



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

 Check for Samples: [INA200-Q1](#), [INA201-Q1](#), [INA202-Q1](#)

### FEATURES

- Qualified for Automotive Applications
- AEC-Q100 Qualified With the Following Results:
  - Device Temperature Grade 1:  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  Ambient Operating Temperature Range
  - Device HBM ESD Classification Level H2
  - Device CDM ESD Classification Level C3B
- Complete Current-Sense Solution
- 0.6-V 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: 500 kHz (INA200-Q1)

- Quiescent Current: 1800  $\mu\text{A}$  (Max)
- Latch-Up Exceeds 100 mA per JESD78
- Package: MSOP-8

### APPLICATIONS

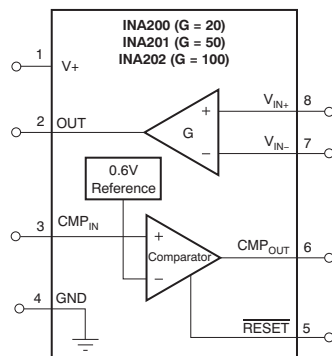
- Automotive Brake and ESP Systems Monitoring
- Automotive Power Windows and Power Seats
- Automotive HEV and EV Battery Monitoring
- Battery-Charger Overcurrent Detection for Notebook Computers
- Power-Supply Protection and  $\pm 12\text{-V}$  Supply Monitoring for Servers
- Circuit Breaker With Provision for Power Limiting

### DESCRIPTION

The INA200-Q1, INA201-Q1, and INA202-Q1 are high-side current-shunt monitors with voltage output. The INA200-Q1–INA202-Q1 can sense drops across shunts at common-mode voltages from  $-16\text{ V}$  to  $80\text{ V}$ . The INA200-Q1–INA202-Q1 are available with three output voltage scales: 20 V/V, 50 V/V, and 100 V/V, with up to 500-kHz bandwidth.

The INA200-Q1, INA201-Q1, and INA202-Q1 also incorporate an open-drain comparator and internal reference providing a 0.6-V threshold. External dividers set the current trip point. The comparator includes a latching capability, which grounding (or leaving open) the RESET pin makes transparent.

The INA200-Q1, INA201-Q1, and INA202-Q1 operate from a single 2.7-V to 18-V supply, drawing a maximum of 1800  $\mu\text{A}$  of supply current. Package options include the very small MSOP-8. Specification for all versions extends over the 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>

T <sub>A</sub>	ORDERABLE PART NUMBER <sup>(2)</sup>	TOP-SIDE MARKING
-40°C to +125°C	INA200AQDGKRQ1	SHZ
	INA201AQDGKRQ1	QWV
	INA202AQDGKRQ1	SIA

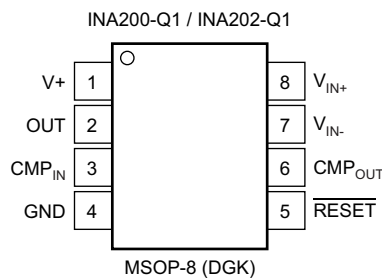
- (1) For the most current package and ordering information see the Package Option Addendum at the end of this document, or see the device product folder at [www.ti.com](http://www.ti.com).  
 (2) Package drawings, thermal data, and symbolization are available at [www.ti.com/packaging](http://www.ti.com/packaging).

### 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
	Common mode <sup>(2)</sup>	-16 to 80
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
Storage temperature	-65 to 150	°C
Junction temperature	150	°C

- (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 do not imply functional operation of the device at these or any other conditions beyond those specified.  
 (2) This voltage may exceed the ratings shown if the current at that pin does not exceed to 5 mA.

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

CURRENT-SHUNT MONITOR PARAMETERS		CONDITIONS	INA200-Q1, INA201-Q1, INA202-Q1			UNIT
			MIN	TYP	MAX	
<b>INPUT</b>						
Full-scale sense input voltage	$V_{SENSE}$	$V_{SENSE} = V_{IN+} - V_{IN-}$		0.15	$(V_S - 0.25) / \text{Gain}$	V
<b>Common-mode input range</b>	$V_{CM}$		<b>-16</b>		<b>80</b>	<b>V</b>
Common-mode rejection	CMR	$V_{IN+} = -16\text{ V}$ to $80\text{ V}$	80	100		dB
<b>Over temperature</b>		<b><math>V_{IN+} = 12\text{ V}</math> to <math>80\text{ V}</math></b>	<b>100</b>	<b>123</b>		<b>dB</b>
Offset voltage, RTI <sup>(1)</sup>	$V_{OS}$			$\pm 0.5$	$\pm 2.5$	mV
25°C to 125°C					$\pm 3$	mV
-40°C to 25°C					$\pm 3.5$	mV
<b>versus temperature</b>	$dV_{OS} / dT$	$T_{MIN}$ to $T_{MAX}$		<b>5</b>		$\mu\text{V}/^{\circ}\text{C}$
<b>versus power supply</b>	PSR	$V_{OUT} = 2\text{ V}$ , $V_{IN+} = 18\text{ V}$ , $2.7\text{ V}$		<b>2.5</b>	<b>100</b>	$\mu\text{V}/\text{V}$
Input bias current, $V_{IN-}$ Pin	$I_B$			$\pm 9$	$\pm 16$	$\mu\text{A}$
<b>OUTPUT (<math>V_{SENSE} \geq 20\text{ mV}</math>)</b>						
Gain:	G					
INA200-Q1				20		V/V
INA201-Q1				50		V/V
INA202-Q1				100		V/V
Gain error		$V_{SENSE} = 20\text{ mV}$ to $100\text{ mV}$		$\pm 0.2\%$	$\pm 1\%$	
<b>Over temperature</b>		<b><math>V_{SENSE} = 20\text{ mV}</math> to <math>100\text{ mV}</math></b>			<b><math>\pm 2\%</math></b>	
Total output error <sup>(2)</sup>		$V_{SENSE} = 120\text{ mV}$ , $V_S = 16\text{ V}$		$\pm 0.75\%$	$\pm 2.2\%$	
<b>Over temperature</b>		<b><math>V_{SENSE} = 120\text{ mV}</math>, <math>V_S = 16\text{ V}</math></b>			<b><math>\pm 3.5\%</math></b>	
Nonlinearity error <sup>(3)</sup>		$V_{SENSE} = 20\text{ mV}$ 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_{SENSE} &lt; 20\text{ mV}</math>)<sup>(4)</sup></b>						
INA200-Q1, INA201-Q1, INA202-Q1		$-16\text{ V} \leq V_{CM} < 0\text{ V}$		300		mV
INA200-Q1		$0\text{ V} \leq V_{CM} \leq V_S$ , $V_S = 5\text{ V}$			0.4	V
INA201-Q1		$0\text{ V} \leq V_{CM} \leq V_S$ , $V_S = 5\text{ V}$			1	V
INA202-Q1		$0\text{ V} \leq V_{CM} \leq V_S$ , $V_S = 5\text{ V}$			2	V
INA200-Q1, INA201-Q1, INA202-Q1		$V_S < V_{CM} \leq 80\text{ V}$		300		mV
<b>VOLTAGE OUTPUT<sup>(5)</sup></b>						
<b>Output Swing to the Positive Rail</b>		$V_{IN-} = 11\text{ V}$ , $V_{IN+} = 12\text{ V}$		<b>(V+) - 0.15</b>	<b>(V+) - 0.25</b>	<b>V</b>
<b>Output Swing to GND<sup>(6)</sup></b>		$V_{IN-} = 0\text{ V}$ , $V_{IN+} = -0.5\text{ V}$		<b>(V_GND) + 0.004</b>	<b>(V_GND) + 0.05</b>	<b>V</b>
<b>FREQUENCY RESPONSE</b>						
Bandwidth:	BW					
INA200-Q1		$C_{LOAD} = 5\text{ pF}$		500		kHz
INA201-Q1		$C_{LOAD} = 5\text{ pF}$		300		kHz
INA202-Q1		$C_{LOAD} = 5\text{ pF}$		200		kHz
Phase margin		$C_{LOAD} < 10\text{ nF}$		40		Degrees
Slew rate	SR			1		V/ $\mu\text{s}$
Settling time (1%)		$V_{SENSE} = 10\text{ mV}_{PP}$ to $100\text{ mV}_{PP}$ , $C_{LOAD} = 5\text{ pF}$		2		$\mu\text{s}$

(1) Extrapolation from measurements of the output at 20 mV and 100 mV  $V_{SENSE}$  provides the offset.

(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](#) section in the [Application Information](#).

(5) See Typical Characteristic curve *Output Swing versus Output Current*.

