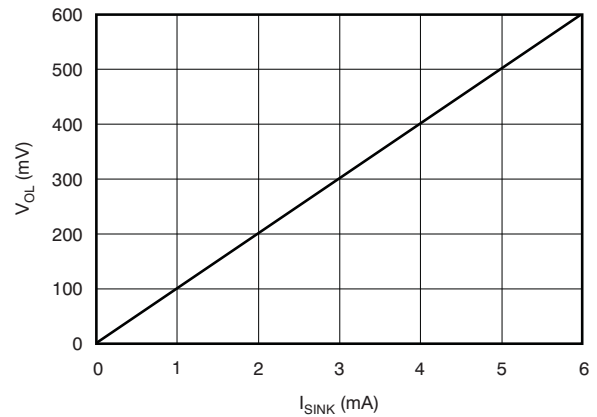
**STEP RESPONSE**



Time (10µs/div)

**Figure 18.**

**COMPARATOR  $V_{OL}$  vs  $I_{SINK}$**



**Figure 19.**



**TYPICAL CHARACTERISTICS (continued)**

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

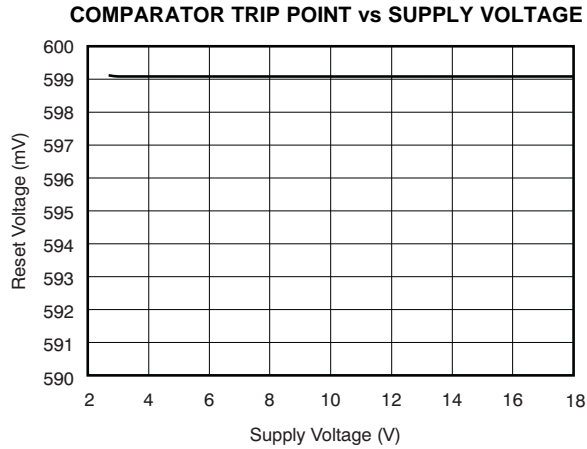


Figure 20.

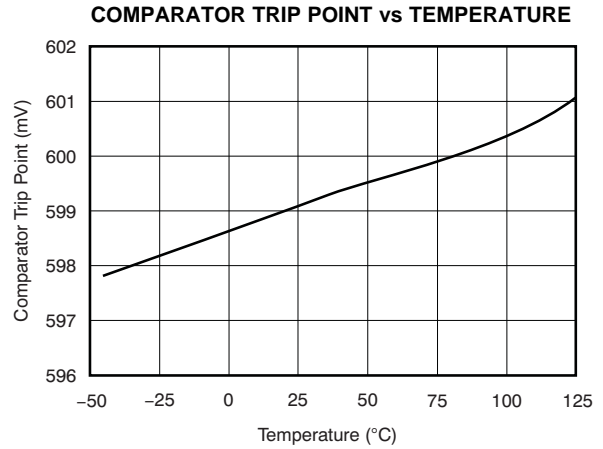


Figure 21.

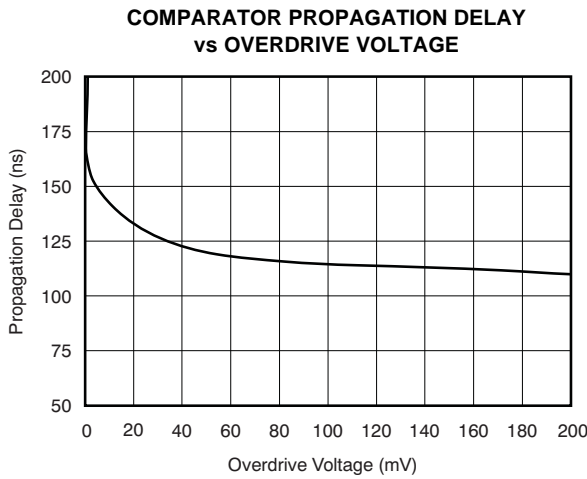


Figure 22.

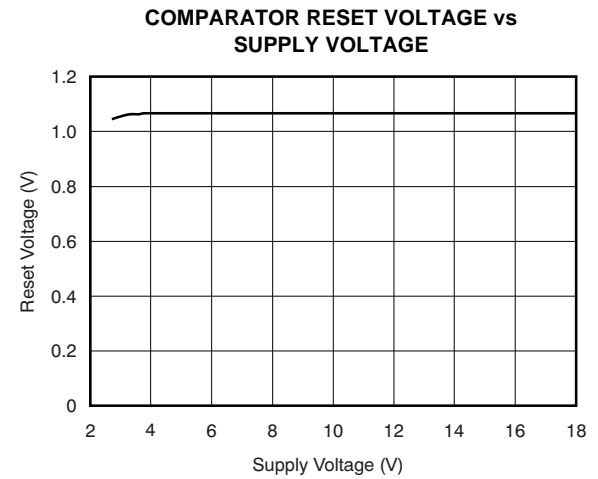


Figure 23.

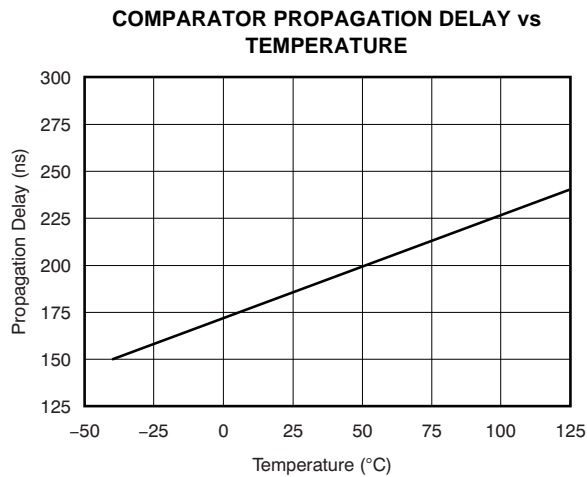


Figure 24.

