INA187 -2V to 42V, Bi-directional, 650kHz, High-Precision Current Sense Amplifier

1 Features

- Wide common-mode voltage:
  - Operational voltage: −2V to +42V
  - Survival voltage: −12V to +48V
- 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:
  - INA187A1: 20V/V
  - INA187A2: 50V/V
  - INA187A3: 100V/V
- Package options: SOT23-6 (DBV)

2 Applications

- Motor drives
- Solenoids and actuators
- Injection molding machine
- Cordless power tools

3 Description

The INA187 is a precise, bidirectional current sense amplifier that can measure voltage drops across shunt resistors over a wide common-mode range from –2V to 42V, 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 INA187 is not only designed for 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.

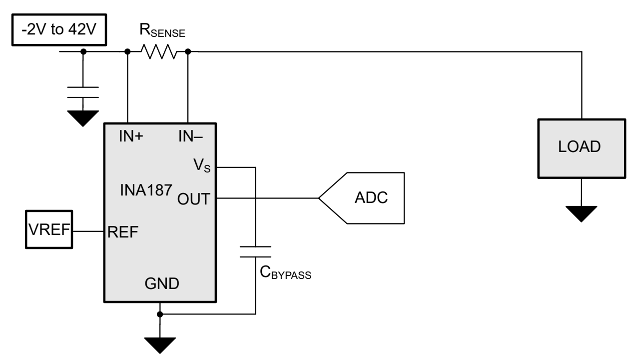
The INA187 operates from a single 2.7V to 12V supply, drawing 650µA of supply current. The INA187 is available in three gain options: 20V/V, 50V/V, 100V/V. Multiple gain options allow for optimization between available shunt resistor values and wide output dynamic range requirements.

The INA187 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(1)	PACKAGE SIZE(2)
INA187	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

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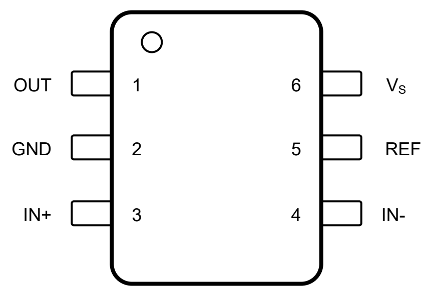
4 Pin Configuration and Functions



Not to scale

Figure 4-1. INA187 : DBV 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 *Adjusting the Output With the Reference Pin* 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)[1]

		MIN	MAX	UNIT
Supply Voltage (V_s)	(V_s – GND)	–0.3	13.2	V
Analog Inputs, V_{IN+}, $V_{IN–}$ [2]	Differential (V_{IN+}) – ($V_{IN–}$)	–6	6	V
Analog Inputs, V_{IN+}, $V_{IN–}$ [2]	Common - mode	–12	48	V
REF		GND – 0.3	V_s + 0.3	V
Output		GND – 0.3	V_s + 0.3	V
T_A	Operating temperature	–55	150	°C
T_J	Junction temperature		150	°C
T_{stg}	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) VIN+ and VIN– are the voltages at the IN+ and IN– pins, respectively.

5.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins[1]	±2000	V
		Charged device model (CDM), per ANSI/ESDA/JEDEC JS-002, all pins[2]	±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_{CM}	Common-mode input range	–2	24	42	V
V_S	Operating supply range	2.7	5	12	V
V_{SENSE}	Differential sense input range	0		V_S / G	V
T_A	Ambient temperature	–40		125	°C

5.4 Thermal Information

THERMAL METRIC[1]		INA187 DBV (SOT-23) 6 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	158.8	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	76.9	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	41.4	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	17.3	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	41.1	°C/W