(6) Specified by design

## ELECTRICAL CHARACTERISTICS: CURRENT-SHUNT MONITOR (continued)

**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  $\text{CMP}_{IN} = \text{GND}$ , unless otherwise noted.

CURRENT-SHUNT MONITOR PARAMETERS	CONDITIONS	INA200-Q1, INA201-Q1, INA202-Q1			UNIT
		MIN	TYP	MAX	
<b>NOISE, RTI</b> Voltage noise density			40		nV/ $\sqrt{\text{Hz}}$

## 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-Q1, INA201-Q1, INA202-Q1			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 versus temperature			0.005	10	nA
				<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	$\text{CMP } V_{OUT} 1\text{ V to } 4\text{ V}$ , $R_L \geq 15\text{ k}\Omega$ connected to 5 V		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 5 V, $C_L = 15\text{ pF}$ , 100-mV input step with 5-mV 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 duration			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; see [Figure 2](#).
- (2) Specified by design
- (3)  $V_{ID}$  refers to the differential voltage at the comparator inputs.
- (4) Pulling the open-drain output to the range of 2.7 V to 18 V is permissible, 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 1.4 V.
- (6) The  $\overline{\text{RESET}}$  input has an internal 2-M $\Omega$  (typical) pulldown. Leaving  $\overline{\text{RESET}}$  open results in a LOW state, with transparent comparator operation.

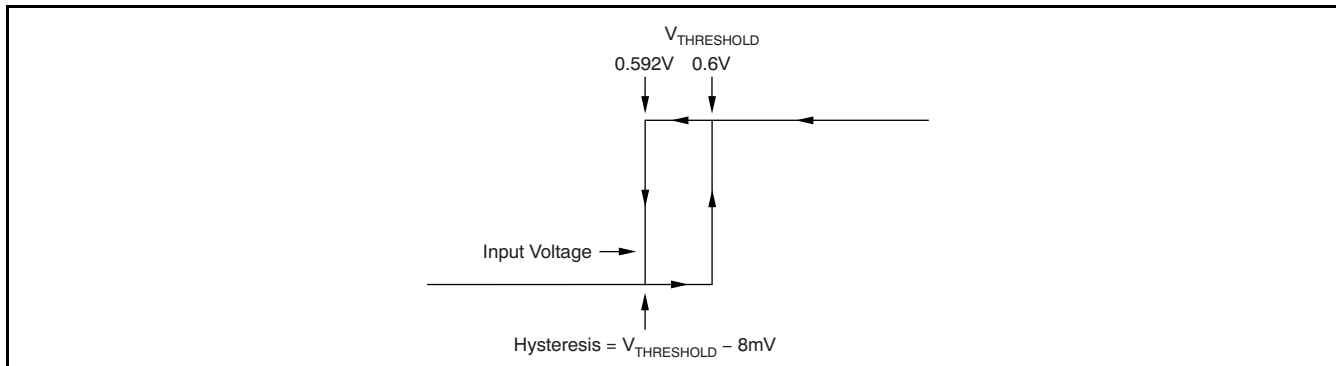


Figure 2. Typical Comparator Hysteresis

### 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-Q1, INA201-Q1, INA202-Q1			UNIT
		MIN	TYP	MAX	
<b>POWER SUPPLY</b>					
Operating power supply	$V_S$	2.7		18	V
Quiescent current	$I_Q$		1350	1800	$\mu\text{A}$
<b>Over temperature</b>	$V_{OUT} = 2\text{ V}$ $V_{SENSE} = 0\text{ mV}$			<b>1850</b>	<b><math>\mu\text{A}</math></b>
Comparator power-on reset threshold <sup>(1)</sup>			1.5		V
<b>TEMPERATURE</b>					
Operating temperature range		-40		125	$^{\circ}\text{C}$
Storage temperature range		-65		150	$^{\circ}\text{C}$
Thermal resistance	$\theta_{JA}$				
MSOP-8 Surface-Mount			200		$^{\circ}\text{C}/\text{W}$

(1) The design of INA200-Q1, INA201-Q1, and INA202-Q1 is for 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.

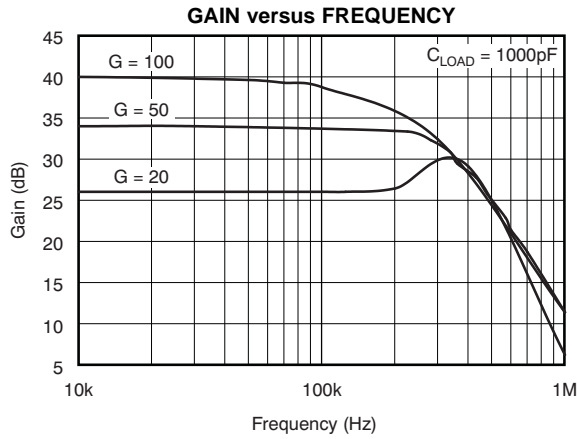


Figure 3.

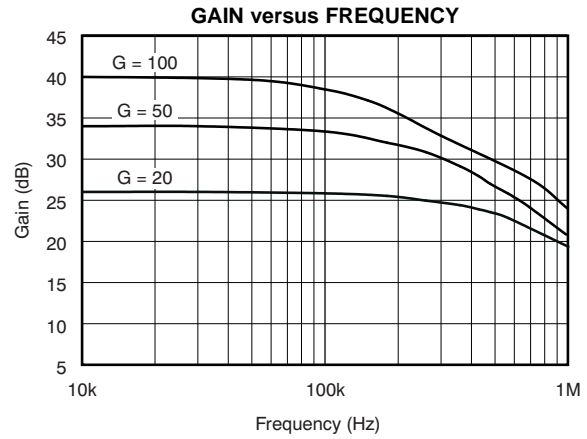


Figure 4.

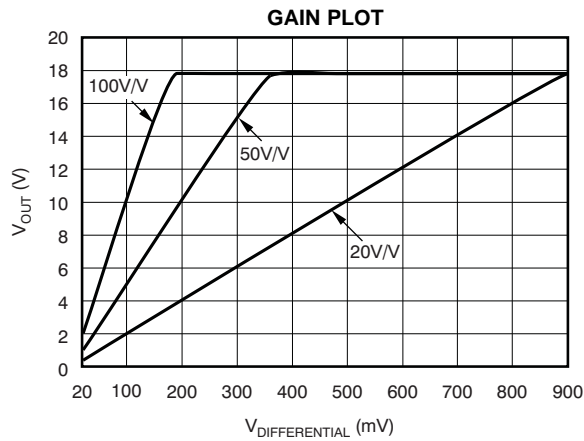


Figure 5.

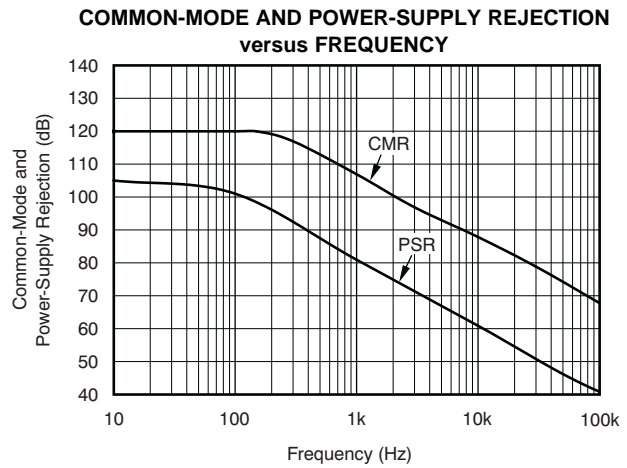


Figure 6.

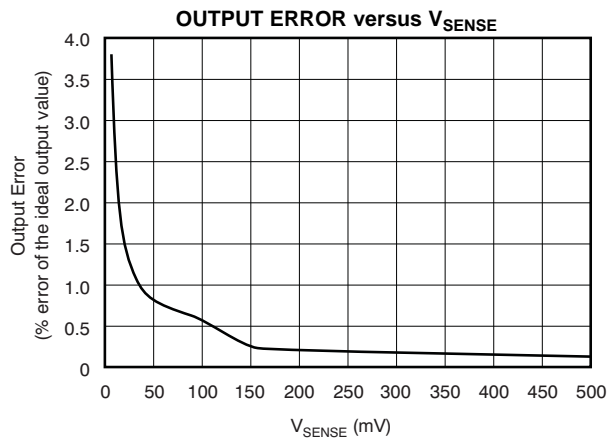


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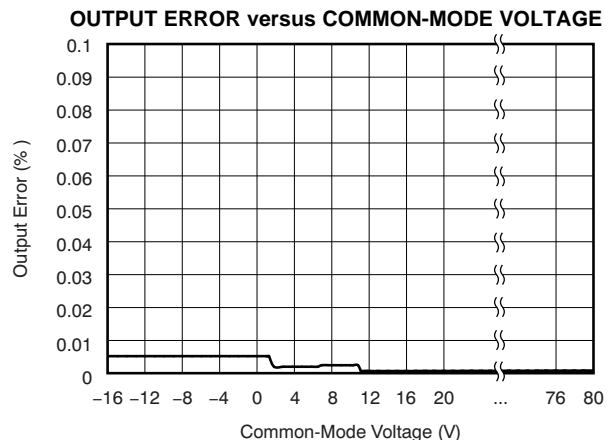


Figure 8.

