

# INA299 -2V to 80V, Bi-directional, 650kHz, High-Precision Current Sense Amplifier

## 1 Features

- Wide common-mode voltage:
  - Operational voltage: -2V to +80V
  - Survival voltage: -12V to +85V
- Bidirectional operation
- High small signal bandwidth: 650kHz (20V/V Gain)
- Slew rate: 2.5V/μs
- Step response settling time to 1%: 6.5μs
- High CMRR: 120dB
- Gain error (maximum) : ±0.25%, ±10ppm/°C drift
- Offset voltage (maximum): ±150μV, ±0.5μV/°C drift
- Operates from 2.7V to 12V supply
- Operational current: 650μA
- Available gains:
  - INA299A1: 20V/V
  - INA299A2: 50V/V
  - INA299A3: 100V/V
- Package options: SOT23-6 (DBV)

## 2 Applications

- [DC/DC Converter](#)
- [ESS battery management systems \(BMS\)](#)
- [Macro remote radio unit \(RRU\)](#)
- [48V rack server](#)
- [48V merchant network & server power supply \(PSU\)](#)

## 3 Description

The INA299 is a precise, bidirectional current sense amplifier that can measure voltage drops across shunt resistors over a wide common-mode range from -2V to 80V, independent of the supply voltage. The high-precision current measurement is achieved through a combination of low offset voltage (±150μV, maximum), small gain error (±0.25%, maximum) and a high DC CMRR (typical 120dB). The INA299 is not only designed for high voltage, bidirectional DC current measurements, but also for high-speed applications (such as transient detection and fast overcurrent protection) with a high signal bandwidth of 650kHz and fast settling time.

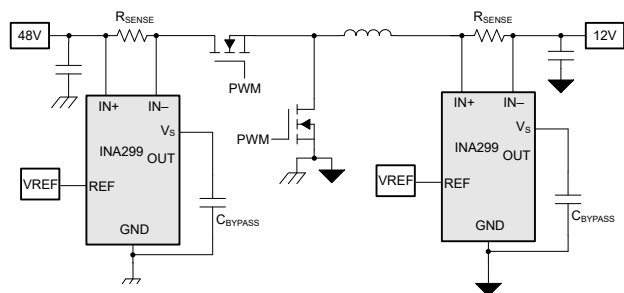
The INA299 operates from a single 2.7V to 12V supply, drawing 650μA of supply current. The INA299 is available in three gain options: 20V/V, 50V/V, 100V/V. Multiple gain options allow for optimization between available shunt resistor values and wide output dynamic range requirements.

The INA299 is specified over operating temperature range of -40°C to +125°C and is offered in a 6-pin SOT-23 package.

### Package Information

PART NUMBER	PACKAGE <sup>(1)</sup>	PACKAGE SIZE <sup>(2)</sup>
INA299	DBV (SOT-23, 6)	2.90mm × 2.80mm

- (1) For all available packages, see the package option addendum at the end of the data sheet.
- (2) The package size (length × width) is a nominal value and includes pins, where applicable.



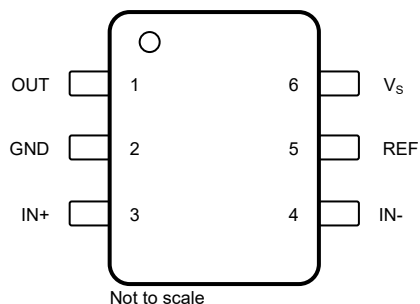
**Typical Application - DC/DC Converter**



## Table of Contents

<b>1 Features</b> .....	<b>1</b>	7.1 Application Information.....	<b>16</b>
<b>2 Applications</b> .....	<b>1</b>	7.2 Typical Application.....	<b>17</b>
<b>3 Description</b> .....	<b>1</b>	7.3 Power Supply Recommendations.....	<b>18</b>
<b>4 Pin Configuration and Functions</b> .....	<b>2</b>	7.4 Layout.....	<b>18</b>
<b>5 Specifications</b> .....	<b>3</b>	<b>8 Device and Documentation Support</b> .....	<b>20</b>
5.1 Absolute Maximum Ratings.....	<b>3</b>	8.1 Documentation Support.....	<b>20</b>
5.2 ESD Ratings.....	<b>3</b>	8.2 Receiving Notification of Documentation Updates.....	<b>20</b>
5.3 Recommended Operating Conditions.....	<b>3</b>	8.3 Support Resources.....	<b>20</b>
5.4 Thermal Information.....	<b>3</b>	8.4 Trademarks.....	<b>20</b>
5.5 Electrical Characteristics.....	<b>4</b>	8.5 Electrostatic Discharge Caution.....	<b>20</b>
5.6 Typical Characteristics.....	<b>6</b>	8.6 Glossary.....	<b>20</b>
<b>6 Detailed Description</b> .....	<b>12</b>	<b>9 Revision History</b> .....	<b>20</b>
6.1 Overview.....	<b>12</b>	<b>10 Mechanical, Packaging, and Orderable Information</b> .....	<b>20</b>
6.2 Functional Block Diagram.....	<b>12</b>	10.1 Mechanical Data.....	<b>21</b>
6.3 Feature Description.....	<b>12</b>	Package Option Addendum.....	<b>24</b>
6.4 Device Functional Modes.....	<b>13</b>	10.2 Tape and Reel Information.....	<b>25</b>
<b>7 Application and Implementation</b> .....	<b>16</b>		

## 4 Pin Configuration and Functions



**Figure 4-1. INA299 : DVB Package 6-Pin SOT-23 Top View**

**Table 4-1. Pin Functions: DBV Package**

PIN		TYPE	DESCRIPTION
NAME	NO.		
GND	2	Ground	Ground
IN+	3	Input	Current-sense amplifier positive input. For high-side applications, connect to bus-voltage side of sense resistor. For low-side applications, connect to load side of sense resistor.
IN–	4	Input	Current-sense amplifier negative input. For high-side applications, connect to load side of sense resistor. For low-side applications, connect to ground side of sense resistor.
OUT	1	Output	Output voltage
REF	5	Input	Reference voltage. Connect to voltage potential from 0V to $V_S$ ; see <a href="#">Adjusting the Output With the Reference Pin</a> for connection options.
$V_S$	6	Power	Power supply, 2.7V to 12V

## 5 Specifications

### 5.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
Supply Voltage (V <sub>S</sub> )	(V <sub>S</sub> – GND)	–0.3	13.2	V
Analog Inputs, V <sub>IN+</sub> , V <sub>IN–</sub> <sup>(2)</sup>	Differential (V <sub>IN+</sub> ) – (V <sub>IN–</sub> )	–6	6	V
Analog Inputs, V <sub>IN+</sub> , V <sub>IN–</sub> <sup>(2)</sup>	Common - mode	–12	85	V
REF		GND – 0.3	V <sub>S</sub> + 0.3	V
Output		GND – 0.3	V <sub>S</sub> + 0.3	V
T <sub>A</sub>	Operating temperature	–55	150	°C
T <sub>J</sub>	Junction temperature		150	°C
T <sub>stg</sub>	Storage temperature	–65	150	°C

- (1) Operation outside the *Absolute Maximum Ratings* may cause permanent device damage. *Absolute Maximum Ratings* do not imply functional operation of the device at these or any other conditions beyond those listed under *Recommended Operating Conditions*. If used outside the *Recommended Operating Conditions* but within the *Absolute Maximum Ratings*, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.
- (2) V<sub>IN+</sub> and V<sub>IN–</sub> are the voltages at the IN+ and IN– pins, respectively.

### 5.2 ESD Ratings

			VALUE	UNIT
V <sub>(ESD)</sub>	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/ JEDEC JS-001, all pins <sup>(1)</sup>	±2000	V
		Charged device model (CDM), per ANSI/ESDA/ JEDEC JS-002, all pins <sup>(2)</sup>	±1000	

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

### 5.3 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
V <sub>CM</sub>	Common-mode input range	–2	48	80	V
V <sub>S</sub>	Operating supply range	2.7	5	12	V
V <sub>SENSE</sub>	Differential sense input range	0		V <sub>S</sub> / G	V
T <sub>A</sub>	Ambient temperature	–40		125	°C

### 5.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		INA299	UNIT
		DBV ( SOT-23)	
		6 PINS	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	158.8	°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	76.9	°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	41.4	°C/W
Ψ <sub>JT</sub>	Junction-to-top characterization parameter	17.3	°C/W
Ψ <sub>JB</sub>	Junction-to-board characterization parameter	41.1	°C/W

THERMAL METRIC <sup>(1)</sup>		INA299	UNIT
		DBV ( SOT-23)	
		6 PINS	
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	°C/W

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

## 5.5 Electrical Characteristics

at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{REF} = V_S / 2$ ,  $V_{SENSE} = 0\text{V}$ ,  $V_{CM} = V_{IN-} = 48\text{V}$ , (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>INPUT</b>						
$V_{CM}$	Common-mode input range <sup>(1)</sup>	$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$	-2		80	V
CMRR	Common-mode rejection ratio, input referred	$2.5\text{V} < V_{CM} < 80\text{V}$ ,	110	120		dB
		$0\text{V} < V_{CM} < 80\text{V}$ ,	80	90		
		$-2\text{V} < V_{CM} \leq 2.5\text{V}$ ,	65			
		$f = 50\text{kHz}$ , $V_{CM} = 12\text{V}$		65		
$V_{os}$	Offset voltage, input referred	$V_{CM} = 2.5\text{V}$	-150		150	$\mu\text{V}$
		$V_{CM} = 2.5\text{V}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$	-200		200	
$dV_{os}/dT$	Offset voltage drift	$V_{CM} = 2.5\text{V}$			$\pm 0.5$	$\mu\text{V}/^\circ\text{C}$
PSRR	Power supply rejection ratio, input referred	$V_{CM} = 2.5\text{V}$ , $2.7\text{V} \leq V_S \leq 12\text{V}$ , $V_{REF} = 1\text{V}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			$\pm 6$	$\mu\text{V}/\text{V}$
$I_B$	Input bias current	$I_{B+}$ , $I_{B-}$ , $V_{CM} = 2.5\text{V}$ , $V_{SENSE} = 0\text{V}$		13	$\pm 21$	$\mu\text{A}$
		$I_{B+}$ , $I_{B-}$ , $V_{CM} = 2.5\text{V}$ , $V_{SENSE} = 0\text{V}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			$\pm 28$	
	Reference input range		0		$V_S$	V
RVRR	Reference voltage rejection ratio, input referred	$V_{REF} = 0.5\text{V}$ to $4.5\text{V}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$		$\pm 5$	$\pm 20$	$\mu\text{V}/\text{V}$
<b>OUTPUT</b>						
G	Gain	INA299A1		20		V/V
		INA299A2		50		
		INA299A3		100		
$G_{ERR}$	Gain error	$V_{CM} = 2.5\text{V}$ , $(\text{GND} + 50\text{mV}) < V_{OUT} < (V_S - 200\text{mV})$			$\pm 0.25$	%
	Gain error drift	$V_{CM} = 2.5\text{V}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$ , $(\text{GND} + 50\text{mV}) < V_{OUT} < (V_S - 200\text{mV})$			10	ppm/ $^\circ\text{C}$
$NL_{ERR}$	Nonlinearity error	$V_{OUT} = 0.5\text{V}$ to $4.5\text{V}$ , $V_{CM} = 12\text{V}$		0.01		%
	Maximum capacitive load	No sustained oscillations, no isolation resistor		500		pF
<b>VOLTAGE OUTPUT</b>						
	Swing to $V_S$ (Power supply rail)	$V_{CM} = 2.5\text{V}$ , $R_L = 10\text{k}\Omega$ to GND	4.9			V
	Swing to ground	$V_{CM} = 2.5\text{V}$ , $R_L = 10\text{k}\Omega$ to GND			80	mV
<b>FREQUENCY RESPONSE</b>						
BW	Bandwidth	INA299A1		650		kHz
		INA299A2		500		
		INA299A3		400		

