

## INA19x電流シャント・モニタ、同相電圧範囲 –16V～+80V

### 1 特長

- 広い同相電圧範囲: –16V～+80V
- 小さい誤差: 温度範囲内で3.0% (最大)
- 帯域幅: 最大500kHz
- 3つの伝達関数を使用可能: 20V/V、50V/V、100V/V
- 静止電流: 900 $\mu$ A (最大)
- 完全な電流検出ソリューション

### 2 アプリケーション

- 溶接機器
- ノートブック・コンピュータ
- 携帯電話
- 通信機器
- オートモーティブ (車載)
- パワー・マネージメント
- バッテリ充電器

### 3 概要

電圧出力機能を備えたINA193～INA198ファミリの電流シャント・モニタは、INA19xの電源電圧に関わらず、–16V～+80Vの同相電圧範囲で分流器における電圧降下を検出できます。20V/V、50V/V、100V/Vの3種類の出力電圧スケールを使用でき、帯域幅が500kHzと広いいため、容易に電流制御ループに使用できます。INA193～INA195デバイスは、それぞれINA196～INA198と機能は同じですが、ピン割り当てが異なります。

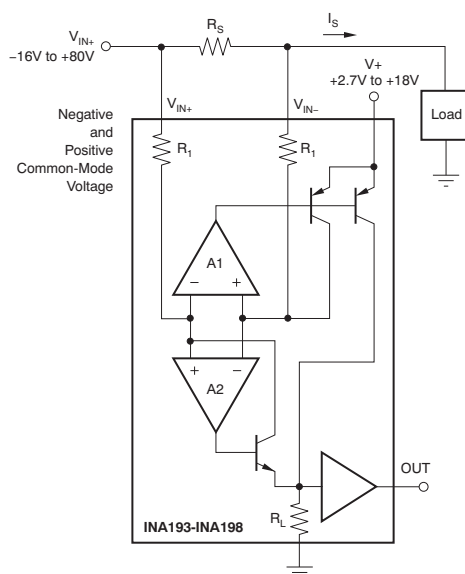
INA193～INA198のデバイスは2.7V～18Vの単一電源で動作し、消費電流は最大900 $\mu$ Aです。これらは動作温度範囲仕様が広く(–40 $^{\circ}$ C～+125 $^{\circ}$ C)、省スペースなSOT-23パッケージで供給されます。

#### 製品情報<sup>(1)</sup>

型番	パッケージ	本体サイズ (公称)
INA193	SOT-23 (5)	2.90mm×1.60mm
INA194		
INA195		
INA196		
INA197		
INA198		

(1) 提供されているすべてのパッケージについては、巻末の注文情報を参照してください。

#### 概略回路図



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## 4 改訂履歴

資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

### Revision F (February 2010) から Revision G に変更

Page

- Added *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section ..... 4

### Revision E (August 2006) から Revision F に変更

Page

- 現行基準に合わせ文書形式を更新 ..... 1
- Added test conditions to Output, *Total Output Error* parameter in Electrical Characteristics:  $V_S = +12V$  ..... 5

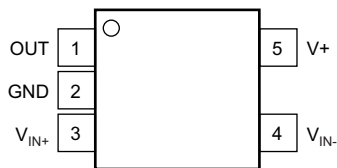
## 5 Device Comparison Table

PART NUMBER	GAIN	PINOUT <sup>(1)</sup>
INA193	20 V/V	Pinout #1
INA194	50 V/V	Pinout #1
INA195	100 V/V	Pinout #1
INA196	20 V/V	Pinout #2
INA197	50 V/V	Pinout #2
INA198	100 V/V	Pinout #2

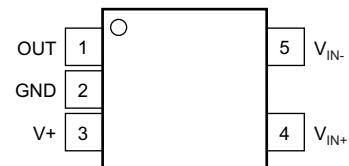
(1) See [Pin Configuration and Functions](#) for Pinout #1 and Pinout #2.

## 6 Pin Configuration and Functions

**DBV Package  
5-Pin SOT-23  
INA193, INA194, INA195 Top View**



**DBV Package  
5-Pin SOT-23  
INA196, INA197, INA198 Top View**



### Pin Functions

NAME	PIN		TYPE	DESCRIPTION
	INA193, INA194, INA195	INA196, INA197, INA198		
	DBV	DBV		
GND	2	2	GND	Ground
OUT	1	1	O	Output voltage
V+	5	3	Analog	Power supply, 2.7 V to 18 V
V <sub>IN+</sub>	3	4	I	Connect to supply side of shunt resistor
V <sub>IN-</sub>	4	5	I	Connect to load side of shunt resistor

## 7 Specifications

### 7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) <sup>(1)</sup>

	MIN	MAX	UNIT
Supply Voltage		18	V
Analog Inputs, $V_{IN+}$ , $V_{IN-}$	-18	18	V
Differential ( $V_{IN+}$ ) – ( $V_{IN-}$ )	-18	18	V
Common-Mode <sup>(2)</sup>	-16	80	V
Analog Output, $Out^{(2)}$	GND – 0.3	(V+) + 0.3	V
Input Current Into Any Pin <sup>(2)</sup>		5	mA
Operating Temperature	-55	150	°C
Junction Temperature		150	°C
Storage temperature, $T_{stg}$	-65	150	°C

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) Input voltage at any pin may exceed the voltage shown if the current at that pin is limited to 5mA.

### 7.2 ESD Ratings

		VALUE	UNIT
$V_{(ESD)}$ Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins <sup>(1)</sup>	±4000	V
	Charged device model (CDM), per JEDEC specification JESD22-C101, all pins <sup>(2)</sup>	±1000	

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

### 7.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

		MIN	NOM	MAX	UNIT
$V_{CM}$	Common-mode input voltage		12		V
$V+$	Operating supply voltage		12		V
$T_A$	Operating free-air temperature	-40		125	°C

### 7.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		INA19x	UNIT
		DBV (SOT-23)	
		5 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	221.7	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	144.7	
$R_{\theta JB}$	Junction-to-board thermal resistance	49.7	
$\Psi_{JT}$	Junction-to-top characterization parameter	26.1	
$\Psi_{JB}$	Junction-to-board characterization parameter	49.0	

- (1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).

## 7.5 Electrical Characteristics

All specifications 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.

PARAMETER	TEST CONDITIONS	$T_A = 25^\circ\text{C}$			$T_A = -40^\circ\text{C to } +125^\circ\text{C}$			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
<b>INPUT</b>								
$V_{SENSE}$	Full-Scale Input Voltage	$V_{SENSE} = V_{IN+} - V_{IN-}$		0.15	$(V_S - 0.2)/\text{Gain}$		-16	V
$V_{CM}$	Common-Mode Input Range				80			V
CMR	Common-Mode Rejection	$V_{IN+} = -16\text{ V to } 80\text{ V}$		80	94			dB
	Common-Mode Rejection, Over Temperature	$V_{IN+} = 12\text{ V to } 80\text{ V}$			100	120		dB
$V_{OS}$	Offset Voltage, RTI				$\pm 0.5$	2		mV
	Offset Voltage, RTI Over Temperature					0.5	3	mV
$dV_{OS}/dT$	Offset Voltage, RTI vs Temperature					2.5		$\mu\text{V}/^\circ\text{C}$
PSR	Offset Voltage, RTI vs Power Supply	$V_S = 2.7\text{ V to } 18\text{ V}$ , $V_{IN+} = 18\text{ V}$				5	100	$\mu\text{V}/\text{V}$
$I_B$	Input Bias Current, $V_{IN-}$ pin					$\pm 8$	$\pm 16$	$\mu\text{A}$
<b>OUTPUT (<math>V_{SENSE} \geq 20\text{ mV}</math>)</b>								
G	Gain	INA193, INA196		20				V/V
		INA194, INA197		50				V/V
		INA195, INA198		100				V/V
	Gain Error	$V_{SENSE} = 20\text{ mV to } 100\text{ mV}$ , $T_A = 25^\circ\text{C}$		$\pm 0.2\%$	$\pm 1\%$			
	Gain Error Over Temperature	$V_{SENSE} = 20\text{ mV to } 100\text{ mV}$					$\pm 2$	
	Total Output Error <sup>(1)</sup>	$V_{SENSE} = 100\text{ mV}$		$\pm 0.75\%$	$\pm 2.2\%$			
	Total Output Error Over Temperature				$\pm 1\%$		$\pm 3\%$	
	Nonlinearity Error	$V_{SENSE} = 20\text{ mV to } 100\text{ mV}$		$\pm 0.002\%$	$\pm 0.1\%$			
$R_O$	Output Impedance				1.5			$\Omega$
	Maximum Capacitive Load	No Sustained Oscillation			10			nF
Output <sup>(2)</sup>	All Devices	$-16\text{ V} \leq V_{CM} < 0\text{ V}$ , $V_{SENSE} < 20\text{ mV}$		300				mV
		$V_S < V_{CM} \leq 80\text{ V}$ , $V_{SENSE} < 20\text{ mV}$		300				
	INA193, INA196					0.4		V
	INA194, INA197	$0\text{ V} \leq V_{CM} \leq V_S$ , $V_S = 5\text{ V}$ , $V_{SENSE} < 20\text{ mV}$				1		V
INA195, INA198					2		V	
<b>VOLTAGE OUTPUT<sup>(3)</sup> (<math>R_L = 100\text{ k}\Omega</math> to GND)</b>								
	Swing to V+ Power-Supply Rail					$(V+) - 0.1$	$(V+) - 0.2$	V
	Swing to GND <sup>(4)</sup>					$(V_{GND}) + 3$	$(V_{GND}) + 50$	mV
<b>FREQUENCY RESPONSE</b>								
BW	Bandwidth	INA193, INA196	$C_{LOAD} = 5\text{ pF}$	500				kHz
		INA194, INA197		300				kHz
		INA195, INA198		200				kHz

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

(2) For details on this region of operation, see the [Accuracy Variations as a Result of  \$V\_{SENSE}\$  and Common-Mode Voltage](#) section.

