



## CURRENT SHUNT MONITOR

### -16V to +80V Common-Mode Range

Check for Samples: [INA193](#), [INA194](#), [INA195](#), [INA196](#), [INA197](#), [INA198](#)

#### FEATURES

- **WIDE COMMON-MODE VOLTAGE:**  
-16V to +80V
- **LOW ERROR: 3.0% Over Temp (max)**
- **BANDWIDTH: Up to 500kHz**
- **THREE TRANSFER FUNCTIONS AVAILABLE:**  
20V/V, 50V/V, and 100V/V
- **QUIESCENT CURRENT: 900 $\mu$ A (max)**
- **COMPLETE CURRENT SENSE SOLUTION**

#### APPLICATIONS

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

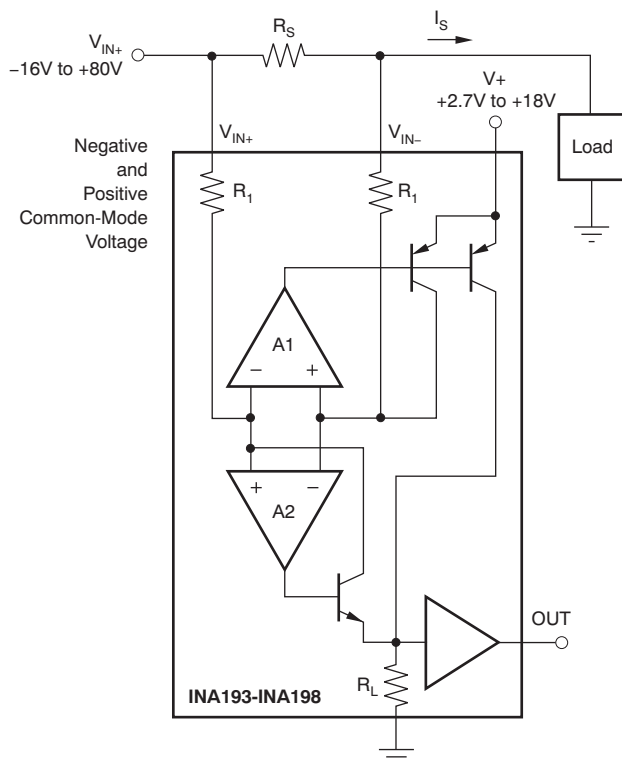
#### DESCRIPTION

The INA193–INA198 family of current shunt monitors with voltage output can sense drops across shunts at common-mode voltages from -16V to +80V, independent of the INA19x supply voltage. They are available with three output voltage scales: 20V/V, 50V/V, and 100V/V. The 500kHz bandwidth simplifies use in current control loops. The INA193–INA195 provide identical functions but alternative pin configurations to the INA196–INA198, respectively.

The INA193–INA198 operate from a single +2.7V to +18V supply, drawing a maximum of 900 $\mu$ A of supply current. They are specified over the extended operating temperature range (-40°C to +125°C), and are offered in a space-saving SOT23 package.

MODEL	GAIN	PACKAGE	PINOUT <sup>(1)</sup>
INA193	20V/V	SOT23-5	Pinout #1
INA194	50V/V	SOT23-5	Pinout #1
INA195	100V/V	SOT23-5	Pinout #1
INA196	20V/V	SOT23-5	Pinout #2
INA197	50V/V	SOT23-5	Pinout #2
INA198	100V/V	SOT23-5	Pinout #2

(1) See [Pin Assignments](#) for Pinout #1 and Pinout #2.



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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.

**PACKAGE INFORMATION<sup>(1)</sup>**

PRODUCT	PACKAGE-LEAD	PACKAGE DESIGNATOR	PACKAGE MARKING
INA193	SOT23-5	DBV	BJJ
INA194	SOT23-5	DBV	BJI
INA195	SOT23-5	DBV	BJK
INA196	SOT23-5	DBV	BJE
INA197	SOT23-5	DBV	BJH
INA198	SOT23-5	DBV	BJL

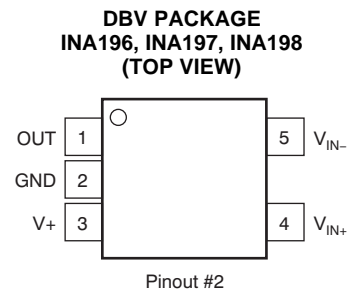
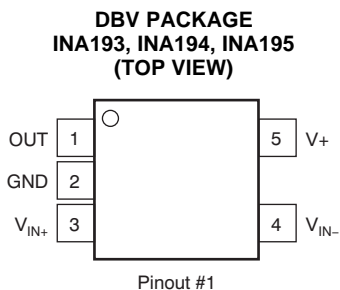
(1) For the most current package and ordering information see the Package Option Addendum at the end of this document, or see the TI web site at [www.ti.com](http://www.ti.com).

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

	INA19x	UNIT
Supply Voltage	+18	V
Analog Inputs, $V_{IN+}$ , $V_{IN-}$ Differential ( $V_{IN+}$ ) – ( $V_{IN-}$ )	–18 to +18	V
Common-Mode <sup>(2)</sup>	–16 to +80	V
Analog Output, Out <sup>(2)</sup>	GND – 0.3 to (V+) + 0.3	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) Input voltage at any pin may exceed the voltage shown if the current at that pin is limited to 5mA.

**PIN ASSIGNMENTS**



**ELECTRICAL CHARACTERISTICS:  $V_S = +12V$** 
**Boldface** limits apply over the specified temperature range,  $T_A = -40^\circ\text{C}$  to  $+125^\circ\text{C}$ .

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

PARAMETER	TEST CONDITIONS	INA193, INA194, INA195, INA196, INA197, INA198			UNIT
		MIN	TYP	MAX	
<b>INPUT</b>					
Full-Scale Input Voltage	$V_{SENSE}$ $V_{SENSE} = V_{IN+} - V_{IN-}$		0.15	$(V_S - 0.2)/\text{Gain}$	V
<b>Common-Mode Input Range</b>	$V_{CM}$	<b>-16</b>		80	<b>V</b>
Common-Mode Rejection	CMR $V_{IN+} = -16V$ to $+80V$	80	94		dB
<b>Over Temperature</b>	<b><math>V_{IN+} = +12V</math> to <math>+80V</math></b>	<b>100</b>	<b>120</b>		<b>dB</b>
Offset Voltage, RTI	$V_{OS}$		$\pm 0.5$	2	mV
<b>Over Temperature</b>			<b>0.5</b>	<b>3</b>	<b>mV</b>
<b>vs Temperature</b>	$dV_{OS}/dT$		<b>2.5</b>		$\mu\text{V}/^\circ\text{C}$
<b>vs Power Supply</b>	PSR $V_S = +2.7V$ to $+18V$ , $V_{IN+} = +18V$		<b>5</b>	<b>100</b>	$\mu\text{V}/V$
Input Bias Current, $V_{IN-}$ pin	$I_B$		$\pm 8$	$\pm 16$	$\mu\text{A}$
<b>OUTPUT (<math>V_{SENSE} \geq 20\text{mV}</math>)</b>					
Gain: INA193, INA196	G		20		V/V
Gain: INA194, INA197			50		V/V
Gain: INA195, INA198			100		V/V
Gain Error	$V_{SENSE} = 20\text{mV}$ to $100\text{mV}$ , $T_A = +25^\circ\text{C}$		$\pm 0.2$	$\pm 1$	%
<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>	<b>%</b>
Total Output Error <sup>(1)</sup>	$V_{SENSE} = 100\text{mV}$		$\pm 0.75$	$\pm 2.2$	%
<b>Over Temperature</b>			<b><math>\pm 1</math></b>	<b><math>\pm 3</math></b>	<b>%</b>
Nonlinearity Error	$V_{SENSE} = 20\text{mV}$ to $100\text{mV}$		$\pm 0.002$	$\pm 0.1$	%
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>(2)</sup></b>					
All Devices	$-16V \leq V_{CM} < 0V$		300		mV
INA193, INA196	$0V \leq V_{CM} \leq V_S$ , $V_S = 5V$			0.4	V
INA194, INA197	$0V \leq V_{CM} \leq V_S$ , $V_S = 5V$			1	V
INA195, INA198	$0V \leq V_{CM} \leq V_S$ , $V_S = 5V$			2	V
All Devices	$V_S < V_{CM} \leq 80V$		300		mV
<b>VOLTAGE OUTPUT<sup>(3)</sup></b>					
<b>Swing to V+ Power-Supply Rail</b>	<b><math>R_L = 100\text{k}\Omega</math> to GND</b>		<b><math>(V+) - 0.1</math></b>	<b><math>(V+) - 0.2</math></b>	<b>V</b>
<b>Swing to GND<sup>(4)</sup></b>			<b><math>(V_{GND}) + 3</math></b>	<b><math>(V_{GND}) + 50</math></b>	<b>mV</b>
<b>FREQUENCY RESPONSE</b>					
Bandwidth, INA193, INA196	BW $C_{LOAD} = 5\text{pF}$		500		kHz
Bandwidth, INA194, INA197	$C_{LOAD} = 5\text{pF}$		300		kHz
Bandwidth, INA195, INA198	$C_{LOAD} = 5\text{pF}$		200		kHz
Phase Margin	$C_{LOAD} < 10\text{nF}$		40		degrees
Slew Rate	SR		1		V/ $\mu\text{s}$
Settling Time (1%)	$t_s$ $V_{SENSE} = 10\text{mV}$ to $100\text{mV}_{PP}$ , $C_{LOAD} = 5\text{pF}$		2		$\mu\text{s}$
<b>NOISE, RTI</b>					
Voltage Noise Density			40		$\text{nV}/\sqrt{\text{Hz}}$