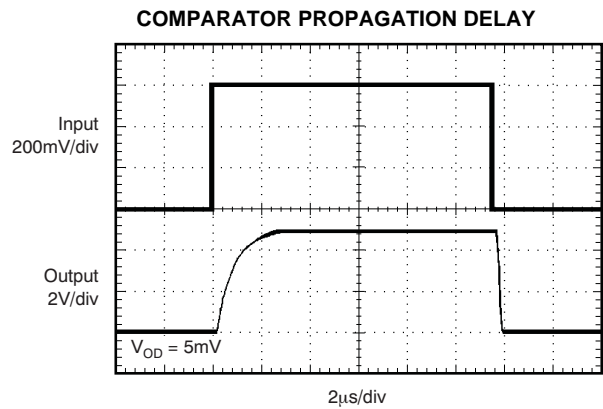


Figure 25.

## APPLICATIONS INFORMATION

### BASIC CONNECTIONS

Figure 26 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:  $V_{SENSE} \geq 20\text{mV}$ ,  $V_{CM} \geq V_S$
- Normal Case 2:  $V_{SENSE} \geq 20\text{mV}$ ,  $V_{CM} < V_S$
- Low  $V_{SENSE}$  Case 1:  $V_{SENSE} < 20\text{mV}$ ,  $-16\text{V} \leq V_{CM} < 0$
- Low  $V_{SENSE}$  Case 2:  $V_{SENSE} < 20\text{mV}$ ,  $0\text{V} \leq V_{CM} \leq V_S$
- Low  $V_{SENSE}$  Case 3:  $V_{SENSE} < 20\text{mV}$ ,  $V_S < V_{CM} \leq 80\text{V}$

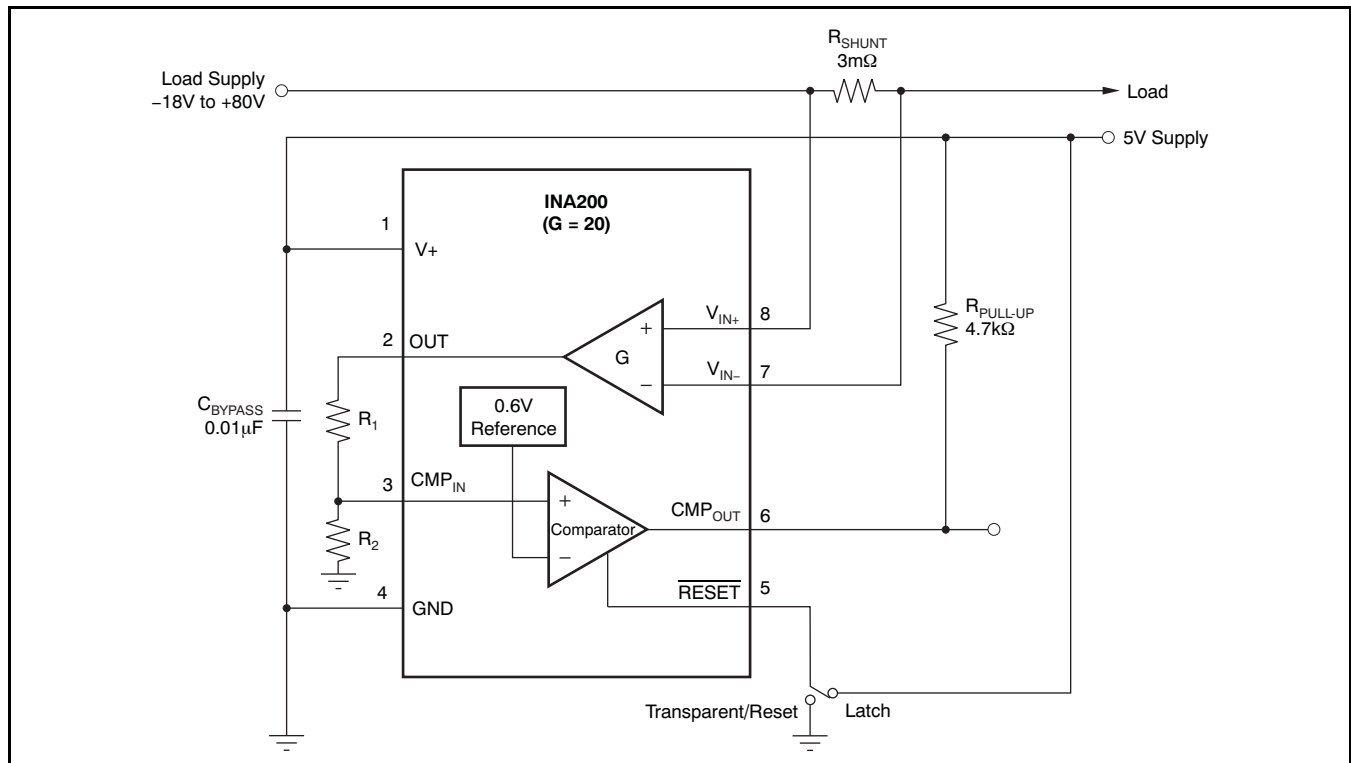


Figure 26. INA200 Basic Connections

**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.

$$G = \frac{V_{OUT1} - V_{OUT2}}{100mV - 20mV} \tag{1}$$

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.