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

(4) Specified by design.

## Electrical Characteristics (continued)

All specifications 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.

PARAMETER	TEST CONDITIONS	$T_A = 25^\circ\text{C}$			$T_A = -40^\circ\text{C to } +125^\circ\text{C}$			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Phase Margin	$C_{LOAD} < 10\text{ nF}$		40					
SR	Slew Rate		1					V/ $\mu\text{s}$
$t_S$	Settling Time (1%)		2					$\mu\text{s}$
<b>NOISE, RTI</b>								
	Voltage Noise Density		40					nV/ $\sqrt{\text{Hz}}$
<b>POWER SUPPLY</b>								
$V_S$	Operating Range				2.7		18	V
$I_Q$	Quiescent Current	$V_{OUT} = 2\text{ V}$	700	900				$\mu\text{A}$
	Quiescent Current Over Temperature	$V_{SENSE} = 0\text{ mV}$				370	950	$\mu\text{A}$
<b>TEMPERATURE RANGE</b>								
	Specified Temperature Range		-40	125				$^\circ\text{C}$
	Operating Temperature Range		-55	150				$^\circ\text{C}$
	Storage Temperature Range		-65	150				$^\circ\text{C}$
$\theta_{JA}$	Thermal Resistance, SOT23		200					$^\circ\text{C/W}$