at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{\text{REF}} = V_S / 2$ ,  $V_{\text{SENSE}} = 0\text{V}$ ,  $V_{\text{CM}} = V_{\text{IN-}} = 48\text{V}$ , (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
	Settling time	$V_{\text{OUT}} = 0.5\text{V}$ to $4.5\text{V}$ step, Output settles to 1%		6.5		$\mu\text{s}$
		$V_{\text{OUT}} = 0.5\text{V}$ to $4.5\text{V}$ step, Output settles to 5%		3		
SR	Slew rate	INA299A1, $V_{\text{SENSE}} = \pm 100\text{mV}$ , INA299A2, $V_{\text{SENSE}} = \pm 40\text{mV}$ , INA299A3, $V_{\text{SENSE}} = \pm 20\text{mV}$ ,		2.5		$\text{V}/\mu\text{s}$
<b>NOISE</b>						
$V_{\text{en}}$	Voltage noise density	$f > 10\text{kHz}$		117		$\text{nV}/\sqrt{\text{Hz}}$
<b>POWER SUPPLY</b>						
$I_Q$	Quiescent current	$V_{\text{CM}} = 2.5\text{V}$		450	600	$\mu\text{A}$
		$V_{\text{CM}} = 2.5\text{V}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			650	$\mu\text{A}$
		$V_{\text{CM}} = -2\text{V}$		950	1100	$\mu\text{A}$
		$V_{\text{CM}} = -2\text{V}$ , $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			1200	$\mu\text{A}$
$T_A$	Specified Range		-40		125	$^\circ\text{C}$

(1) Common-mode voltage at both  $V_{\text{IN+}}$  and  $V_{\text{IN-}}$  must not exceed the specified common-mode input range.

## 5.6 Typical Characteristics

at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{\text{SENSE}} = V_{\text{IN}+} - V_{\text{IN}-} = 0\text{V}$ ,  $V_{\text{CM}} = V_{\text{IN-}} = 48\text{V}$ , and  $V_{\text{REF}} = V_S / 2$  (unless otherwise noted)

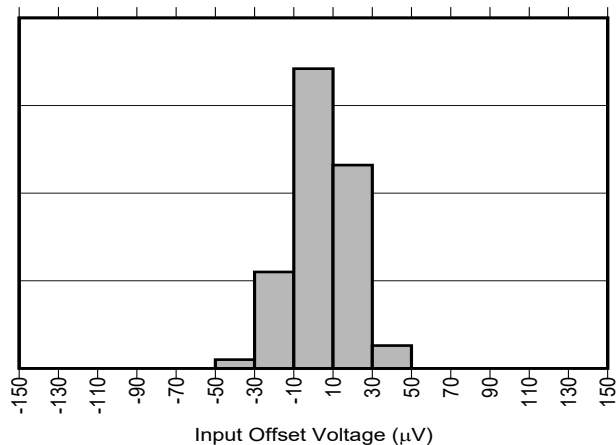


Figure 5-1. INA299 Input Offset Voltage Production Distribution

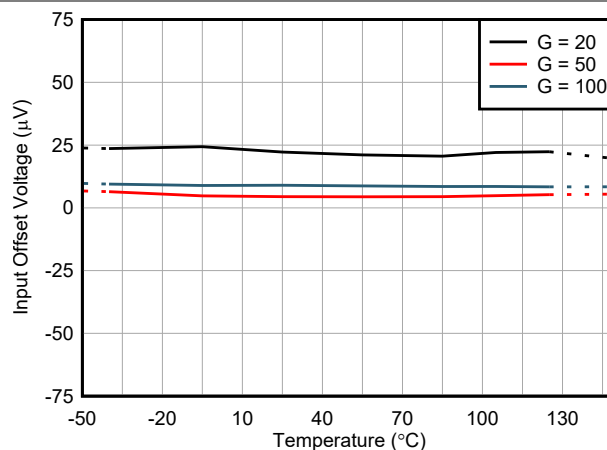


Figure 5-2. Input Offset Voltage vs Temperature

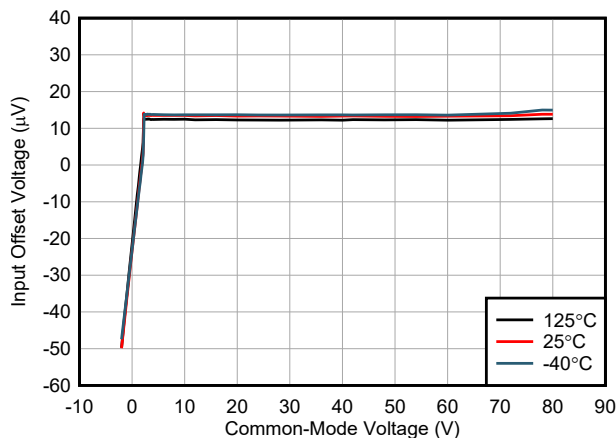


Figure 5-3. Input Offset Voltage vs Common-Mode Voltage

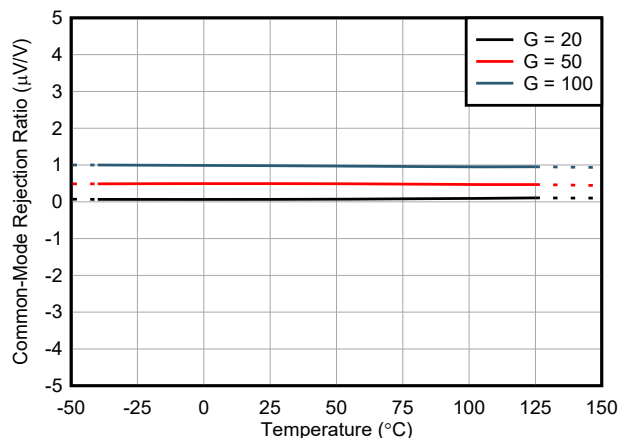


Figure 5-4. Common-Mode Rejection Ratio vs Temperature

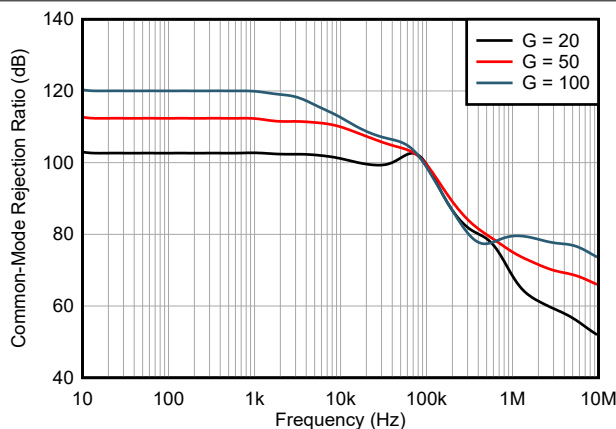


Figure 5-5. Common-Mode Rejection Ratio vs Frequency

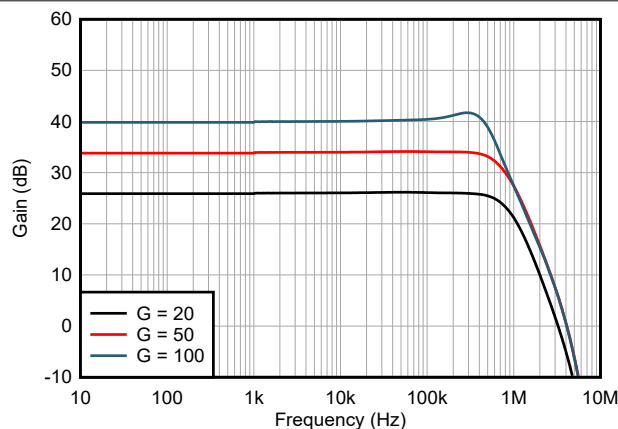


Figure 5-6. Gain vs Frequency

## 5.6 Typical Characteristics (continued)

at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{\text{SENSE}} = V_{\text{IN}+} - V_{\text{IN}-} = 0\text{V}$ ,  $V_{\text{CM}} = V_{\text{IN}-} = 48\text{V}$ , and  $V_{\text{REF}} = V_S / 2$  (unless otherwise noted)