**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.

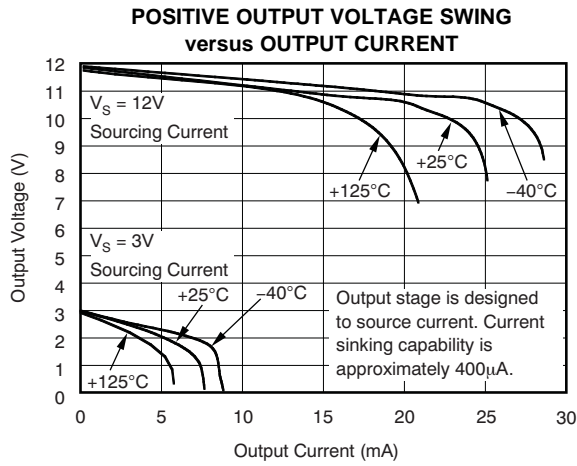


Figure 9.

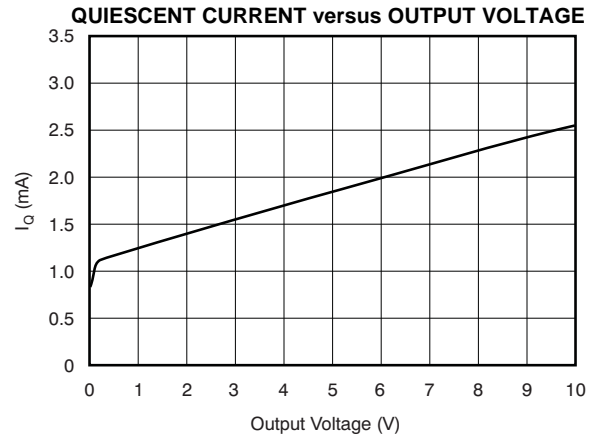


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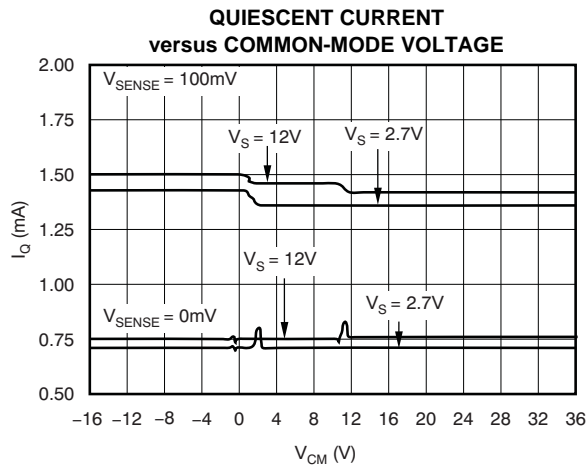


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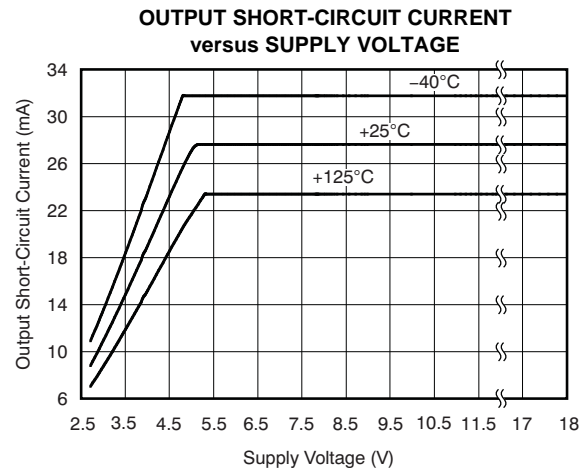


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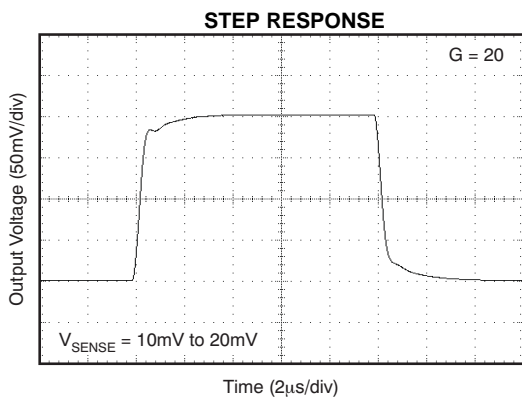


Figure 13.

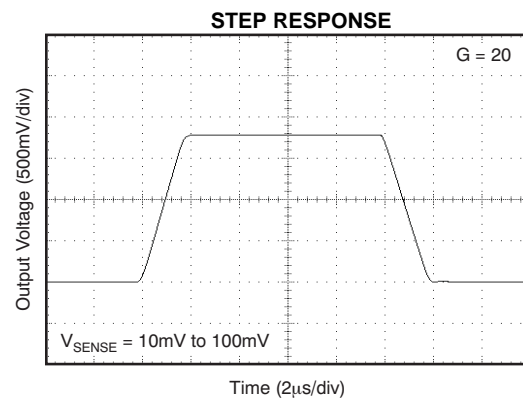
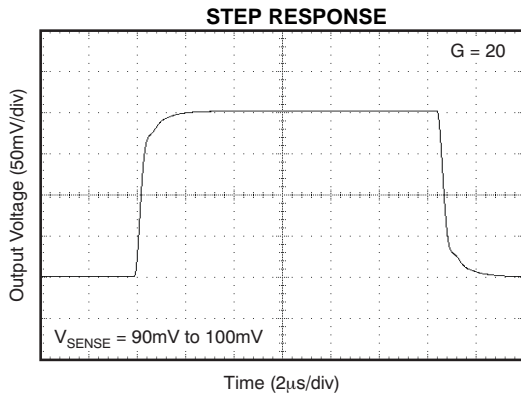


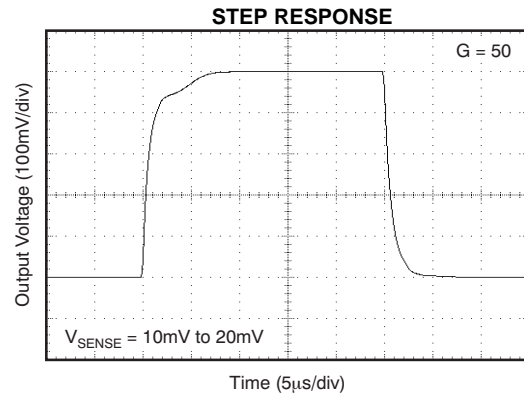
Figure 14.

**TYPICAL CHARACTERISTICS (continued)**

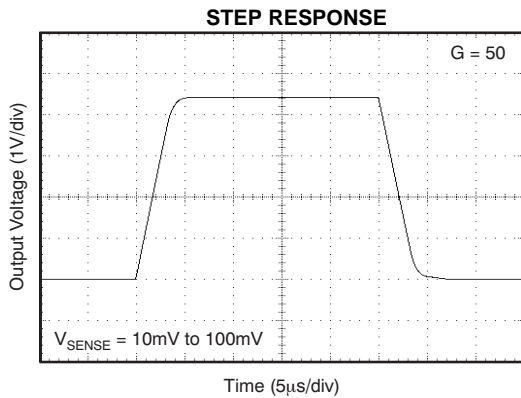
At  $T_A = 25^\circ\text{C}$ ,  $V_S = 12\text{ V}$ ,  $V_{IN+} = 12\text{ V}$ , and  $V_{SENSE} = 100\text{ mV}$ , unless otherwise noted.