## 7.6 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.

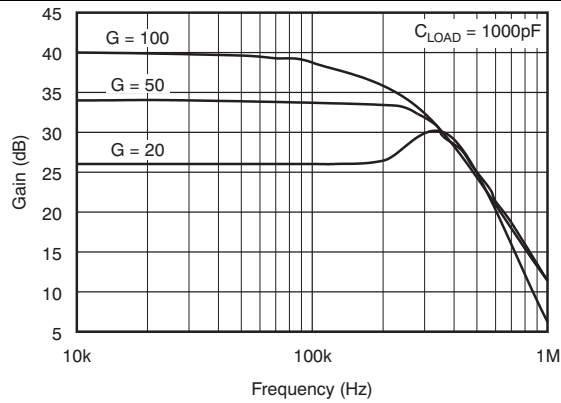


Figure 1. Gain vs Frequency

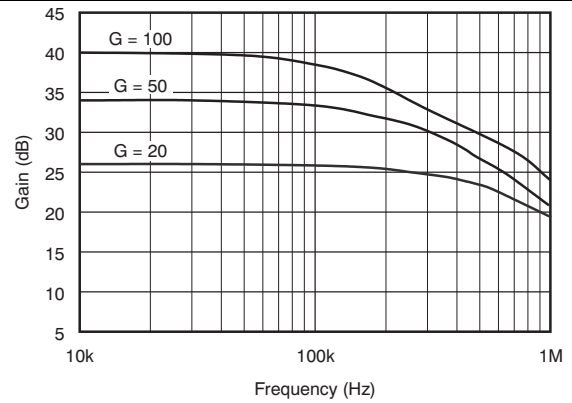


Figure 2. Gain vs Frequency

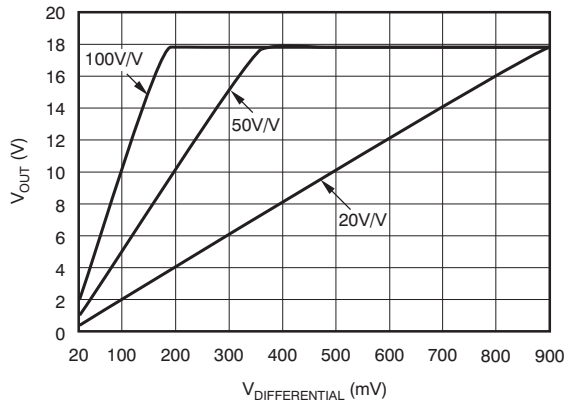


Figure 3. Gain Plot

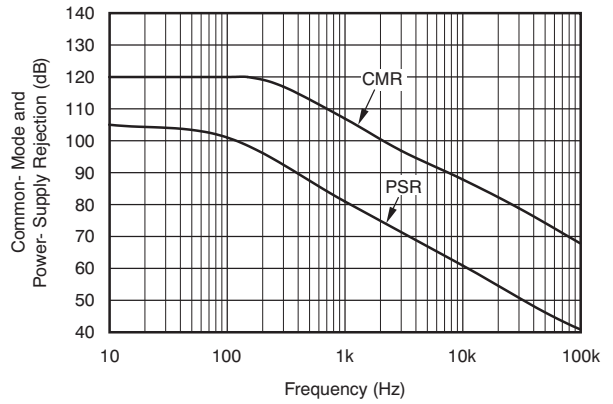


Figure 4. Common-Mode and Power-Supply Rejection vs Frequency

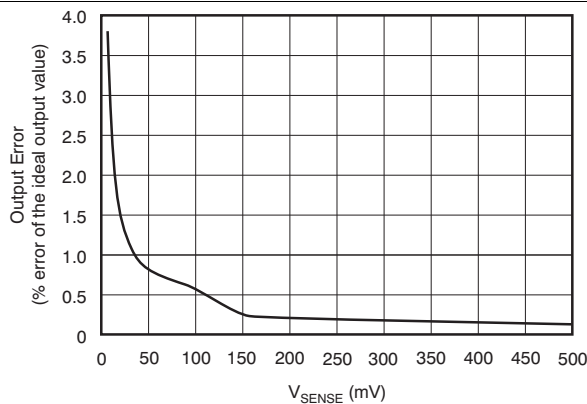


Figure 5. Output Error vs  $V_{SENSE}$

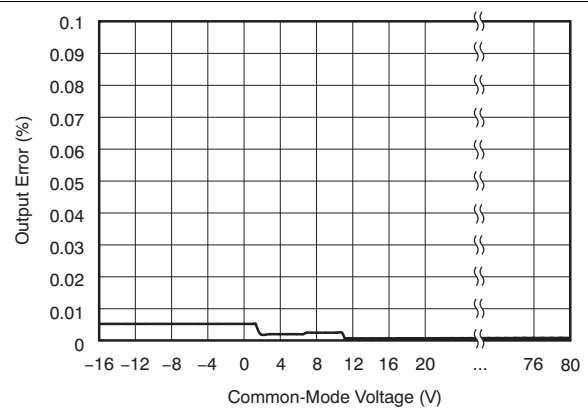


Figure 6. Output Error vs Common-Mode Voltage

### 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.

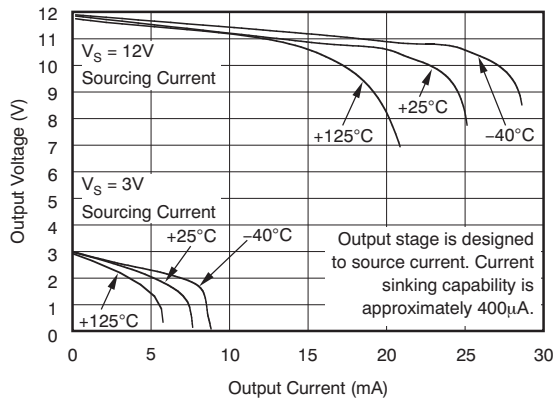


Figure 7. Positive Output Voltage Swing vs Output Current

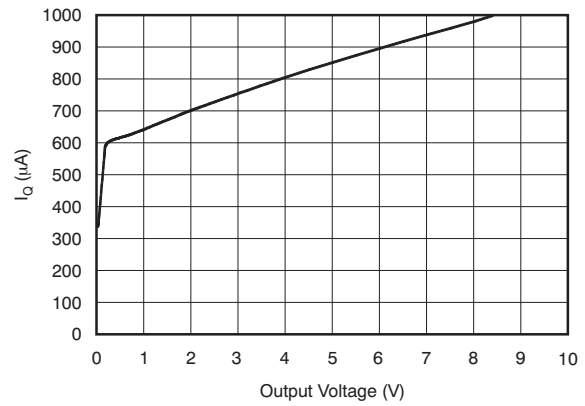


Figure 8. Quiescent Current vs Output Voltage

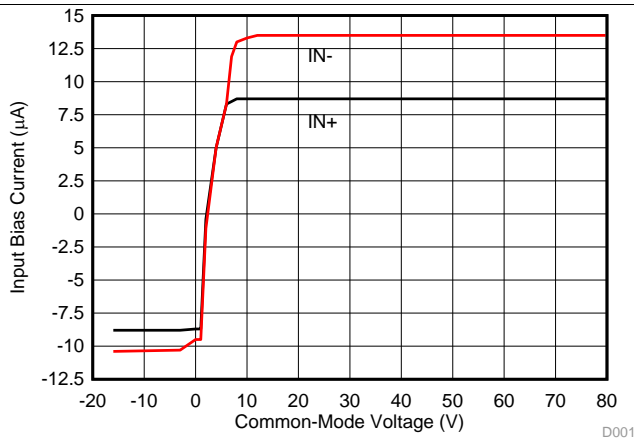


Figure 9. Input Bias Current vs Common Mode Voltage  
 $V_S = 5\text{ V}$

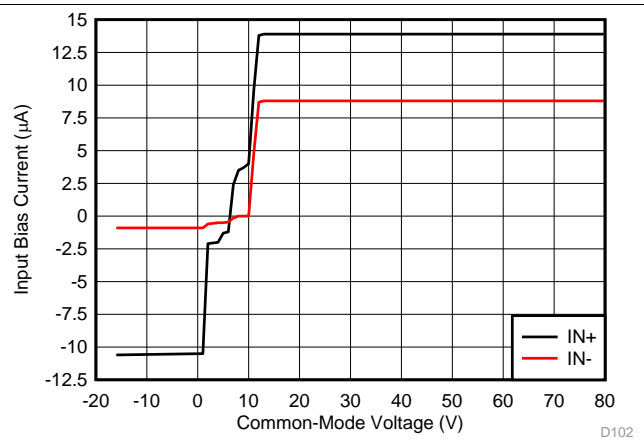


Figure 10. Input Bias Current vs Common Mode Voltage  
 $V_S = 12\text{ V}$

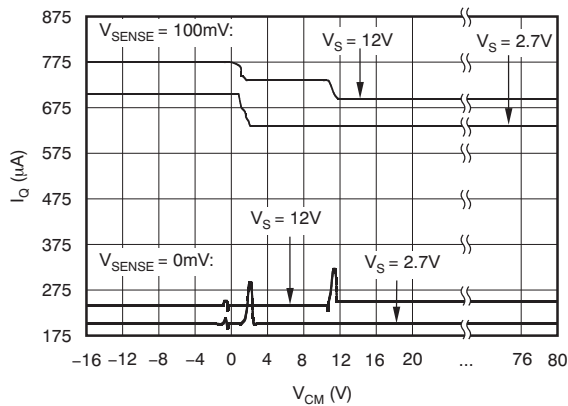


Figure 11. Quiescent Current vs Common-Mode Voltage

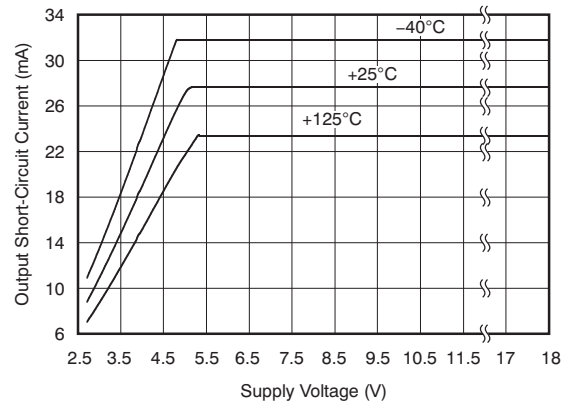
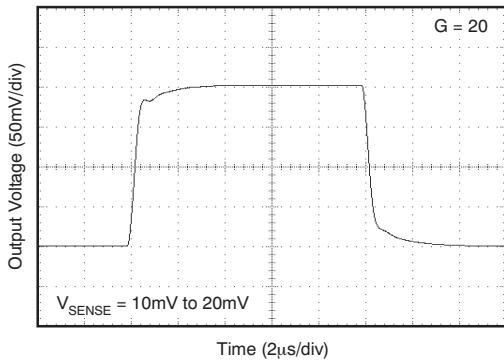


Figure 12. Output Short-Circuit Current vs Supply Voltage

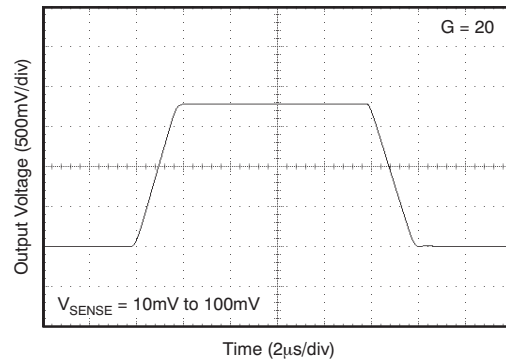


**Typical Characteristics (continued)**

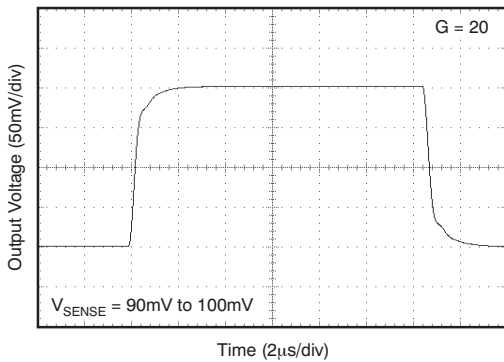
All specifications at  $T_A = 25^\circ\text{C}$ ,  $V_S = 12\text{ V}$ , and  $V_{IN+} = 12\text{ V}$ , and  $V_{SENSE} = 100\text{ mV}$ , unless otherwise noted.