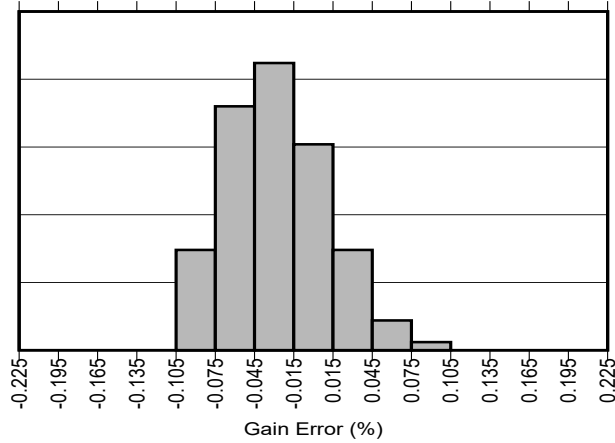


Figure 5-7. INA299 Gain Error Production Distribution

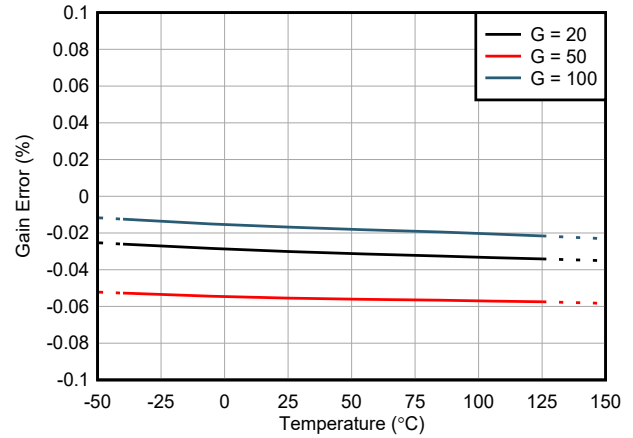


Figure 5-8. Gain Error vs Temperature

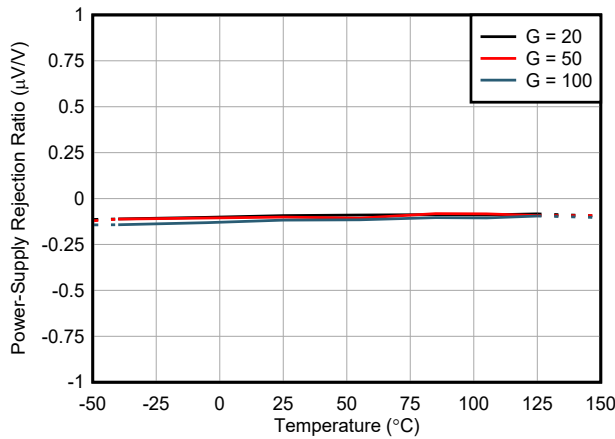


Figure 5-9. Power-Supply Rejection Ratio vs Temperature

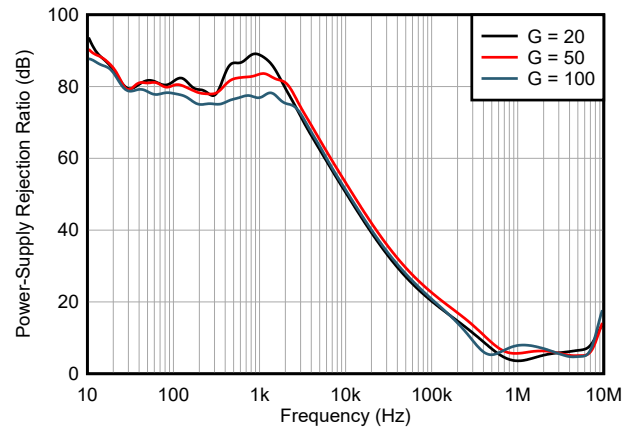


Figure 5-10. Power-Supply Rejection Ratio vs Frequency

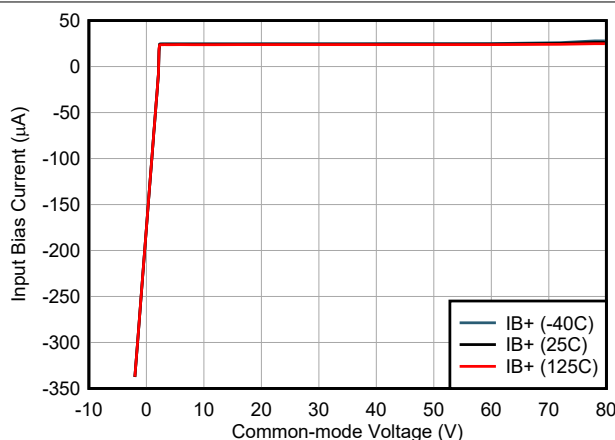


Figure 5-11. Input Bias Current vs Common-Mode Voltage

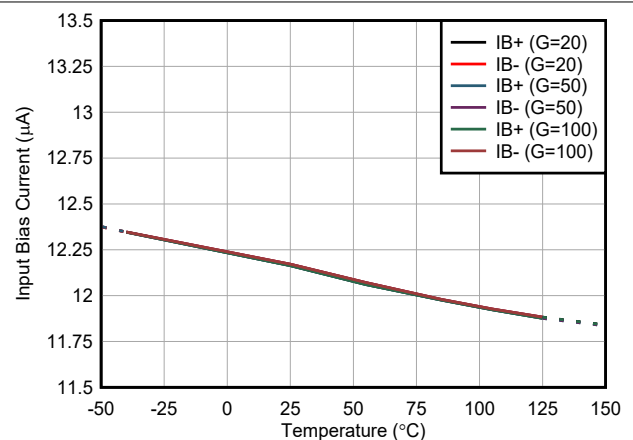


Figure 5-12. Input Bias Current vs Temperature

## 5.6 Typical Characteristics (continued)

at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{\text{SENSE}} = V_{\text{IN}+} - V_{\text{IN}-} = 0\text{V}$ ,  $V_{\text{CM}} = V_{\text{IN}-} = 48\text{V}$ , and  $V_{\text{REF}} = V_S / 2$  (unless otherwise noted)

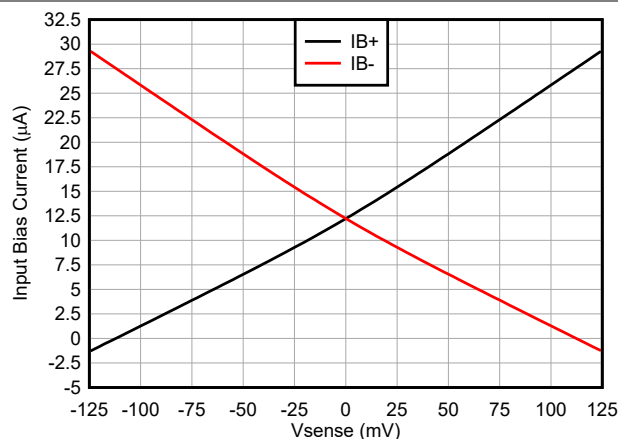


Figure 5-13. INA299 Gain = 20V/V, Input Bias Current vs  $V_{\text{SENSE}}$

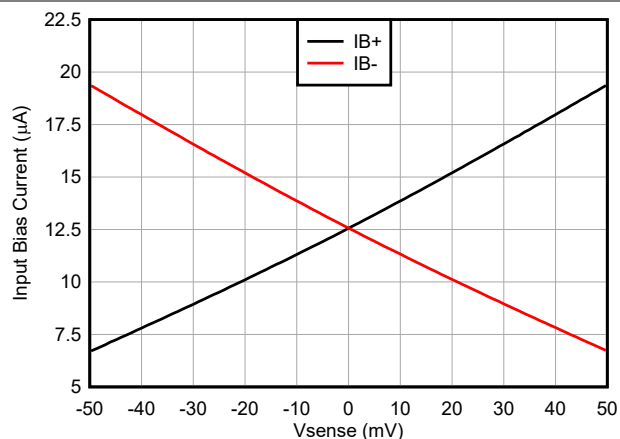


Figure 5-14. INA299 Gain = 50V/V, Input Bias Current vs  $V_{\text{SENSE}}$

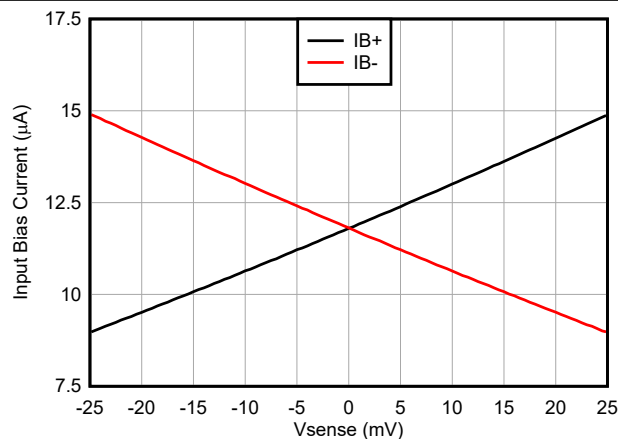


Figure 5-15. INA299 Gain = 100V/V Input Bias Current vs  $V_{\text{SENSE}}$

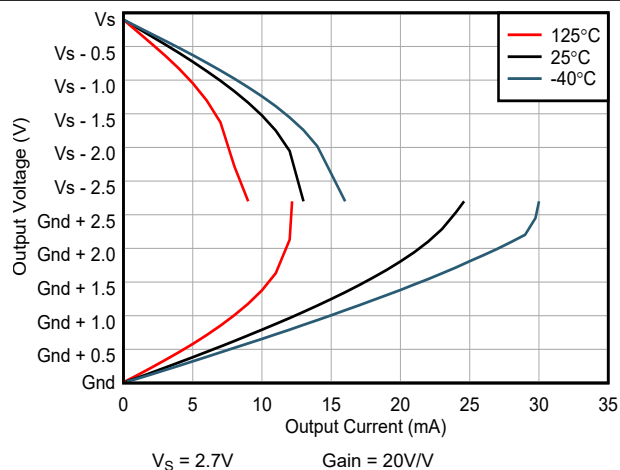


Figure 5-16. Output Voltage vs Output Current

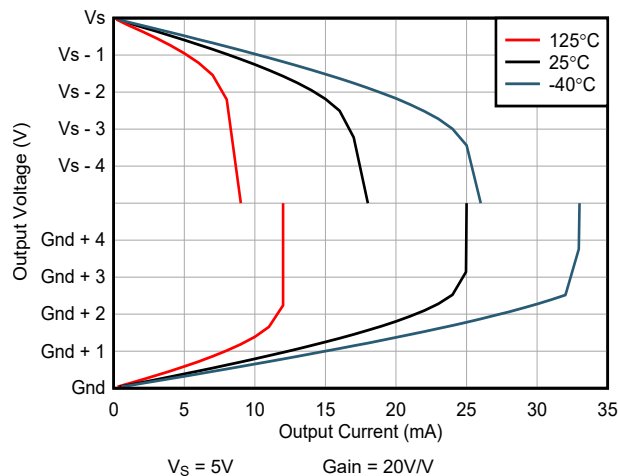


Figure 5-17. Output Voltage vs Output Current

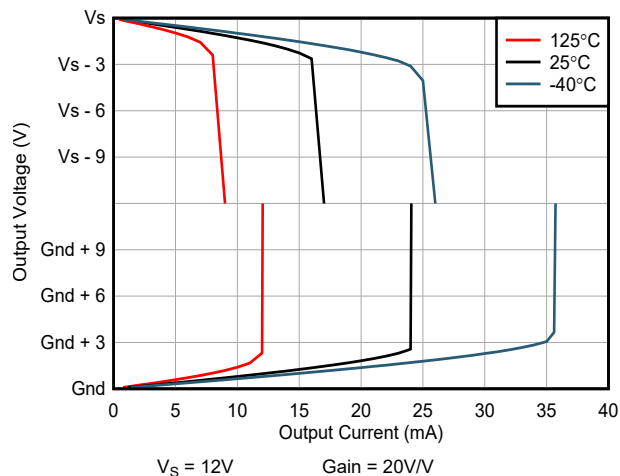
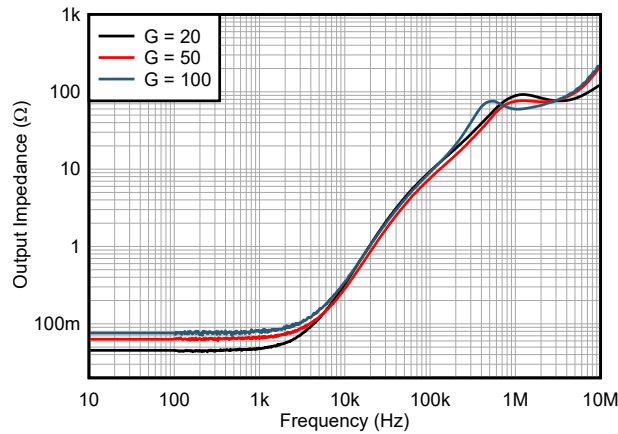