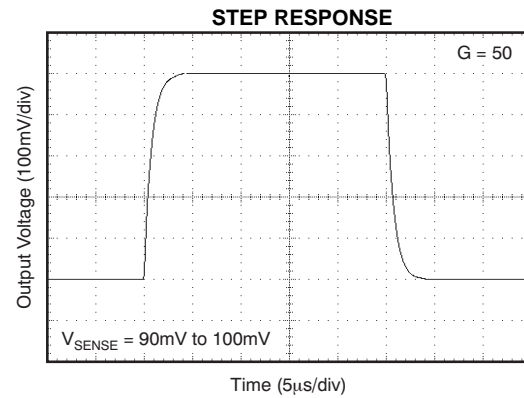
**Figure 15.**



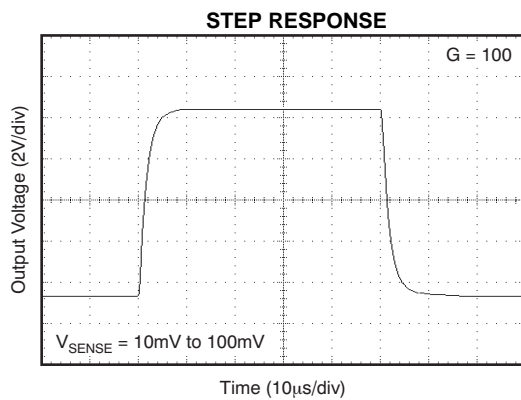
**Figure 16.**



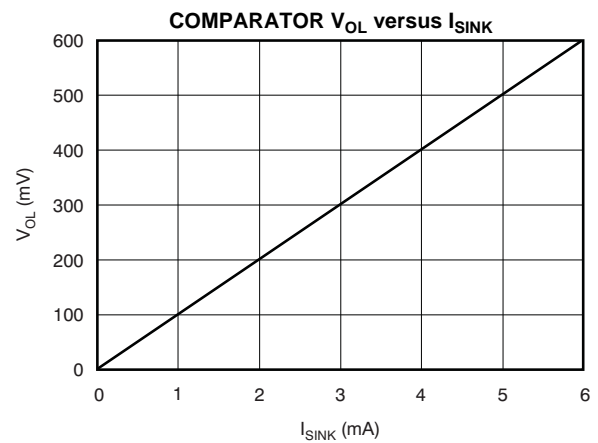
**Figure 17.**



**Figure 18.**



**Figure 19.**



**Figure 20.**

**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.

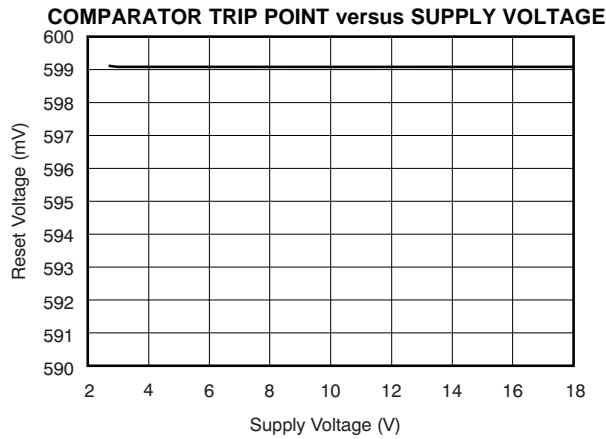


Figure 21.

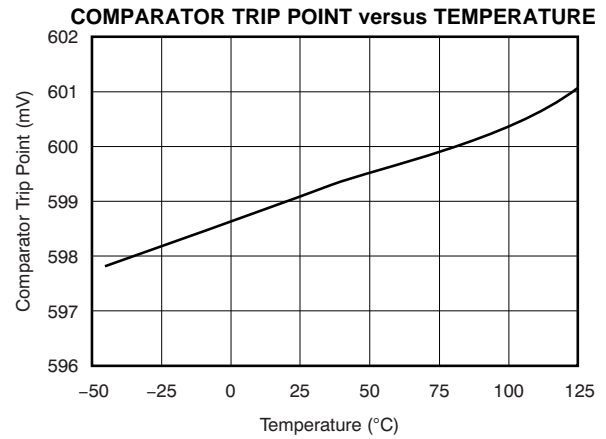


Figure 22.

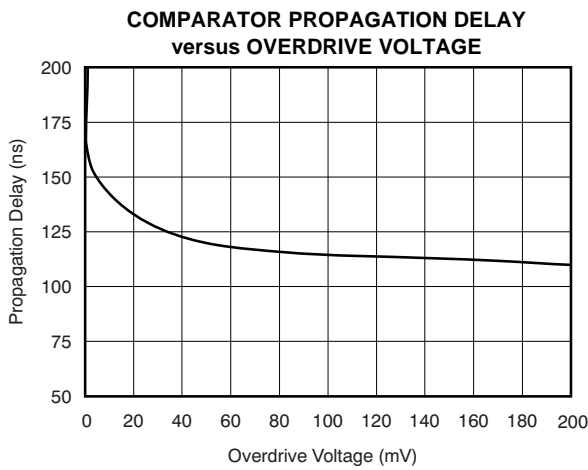


Figure 23.

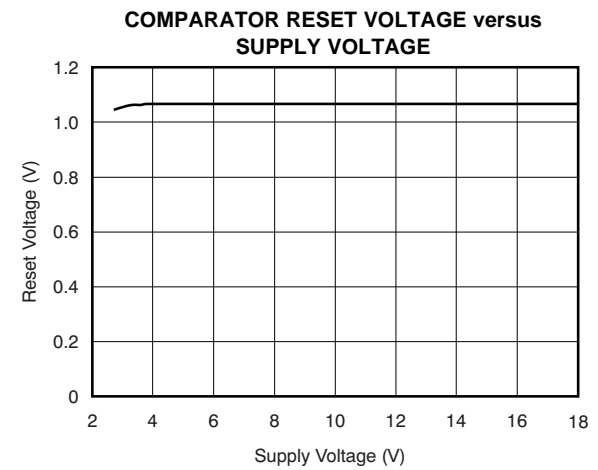


Figure 24.

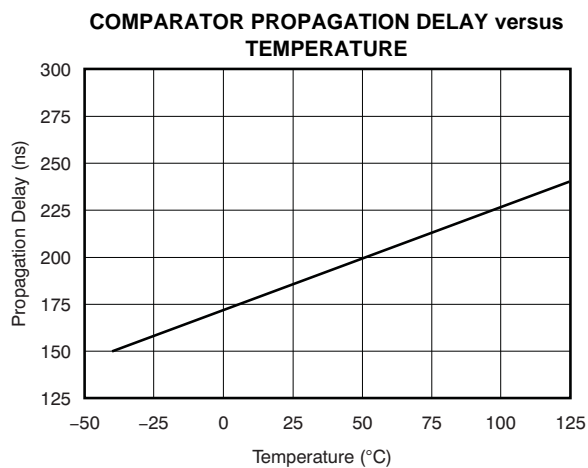


Figure 25.

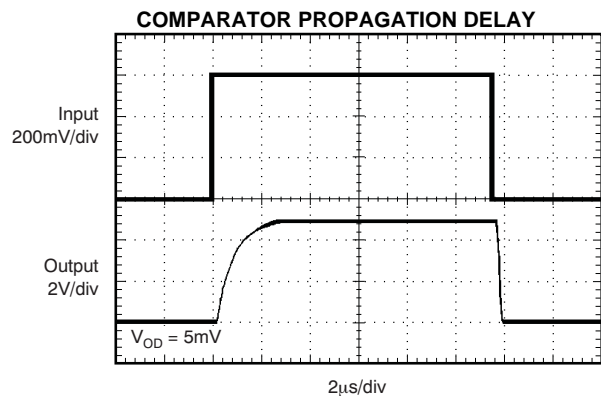


Figure 26.

## APPLICATION INFORMATION

### BASIC CONNECTIONS

Figure 27 shows the basic connections of the INA200-Q1, INA201-Q1, and INA202-Q1. Connect the input pins,  $V_{IN+}$  and  $V_{IN-}$ , as closely as possible to the shunt resistor to minimize any resistance in series with the shunt resistance.

Stability requires the use of power-supply bypass capacitors. 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-Q1, INA201-Q1, and INA202-Q1 can accurately measure beyond the power-supply voltage,  $V+$ . For example, the  $V+$  power supply can be 5 V, whereas the load power-supply voltage is up to 80 V. However, the voltages on the power-supply pins limit the output voltage range of the OUT terminal.