THERMAL METRIC[(1)]		INA187 DBV (SOT-23) 6 PINS	UNIT
$R_{\theta JC(bot)}$	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 °C, V_S = 5V, V_{REF} = V_S / 2, V_{SENSE} = 0V, V_{CM} = V_{IN-} = 24V, (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
INPUT						
V_{CM}	Common-mode input range[(1)]	T_A = -40°C to +125°C	–2		42	V
CMRR	Common-mode rejection ratio, input referred	2.5V < V_{CM} < 42V,	110	120		dB
		0V < V_{CM} < 42V,	80	90		
		-2V < V_{CM} ≤ 2.5V,	65			
		f = 50kHz, V_{CM} = 12V		65		
V_{os}	Offset voltage, input referred	V_{CM} = 2.5V	–150		150	µV
		V_{CM} = 2.5V, T_A = -40°C to +125°C	–200		200	
dV_{os}/dT	Offset voltage drift	V_{CM} = 2.5V			±0.5	µV/°C
PSRR	Power supply rejection ratio, input referred	V_{CM} = 2.5V, 2.7V ≤ V_S ≤ 12V, V_{REF} = 1V T_A = -40°C to +125°C			±6	µV/V
I_B	Input bias current	I_{B+}, I_{B-}, V_{CM} = 2.5V, V_{SENSE} = 0V		13	± 21	µA
		I_{B+}, I_{B-}, V_{CM} = 2.5V, V_{SENSE} = 0V, T_A = -40°C to +125°C			±28	
	Reference input range		0		V_S	V
RVRR	Reference voltage rejection ratio, input referred	V_{REF}= 0.5V to 4.5V, T_A = –40°C to +125°C		±5	±20	µV/V
OUTPUT						
G	Gain	INA187A1		20		V/V
		INA187A2		50		
		INA187A3		100		
G_{ERR}	Gain error	V_{CM} = 2.5V, (GND + 50mV) < V_{OUT} < (VS - 200mV)			±0.25	%
	Gain error drift	V_{CM} = 2.5V, T_A = -40°C to +125°C, (GND + 50mV) < V_{OUT} < (VS - 200mV)			10	ppm/°C
NL_{ERR}	Nonlinearity error	V_{OUT} = 0.5V to 4.5V, V_{CM} = 12V		0.01		%
	Maximum capacitive load	No sustained oscillations, no isolation resistor		500		pF
VOLTAGE OUTPUT						
	Swing to Vs (Power supply rail)	V_{CM} = 2.5V, RL = 10kΩ to GND	4.9			V
	Swing to ground	V_{CM} = 2.5V, RL = 10kΩ to GND			80	mV
FREQUENCY RESPONSE						
BW	Bandwidth	INA187A1		650		kHz
		INA187A2		500		
		INA187A3		400		

at T_A = 25 °C, V_S = 5V, V_{REF} = V_S / 2, V_{SENSE} = 0V, V_{CM} = V_{IN-} = 24V, (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
	Settling time	V_{OUT} = 0.5V to 4.5V step, Output settles to 1%		6.5		µs
		V_{OUT} = 0.5V to 4.5V step, Output settles to 5%		3		
SR	Slew rate	INA187A1, V_{SENSE} = ±100mV, INA187A2, V_{SENSE} = ±40mV, INA187A3, V_{SENSE} = ±20mV,		2.5		V/µs
NOISE						
Ven	Voltage noise density	f > 10kHz		117		nV/√Hz
POWER SUPPLY						
I_Q	Quiescent current	V_{CM} = 2.5V		450	600	µA
		V_{CM} = 2.5V, T_A = -40°C to +125°C			650	µA
		V_{CM} = -2V		950	1100	µA
		V_{CM} = -2V, T_A = -40°C to +125°C			1200	µA
T_A	Specified Range		–40		125	°C

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

5.6 Typical Characteristics

at T_A = 25°C, V_S = 5V, V_{SENSE} = V_{IN+} – $V_{IN–}$ = 0V, V_{CM} = $V_{IN–}$ = 24V, and V_{REF} = V_S / 2 (unless otherwise noted)