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

In the [Typical Characteristics](#), the *Output Error vs Common-Mode Voltage* curve (Figure 7) 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:  $V_{SENSE} \geq 20mV$ ,  $V_{CM} < V_S$**

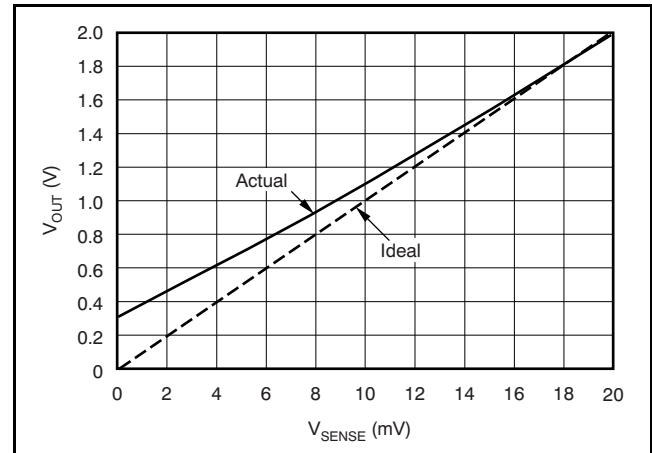
This region of operation has slightly less accuracy than Normal Case 1 as a result of the common-mode operating area in which the part functions, as seen in the *Output Error vs Common-Mode Voltage* curve (Figure 7). As noted, for this graph  $V_S = 12V$ ; for  $V_{CM} < 12V$ , the Output Error increases 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:**  
 $V_{SENSE} < 20mV$ ,  $-16V \leq V_{CM} < 0$ ; 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 27 illustrates this effect using the INA202 (Gain = 100).



**Figure 27. Example for Low  $V_{SENSE}$  Cases 1 and 3 (INA202, Gain = 100)**

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

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 28 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.

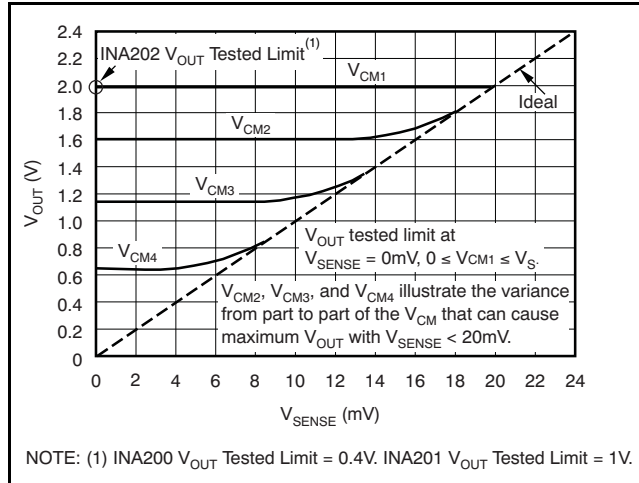


Figure 28. Example for Low  $V_{SENSE}$  Case 2 (INA202, Gain = 100)

### 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  $\pm 30\%$ . (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  $5k\Omega + 30\%$  input impedance; this is illustrated in Figure 29. 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:

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

Total effect on gain error can be calculated by replacing the  $5k\Omega$  term with  $5k\Omega - 30\%$  (or  $3.5k\Omega$ ) or  $5k\Omega + 30\%$  (or  $6.5k\Omega$ ). The tolerance extremes of  $R_{\text{FILT}}$  can also be inserted into the equation. If a pair of  $100\Omega$  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  $5k\Omega$  resistor ( $3.5k\Omega$ ), and the higher excursion of  $R_{\text{FILT}} - 3\%$  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  $1.3\mu\text{s}$  (typical) response time. The output of the comparator latches and is reset through the  $\text{RESET}$  pin; see Figure 30.