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

(2) For details on this region of operation, see the [Accuracy Variations](#) section in the [Applications Information](#).

(3) See Typical Characteristic curve *Output Swing vs Output Current*, [Figure 7](#).

(4) Specified by design.

**ELECTRICAL CHARACTERISTICS:  $V_S = +12V$  (continued)**

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

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

PARAMETER	TEST CONDITIONS	INA193, INA194, INA195, INA196, INA197, INA198			UNIT
		MIN	TYP	MAX	
<b>POWER SUPPLY</b>					
Operating Range	$V_S$	<b>+2.7</b>		<b>+18</b>	V
Quiescent Current	$I_Q$		700	900	$\mu A$
Over Temperature	$V_{OUT} = 2V$ $V_{SENSE} = 0mV$		<b>370</b>	<b>950</b>	$\mu A$
<b>TEMPERATURE RANGE</b>					
Specified Temperature Range		-40		+125	$^{\circ}C$
Operating Temperature Range		-55		+150	$^{\circ}C$
Storage Temperature Range		-65		+150	$^{\circ}C$
Thermal Resistance, SOT23	$\theta_{JA}$		200		$^{\circ}C/W$

### TYPICAL CHARACTERISTICS

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

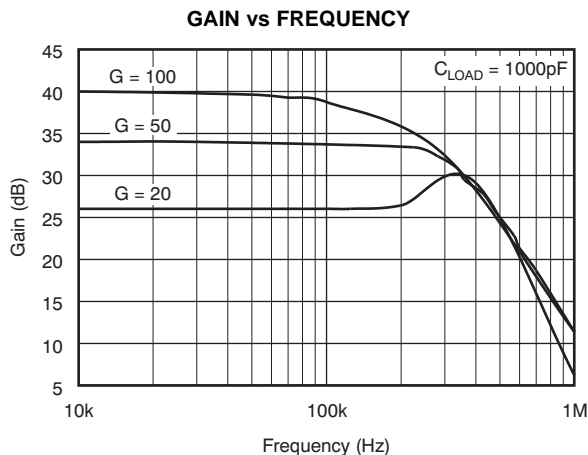


Figure 1.

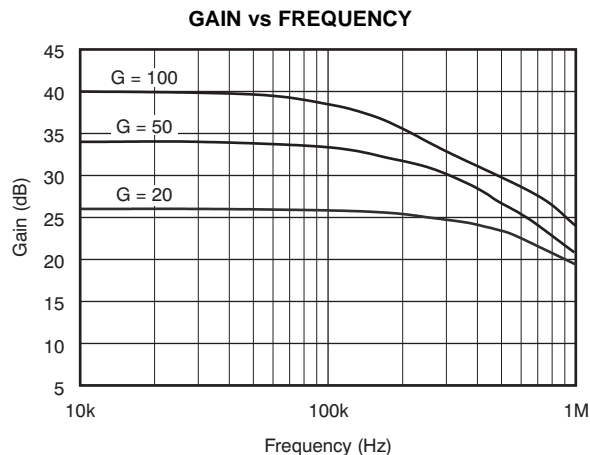


Figure 2.

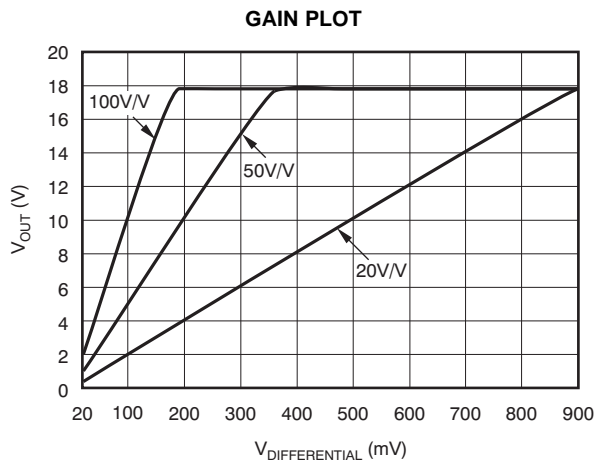


Figure 3.

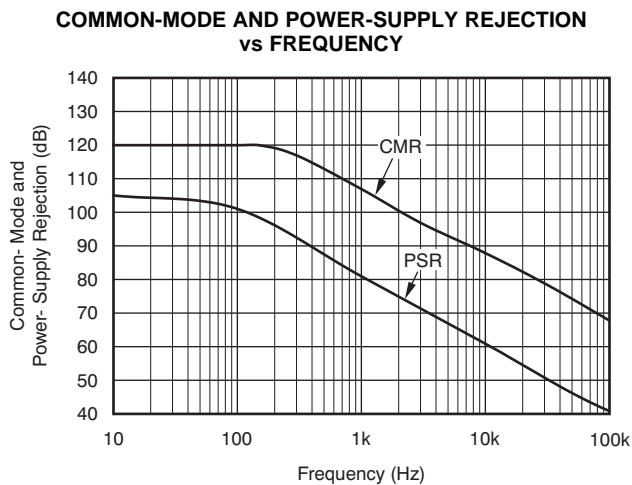


Figure 4.

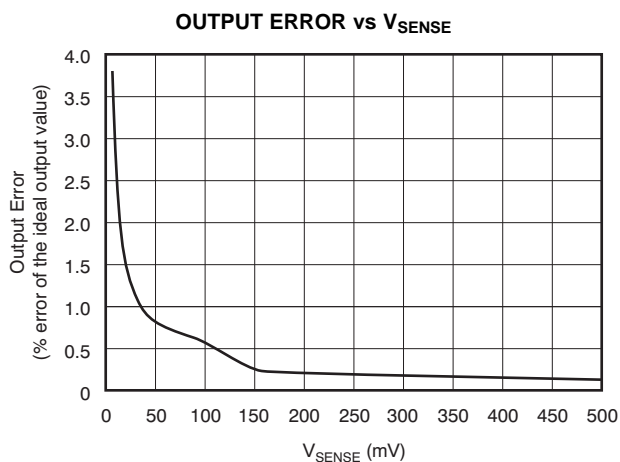


Figure 5.