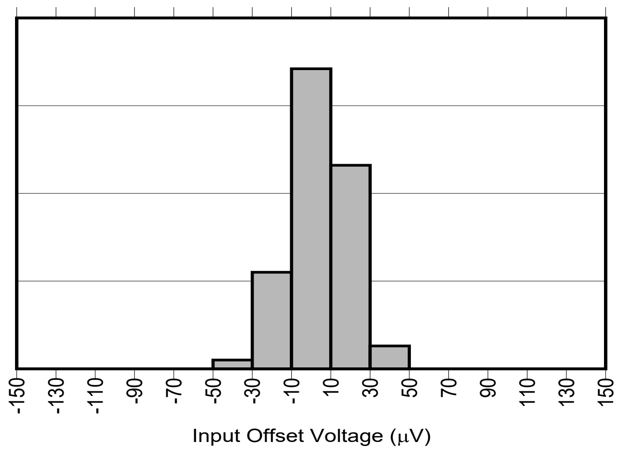


Figure 5-1. INA187 Input Offset Voltage Production Distribution

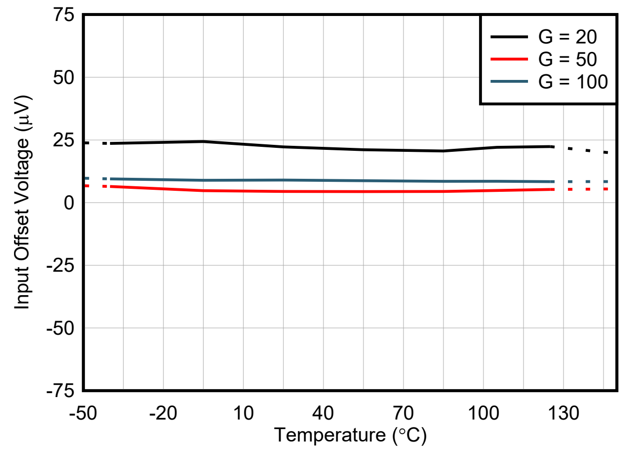


Figure 5-2. Input Offset Voltage vs Temperature

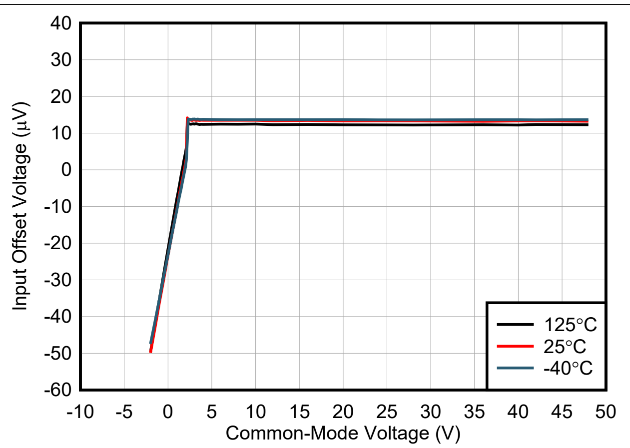


Figure 5-3. Input Offset Voltage vs Common-Mode Voltage

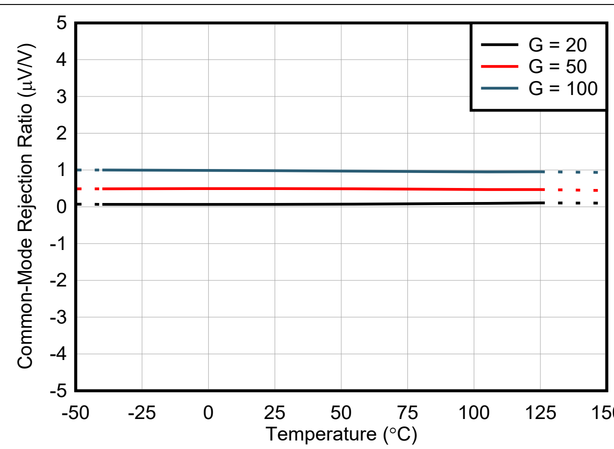


Figure 5-4. Common-Mode Rejection Ratio vs Temperature

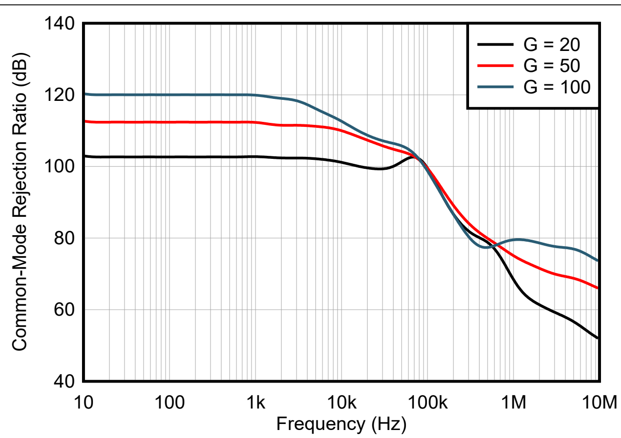


Figure 5-5. Common-Mode Rejection Ratio vs Frequency

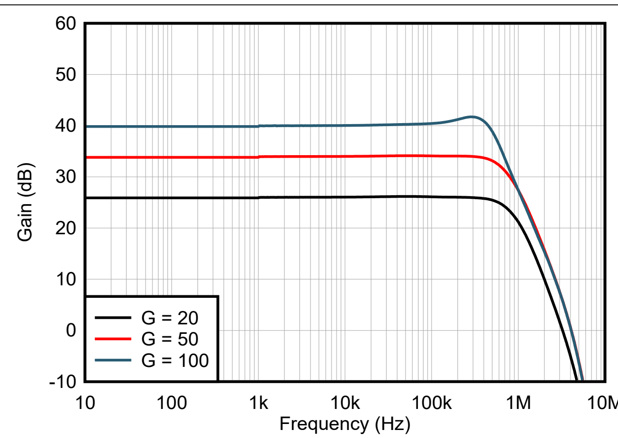


Figure 5-6. Gain vs Frequency

5.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5V, V_{SENSE} = V_{IN+} – $V_{IN–}$ = 0V, V_{CM} = $V_{IN–}$ = 24V, and V_{REF} = V_S / 2 (unless otherwise noted)