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

The accuracy of the INA200-Q1, INA201-Q1, and INA202-Q1 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,  $V_S$ . The expression for  $V_{CM}$  is  $(V_{IN+} + V_{IN-}) / 2$ ; however, in practice,  $V_{CM}$  is effectively 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:  $V_{SENSE} \geq 20$  mV,  $V_{CM} \geq V_S$
- Normal Case 2:  $V_{SENSE} \geq 20$  mV,  $V_{CM} < V_S$
- Low  $V_{SENSE}$  Case 1:  $V_{SENSE} < 20$  mV,  $-16$  V  $\leq V_{CM} < 0$
- Low  $V_{SENSE}$  Case 2:  $V_{SENSE} < 20$  mV,  $0$  V  $\leq V_{CM} \leq V_S$
- Low  $V_{SENSE}$  Case 3:  $V_{SENSE} < 20$  mV,  $V_S < V_{CM} \leq 80$  V

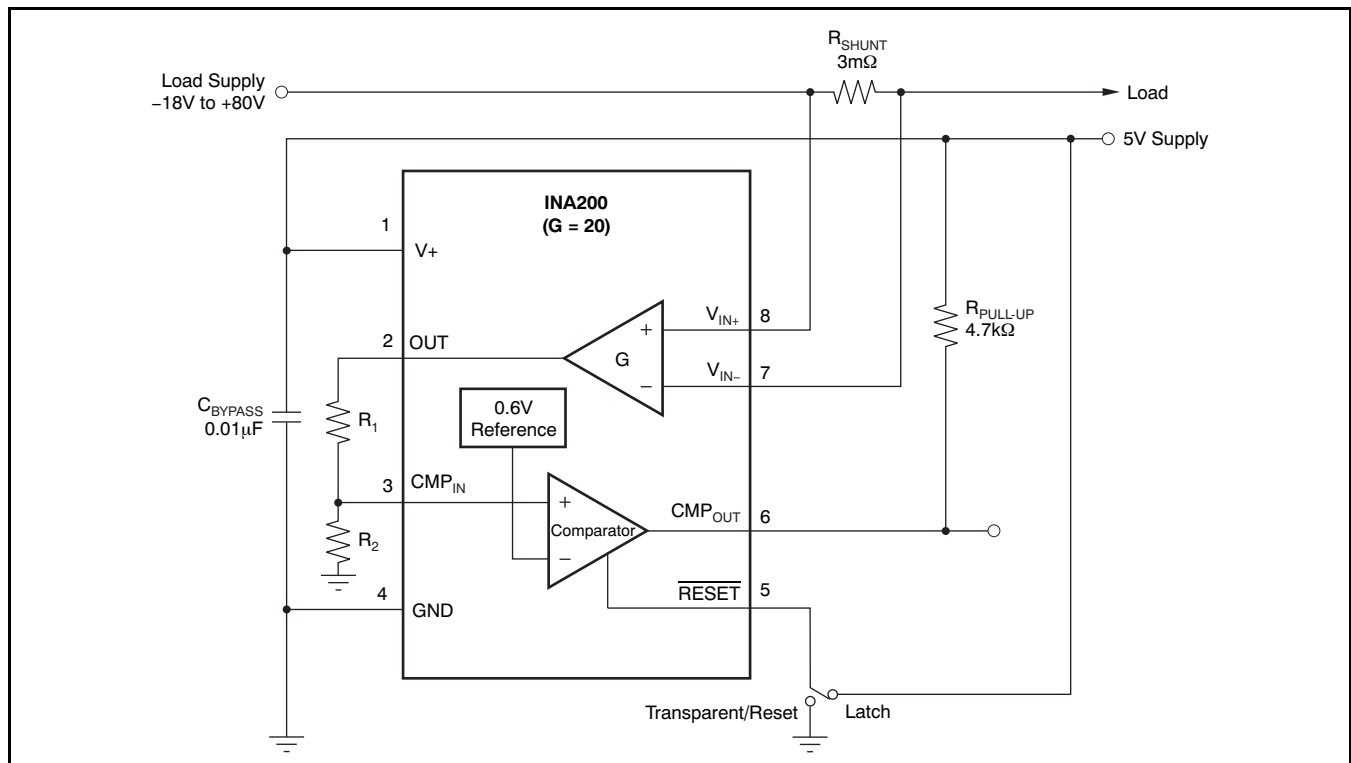


Figure 27. INA200-Q1 Basic Connections

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

This region of operation provides the highest accuracy. Here, use of a two-step method characterizes and measures the input offset voltage. First, Equation 1 determines the gain.

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

where:

$V_{OUT1}$  = output voltage with  $V_{SENSE} = 100\text{ mV}$

$V_{OUT2}$  = output voltage with  $V_{SENSE} = 20\text{ mV}$

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

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

In the Typical Characteristics, the Output Error versus Common-Mode Voltage curve (Figure 8) shows the highest accuracy for the this region of operation. In this plot,  $V_S = 12\text{ V}$ ; for  $V_{CM} \geq 12\text{ V}$ , the output error is at its minimum. Using this case also creates the  $V_{SENSE} \geq 20\text{ mV}$  output specifications in the Electrical Characteristics table.

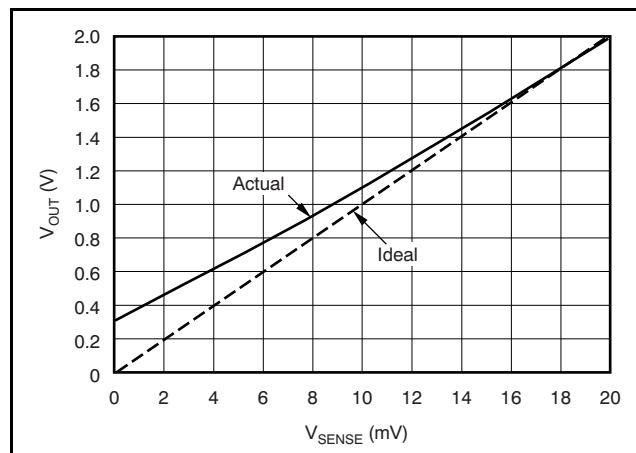
**Normal Case 2:  $V_{SENSE} \geq 20\text{ mV}$ ,  $V_{CM} < V_S$**

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 versus Common-Mode Voltage curve (Figure 8). As noted, for this graph  $V_S = 12\text{ V}$ ; for  $V_{CM} < 12\text{ V}$ , the output error increases as  $V_{CM}$  becomes less than  $12\text{ V}$ , with a typical maximum error of 0.005% at the most negative  $V_{CM} = -16\text{ V}$ .

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

Although not designed for accurate operation in either of these regions, the INA200-Q1 family of devices can have exposure to these conditions in some applications. For example, when monitoring power supplies being switched on and off with  $V_S$  still applied to the INA200-Q1, INA201-Q1, or INA202-Q1, it is important to know what the behavior of the devices is in these regions.

As  $V_{SENSE}$  approaches 0 mV, 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  $V_{OUT} = 300\text{ mV}$  for  $V_{SENSE} = 0\text{ mV}$ . As  $V_{SENSE}$  approaches 20 mV,  $V_{OUT}$  returns to the expected output value with accuracy as specified in the Electrical Characteristics. Figure 28 illustrates this effect using the INA202-Q1 (Gain = 100).



**Figure 28. Example for Low  $V_{SENSE}$  Cases 1 and 3 (INA202-Q1, Gain = 100)**

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

This region of operation is the least accurate for the INA200-Q1 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 0 V. Within this region, as  $V_{SENSE}$  approaches 20 mV, device operation is closer to that described by Normal Case 2. Figure 29 illustrates this behavior for the INA202-Q1. To test the  $V_{OUT}$  maximum peak for this case, maintain a constant  $V_S$ , set  $V_{SENSE} = 0\text{ mV}$ , and sweep  $V_{CM}$  from 0 V to  $V_S$ . The exact  $V_{CM}$  at which  $V_{OUT}$  peaks during this test varies from part to part, but the tested  $V_{OUT}$  maximum peak for any part is less than the specified  $V_{OUT}$  test limit.

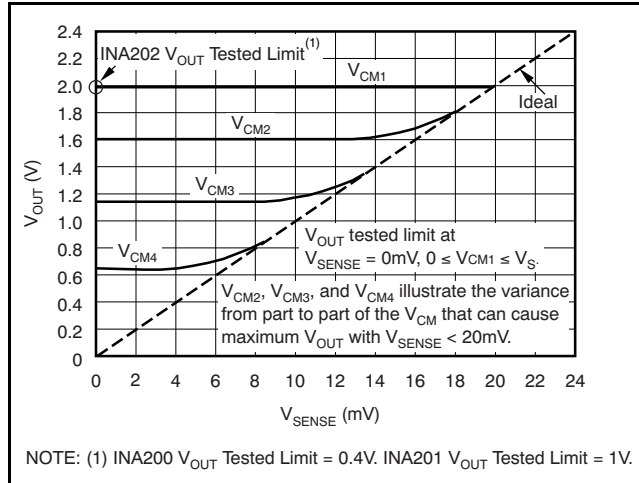


Figure 29. Example for Low  $V_{SENSE}$  Case 2 (INA202-Q1, Gain = 100)

### 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, whereas low values of  $R_S$  minimize voltage loss in the supply line. Most applications attain best performance with an  $R_S$  value that provides a full-scale shunt voltage range of 50 mV to 100 mV. Maximum input voltage for accurate measurements is 500 mV.