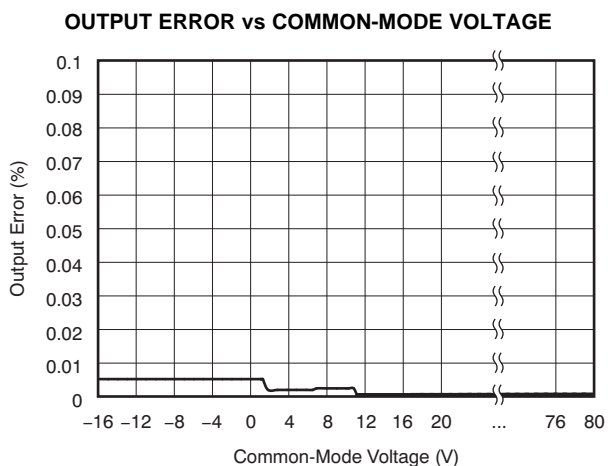


Figure 6.

**TYPICAL CHARACTERISTICS (continued)**

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

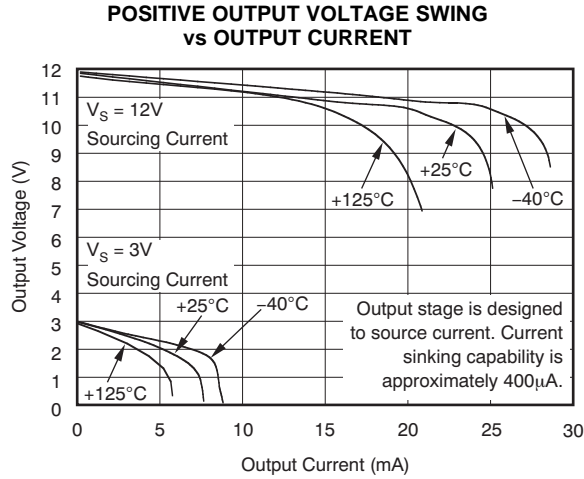


Figure 7.

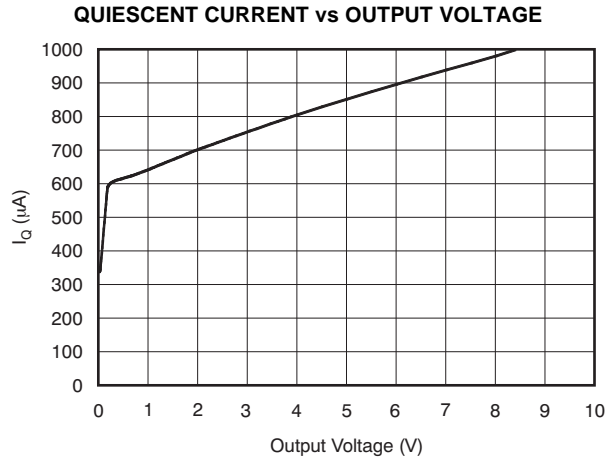


Figure 8.

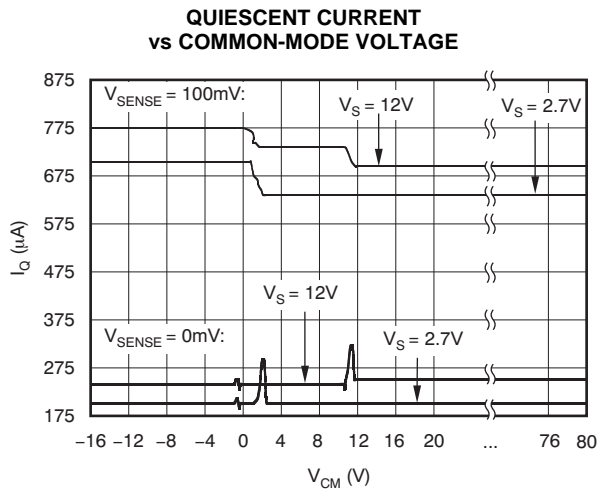


Figure 9.

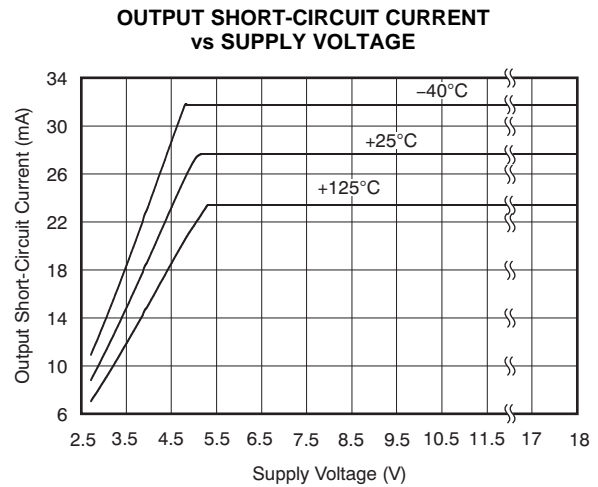


Figure 10.

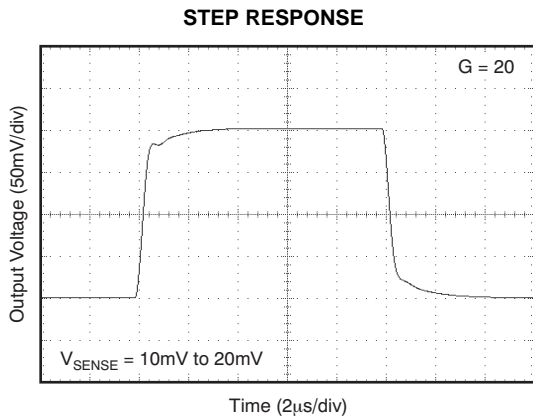


Figure 11.

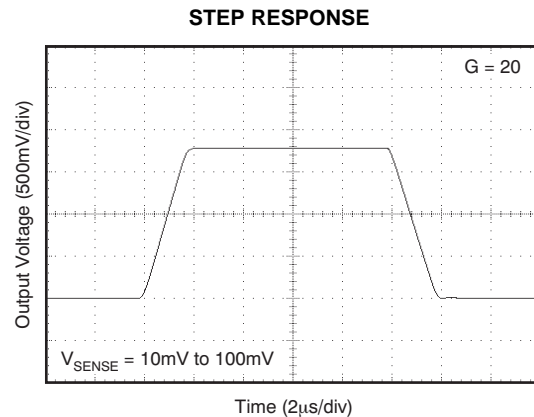
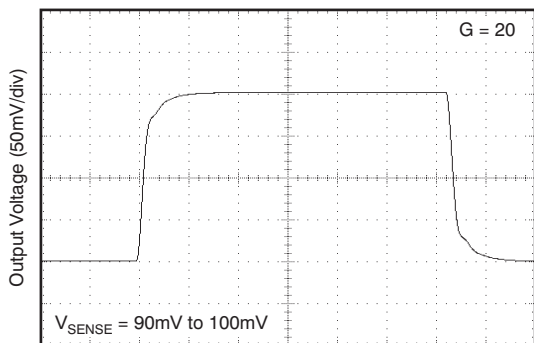


Figure 12.