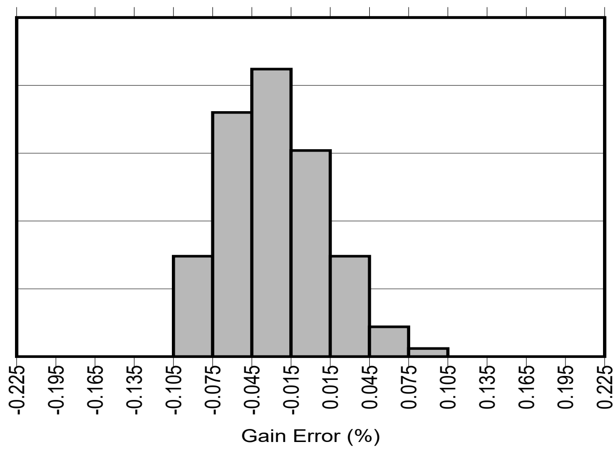


Figure 5-7. INA187 Gain Error Production Distribution

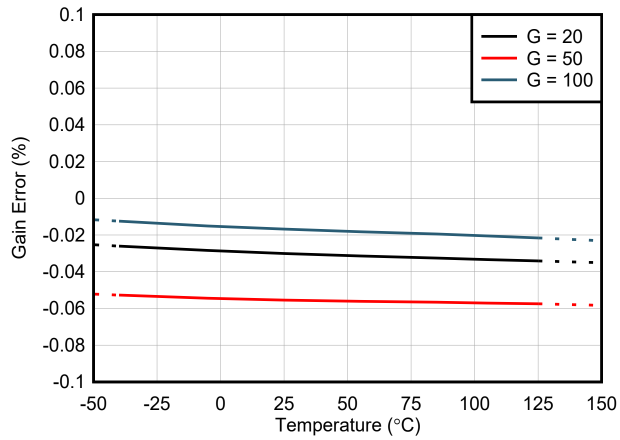


Figure 5-8. Gain Error vs Temperature

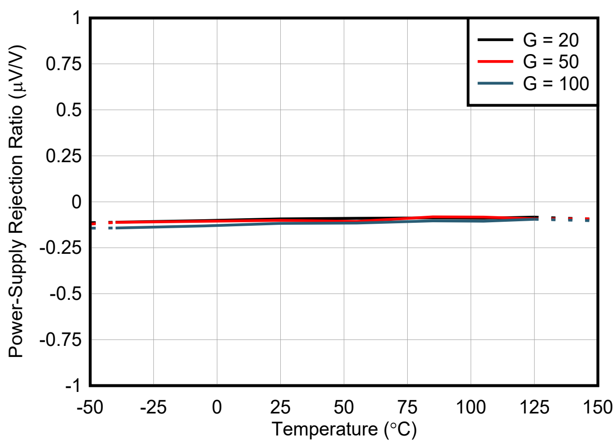


Figure 5-9. Power-Supply Rejection Ratio vs Temperature

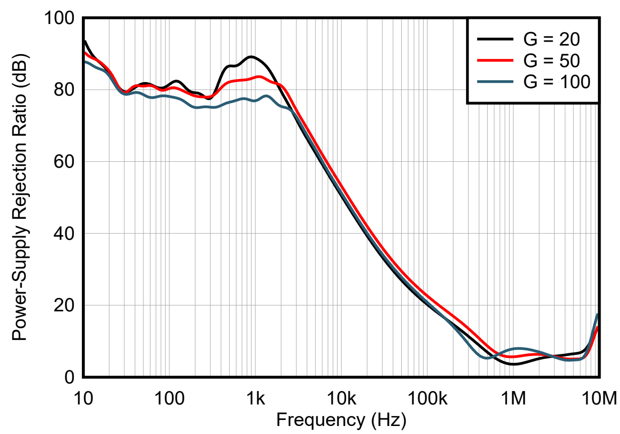


Figure 5-10. Power-Supply Rejection Ratio vs Frequency

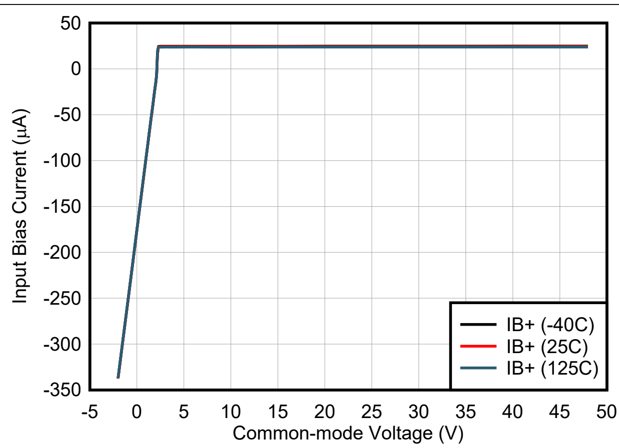


Figure 5-11. Input Bias Current vs Common-Mode Voltage