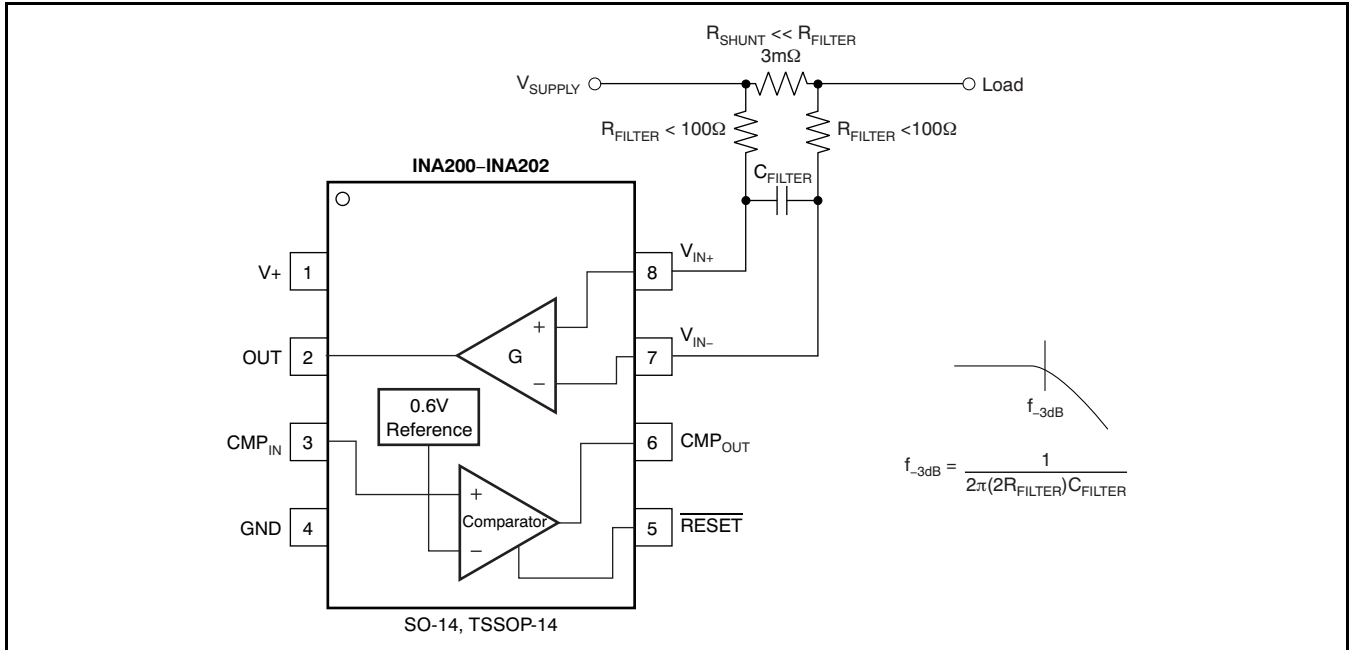


Figure 29. Input Filter (Gain Error—1.5% to -2.2%)