### TRANSIENT PROTECTION

The  $-16$  V to 80 V common-mode range of the INA200-Q1, INA201-Q1, and INA202-Q1 is ideal for withstanding automotive fault conditions ranging from 12-V battery reversal up to 80-V transients, because there is need for additional protective components up to those levels. In the event that the INA200-Q1, INA201-Q1, and INA202-Q1 are exposed to transients on the inputs in excess of their ratings, then external transient absorption with semiconductor transient absorbers (such as Zeners) is necessary. TI does not recommend the use of MOVs or VDRs except when they are used in addition to a semiconductor transient absorber. Select the transient absorber such that it never allows exposure of the INA200-Q1, INA201-Q1, and INA202-Q1 to transients greater than 80 V (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-Q1, INA201-Q1, and INA202-Q1 do not lend themselves to using external resistors in series with the inputs, because the

internal gain resistors can vary up to  $\pm 30\%$ . (If gain accuracy is not important, then one can add resistors in series with the INA200-Q1, INA201-Q1, and INA202-Q1 inputs with two equal resistors on each input.)

### OUTPUT VOLTAGE RANGE

The output of the INA200-Q1, INA201-Q1, and INA202-Q1 is accurate within the output voltage swing range set by the power supply pin,  $V_+$ . Best illustration of this performance occurs when using the INA202-Q1 (a gain-of-100 version), where a 100-mV full-scale input from the shunt resistor requires an output voltage swing of 10V, and a power-supply voltage sufficient to achieve 10 V on the output.

### INPUT FILTERING

An obvious and straightforward location for filtering is at the output of the INA200-Q1, INA201-Q1, and INA202-Q1 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-Q1, INA201-Q1, and INA202-Q1, but the internal  $5\text{-k}\Omega + 30\%$  input impedance complicates input filtering, as illustrated in Figure 30. Using the lowest possible resistor values minimizes both the initial shift in gain and effects of tolerance. Equation 3 gives the effect on initial gain:

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

To calculate the total effect on gain error, replace the  $5\text{-k}\Omega$  term with  $5\text{ k}\Omega - 30\%$ , (or  $3.5\text{ k}\Omega$ ) or  $5\text{ k}\Omega + 30\%$  (or  $6.5\text{ k}\Omega$ ). One can also be insert the tolerance extremes of  $R_{\text{FILT}}$  into the equation. If using a pair of 100- $\Omega$  1% resistors on the inputs, the initial gain error is 1.96%. Worst-case tolerance conditions always occur at the lower excursion of the internal  $5\text{-k}\Omega$  resistor ( $3.5\text{-k}\Omega$ ), and the higher excursion of  $R_{\text{FILT}} - 3\%$  in this case.

Note that one must then combine the specified accuracy of the INA200-Q1, INA201-Q1, and INA202-Q1 in addition to these tolerances. Although 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-Q1, INA201-Q1, and INA202-Q1 devices incorporate an open-drain comparator. This comparator typically has 2 mV of offset and a 1.3  $\mu\text{s}$  (typical) response time. The RESET pin latches and resets the output of the comparator; see Figure 31.

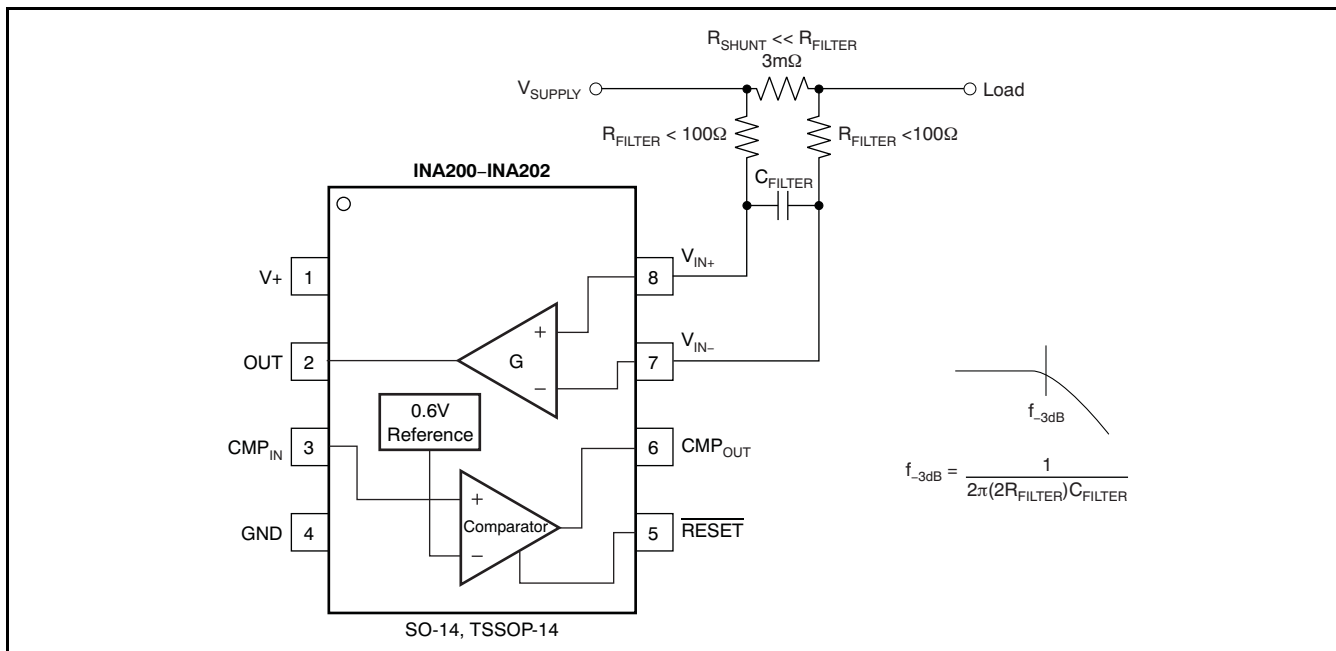


Figure 30. Input Filter (Gain Error—1.5% to -2.2%)