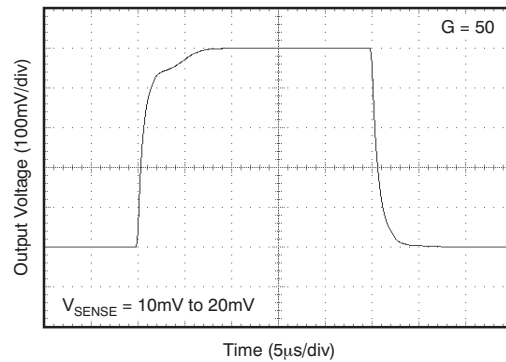
**Figure 13. Step Response**



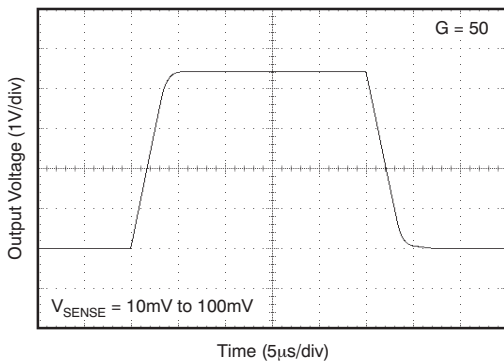
**Figure 14. Step Response**



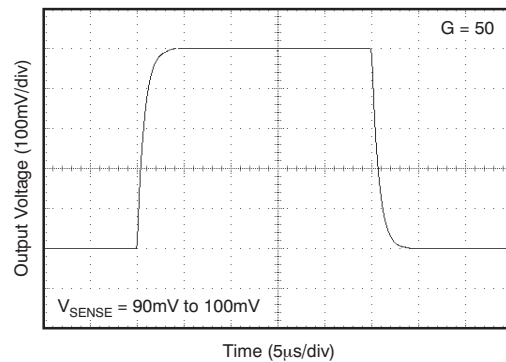
**Figure 15. Step Response**



**Figure 16. Step Response**



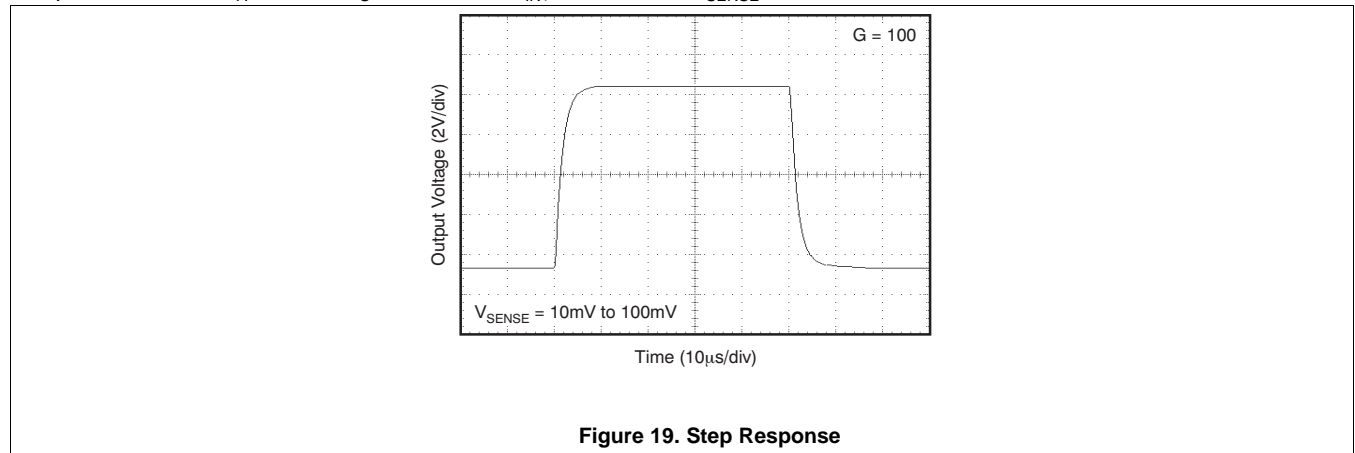
**Figure 17. Step Response**



**Figure 18. Step Response**

## 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.



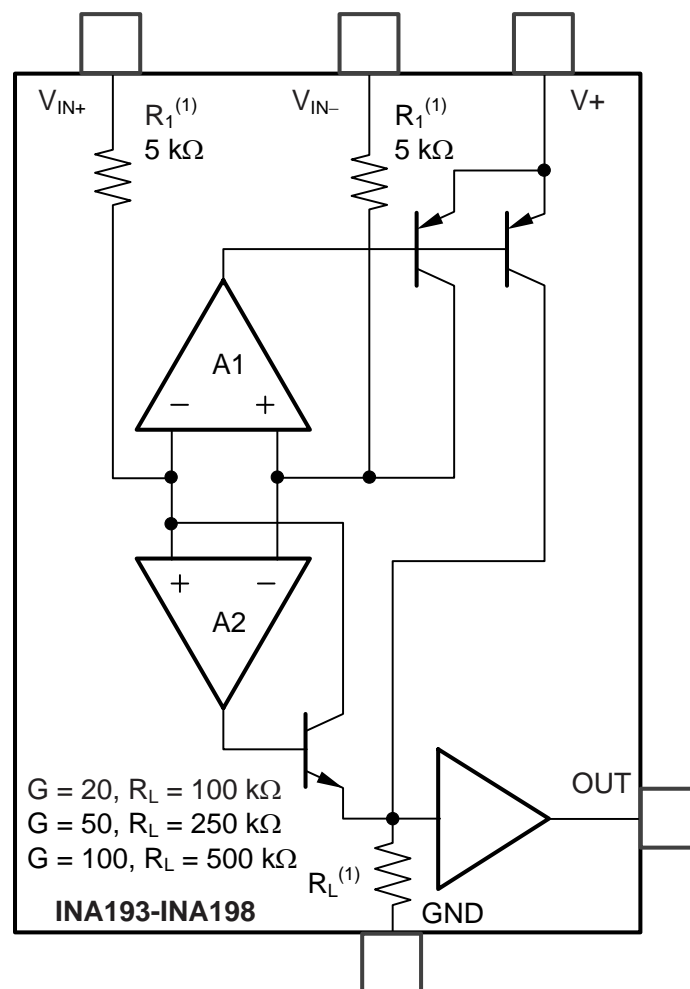
## 8 Detailed Description

### 8.1 Overview

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

The INA193–INA198 devices operate from a single  $+2.7\text{-V}$  to  $+18\text{-V}$  supply, drawing a maximum of  $900\text{ }\mu\text{A}$  of supply current. They are specified over the extended operating temperature range ( $-40^\circ\text{C}$  to  $+125^\circ\text{C}$ ), and are offered in a space-saving SOT-23 package.

### 8.2 Functional Block Diagram



## 8.3 Feature Description

### 8.3.1 Basic Connection

Figure 20 shows the basic connection of the INA193-INA198. To minimize any resistance in series with the shunt resistor, connect the input pins,  $V_{IN+}$  and  $V_{IN-}$ , as closely as possible to the shunt resistor.

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.

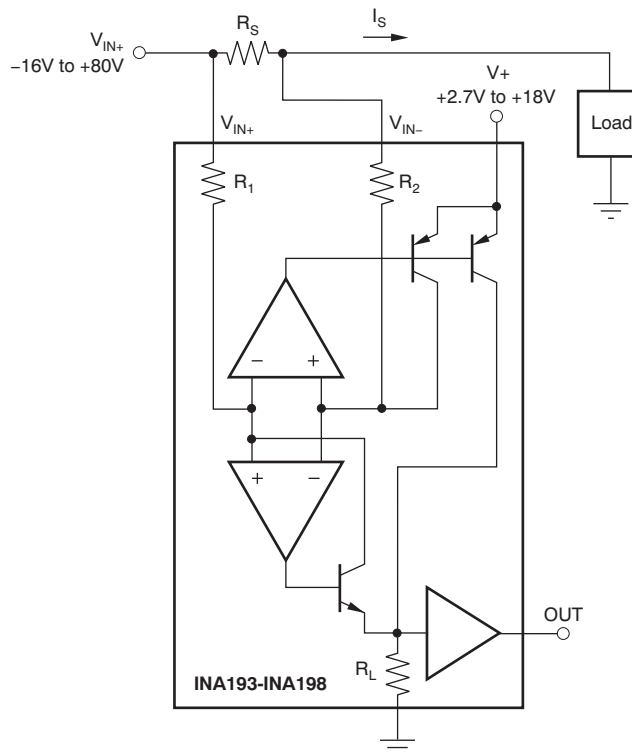


Figure 20. INA193-INA198 Basic Connection

### 8.3.2 Selecting $R_S$

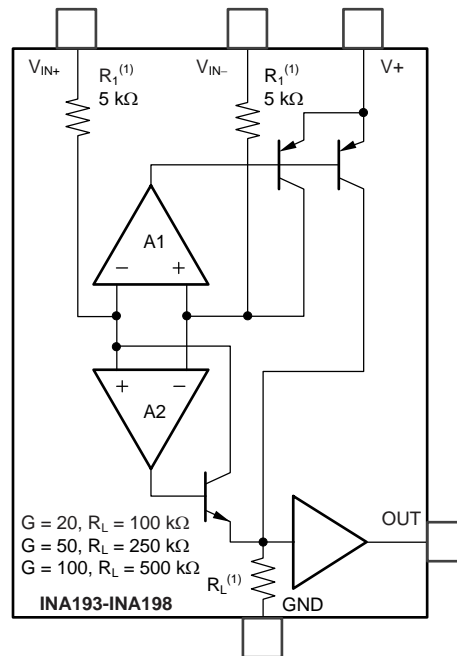
The value chosen for the shunt resistor,  $R_S$ , depends on the application and is a compromise between small-signal accuracy and maximum permissible voltage loss in the measurement line. High values of  $R_S$  provide better accuracy at lower currents by minimizing the effects of offset, while low 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 50 mV to 100 mV. Maximum input voltage for accurate measurements is 500 mV.

### 8.3.3 Inside the INA193-INA198

The INA193-INA198 devices use a new, unique internal circuit topology that provides common-mode range extending from  $-16$  to  $80$  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 devices provide 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 21) shows the basic circuit function. When the common-mode voltage is positive, amplifier A2 is active.