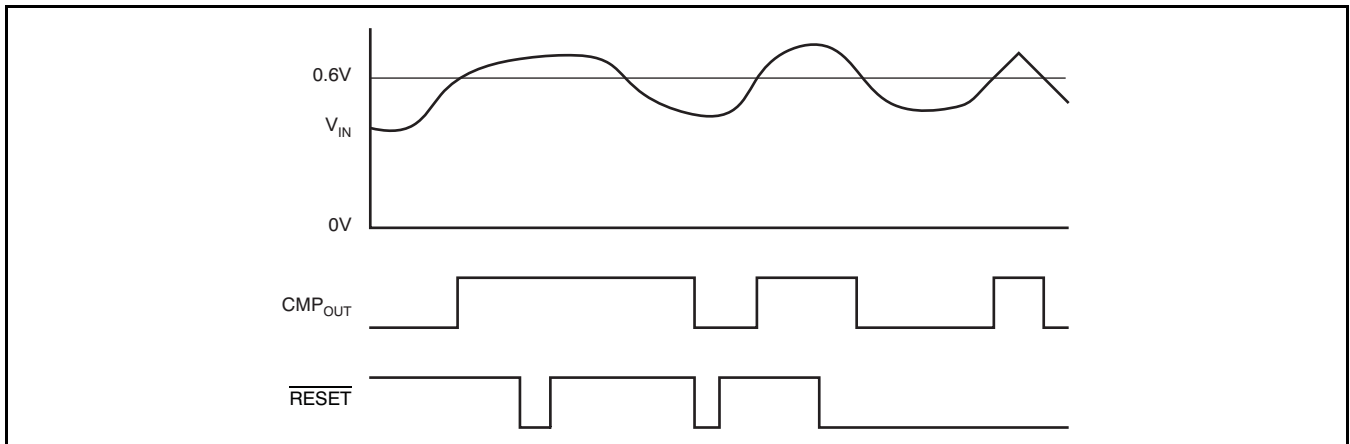


Figure 30. Comparator Latching Capability

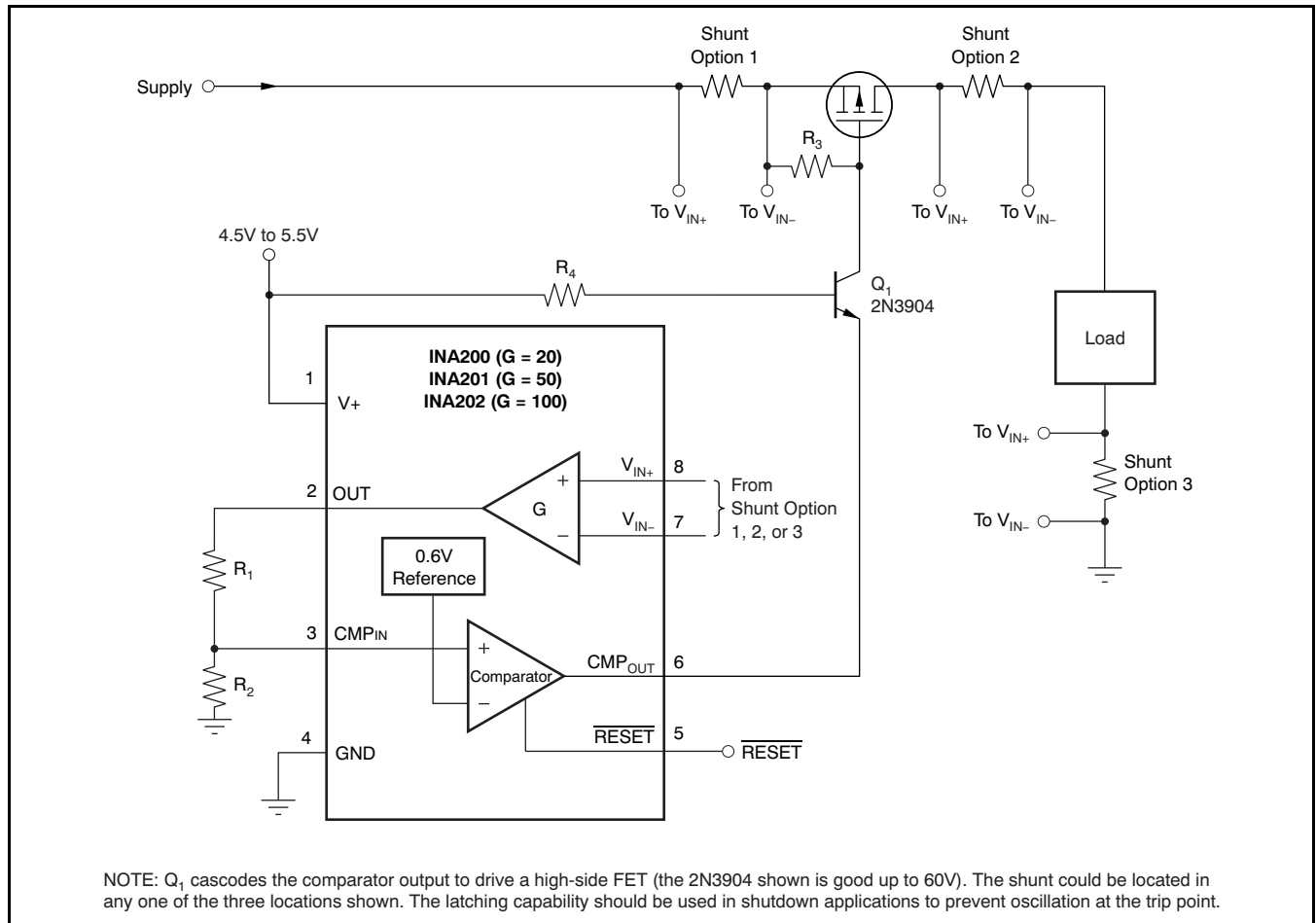


Figure 31. High-Side Switch Over-Current Shutdown

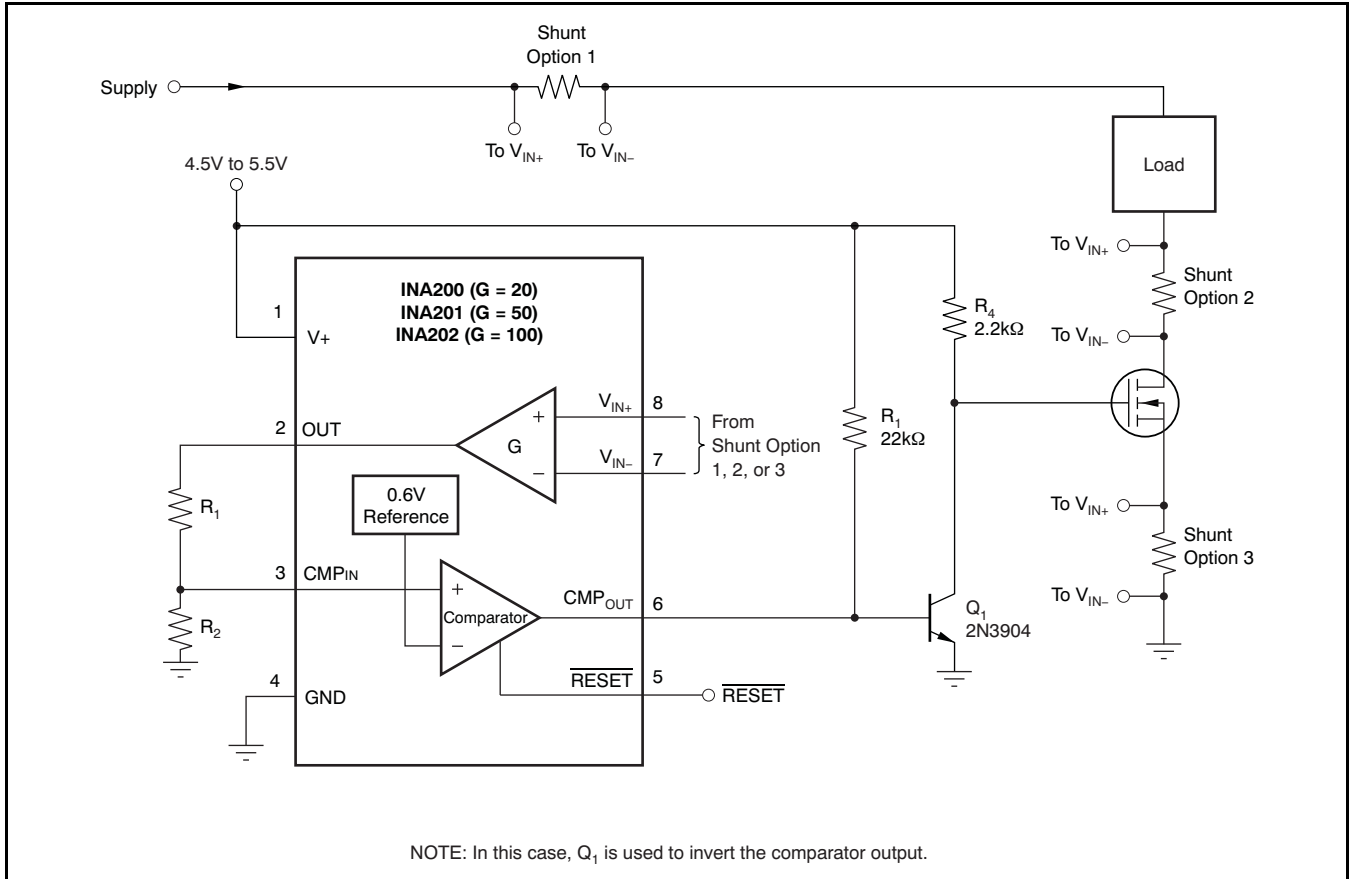


Figure 32. Low-Side Switch Over-Current Shutdown

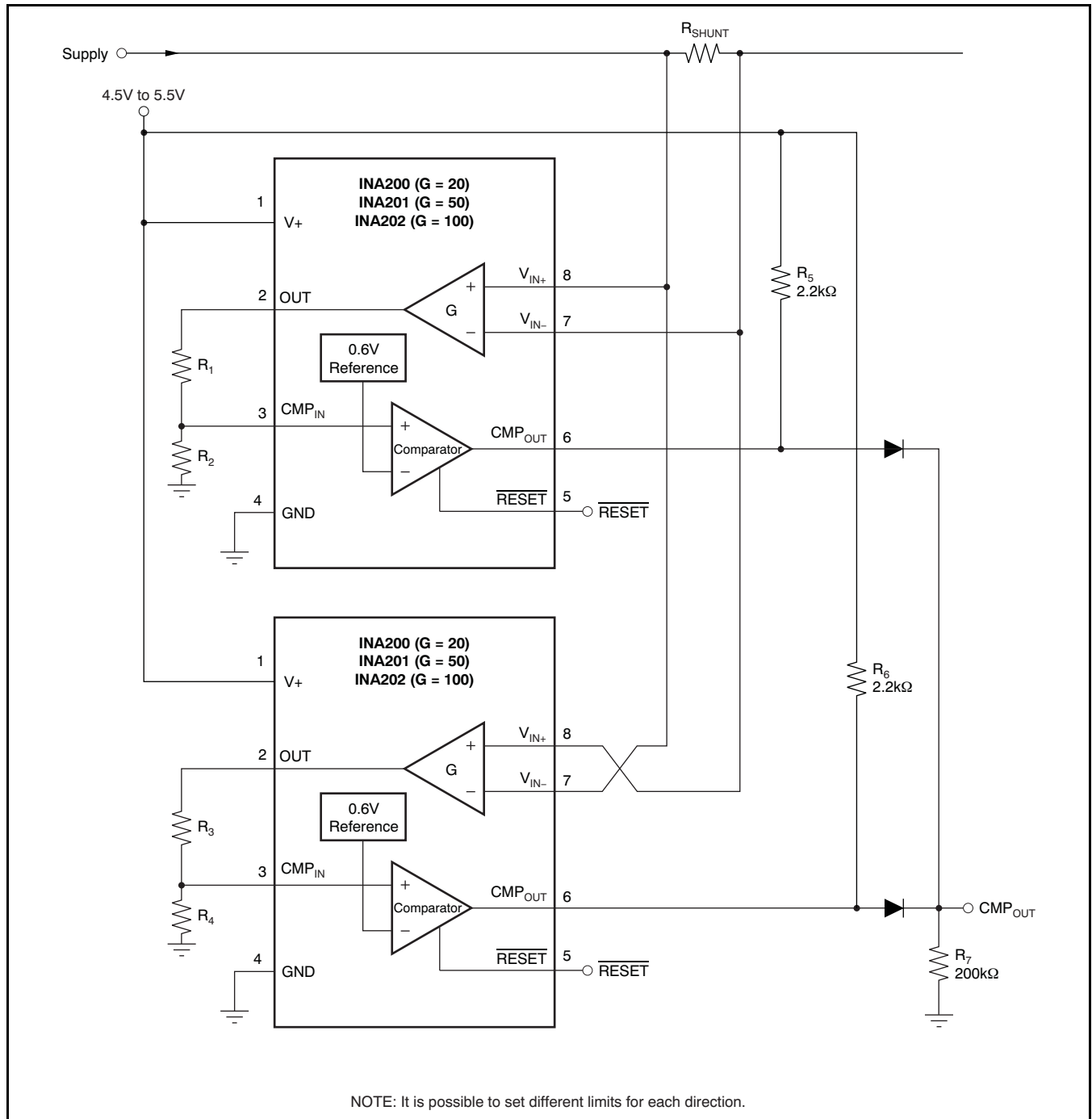


Figure 33. Bidirectional Over-Current Comparator



## REVISION HISTORY

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

<b>Changes from Revision B (October, 2007) to Revision C</b>	<b>Page</b>
• Changed title of data sheet .....	1
• Updated document format to current standards .....	1
• Revised front-page figure .....	1

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/ Ball Finish	MSL Peak Temp <sup>(3)</sup>	Samples (Requires Login)
INA200AID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	Contact TI Distributor or Sales Office
INA200AIDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	Contact TI Distributor or Sales Office
INA200AIDGKR	ACTIVE	MSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Request Free Samples</a>
INA200AIDGKRG4	ACTIVE	MSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Request Free Samples</a>
INA200AIDGKT	ACTIVE	MSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Purchase Samples</a>
INA200AIDGKTG4	ACTIVE	MSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Purchase Samples</a>
INA200AIDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Purchase Samples</a>
INA200AIDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Purchase Samples</a>
INA201AID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Purchase Samples</a>
INA201AIDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Purchase Samples</a>
INA201AIDGKR	ACTIVE	MSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Request Free Samples</a>
INA201AIDGKRG4	ACTIVE	MSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Request Free Samples</a>
INA201AIDGKT	ACTIVE	MSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Purchase Samples</a>
INA201AIDGKTG4	ACTIVE	MSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Purchase Samples</a>
INA201AIDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Purchase Samples</a>
INA201AIDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Purchase Samples</a>
INA202AID	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Request Free Samples</a>