Figure 5-18. Output Voltage vs Output Current

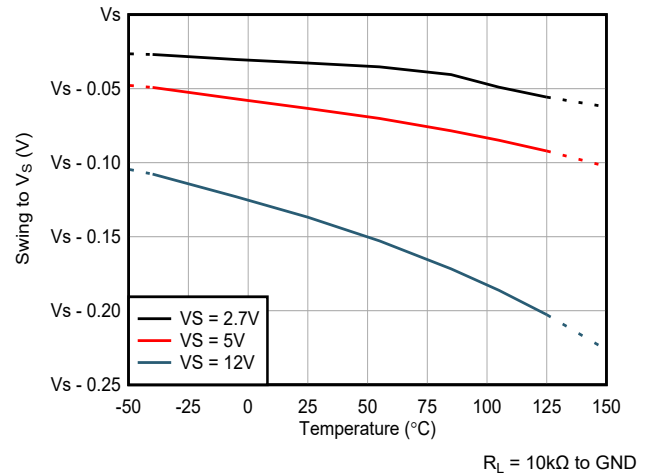


## 5.6 Typical Characteristics (continued)

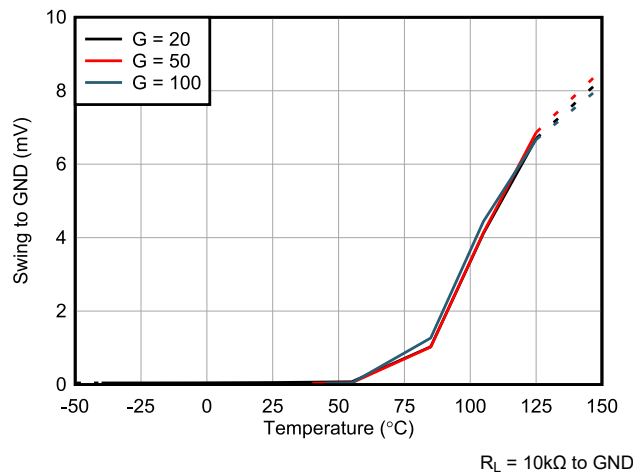
at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{\text{SENSE}} = V_{\text{IN}+} - V_{\text{IN}-} = 0\text{V}$ ,  $V_{\text{CM}} = V_{\text{IN}-} = 48\text{V}$ , and  $V_{\text{REF}} = V_S / 2$  (unless otherwise noted)



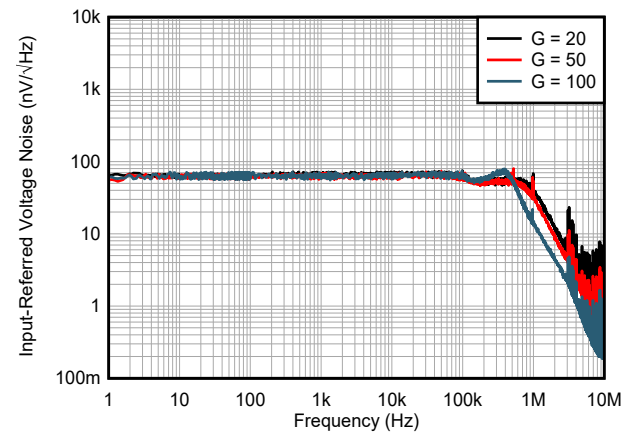
**Figure 5-19. Output Impedance vs Frequency**



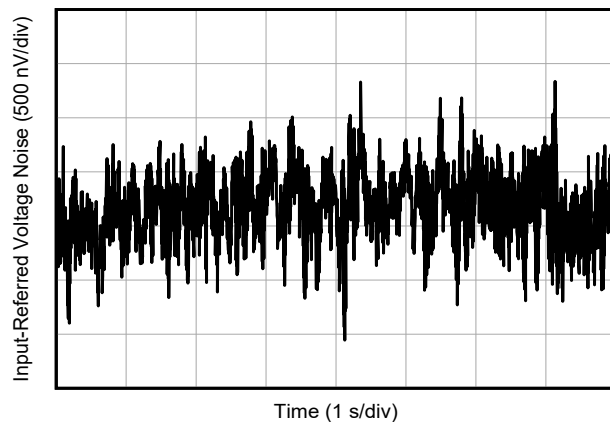
**Figure 5-20. Swing to Supply vs Temperature**



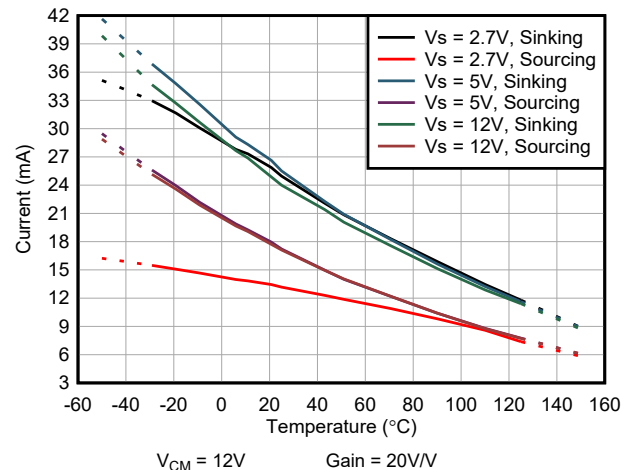
**Figure 5-21. Swing to GND vs Temperature**



**Figure 5-22. Input Referred Noise vs Frequency**



**Figure 5-23. 0.1Hz to 10Hz Voltage Noise**



**Figure 5-24. Short-Circuit Current vs Temperature**

## 5.6 Typical Characteristics (continued)

at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{\text{SENSE}} = V_{\text{IN}+} - V_{\text{IN}-} = 0\text{V}$ ,  $V_{\text{CM}} = V_{\text{IN}-} = 48\text{V}$ , and  $V_{\text{REF}} = V_S / 2$  (unless otherwise noted)