**Feature Description (continued)**

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 21. INA193-INA198 Simplified Circuit Diagram**

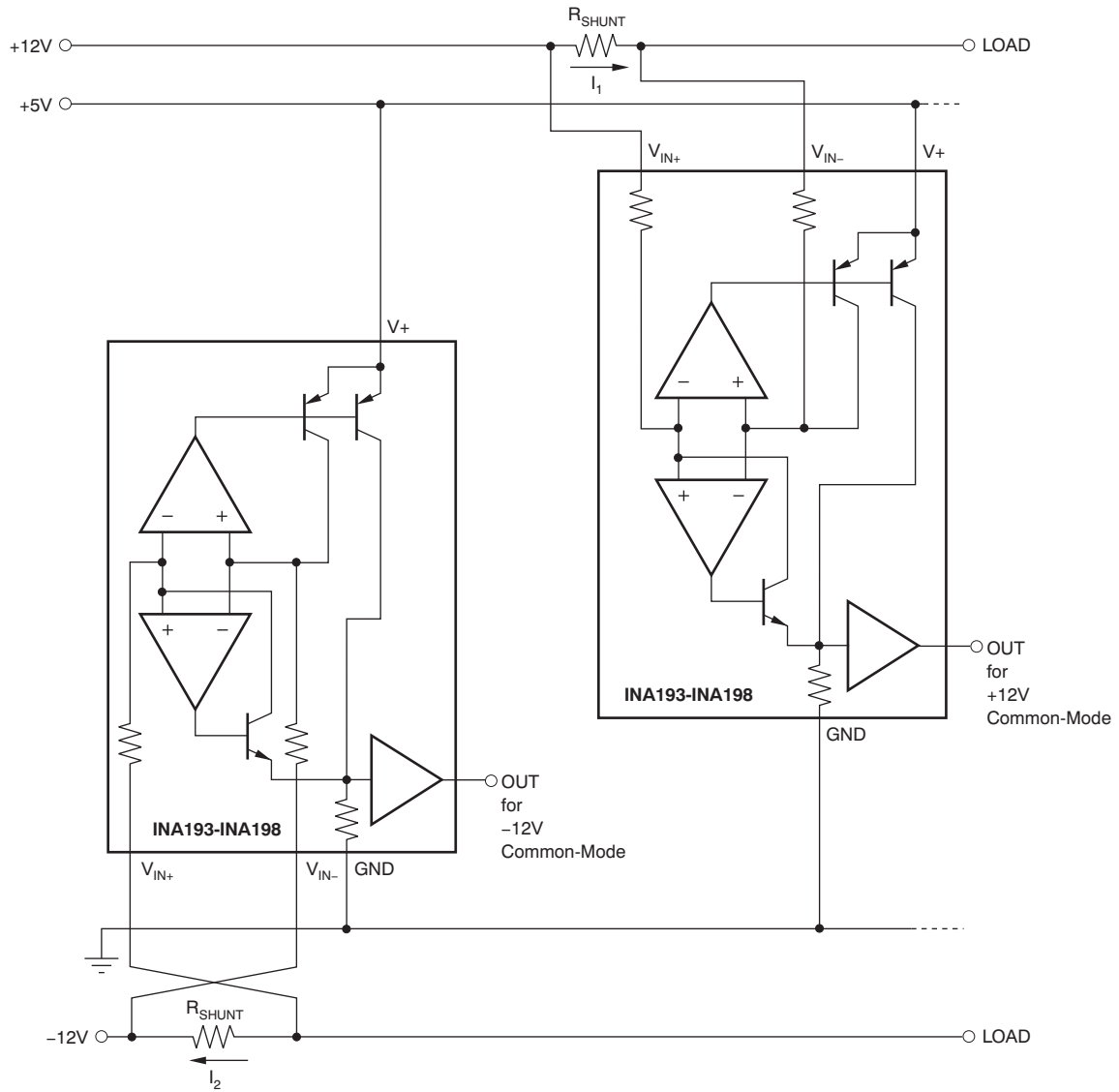


Figure 22. Monitor Bipolar Output Power-Supply Current

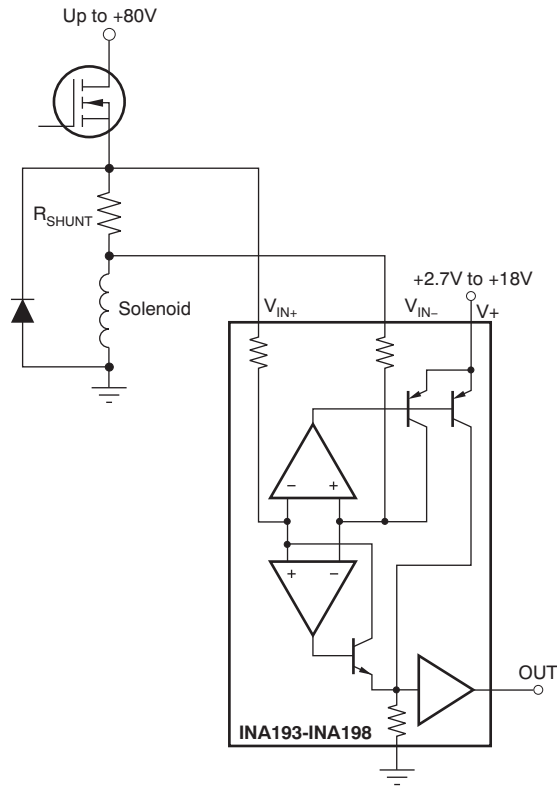
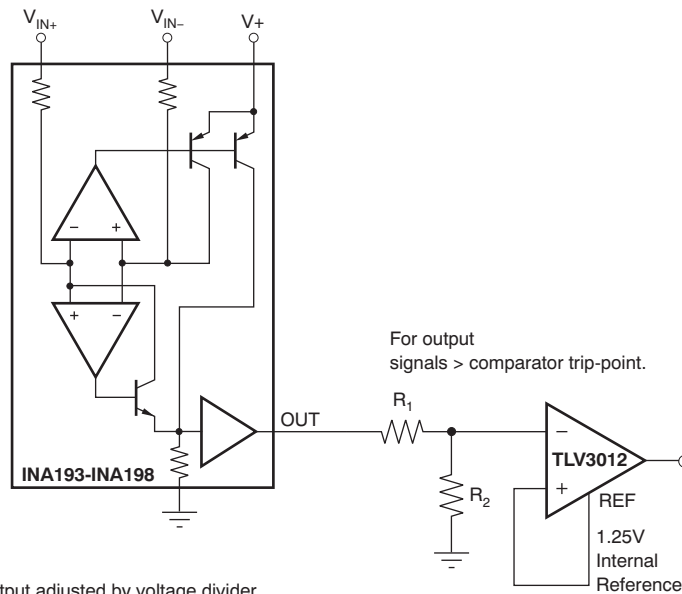
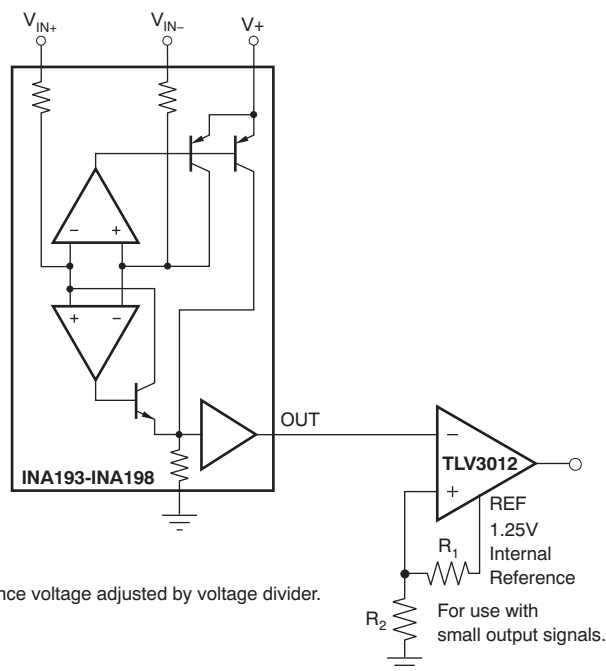


Figure 23. Inductive Current Monitor Including Flyback



(a) INA193-INA198 output adjusted by voltage divider.



(b) Comparator reference voltage adjusted by voltage divider.

Figure 24. INA193-INA198 with Comparator

## 8.4 Device Functional Modes

### 8.4.1 Input Filtering

An obvious and straightforward location for filtering is at the output of the INA193-INA198 devices; 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 devices, which is complicated by the internal 5-k $\Omega$  + 30% input impedance; this is illustrated in [Figure 25](#). 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 1](#):



## Device Functional Modes (continued)

$$\text{GainError\%} = 100 - \left( \frac{5\text{k}\Omega}{5\text{k}\Omega + R_{\text{FILT}}} \right) \times 100 \quad (1)$$

Total effect on gain error can be calculated by replacing the 5-k $\Omega$  term with 5 k $\Omega$  – 30%, (or 3.5 k $\Omega$ ) or 5 k $\Omega$  + 30% (or 6.5 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-k $\Omega$  resistor (3.5 k $\Omega$ ), and the higher excursion of  $R_{\text{FILT}}$  – 3% in this case.

Note that the specified accuracy of the INA193-INA198 devices 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.