**TYPICAL CHARACTERISTICS (continued)**

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

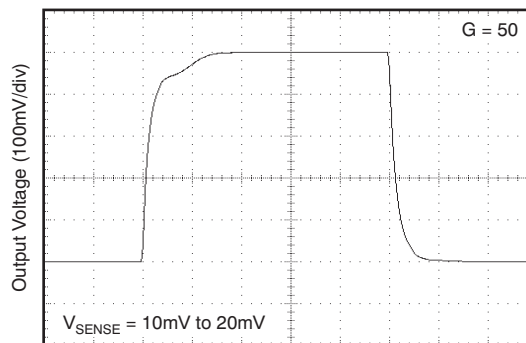
**STEP RESPONSE**



Time (2µs/div)

**Figure 13.**

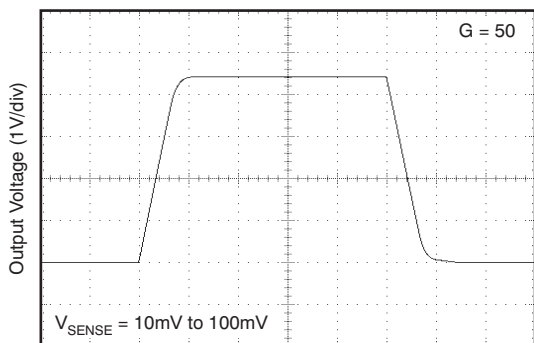
**STEP RESPONSE**



Time (5µs/div)

**Figure 14.**

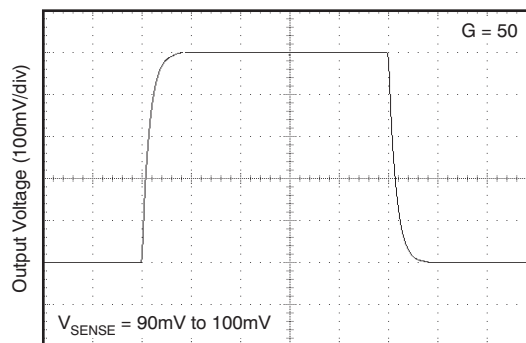
**STEP RESPONSE**



Time (5µs/div)

**Figure 15.**

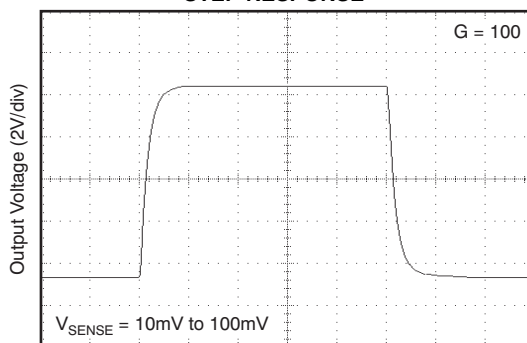
**STEP RESPONSE**



Time (5µs/div)

**Figure 16.**

**STEP RESPONSE**



Time (10µs/div)

**Figure 17.**

## APPLICATIONS INFORMATION

### BASIC CONNECTION

Figure 18 shows the basic connection of the INA193-INA198. 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.

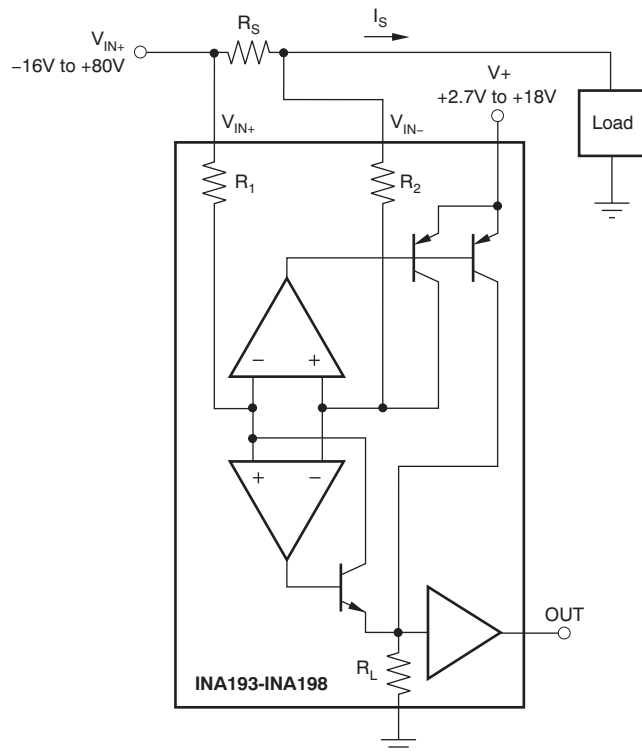


Figure 18. INA193-INA198 Basic Connection

### POWER SUPPLY

The input circuitry of the INA193-INA198 can accurately measure beyond its 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 INA193-INA198 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:  $V_{SENSE} < 20\text{mV}$ ,  $V_S < V_{CM} \leq 80\text{V}$

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

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.

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

where:

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

$V_{OUT2}$  = Output Voltage with  $V_{SENSE} = 20\text{mV}$  (1)

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 vs Common-Mode Voltage* curve (Figure 6) shows the highest accuracy for 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. This case is also used to create the  $V_{SENSE} \geq 20\text{mV}$  output specifications in the Electrical Characteristics table.



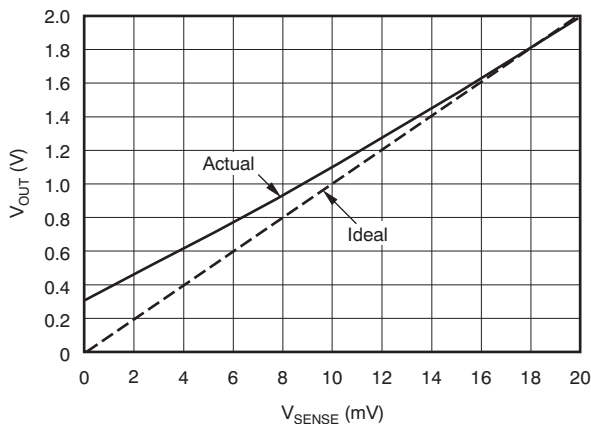
**Normal Case 2:  $V_{SENSE} \geq 20\text{mV}$ ,  $V_{CM} < V_S$**

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 vs Common-Mode Voltage* curve (Figure 6). 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 the INA193–INA198 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 INA193–INA198. It is important to know what the behavior of the devices will be in these regions.

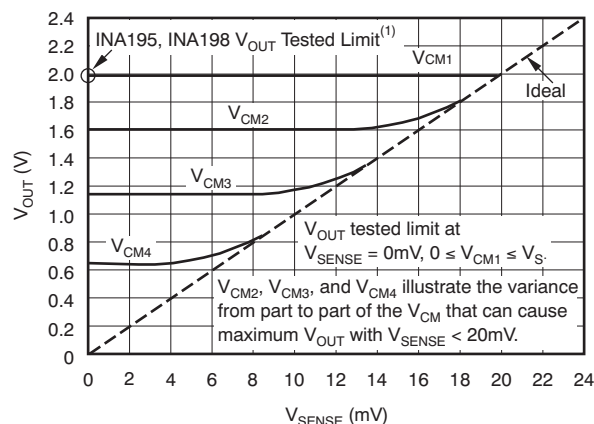
As  $V_{SENSE}$  approaches  $0\text{mV}$ , in these  $V_{CM}$  regions, the device output accuracy degrades. A larger-than-normal offset can appear at the current shunt monitor output with a typical maximum value of  $V_{OUT} = 300\text{mV}$  for  $V_{SENSE} = 0\text{mV}$ . As  $V_{SENSE}$  approaches  $20\text{mV}$ ,  $V_{OUT}$  returns to the expected output value with accuracy as specified in the *Electrical Characteristics*. Figure 19 illustrates this effect using the INA195 and INA198 (Gain = 100).