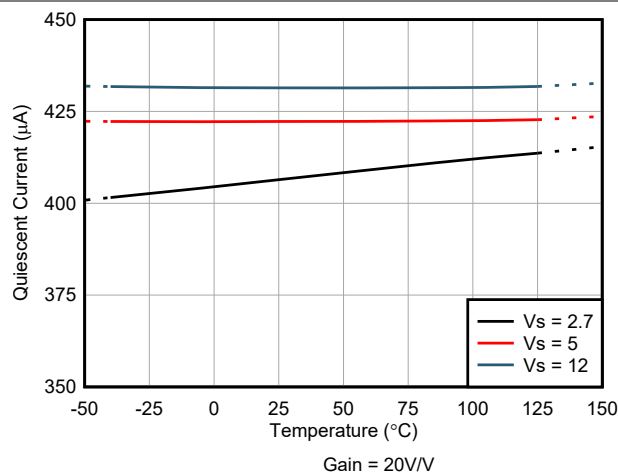


Figure 5-25. Quiescent Current vs Temperature

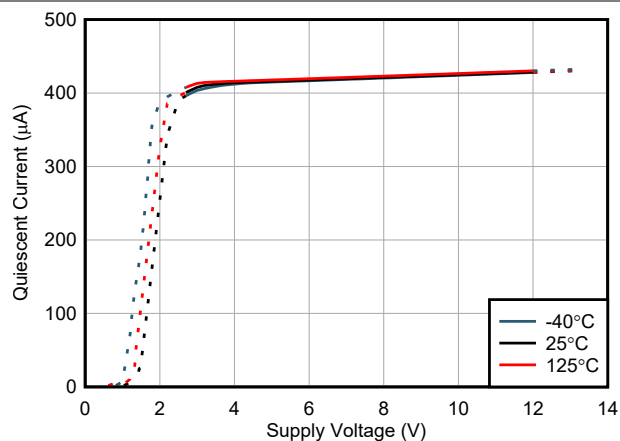


Figure 5-26. Quiescent Current vs Supply Voltage

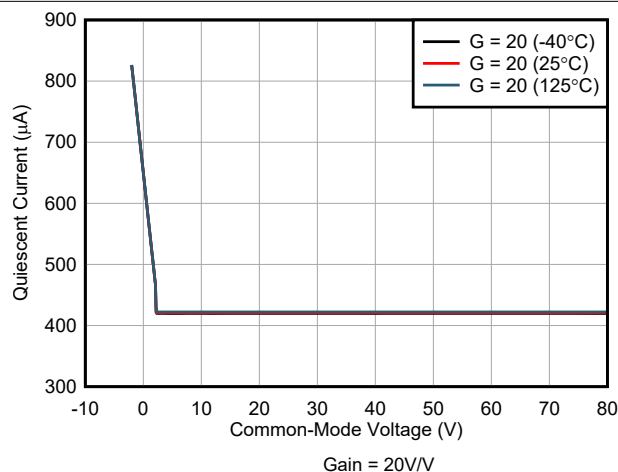


Figure 5-27. Quiescent Current vs Common-Mode Voltage

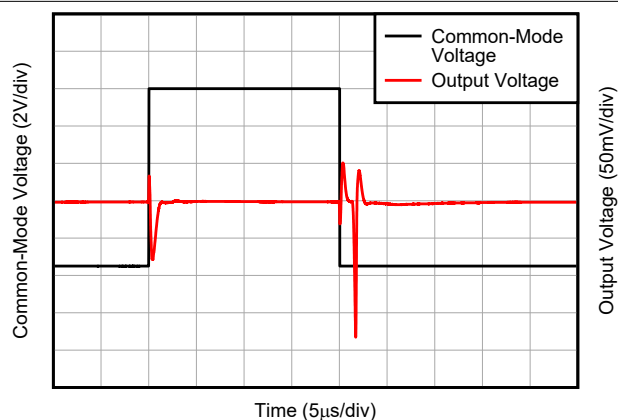


Figure 5-28. Common-Mode Voltage Fast Transient Pulse

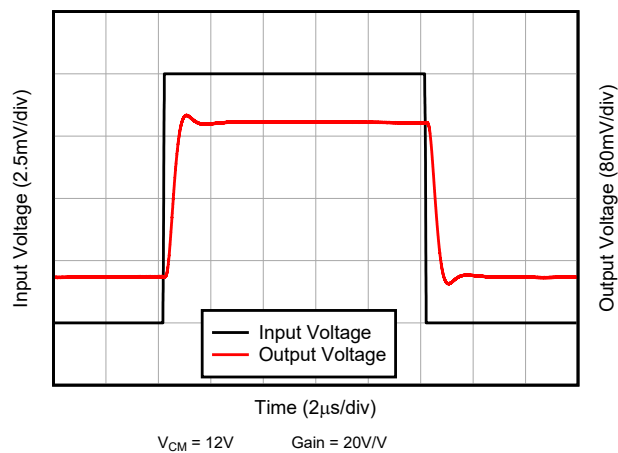


Figure 5-29. Small Step Response

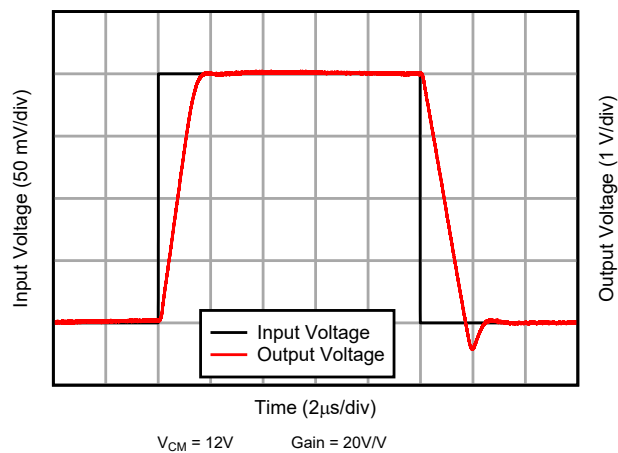
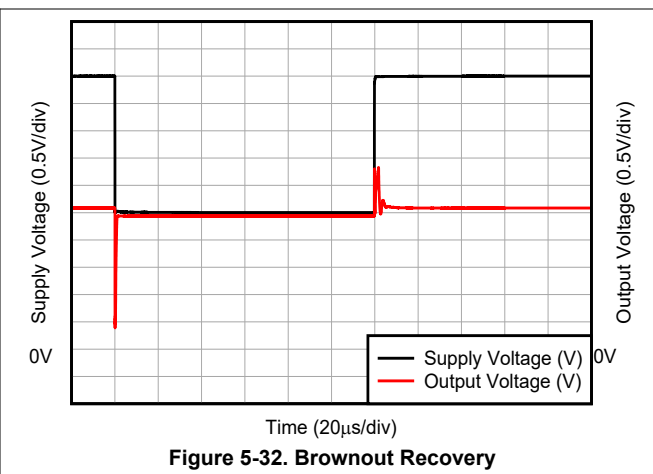
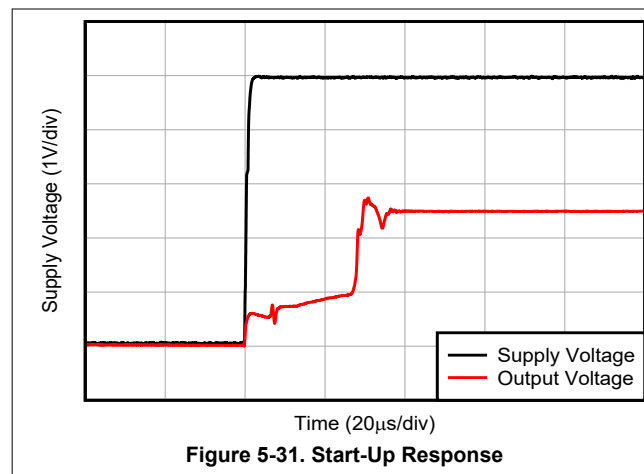


Figure 5-30. Large Step Response

## 5.6 Typical Characteristics (continued)

at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{V}$ ,  $V_{\text{SENSE}} = V_{\text{IN}+} - V_{\text{IN}-} = 0\text{V}$ ,  $V_{\text{CM}} = V_{\text{IN}-} = 48\text{V}$ , and  $V_{\text{REF}} = V_S / 2$  (unless otherwise noted)

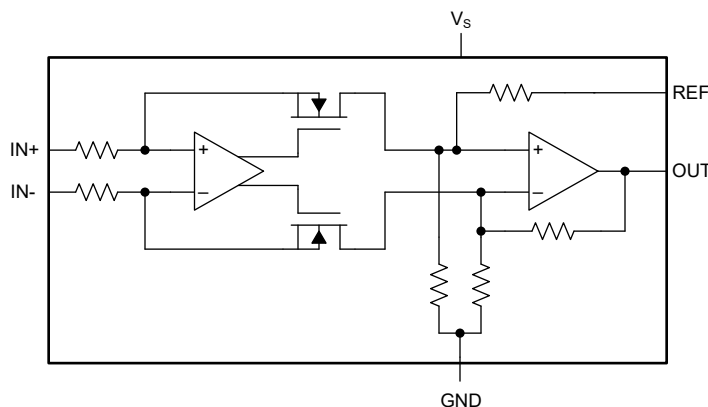


## 6 Detailed Description

### 6.1 Overview

The INA299 is a high-side or low-side bidirectional, high-bandwidth current-sense amplifier that offers a wide common-mode range, precision zero-drift topology, good common-mode rejection ratio (CMRR) and fast slew rate. Different gain versions are available to optimize the output dynamic range based on the application. The INA299 is designed using an architecture that enables low bias currents of 13 $\mu$ A with a specified common-mode voltage range from  $-2$ V to 80V with signal bandwidths up to 650kHz.

### 6.2 Functional Block Diagram



### 6.3 Feature Description

#### 6.3.1 Amplifier Input Common-Mode Signal

The INA299 supports large input common-mode voltages from  $-2$ V to  $+80$ V. The internal topology of the INA299 allows the common-mode range to exceed the power-supply voltage ( $V_S$ ). This allows for the INA299 to be used for low-side or high-side current-sensing applications that extend beyond the supply range of 2.7V to 12V.

#### 6.3.2 Low Input Bias Current

The INA299 inputs draw 13 $\mu$ A (typical) bias current per input pin at common-mode voltages as high as 80V, which enables precision current sensing on applications that require lower current leakage. The input bias current is proportional to the common-mode voltage at  $-2$ V to 2.5V, after that the input bias current of the INA299 remains constant over the entire common-mode voltage range.

#### 6.3.3 Low $V_{SENSE}$ Operation

The INA299 features high performance operation across the entire valid  $V_{SENSE}$  range. The zero-drift input architecture of the INA299 provides the low offset voltage and low offset drift needed to measure low  $V_{SENSE}$  levels accurately across the wide operating temperature of  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ . Low  $V_{SENSE}$  operation is particularly beneficial when using low ohmic shunts for low current measurements, as power losses across the shunt are significantly reduced.

#### 6.3.4 Wide Fixed Gain Output

The INA299 maximum gain error is  $\pm 0.25\%$  at room temperature, with a maximum drift of  $\pm 10\text{ppm}/^{\circ}\text{C}$  over the full temperature range of  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ . The INA299 is available in multiple gain options of 20V/V, 50V/V, and 100V/V which the system designer must select based on the desired signal-to-noise ratio and other system requirements, such as the dynamic current range and full-scale output voltage target.

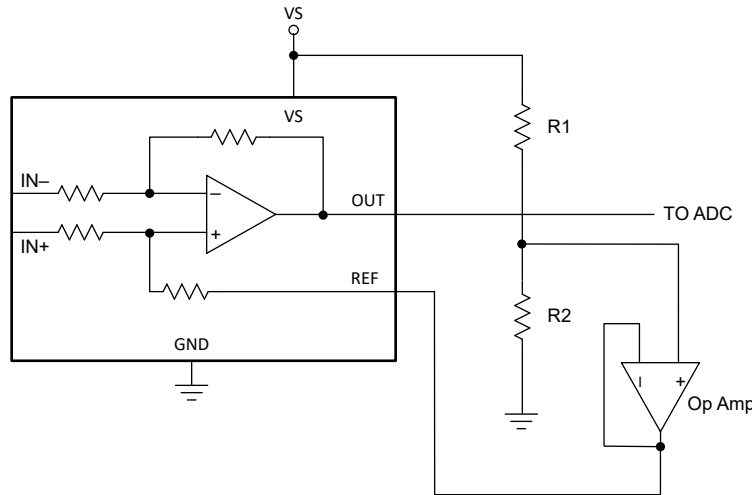
#### 6.3.5 Wide Supply Range

The INA299 operates with a wide supply range from 2.7V to 12V. While the input common-mode voltage range of the INA299 is independent of the supply voltage, the output voltage is bound by the supply voltage applied to the device. The output voltage can range from as low as 80mV to as high as 100mV below the supply voltage.

## 6.4 Device Functional Modes

### 6.4.1 Adjusting the Output With the Reference Pin

Figure 6-1 shows the reference pin driven at the divided supply voltage to bias the output at the same voltage when differential input voltage is 0V. The INA299 output is configurable to allow for unidirectional or bidirectional operation.