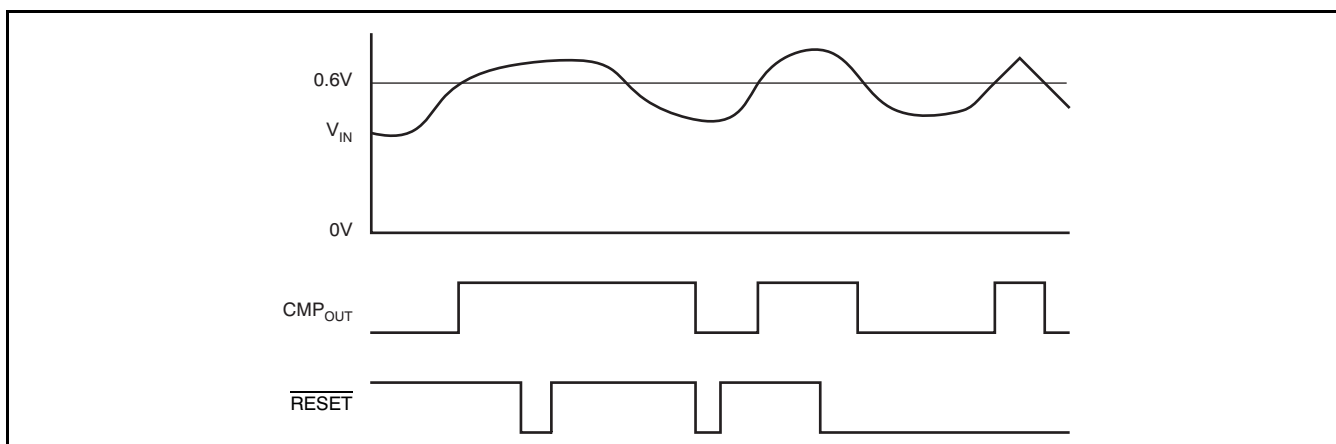


Figure 31. Comparator Latching Capability

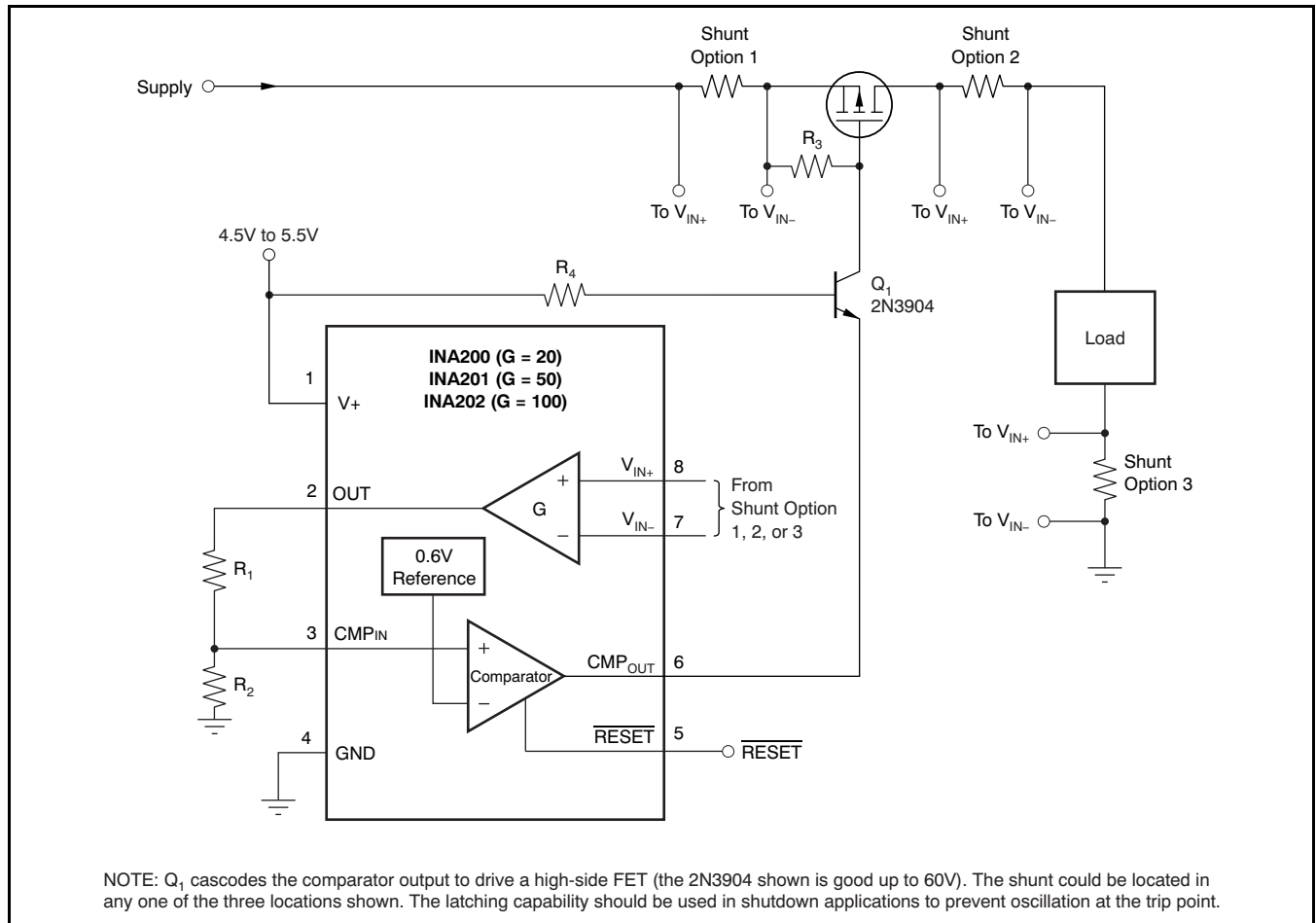
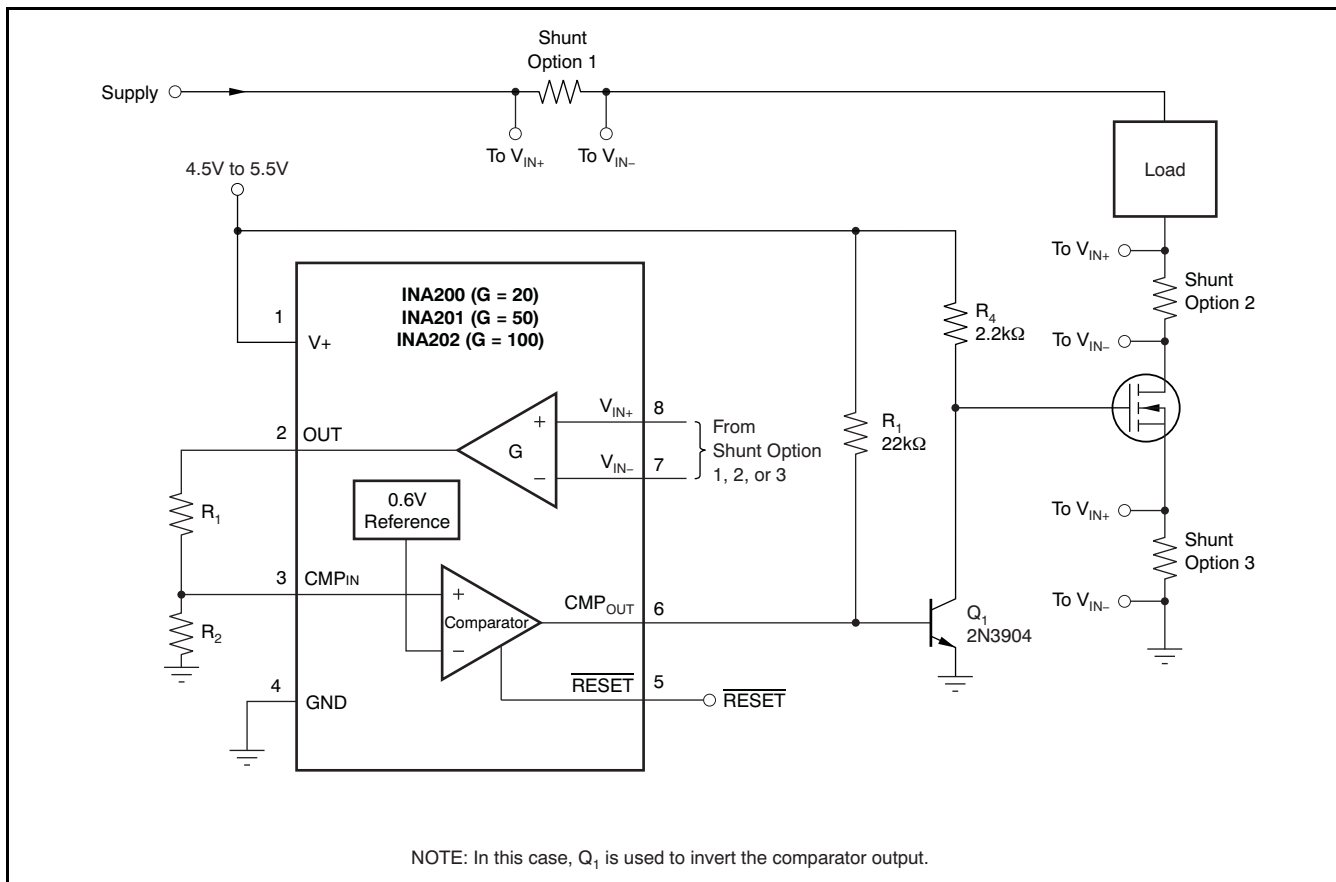