**Figure 19. Example for Low  $V_{SENSE}$  Cases 1 and 3 (INA195, INA198: 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 INA193–INA198 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  $0\text{V}$ . Within this region, as  $V_{SENSE}$  approaches  $20\text{mV}$ , device operation is closer to that described by Normal Case 2. Figure 20 illustrates this behavior for the INA195. The  $V_{OUT}$  maximum peak for this case is tested by maintaining a constant  $V_S$ , setting  $V_{SENSE} = 0\text{mV}$  and sweeping  $V_{CM}$  from  $0\text{V}$  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.



(1) INA193, INA196  $V_{OUT}$  Tested Limit =  $0.4\text{V}$ . INA194, INA197  $V_{OUT}$  Tested Limit =  $1\text{V}$ .

**Figure 20. Example for Low  $V_{SENSE}$  Case 2 (INA195, INA198: Gain = 100)**

## SHUTDOWN

Because the INA193-INA198 consume a quiescent current less than 1mA, they can be powered by either the output of logic gates or by transistor switches to supply power. Use a totem-pole output buffer or gate that can provide sufficient drive along with 0.1μF bypass capacitor, preferably ceramic with good high-frequency characteristics. This gate should have a supply voltage of 3V or greater because the INA193-INA198 requires a minimum supply greater than 2.7V. In addition to eliminating quiescent current, this gate also turns off the 10μA bias current present at each of the inputs. An example shutdown circuit is shown in Figure 21.

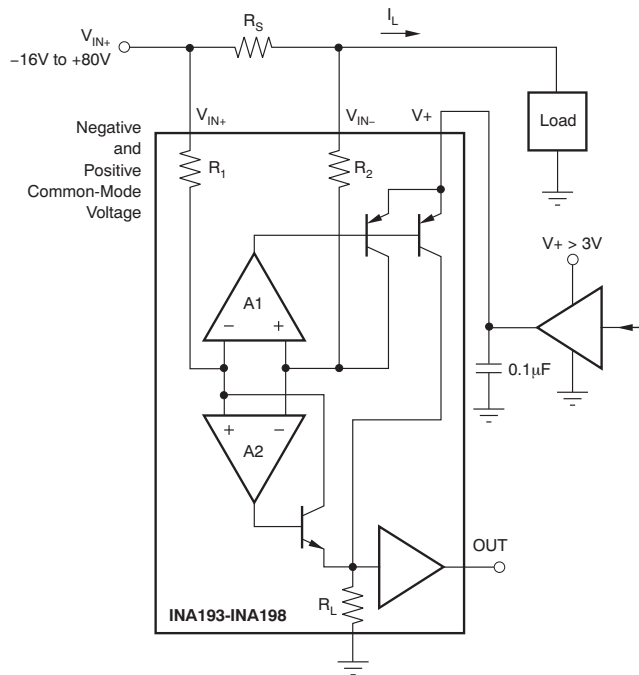


Figure 21. INA193-INA198 Example Shutdown Circuit

## 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 INA193-INA198 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 INA193-INA198 is exposed to transients on the inputs in excess of its ratings, then external transient absorption with semiconductor transient absorbers (zeners or Transzorbs) 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 INA193-INA198 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 INA193-INA198 does not lend itself to using external resistors in series with the inputs because the internal gain resistors can vary up to ±30%. (If gain accuracy is not important, then resistors can be added in series with the INA193-INA198 inputs with two equal resistors on each input.)

## OUTPUT VOLTAGE RANGE

The output of the INA193-INA198 is accurate within the output voltage swing range set by the power-supply pin,  $V_+$ . This is best illustrated when using the INA195 or INA198 (which are both versions using a gain of 100), 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.

## RFI/EMI

Attention to good layout practices is always recommended. Keep traces short and, when possible, use a printed circuit board (PCB) ground plane with surface-mount components placed as close to the device pins as possible. Small ceramic capacitors placed directly across amplifier inputs can reduce RFI/EMI sensitivity. PCB layout should locate the amplifier as far away as possible from RFI sources. Sources can include other components in the same system as the amplifier itself, such as inductors (particularly switched inductors handling a lot of current and at high frequencies). RFI can generally be identified as a variation in offset voltage or dc signal levels with changes in the interfering RF signal. If the amplifier cannot be located away from sources of radiation, shielding may be needed. Twisting wire input leads makes them more resistant to RF fields. The difference in input pin location of the INA193-INA195 versus the INA196-INA198 may provide different EMI performance.

## INPUT FILTERING

An obvious and straightforward location for filtering is at the output of the INA193-INA198; 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 INA193-INA198, which is complicated by the internal  $5\text{k}\Omega + 30\%$  input impedance; this is illustrated in Figure 22. 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:

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

Total effect on gain error can be calculated by replacing 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  $6.5\text{k}\Omega$ ). 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 approximately 2%. Worst-case tolerance conditions will 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 the specified accuracy of the INA193-INA198 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.

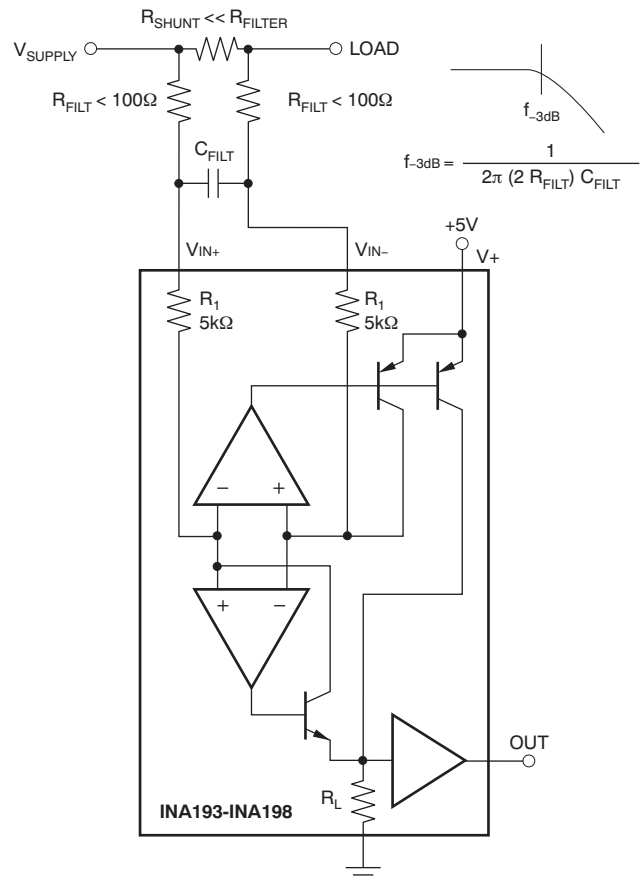
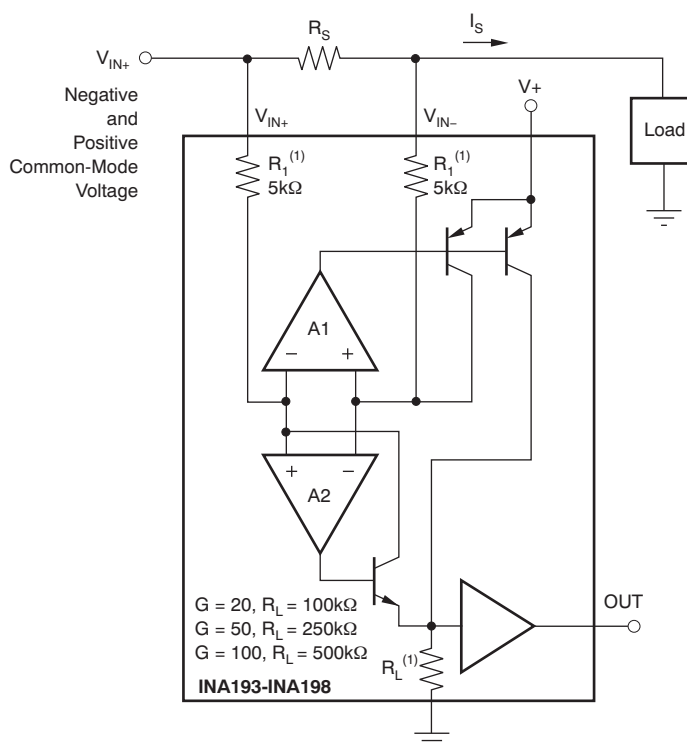