**Figure 6-1. Reference Pin Adjusting the Output**

The output voltage is set by applying a voltage to the reference input pin, REF. REF is connected to a precisely matched internal gain network. When REF is connected to buffered divided supply voltage, the output is set at the mid-point voltage when current-sense input voltage is 0V as shown in Equation 1. In most bidirectional applications REF is driven to mid supply to set the output voltage to mid-supply.

$$V_{OUT} = G \times (V_{IN+} - V_{IN-}) + V_{REF} \quad (1)$$

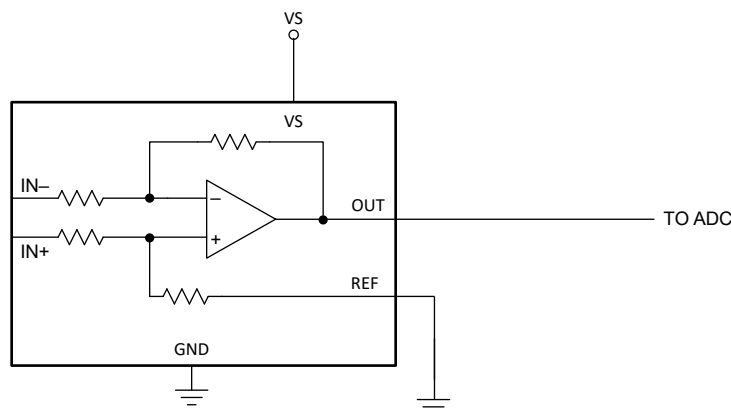
### 6.4.2 Reference Pin Connections for Unidirectional Current Measurements

Unidirectional operation allows current measurements through a resistive shunt in one direction. For unidirectional operation, connect the device reference pin to the negative rail (see the [Ground Referenced Output](#) section) or the positive rail (see the [VS Referenced Output](#) section). The required differential input polarity depends on the reference input setting. The amplifier output moves away from the referenced rail proportional to the current passing through the external shunt resistor. If the amplifier reference pin is connected to the positive rail, then the input polarity must be negative to move the amplifier output down (towards ground). If the amplifier reference pin is connected to ground, then the input polarity must be positive to move the amplifier output up (towards supply).

The following sections describe how to configure the output for unidirectional operation cases.

#### 6.4.2.1 Ground Referenced Output

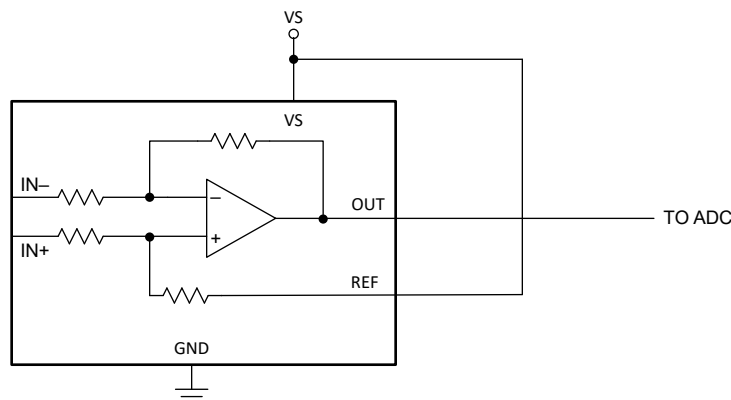
When using the INA299 in a unidirectional mode with a ground referenced output, the reference input is connected to ground. This configuration takes the output to ground when there is a 0V differential at the input (see [Figure 6-2](#)).



**Figure 6-2. Ground Referenced Output**

#### 6.4.2.2 VS Referenced Output

Unidirectional mode with a VS referenced output is configured by connecting the reference pin to the positive supply. Use this configuration for circuits that has negative current magnitude. This configuration takes the output to the supply when there is a 0V differential at the input (see [Figure 6-3](#)).



**Figure 6-3. VS Referenced Output**

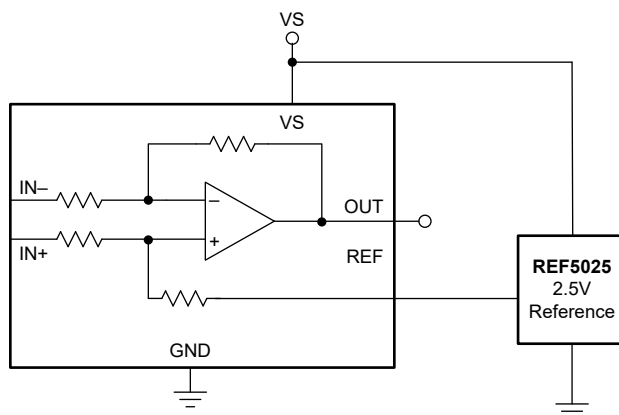
#### 6.4.3 Reference Pin Connections for Bidirectional Current Measurements

The INA299 measures the differential voltage developed by current flowing through a resistor, commonly referred to as a current-sensing resistor or a current-shunt resistor. The INA299 can operate in either a unidirectional or bidirectional mode based on the voltage potential placed on the reference pin.

The linear range of the output stage is limited to how close the output voltage can approach ground as well the supply voltage as described in the [Specifications](#). The value of the current-sensing resistor along with the current range to be measured, optimum gain option, as well as the voltage applied to the reference pin must be selected to keep the INA299 within the linear region of operation.

##### 6.4.3.1 Output Set to External Reference Voltage

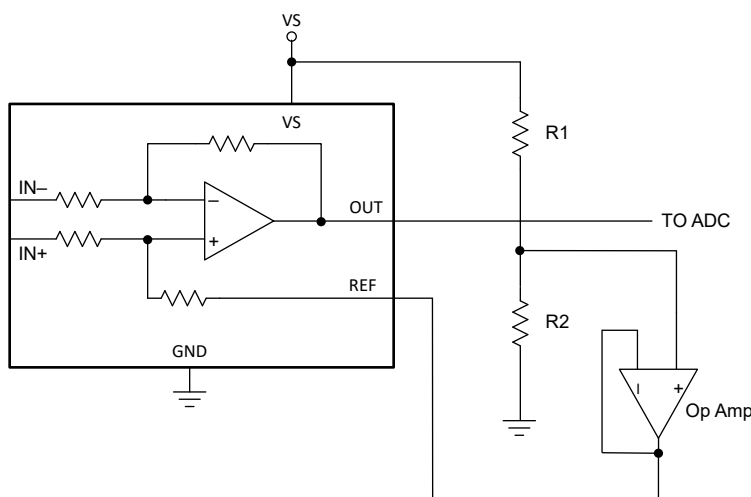
Connecting the reference pin to an external reference voltage results in an output voltage equal to the reference voltage for the condition of shorted input pins or a 0V differential input. [Figure 6-4](#) shows this configuration. The output voltage decreases below the reference voltage when the IN+ pin is negative relative to the IN- pin and increases when the IN+ pin is positive relative to the IN- pin. This technique is the most accurate way to bias the output to a precise voltage.



**Figure 6-4. External Reference Output**

#### 6.4.3.2 Output Set to Mid-Supply Voltage

Figure 6-5 shows by connecting the reference pin to equally divide supply voltage VS sets the output at half of the supply voltage when there is no differential input. This method creates a ratiometric offset to the supply voltage, where the output voltage remains at  $VS / 2$  for 0V applied to the inputs.



**Figure 6-5. Mid-Supply Voltage Output**

## 7 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, as well as validating and testing their design implementation to confirm system functionality.

### 7.1 Application Information

The INA299 amplifies the voltage developed across a current-sensing resistor as current flows through the resistor to the load. The wide input common-mode voltage range and high common-mode rejection of the INA299 make it usable over a wide range of voltage rails while still maintaining an accurate current measurement.

#### 7.1.1 $R_{SENSE}$ and Device Gain Selection

The accuracy of any current-sense amplifier is maximized by choosing the largest current-sense resistor value possible. A larger value sense resistor maximizes the differential input signal for a given amount of current flow and reduces the error contribution of the offset voltage. However, there are practical limits as to how large the current-sense resistor value can be in a given application because of the physical dimensions of the package, package construction, and maximum power dissipation. Equation 2 gives the maximum value for the current-sense resistor for a given power dissipation budget:

$$R_{SENSE} < \frac{PD_{MAX}}{I_{MAX}^2} \quad (2)$$

where:

- $PD_{MAX}$  is the maximum allowable power dissipation in  $R_{SENSE}$ .
- $I_{MAX}$  is the maximum current that flows through  $R_{SENSE}$ .

An additional limitation on the size of the current-sense resistor and device gain is due to the power-supply voltage,  $V_S$ , and device swing-to-rail limitations. To verify that the current-sense signal is properly passed to the output, both positive and negative output swing limitations must be examined. Equation 3 provides the maximum values of  $R_{SENSE}$  and GAIN to keep the device from exceeding the positive swing limitation.

$$I_{MAX} \times R_{SENSE} \times GAIN < V_{SP} \quad (3)$$

where:

- $I_{MAX}$  is the maximum current that flows through  $R_{SENSE}$ .
- GAIN is the gain of the current-sense amplifier.
- $V_{SP}$  is the positive output swing of the device as specified in the [Specifications](#).

To avoid positive output swing limitations when selecting the value of  $R_{SENSE}$ , there is always a trade-off between the value of the sense resistor and the gain of the device under consideration. If the sense resistor selected for the maximum power dissipation is too large, then selecting a lower gain device is possible to avoid positive swing limitations.

The negative swing limitation places a limit on how small the sense resistor value can be for a given application. Equation 4 provides the limit on the minimum value of the sense resistor.

$$I_{MIN} \times R_{SENSE} \times GAIN > V_{SN} \quad (4)$$

where:



- $I_{MIN}$  is the minimum current that flows through  $R_{SENSE}$ .
- GAIN is the gain of the current-sense amplifier.
- $V_{SN}$  is the negative output swing of the device as specified in the [Specifications](#).

Table 7-1 shows an example of the different results obtained from using five different gain versions of the INA299. From the table data, the highest gain device allows a smaller current-shunt resistor and decreased power dissipation in the element.

**Table 7-1.  $R_{SENSE}$  Selection and Power Dissipation <sup>(1)</sup>**

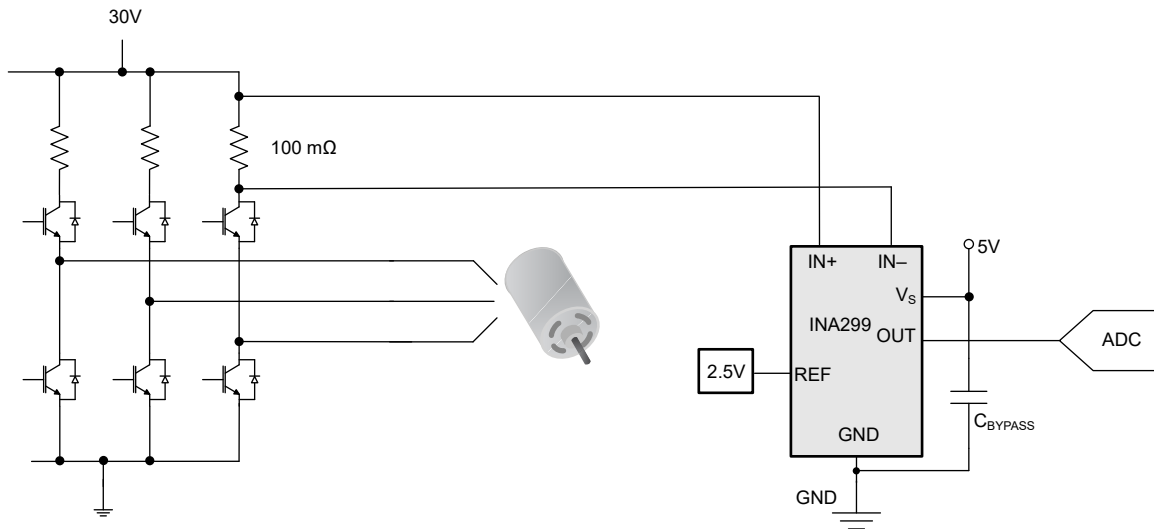
PARAMETER		EQUATION	RESULTS AT $V_S = 5V$		
			A1 DEVICES	A2 DEVICES	A3 DEVICES
G	Gain		20V/V	50V/V	100V/V
$V_{SENSE}$	Ideal differential input voltage	$V_{SENSE} = V_{OUT} / G$	250mV	100mV	50mV
$R_{SENSE}$	Current sense resistor value	$R_{SENSE} = V_{SENSE} / I_{MAX}$	25mΩ	10mΩ	5mΩ
$P_{SENSE}$	Current-sense resistor power dissipation	$R_{SENSE} \times I_{MAX}^2$	2.5W	1W	0.5W

(1) Design example with 10A full-scale current with maximum output voltage set to 5V.