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/ Ball Finish	MSL Peak Temp <sup>(3)</sup>	Samples (Requires Login)
INA202AIDG4	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Request Free Samples</a>
INA202AIDGKR	ACTIVE	MSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Request Free Samples</a>
INA202AIDGKRG4	ACTIVE	MSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Request Free Samples</a>
INA202AIDGKT	ACTIVE	MSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Purchase Samples</a>
INA202AIDGKTG4	ACTIVE	MSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Purchase Samples</a>
INA202AIDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Purchase Samples</a>
INA202AIDRG4	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	<a href="#">Purchase Samples</a>

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

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

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

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

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

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

<sup>(2)</sup> 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.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**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)

<sup>(3)</sup> 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**

**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
INA200AIDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	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
INA201AIDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	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
INA202AIDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	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
INA200AIDR	SOIC	D	8	2500	346.0	346.0	29.0
INA201AIDGKR	MSOP	DGK	8	2500	346.0	346.0	29.0
INA201AIDGKT	MSOP	DGK	8	250	190.5	212.7	31.8
INA201AIDR	SOIC	D	8	2500	346.0	346.0	29.0
INA202AIDGKR	MSOP	DGK	8	2500	346.0	346.0	29.0
INA202AIDGKT	MSOP	DGK	8	250	190.5	212.7	31.8
INA202AIDR	SOIC	D	8	2500	346.0	346.0	29.0

DGK (S-PDSO-G8)

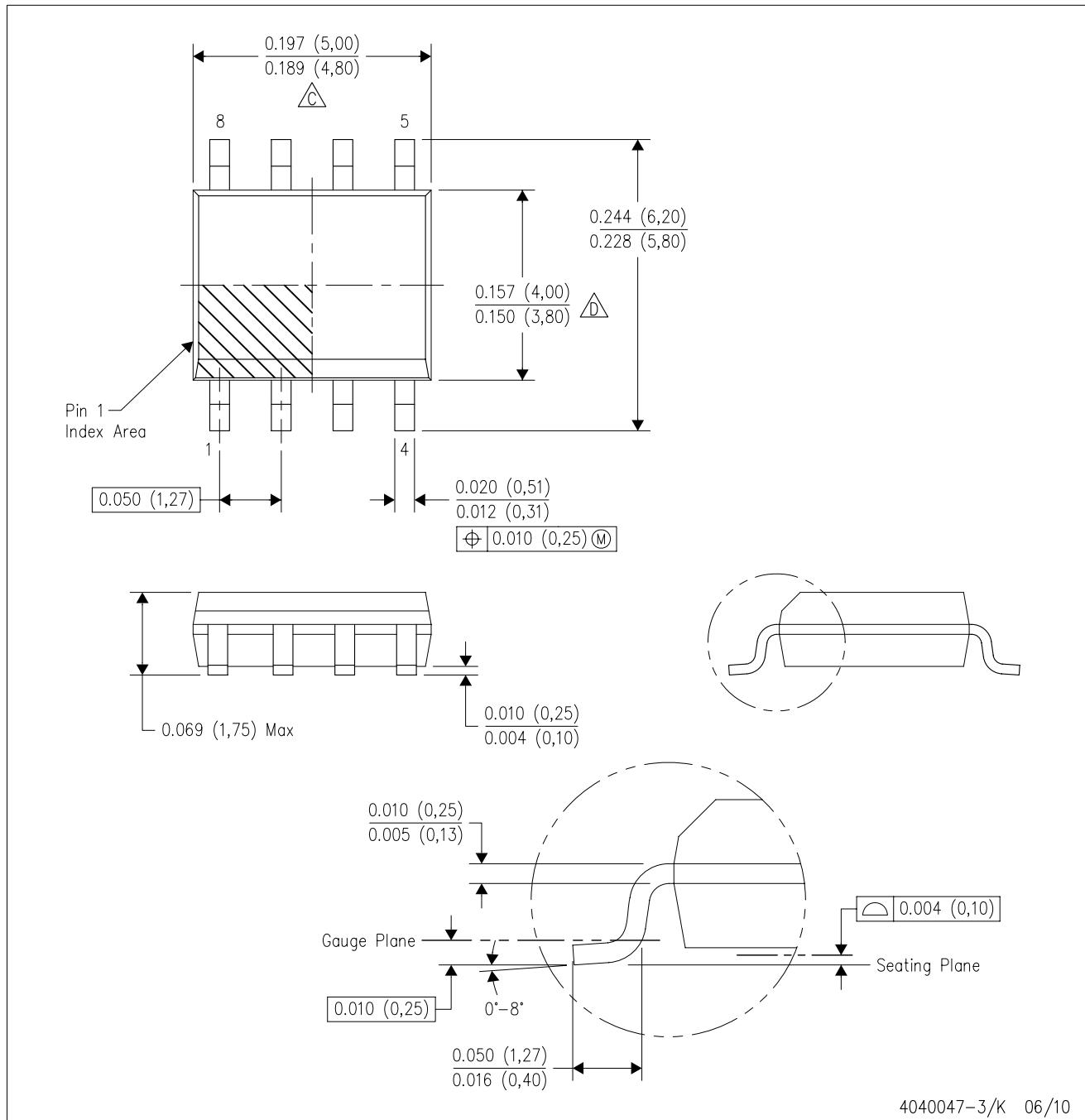
PLASTIC SMALL-OUTLINE PACKAGE



- 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.