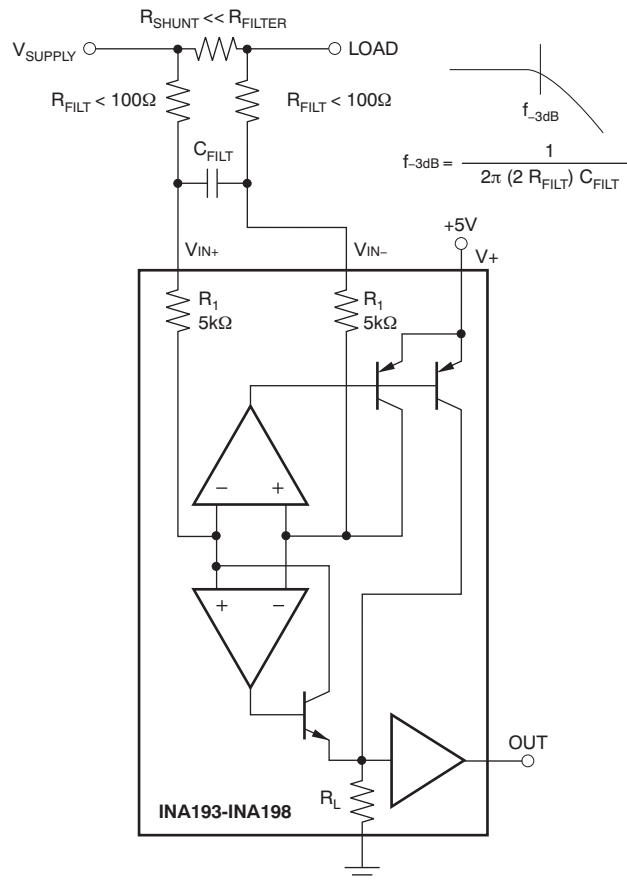


Figure 25. Input Filter (Gain Error – 1.5% To –2.2%)

### 8.4.2 Accuracy Variations as a Result of $V_{\text{SENSE}}$ and Common-Mode Voltage

The accuracy of the INA193–INA198 current shunt monitors is a function of two main variables:  $V_{\text{SENSE}}$  ( $V_{\text{IN}+} - V_{\text{IN}-}$ ) and common-mode voltage,  $V_{\text{CM}}$ , relative to the supply voltage,  $V_{\text{S}}$ .  $V_{\text{CM}}$  is expressed as  $(V_{\text{IN}+} + V_{\text{IN}-})/2$ ; however, in practice,  $V_{\text{CM}}$  is seen as the voltage at  $V_{\text{IN}+}$  because the voltage drop across  $V_{\text{SENSE}}$  is usually small.

This section addresses the accuracy of these specific operating regions:

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

## Device Functional Modes (continued)

Low  $V_{SENSE}$  Case 3:  $V_{SENSE} < 20\text{mV}$ ,  $V_S < V_{CM} \leq 80\text{V}$

### 8.4.2.1 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 2](#).

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

where:

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

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

(2)

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 3](#).

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

(3)

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.

### 8.4.2.2 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  $V_{CM} = -16\text{V}$ .

## Device Functional Modes (continued)

### 8.4.2.3 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 devices. It is important to know what the behavior of the devices will be 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 26 illustrates this effect using the INA195 and INA198 devices (Gain = 100).

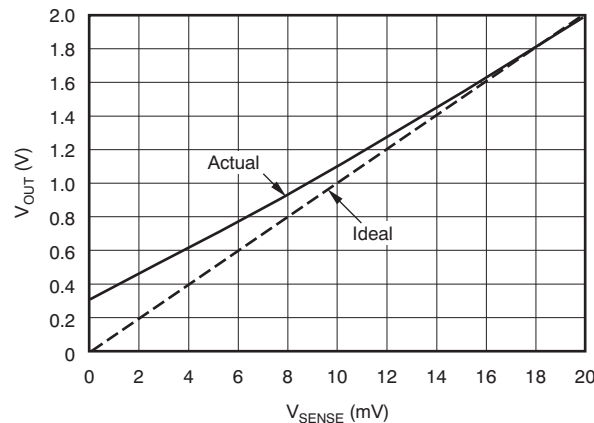
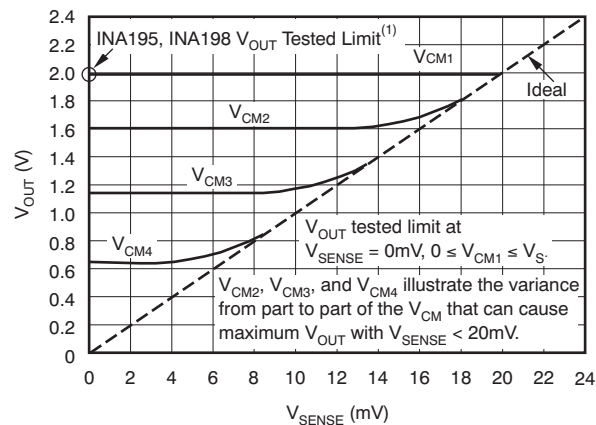


Figure 26. Example for Low  $V_{SENSE}$  Cases 1 and 3 (INA195, INA198: Gain = 100)

### 8.4.2.4 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 of devices. 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 27 illustrates this behavior for the INA195 device. 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 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.

## Device Functional Modes (continued)

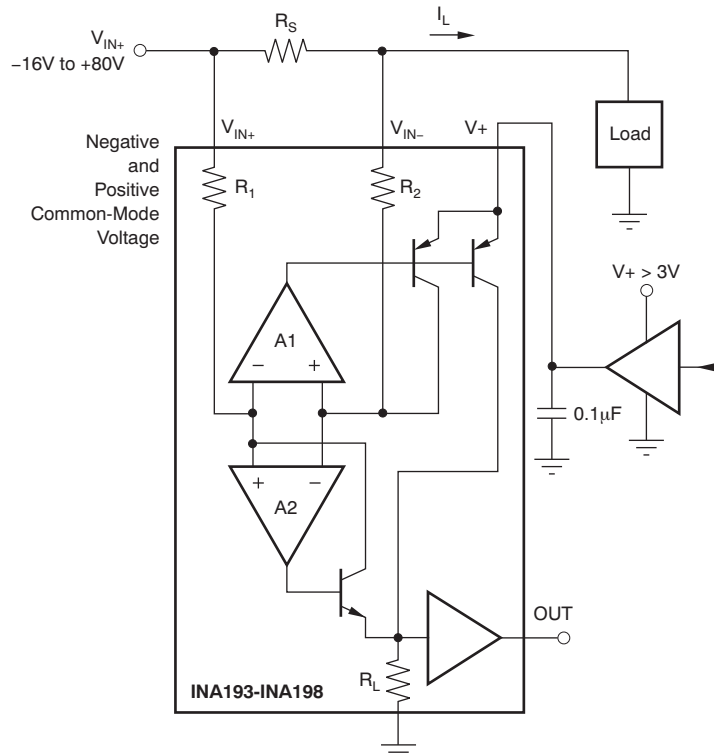


(1) INA193, INA196  $V_{OUT}$  Tested Limit = 0.4V. INA194, INA197  $V_{OUT}$  Tested Limit = 1V.

**Figure 27. Example for Low  $V_{SENSE}$  Case 2 (INA195, INA198: Gain = 100)**

### 8.4.3 Shutdown

Because the INA193-INA198 devices consume a quiescent current less than 1 mA, 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 0.1- $\mu$ F bypass capacitor, preferably ceramic with good high-frequency characteristics. This gate should have a supply voltage of 3 V or greater because the INA193-INA198 devices require a minimum supply greater than 2.7 V. In addition to eliminating quiescent current, this gate also turns off the 10- $\mu$ A bias current present at each of the inputs. An example shutdown circuit is shown in Figure 28.



**Figure 28. INA193-INA198 Example Shutdown Circuit**

## Device Functional Modes (continued)

### 8.4.4 Transient Protection

The  $-16\text{-V}$  to  $+80\text{-V}$  common-mode range of the INA193-INA198 devices is ideal for withstanding automotive fault conditions ranging from 12-V battery reversal up to 80-V transients, since no additional protective components are needed up to those levels. In the event that the INA193-INA198 devices are 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 devices to be exposed to transients greater than  $+80\text{ V}$  (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 INA193-INA198 devices 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 resistors can be added in series with the INA193-INA198 inputs with two equal resistors on each input.)

### 8.4.5 Output Voltage Range

The output of the INA193-INA198 devices are accurate within the output voltage swing range set by the power-supply pin,  $V+$ . This is best illustrated when using the INA195 or INA198 devices (which are both versions using a gain of 100), where a 100-mV full-scale input from the shunt resistor requires an output voltage swing of  $+10\text{ V}$ , and a power-supply voltage sufficient to achieve  $+10\text{ V}$  on the output.

## 9 Application and Implementation

### NOTE

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

### 9.1 Application Information

The INA193-INA198 devices measure the voltage developed across a current-sensing resistor when current passes through it. The ability to have shunt common-mode voltages from  $-16\text{-V}$  to  $+80\text{-V}$  drive and control the output signal with  $V_s$  offers multiple configurations, as discussed throughout this section.