## 7.2 Typical Application

The INA299 is a bidirectional, current-sense amplifier capable of measuring currents through a resistive shunt with common-mode voltages from  $-2V$  to  $+80V$ .

### 7.2.1 High-side Current Sensing in Motor Application



**Figure 7-1. High-Side Motor Current-Sense Application Circuit**

#### 7.2.1.1 Design Requirements

In this example application, the common-mode voltage ranges from 0V to 30V. The maximum sense current is 0.5A, and a 5V supply is available for the INA299. Following the design guidelines from  [\$R\_{SENSE}\$  and Device Gain Selection](#), a  $R_{SENSE}$  of 100mΩ and a gain of 50V/V are selected to provide good output dynamic range. Table 7-2 lists the design setup for this application.

**Table 7-2. Design Parameters**

DESIGN PARAMETERS	EXAMPLE VALUE
Power supply voltage	5V
Common mode voltage range	30V
Maximum sense current	0.5A
$R_{SENSE}$ resistor	100mΩ

**Table 7-2. Design Parameters (continued)**

DESIGN PARAMETERS	EXAMPLE VALUE
Gain option	50V/V

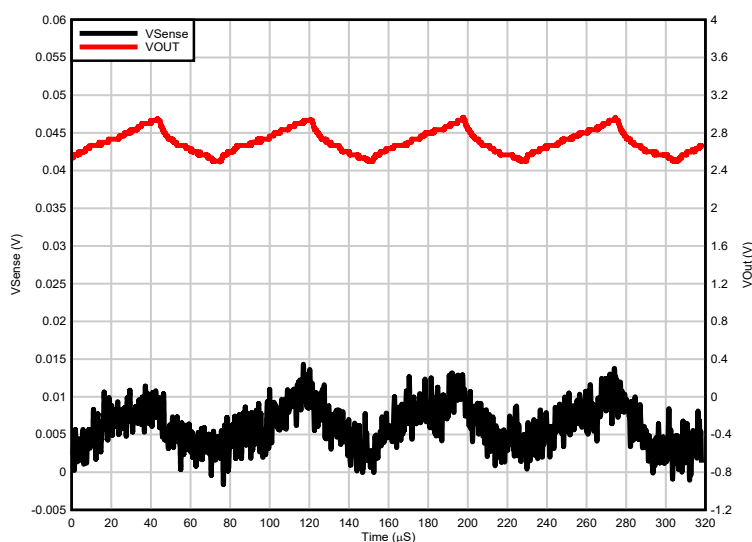
### 7.2.1.2 Detailed Design Procedure

The INA299 is designed to measure a typical high-side current in motor application. The INA299 measures current across the 100mΩ shunt that is placed at supply in series with half-bridge driving a motor. The INA299 measures the differential voltage across the shunt resistor, and the signal is internally amplified with a gain of 50V/V. The output of the INA299 is connected to the analog-to-digital converter (ADC) of an MCU to digitize the current measurements.

Measuring current on the motor can provide indication of failure. Measuring high-side current also indicates if there are any ground faults on the motor or the FETs that can be damaged in an application. The INA299, with high bandwidth and slew rate, can be used to detect fast overcurrent conditions to prevent the motor damage from short-to-ground faults.

### 7.2.1.3 Application Curve

Figure 7-2 shows the current response of a motor.


**Figure 7-2. High-Side Motor Current Measurement**

## 7.3 Power Supply Recommendations

The INA299 makes accurate measurements beyond the connected power-supply voltage ( $V_S$ ) because the inputs (IN+ and IN–) can operate anywhere between –2V and +80V independent of  $V_S$ . For example, with the  $V_S$  power supply equal to 5V, the common-mode voltage of the measured shunt can be as high as +80V.

### 7.3.1 Power Supply Decoupling

Place the power-supply bypass capacitor as close to the supply and ground pins as possible. TI recommends a bypass capacitor value of 0.1μF. Additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies.

## 7.4 Layout

### 7.4.1 Layout Guidelines

Attention to good layout practices is always recommended.

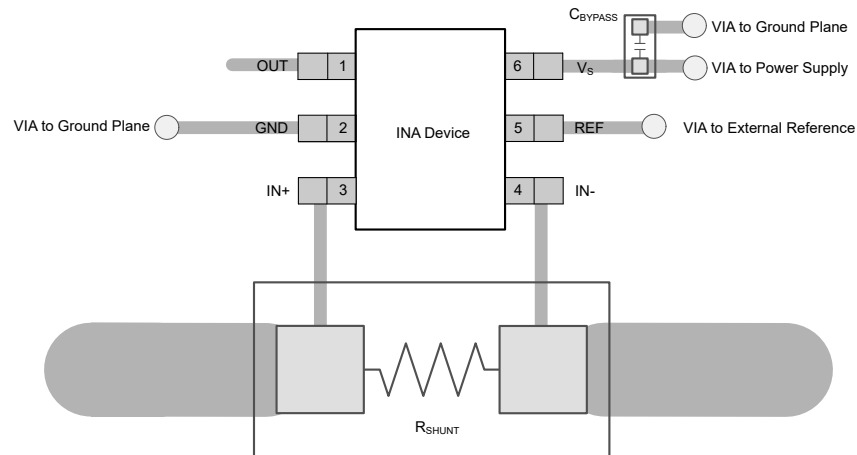
- Connect the input pins to the sensing resistor using a Kelvin or 4-wire connection. This connection technique makes sure that only the current-sensing resistor impedance is detected between the input pins. Poor routing

of the current-sensing resistor commonly results in additional resistance present between the input pins.

Given the very low ohmic value of the current sense resistor, any additional high-current carrying impedance can cause significant measurement errors.

- Place the power-supply bypass capacitor as close to the device power supply and ground pins as possible. The recommended value of this bypass capacitor is 0.1  $\mu\text{F}$ . Additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies.

### 7.4.2 Layout Examples



**Figure 7-3. INA299 SOT-23 6-pin (DBV) Package Recommended Layout**

## 8 Device and Documentation Support

### 8.1 Documentation Support

#### 8.1.1 Related Documentation

For related documentation see the following: Texas Instruments,

- Texas Instruments, [INA299xEVM](#), EVM User's Guide

### 8.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

### 8.3 Support Resources

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

### 8.4 Trademarks

TI E2E™ is a trademark of Texas Instruments.

All trademarks are the property of their respective owners.

### 8.5 Electrostatic Discharge Caution



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.

### 8.6 Glossary

#### [TI Glossary](#)

This glossary lists and explains terms, acronyms, and definitions.