D (R-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE

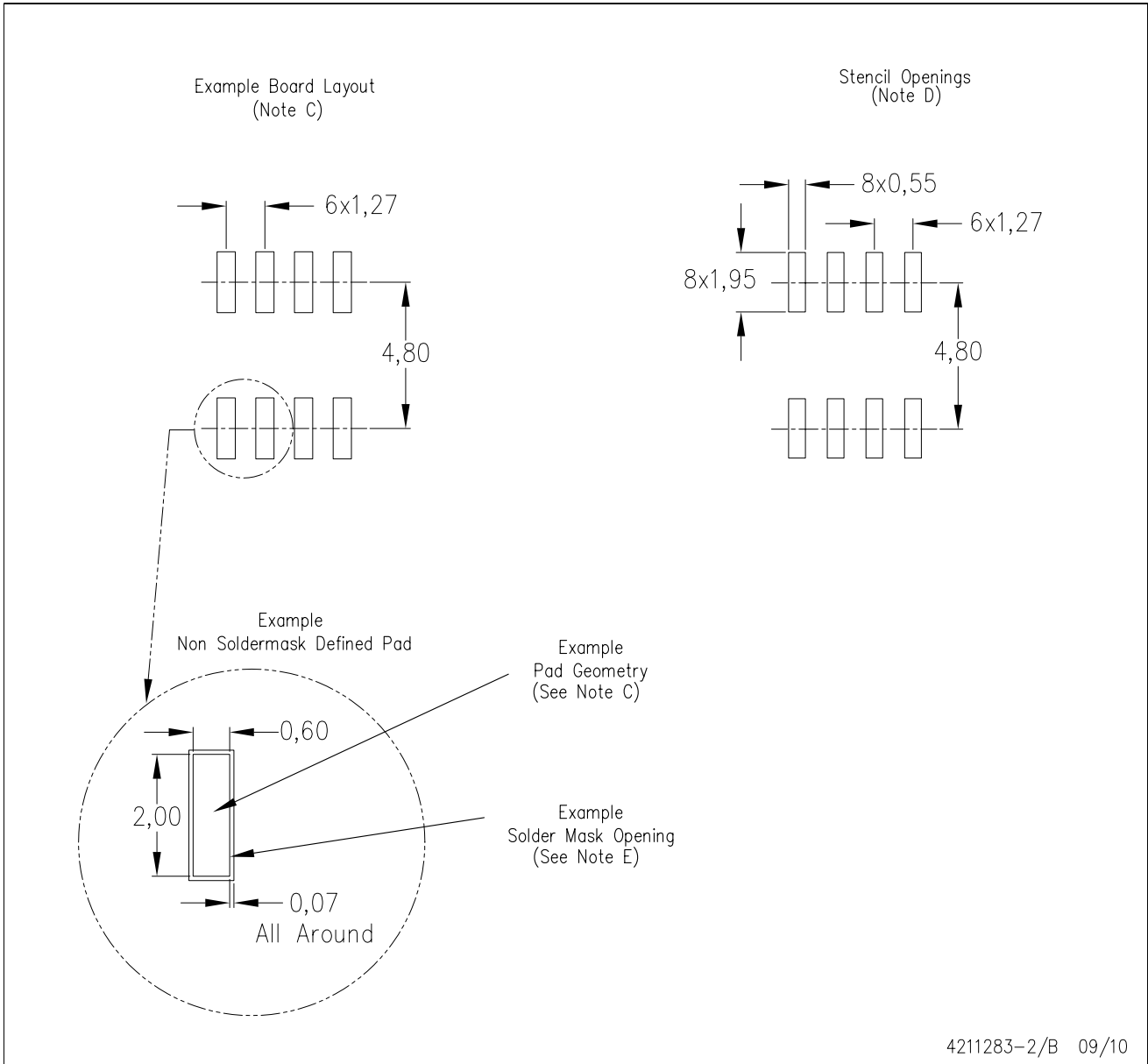


NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 (0,15) per end.  
 D. Body width does not include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



D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Publication IPC-7351 is recommended for alternate designs.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
  - Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

<b>Products</b>		<b>Applications</b>	
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>	Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>	Automotive	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>	Communications and Telecom	<a href="http://www.ti.com/communications">www.ti.com/communications</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>	Computers and Peripherals	<a href="http://www.ti.com/computers">www.ti.com/computers</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>	Consumer Electronics	<a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>	Energy	<a href="http://www.ti.com/energy">www.ti.com/energy</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>	Industrial	<a href="http://www.ti.com/industrial">www.ti.com/industrial</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>	Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>	Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>	Space, Avionics & Defense	<a href="http://www.ti.com/space-avionics-defense">www.ti.com/space-avionics-defense</a>
RF/IF and ZigBee® Solutions	<a href="http://www.ti.com/lprf">www.ti.com/lprf</a>	Video and Imaging	<a href="http://www.ti.com/video">www.ti.com/video</a>
		Wireless	<a href="http://www.ti.com/wireless-apps">www.ti.com/wireless-apps</a>

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