### 9.2 Typical Application

The device is a unidirectional, current-sense amplifier capable of measuring currents through a resistive shunt with shunt common-mode voltages from  $-16\text{ V}$  to  $80\text{ V}$ . Two devices can be configured for bidirectional monitoring and is common in applications that include charging and discharging operations where the current flow-through resistor can change directions.

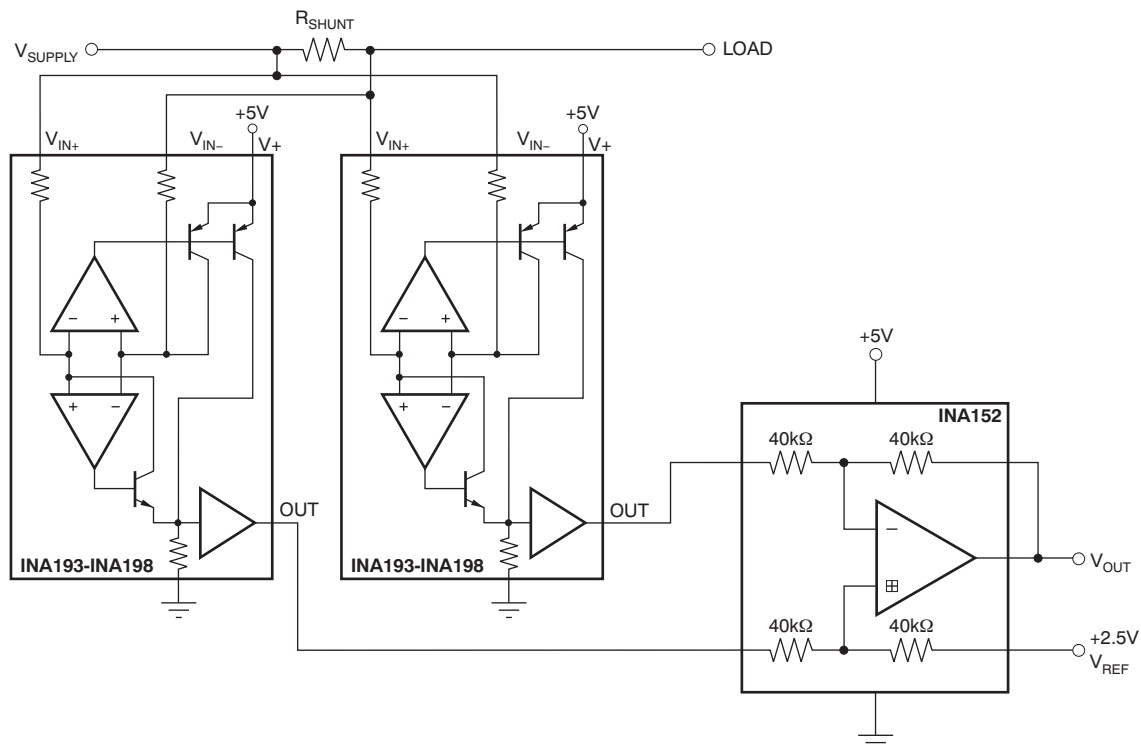


Figure 29. Bi-Directional Current Monitoring

#### 9.2.1 Design Requirements

$V_{supply}$  is set to  $12\text{ V}$ ,  $V_{ref}$  at  $2.5\text{ V}$  and a  $10\text{-m}\Omega$  shunt. The accuracy of the current will typically be less than  $0.5\%$  for current greater than  $\pm 2\text{ A}$ . For current lower than  $\pm 2\text{ A}$ , the accuracy will vary; use the [Device Functional Modes](#) section for accuracy considerations.

## Typical Application (continued)

### 9.2.2 Detailed Design Procedure

The ability to measure this current flowing in both directions is enabled by adding a unity gain amplifier with a  $V_{REF}$ , as shown in Figure 29. The output then responds by increasing above  $V_{REF}$  for positive differential signals (relative to the IN – pin) and responds by decreasing below  $V_{REF}$  for negative differential signals. This reference voltage applied to the REF pin can be set anywhere between 0 V to  $V+$ . For bidirectional applications,  $V_{REF}$  is typically set at mid-scale for equal signal range in both current directions. In some cases, however,  $V_{REF}$  is set at a voltage other than mid-scale when the bidirectional current and corresponding output signal do not need to be symmetrical.

### 9.2.3 Application Curve

An example output response of a bidirectional configuration is shown in Figure 30. With the REF pin connected to a reference voltage, 2.5 V in this case, the output voltage is biased upwards by this reference level. The output rises above the reference voltage for positive differential input signals and falls below the reference voltage for negative differential input signals.

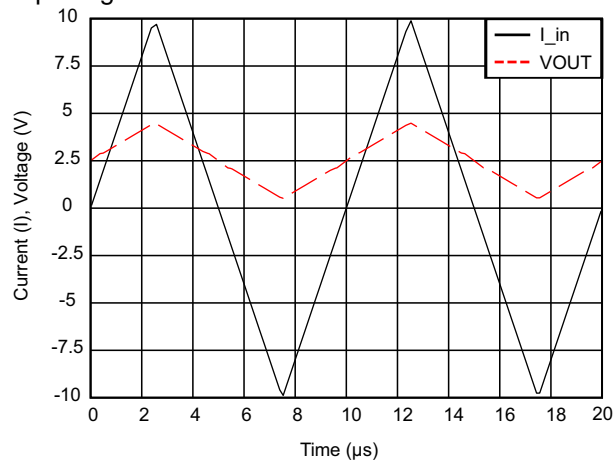


Figure 30. Output Voltage vs Shunt Input Current

## 10 Power Supply Recommendations

The input circuitry of the INA193-INA198 devices can accurately measure beyond its 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. The output voltage range of the OUT terminal, however, is limited by the voltages on the power-supply pin.

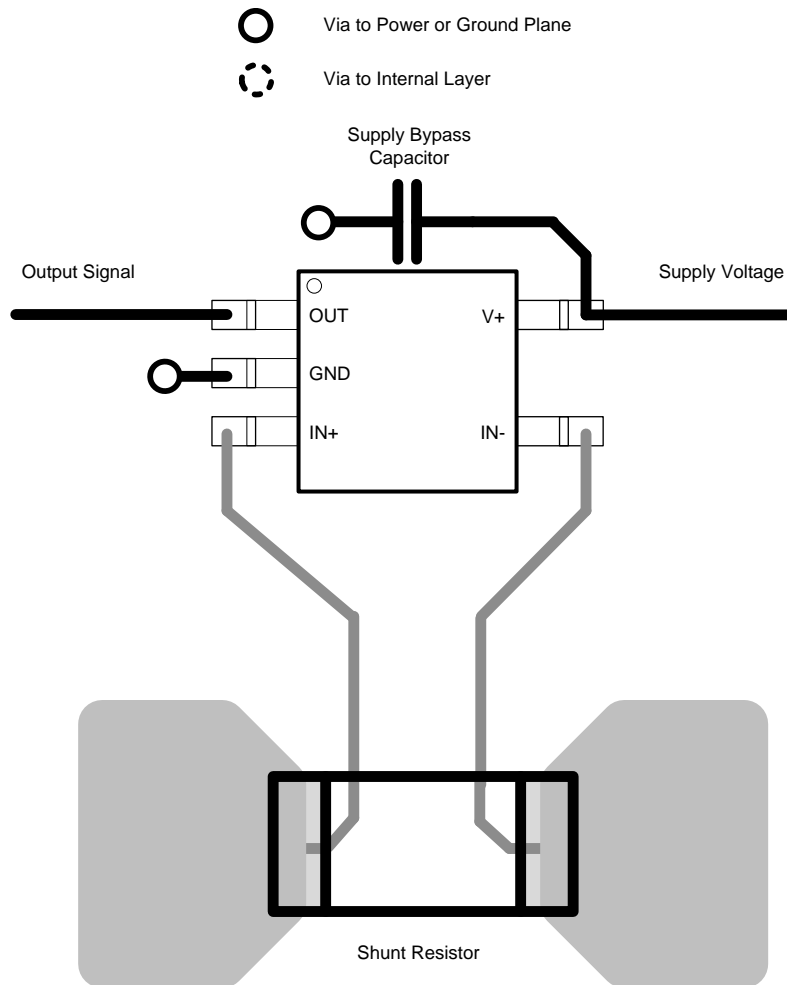
## 11 Layout

### 11.1 Layout Guidelines

#### 11.1.1 RFI and 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 devices versus the INA196-INA198 devices may provide different EMI performance.

## 11.2 Layout Example



**Figure 31. Recommended Layout**



## 12 デバイスおよびドキュメントのサポート

### 12.1 関連リンク

次の表に、クイック・アクセス・リンクを示します。カテゴリには、技術資料、サポートおよびコミュニティ・リソース、ツールとソフトウェア、およびサンプル注文またはご購入へのクイック・アクセスが含まれます。

表 1. 関連リンク

製品	プロダクト・フォルダ	サンプルとご購入	技術資料	ツールとソフトウェア	サポートとコミュニティ
INA193	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>
INA194	<a href="#">ここをクリックしてください</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>
INA195	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>
INA196	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>
INA197	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>
INA198	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>	<a href="#">ここをクリック</a>

### 12.2 商標

All trademarks are the property of their respective owners.