Figure 22. Input Filter (Gain Error – 1.5% to –2.2%)

## INSIDE THE INA193-INA198

The INA193-INA198 uses a new, unique internal circuit topology that provides common-mode range extending from  $-16\text{V}$  to  $+80\text{V}$  while operating from a single power supply. The common-mode rejection in a classic instrumentation amplifier approach is limited by the requirement for accurate resistor matching. By converting the induced input voltage to a current, the INA193-INA198 provides common-mode rejection that is no longer a function of closely matched resistor values, providing the enhanced performance necessary for such a wide common-mode range. A simplified diagram (shown in Figure 23) shows the basic circuit function. When the common-mode voltage is positive, amplifier A2 is active.

The differential input voltage,  $(V_{IN+}) - (V_{IN-})$  applied across  $R_S$ , is converted to a current through a resistor. This current is converted back to a voltage through  $R_L$ , and then amplified by the output buffer amplifier. When the common-mode voltage is negative, amplifier A1 is active. The differential input voltage,  $(V_{IN+}) - (V_{IN-})$  applied across  $R_S$ , is converted to a current through a resistor. This current is sourced from a precision current mirror whose output is directed into  $R_L$  converting the signal back into a voltage and amplified by the output buffer amplifier. Patent-pending circuit architecture ensures smooth device operation, even during the transition period where both amplifiers A1 and A2 are active.



(1) Nominal resistor values are shown.  $\pm 15\%$  variation is possible. Resistor ratios are matched to  $\pm 1\%$ .