## 9 Revision History

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

DATE	REVISION	NOTES
May 2025	*	Initial Release

## 10 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

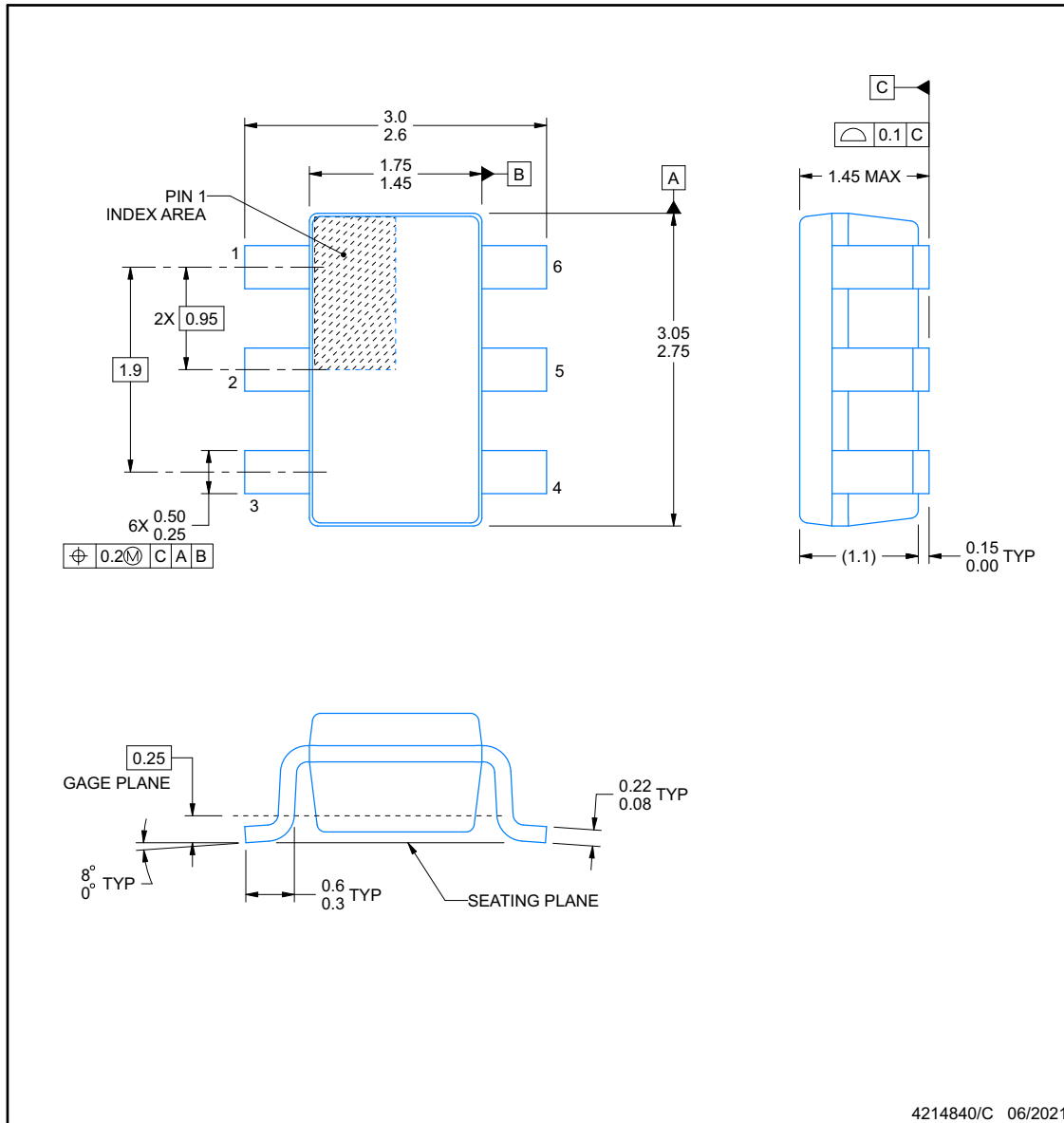
## 10.1 Mechanical Data



**DBV0006A**

**PACKAGE OUTLINE**  
**SOT-23 - 1.45 mm max height**

SMALL OUTLINE TRANSISTOR



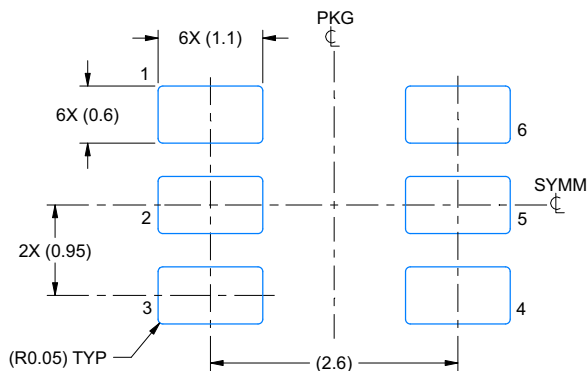
4214840/C 06/2021

### NOTES:

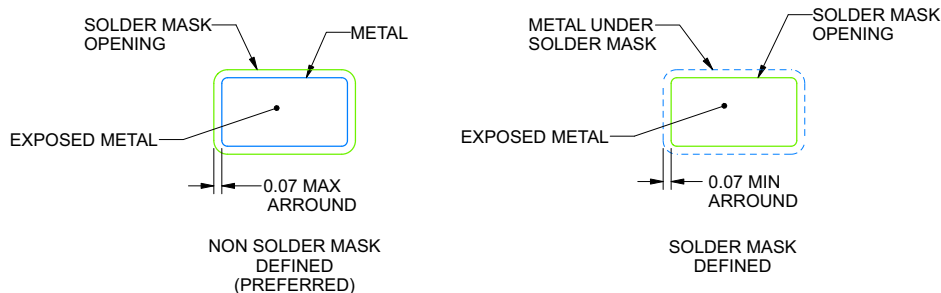
- All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
- This drawing is subject to change without notice.
- Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.25 per side.
- Leads 1,2,3 may be wider than leads 4,5,6 for package orientation.
- Reference JEDEC MO-178.

**EXAMPLE BOARD LAYOUT****DBV0006A****SOT-23 - 1.45 mm max height**

SMALL OUTLINE TRANSISTOR



**LAND PATTERN EXAMPLE**  
EXPOSED METAL SHOWN  
SCALE:15X

**SOLDER MASK DETAILS**

4214840/C 06/2021

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

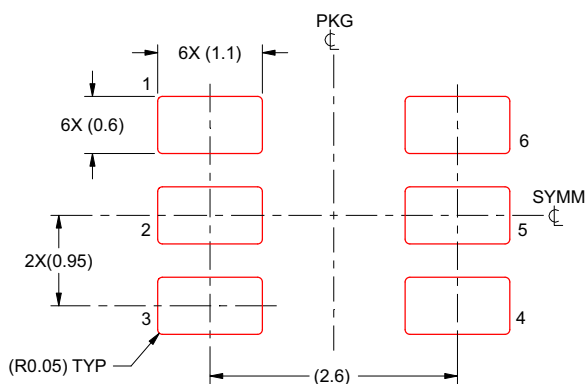
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## EXAMPLE STENCIL DESIGN

**DBV0006A**

**SOT-23 - 1.45 mm max height**

SMALL OUTLINE TRANSISTOR



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

4214840/C 06/2021

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.

## Package Option Addendum

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead finish/ Ball material <sup>(6)</sup>	MSL Peak Temp <sup>(3)</sup>	Op Temp (°C)	Device Marking <sup>(4) (5)</sup>
INA299A1IDBVR	ACTIVE	SOT-23	DRV	6	3000	RoHS & Green	MATTE TIN	Level-1-260C-UNLIM	-40 to 125	3OPF
INA299A2IDBVR	ACTIVE	SOT-23	DRV	6	3000	RoHS & Green	MATTE TIN	Level-1-260C-UNLIM	-40 to 125	3OQF
INA299A3IDBVR	ACTIVE	SOT-23	DRV	6	3000	RoHS & Green	MATTE TIN	Level-1-260C-UNLIM	-40 to 125	3ORF

- (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) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

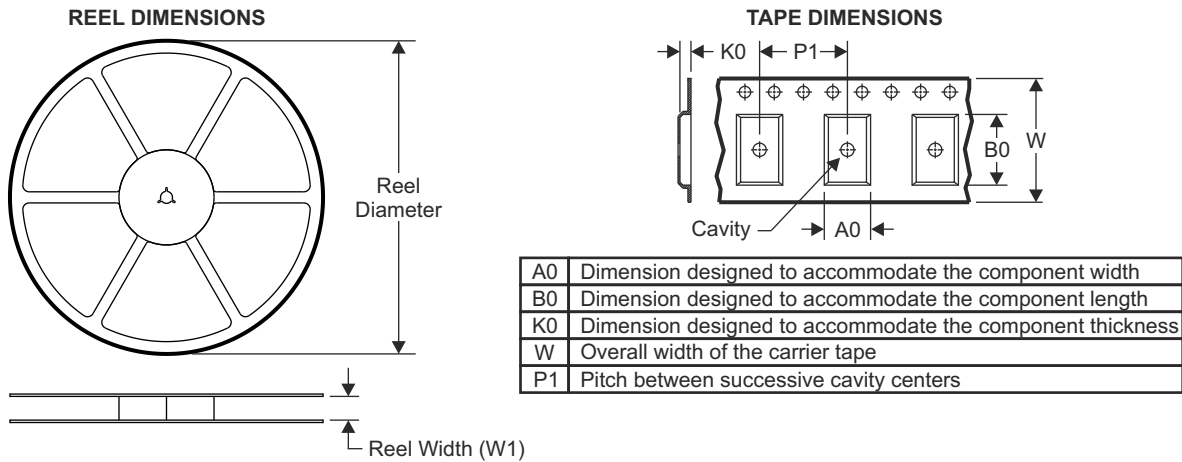
- (3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.
- (4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.
- (5) Multiple 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 finish/Ball material - Orderable Devices 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.

**Important Information and Disclaimer:** The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

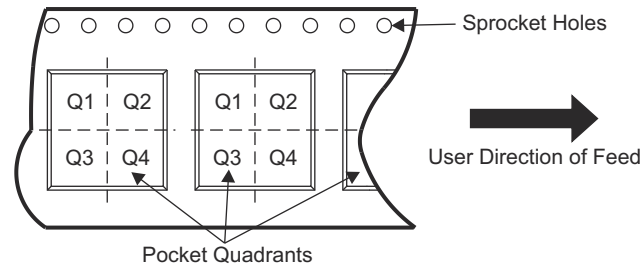
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.



## 10.2 Tape and Reel Information

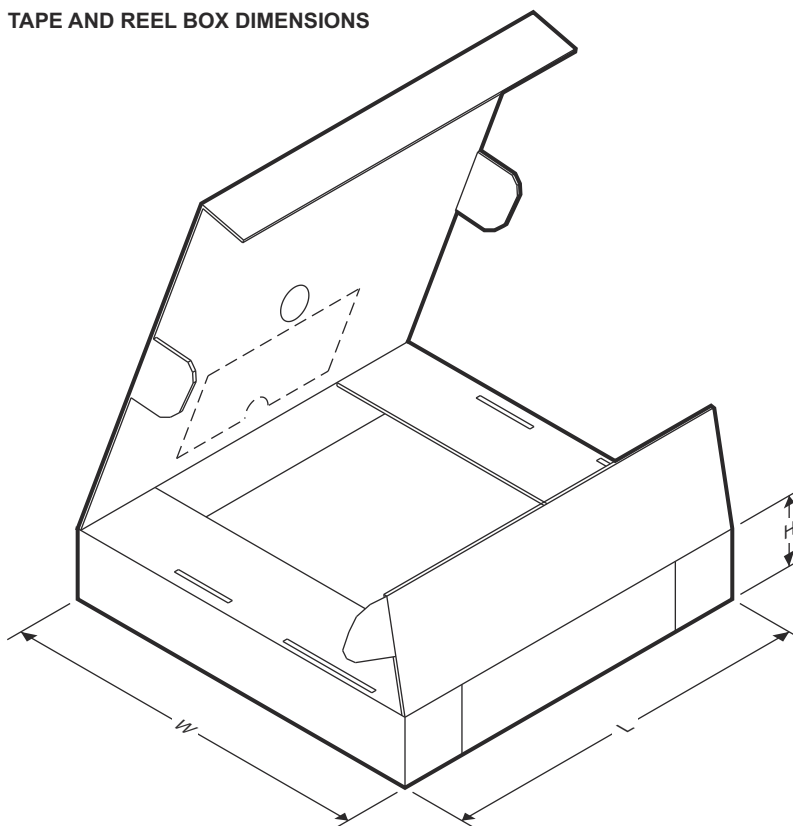


### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



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
INA299A1IDBVR	SOT-23	DRV	6	3000	180	8.4	3.2	3.2	1.4	4	8	3
INA299A2IDBVR	SOT-23	DRV	6	3000	180	8.4	3.2	3.2	1.4	4	8	3
INA299A3IDBVR	SOT-23	DRV	6	3000	180	8.4	3.2	3.2	1.4	4	8	3

## TAPE AND REEL BOX DIMENSIONS



Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
INA299A1IDBVR	SOT-23	DRV	6	3000	210	185	35
INA299A2IDBVR	SOT-23	DRV	6	3000	210	185	35
INA299A3IDBVR	SOT-23	DRV	6	3000	210	185	35

## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2025, Texas Instruments Incorporated