### 12.3 静電気放電に関する注意事項



これらのデバイスは、限定的なESD（静電破壊）保護機能を内蔵しています。保存時または取り扱い時は、MOSゲートに対する静電破壊を防止するために、リード線同士をショートさせておくか、デバイスを導電フォームに入れる必要があります。

### 12.4 用語集

SLYZ022 — TI用語集.

この用語集には、用語や略語の一覧および定義が記載されています。

## 13 メカニカル、パッケージ、および注文情報

以降のページには、メカニカル、パッケージ、および注文に関する情報が記載されています。この情報は、そのデバイスについて利用可能な最新のデータです。このデータは予告なく変更されることがあり、ドキュメントが改訂される場合もあります。本データシートのブラウザ版を使用されている場合は、画面左側の説明をご覧ください。

**PACKAGING INFORMATION**

Orderable part number	Status (1)	Material type (2)	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
<a href="#">INA193AIDBVR</a>	Active	Production	SOT-23 (DBV)   5	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJJ
INA193AIDBVR.A	Active	Production	SOT-23 (DBV)   5	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJJ
INA193AIDBVR1G4.A	Active	Production	SOT-23 (DBV)   5	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJJ
<a href="#">INA193AIDBVT</a>	Active	Production	SOT-23 (DBV)   5	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJJ
INA193AIDBVT.A	Active	Production	SOT-23 (DBV)   5	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJJ
<a href="#">INA194AIDBVR</a>	Active	Production	SOT-23 (DBV)   5	3000   LARGE T&R	Yes	NIPDAU   SN	Level-2-260C-1 YEAR	-40 to 125	BJI
INA194AIDBVR.A	Active	Production	SOT-23 (DBV)   5	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJI
INA194AIDBVR1G4.A	Active	Production	SOT-23 (DBV)   5	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJI
<a href="#">INA194AIDBVT</a>	Active	Production	SOT-23 (DBV)   5	250   SMALL T&R	Yes	NIPDAU   SN	Level-2-260C-1 YEAR	-40 to 125	BJI
INA194AIDBVT.A	Active	Production	SOT-23 (DBV)   5	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJI
<a href="#">INA195AIDBVR</a>	Active	Production	SOT-23 (DBV)   5	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJK
INA195AIDBVR.A	Active	Production	SOT-23 (DBV)   5	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJK
INA195AIDBVRG4.A	Active	Production	SOT-23 (DBV)   5	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJK
<a href="#">INA195AIDBVT</a>	Active	Production	SOT-23 (DBV)   5	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJK
INA195AIDBVT.A	Active	Production	SOT-23 (DBV)   5	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJK
<a href="#">INA196AIDBVR</a>	Active	Production	SOT-23 (DBV)   5	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJE
INA196AIDBVR.A	Active	Production	SOT-23 (DBV)   5	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJE
INA196AIDBVR1G4.A	Active	Production	SOT-23 (DBV)   5	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJE
<a href="#">INA196AIDBVT</a>	Active	Production	SOT-23 (DBV)   5	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJE
INA196AIDBVT.A	Active	Production	SOT-23 (DBV)   5	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJE
<a href="#">INA197AIDBVR</a>	Active	Production	SOT-23 (DBV)   5	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJH
INA197AIDBVR.A	Active	Production	SOT-23 (DBV)   5	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJH
INA197AIDBVR1G4.A	Active	Production	SOT-23 (DBV)   5	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJH
<a href="#">INA197AIDBVT</a>	Active	Production	SOT-23 (DBV)   5	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJH
INA197AIDBVT.A	Active	Production	SOT-23 (DBV)   5	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJH
<a href="#">INA198AIDBVR</a>	Active	Production	SOT-23 (DBV)   5	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJL
INA198AIDBVR.A	Active	Production	SOT-23 (DBV)   5	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJL
INA198AIDBVRG4.A	Active	Production	SOT-23 (DBV)   5	3000   LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJL
<a href="#">INA198AIDBVT</a>	Active	Production	SOT-23 (DBV)   5	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJL

Orderable part number	Status (1)	Material type (2)	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
INA198AIDBVT.A	Active	Production	SOT-23 (DBV)   5	250   SMALL T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	BJL

(1) **Status:** For more details on status, see our [product life cycle](#).

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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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
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	3.3	3.2	1.4	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

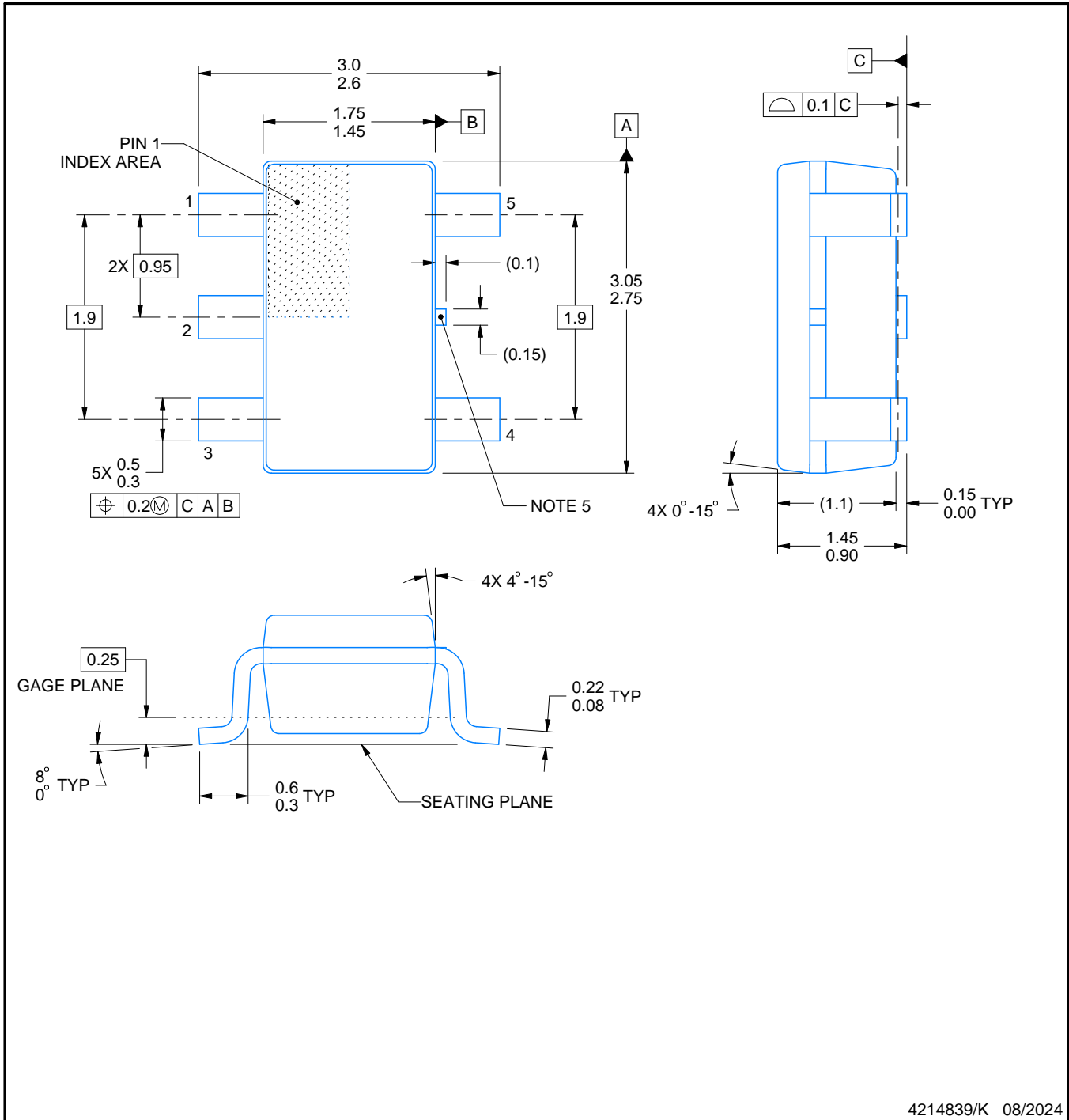
# DBV0005A



# PACKAGE OUTLINE

## SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



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### NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC MO-178.
4. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25 mm per side.
5. Support pin may differ or may not be present.

# EXAMPLE BOARD LAYOUT

DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:15X



SOLDER MASK DETAILS

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NOTES: (continued)

- 6. Publication IPC-7351 may have alternate designs.
- 7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE:15X

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NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.



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