**Figure 23. INA193-INA198 Simplified Circuit Diagram**

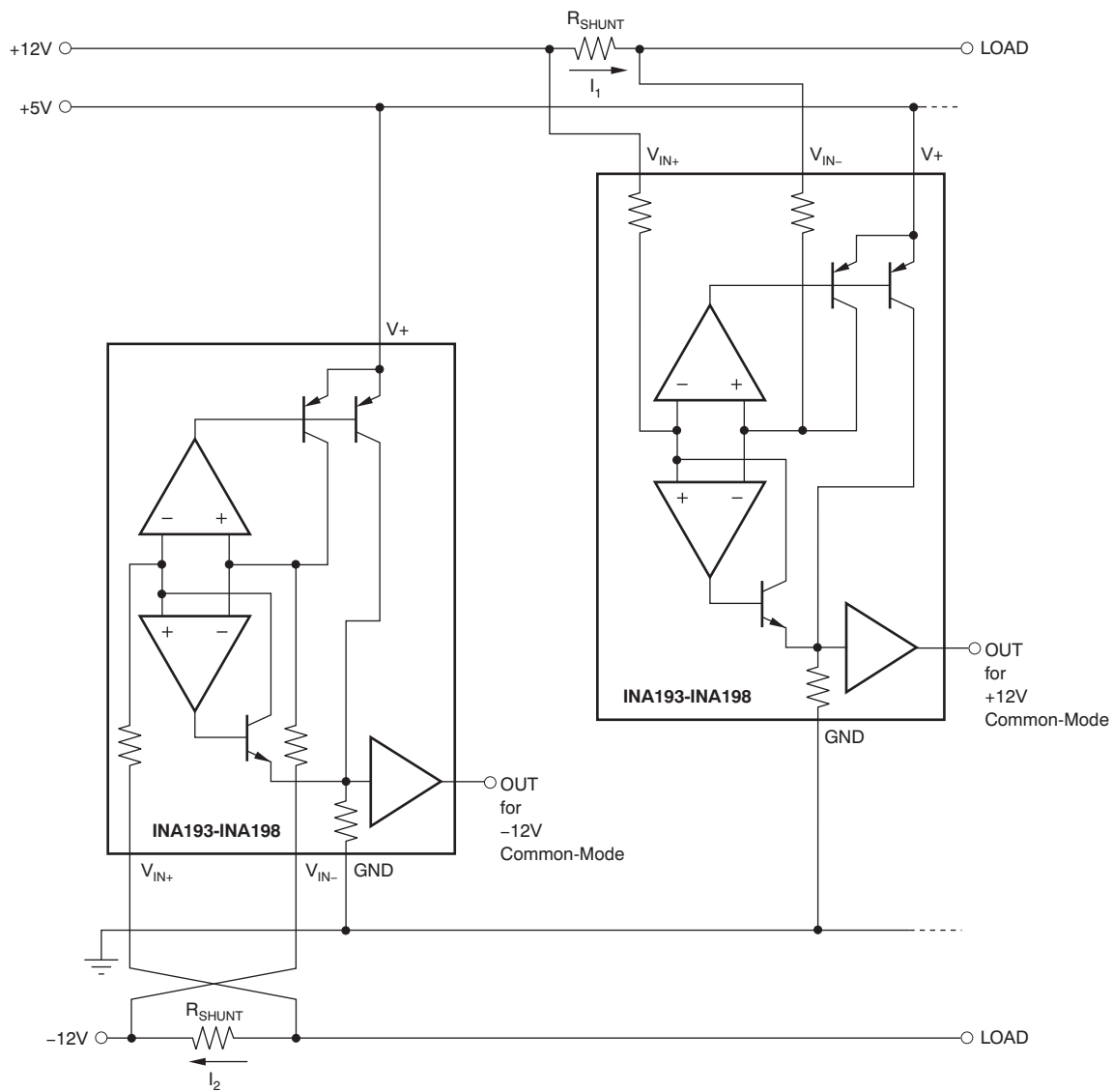


Figure 24. Monitor Bipolar Output Power-Supply Current

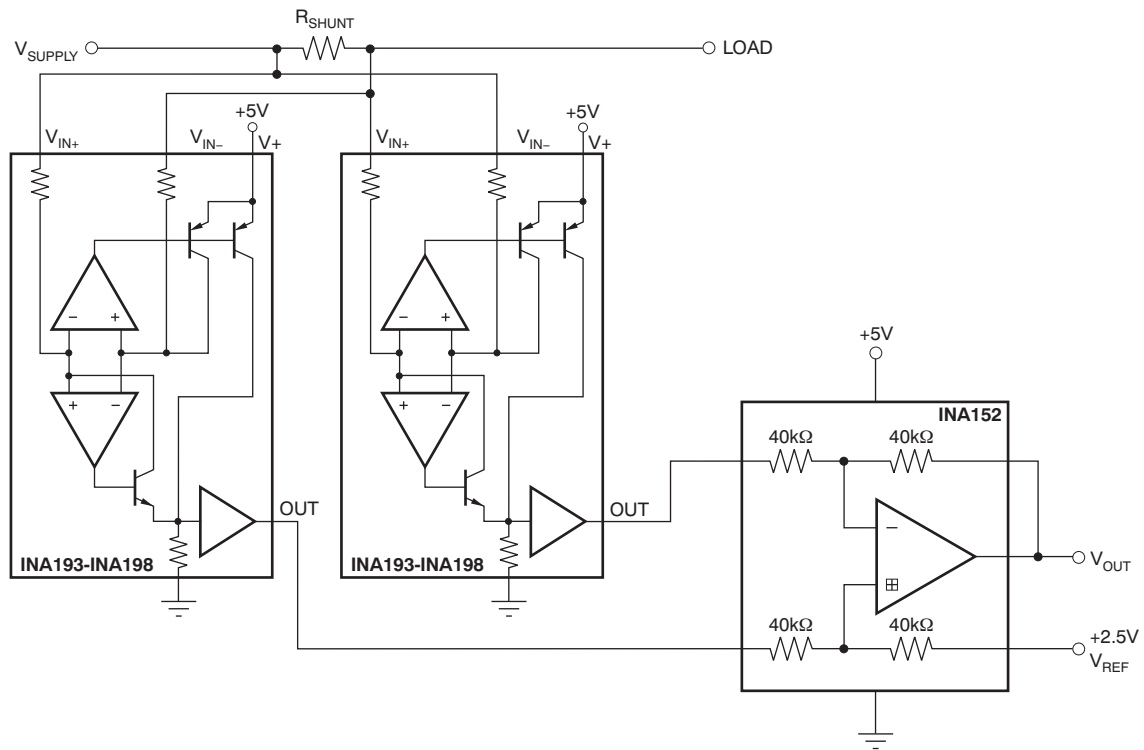


Figure 25. Bi-Directional Current Monitoring

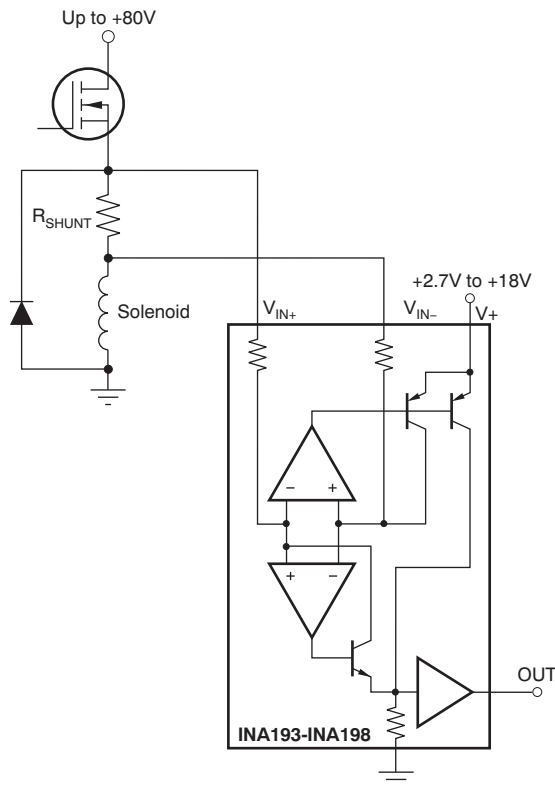


Figure 26. Inductive Current Monitor Including Flyback

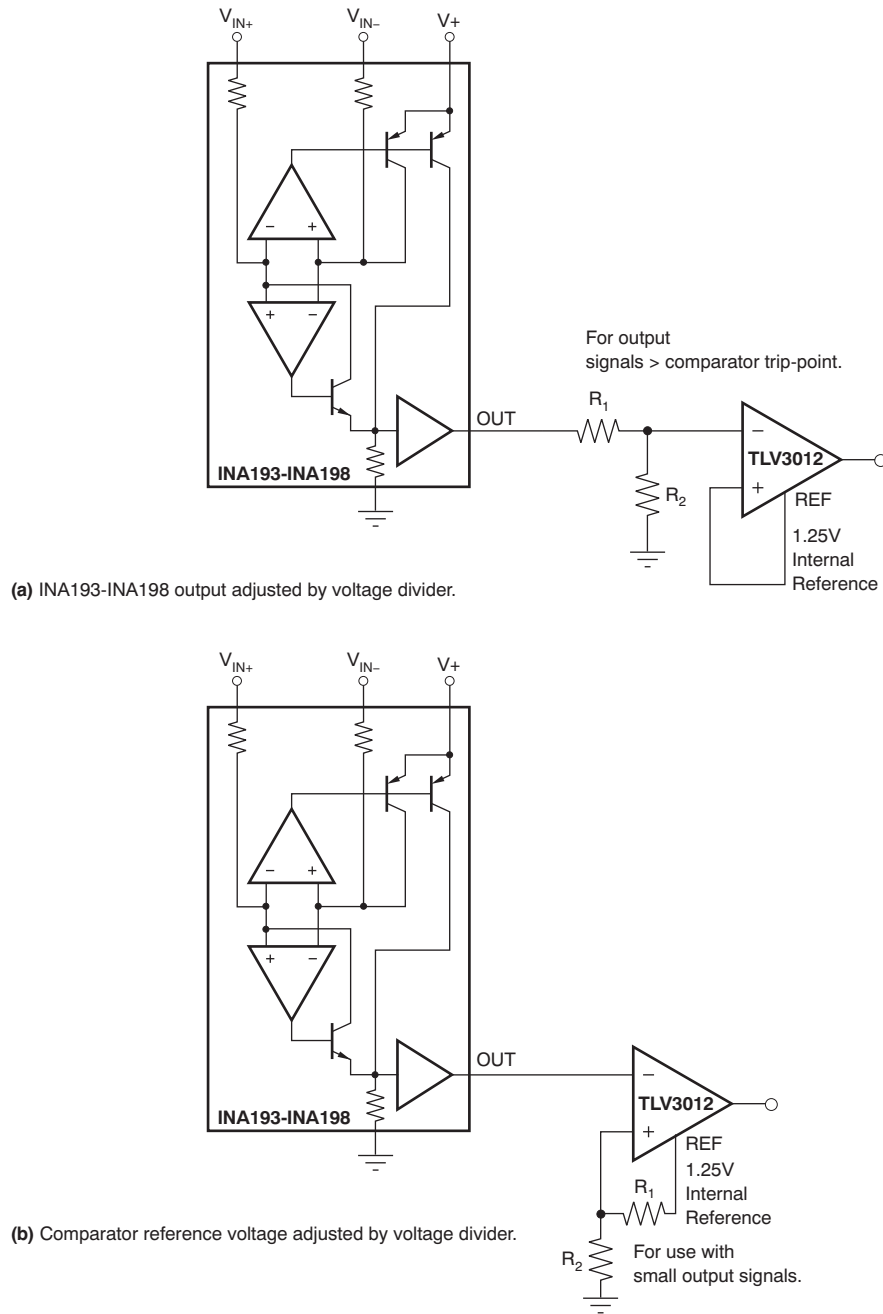


Figure 27. INA193-INA198 With Comparator

## REVISION HISTORY

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

Changes from Revision E (August 2006) to Revision F	Page
• Updated document format to current standards .....	1
• Added test conditions to Output, <i>Total Output Error</i> parameter in Electrical Characteristics: $V_S = +12V$ .....	3



**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
INA193AIDBVR	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJJ	<a href="#">Samples</a>
INA193AIDBVRG4	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJJ	<a href="#">Samples</a>
INA193AIDBVT	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJJ	<a href="#">Samples</a>
INA193AIDBVTG4	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJJ	<a href="#">Samples</a>
INA194AIDBVR	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJI	<a href="#">Samples</a>
INA194AIDBVRG4	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJI	<a href="#">Samples</a>
INA194AIDBVT	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJI	<a href="#">Samples</a>
INA194AIDBVTG4	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJI	<a href="#">Samples</a>
INA195AIDBVR	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJK	<a href="#">Samples</a>
INA195AIDBVRG4	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJK	<a href="#">Samples</a>
INA195AIDBVT	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJK	<a href="#">Samples</a>
INA195AIDBVTG4	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJK	<a href="#">Samples</a>
INA196AIDBVR	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJE	<a href="#">Samples</a>
INA196AIDBVRG4	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJE	<a href="#">Samples</a>
INA196AIDBVT	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJE	<a href="#">Samples</a>
INA196AIDBVTG4	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJE	<a href="#">Samples</a>
INA197AIDBVR	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJH	<a href="#">Samples</a>

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
INA197AIDBVRG4	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJH	<a href="#">Samples</a>
INA197AIDBVT	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJH	<a href="#">Samples</a>
INA197AIDBVTG4	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJH	<a href="#">Samples</a>
INA198AIDBVR	ACTIVE	SOT-23	DBV	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJL	<a href="#">Samples</a>
INA198AIDBVRG4	ACTIVE	SOT-23	DBV	5		TBD	Call TI	Call TI	-40 to 125		<a href="#">Samples</a>
INA198AIDBVT	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJL	<a href="#">Samples</a>
INA198AIDBVTG4	ACTIVE	SOT-23	DBV	5	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJL	<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.