Figure 32. High-Side Switch Overcurrent Shutdown



**Figure 33. Low-Side Switch Overcurrent Shutdown**

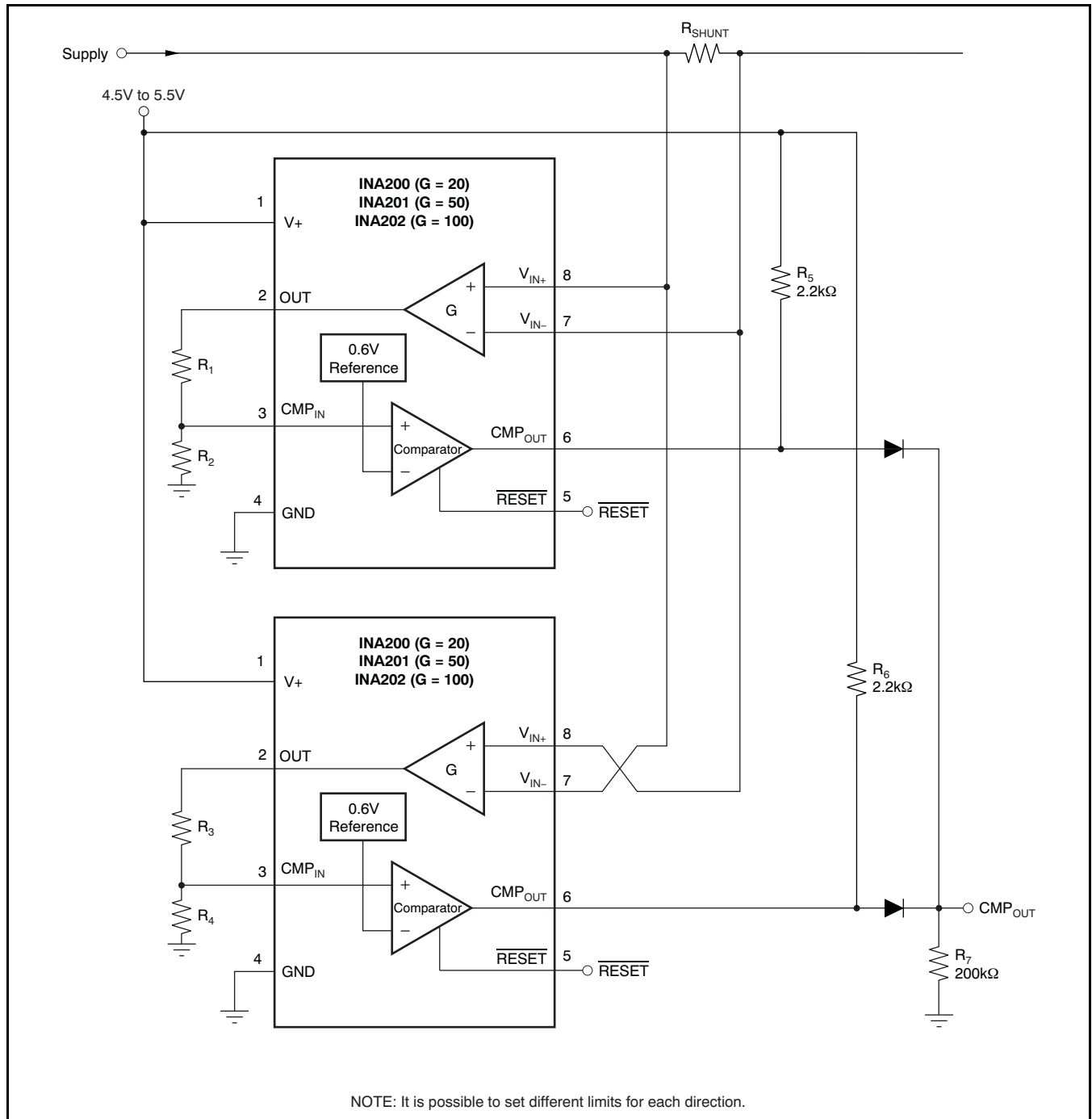


Figure 34. Bidirectional Overcurrent Comparator

## REVISION HISTORY

Changes from Revision A (September 2012) to Revision B	Page
• Changed from Mixed Production status to Production Data. ....	1
• Changed device graphic from pair to single. ....	1
• Added AEC-Q100 info to Features. ....	1
• Replaced Applications section with the following bullet points: Automotive Brake and ESP Systems Monitoring, Automotive Power Windows and Power Seats, Automotive HEV and EV Battery Monitoring, Battery Charger Overcurrent Detection for Notebook Computers, Power Supply Protection and $\pm$ 12-V Supply Monitoring for Servers, and Circuit Breaker With Provision for Power Limiting. ....	1
• Changed top-side marking for INA200AQDGKRQ1 from product preview to SHZ; changed top-side marking for INA202AQDGKRQ1 from product preview to SIA; realigned columns to center. ....	2
• Added second table note to Ordering Information table. ....	2
• Removed D package from pin configuration image. ....	2

**PACKAGING INFORMATION**

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
INA200AQDGKRQ1	ACTIVE	VSSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	SHZ	<a href="#">Samples</a>
INA201AQDGKRQ1	ACTIVE	VSSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU   CU NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	QWV	<a href="#">Samples</a>
INA202AQDGKRQ1	ACTIVE	VSSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	SIA	<a href="#">Samples</a>

(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.

**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)

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

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**OTHER QUALIFIED VERSIONS OF INA200-Q1, INA201-Q1, INA202-Q1 :**

- Catalog: [INA200](#), [INA201](#), [INA202](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

## 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
INA200AQDGKRQ1	VSSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
INA201AQDGKRQ1	VSSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
INA202AQDGKRQ1	VSSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1

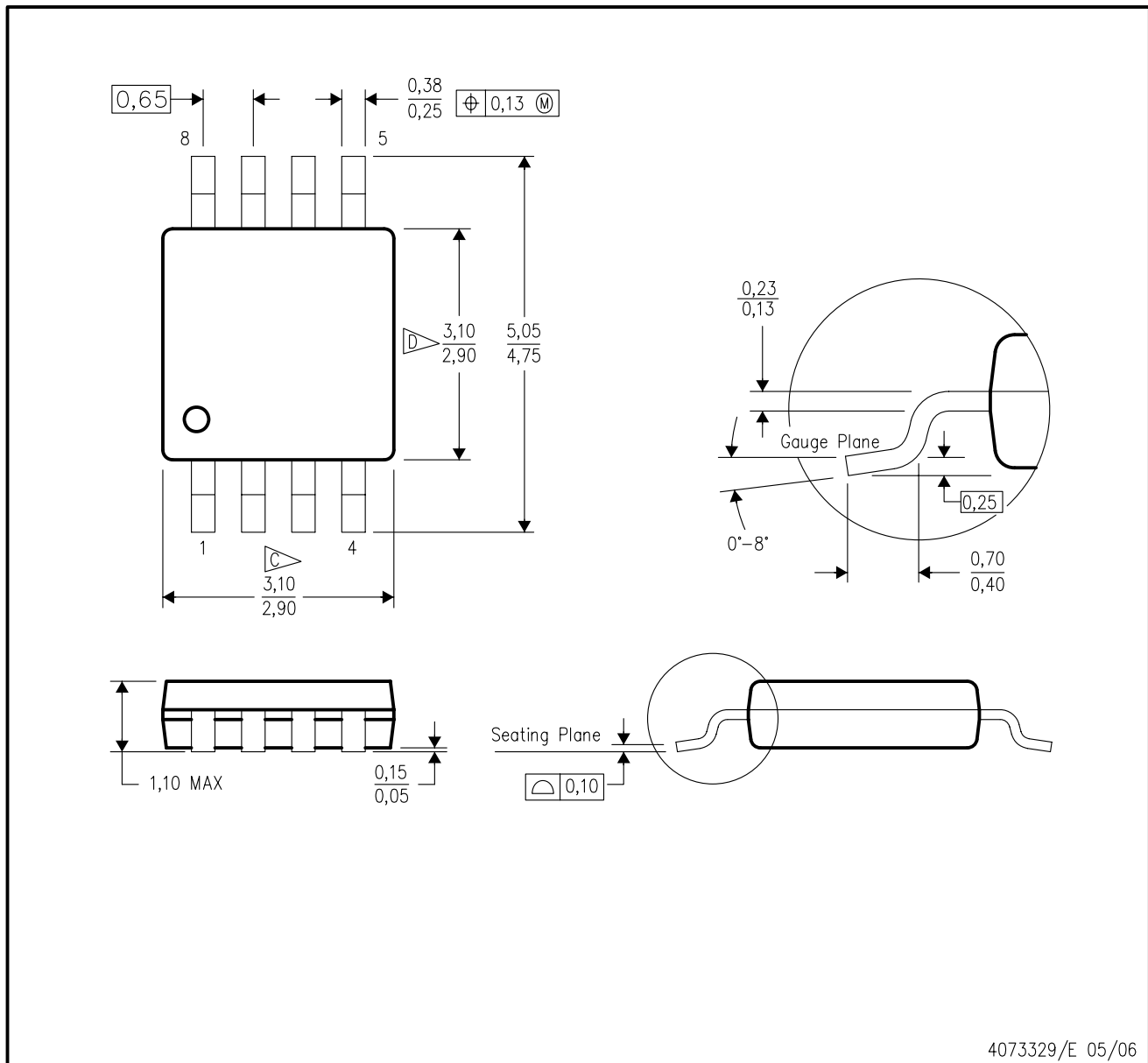
**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
INA200AQDGKRQ1	VSSOP	DGK	8	2500	366.0	364.0	50.0
INA201AQDGKRQ1	VSSOP	DGK	8	2500	366.0	364.0	50.0
INA202AQDGKRQ1	VSSOP	DGK	8	2500	366.0	364.0	50.0

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.



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate designs.
  - D. 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.
  - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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