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(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.

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**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
INA193AIDBVR	SOT-23	DBV	5	3000	178.0	9.0	3.23	3.17	1.37	4.0	8.0	Q3
INA193AIDBVT	SOT-23	DBV	5	250	178.0	9.0	3.3	3.2	1.4	4.0	8.0	Q3
INA194AIDBVR	SOT-23	DBV	5	3000	178.0	9.0	3.23	3.17	1.37	4.0	8.0	Q3
INA194AIDBVT	SOT-23	DBV	5	250	178.0	9.0	3.3	3.2	1.4	4.0	8.0	Q3
INA195AIDBVR	SOT-23	DBV	5	3000	178.0	9.0	3.3	3.2	1.4	4.0	8.0	Q3
INA195AIDBVT	SOT-23	DBV	5	250	178.0	9.0	3.3	3.2	1.4	4.0	8.0	Q3
INA196AIDBVR	SOT-23	DBV	5	3000	178.0	9.0	3.3	3.2	1.4	4.0	8.0	Q3
INA196AIDBVT	SOT-23	DBV	5	250	178.0	9.0	3.3	3.2	1.4	4.0	8.0	Q3
INA197AIDBVR	SOT-23	DBV	5	3000	178.0	9.0	3.3	3.2	1.4	4.0	8.0	Q3
INA197AIDBVT	SOT-23	DBV	5	250	178.0	9.0	3.3	3.2	1.4	4.0	8.0	Q3
INA198AIDBVR	SOT-23	DBV	5	3000	178.0	9.0	3.3	3.2	1.4	4.0	8.0	Q3
INA198AIDBVT	SOT-23	DBV	5	250	178.0	9.0	3.23	3.17	1.37	4.0	8.0	Q3

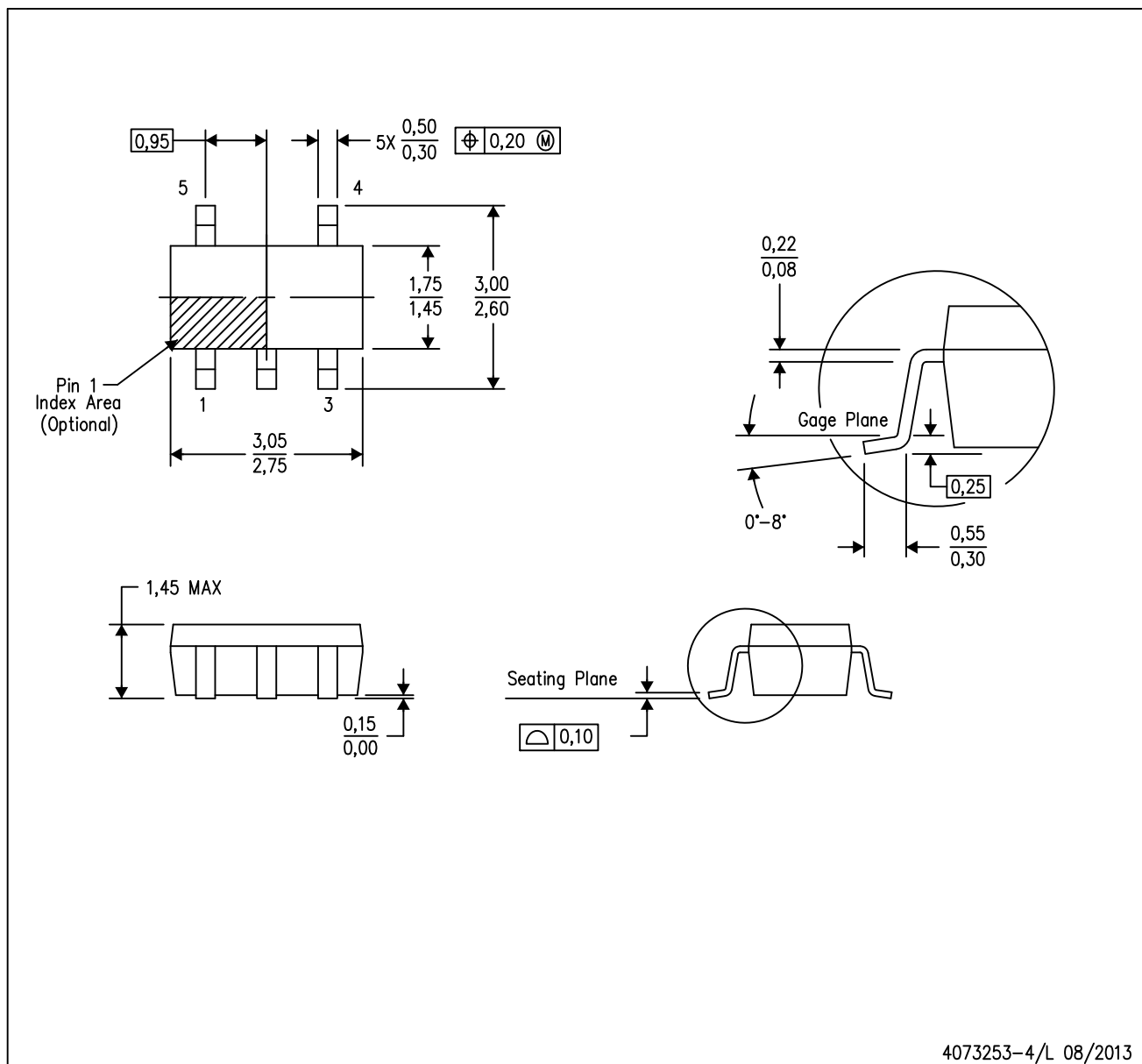
**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
INA193AIDBVR	SOT-23	DBV	5	3000	180.0	180.0	18.0
INA193AIDBVT	SOT-23	DBV	5	250	180.0	180.0	18.0
INA194AIDBVR	SOT-23	DBV	5	3000	180.0	180.0	18.0
INA194AIDBVT	SOT-23	DBV	5	250	180.0	180.0	18.0
INA195AIDBVR	SOT-23	DBV	5	3000	180.0	180.0	18.0
INA195AIDBVT	SOT-23	DBV	5	250	180.0	180.0	18.0
INA196AIDBVR	SOT-23	DBV	5	3000	180.0	180.0	18.0
INA196AIDBVT	SOT-23	DBV	5	250	180.0	180.0	18.0
INA197AIDBVR	SOT-23	DBV	5	3000	180.0	180.0	18.0
INA197AIDBVT	SOT-23	DBV	5	250	180.0	180.0	18.0
INA198AIDBVR	SOT-23	DBV	5	3000	180.0	180.0	18.0
INA198AIDBVT	SOT-23	DBV	5	250	180.0	180.0	18.0

DBV (R-PDSO-G5)

PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
  - D. Falls within JEDEC MO-178 Variation AA.

DBV (R-PDSO-G5)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
  - D. Publication IPC-7351 is recommended for alternate designs.
  - E. 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. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.

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### Applications

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Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
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