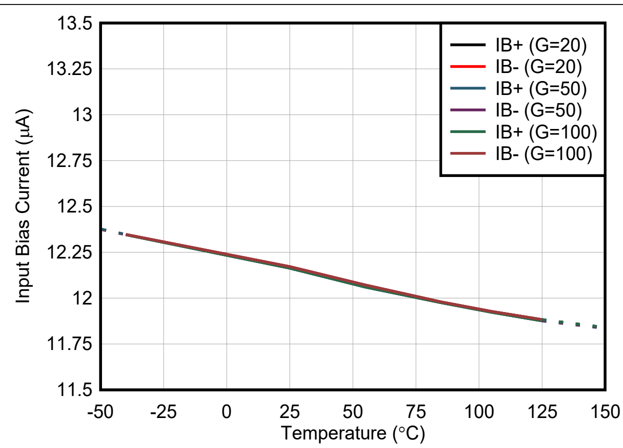


Figure 5-12. Input Bias Current vs Temperature

5.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5V, V_{SENSE} = V_{IN+} – $V_{IN–}$ = 0V, V_{CM} = $V_{IN–}$ = 24V, and V_{REF} = V_S / 2 (unless otherwise noted)

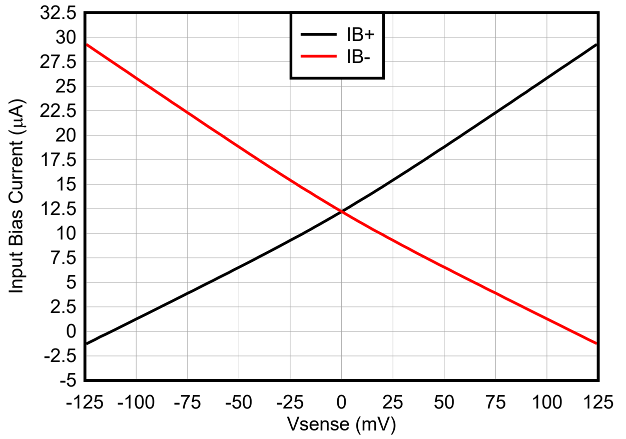


Figure 5-13. INA187 Gain = 20V/V, Input Bias Current vs V_{SENSE}

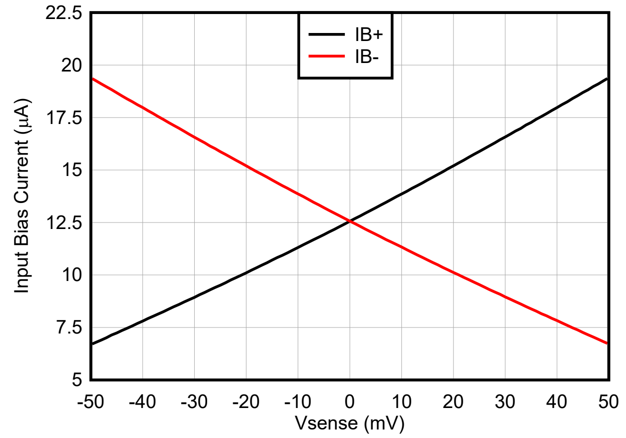


Figure 5-14. INA187 Gain = 50V/V, Input Bias Current vs V_{SENSE}

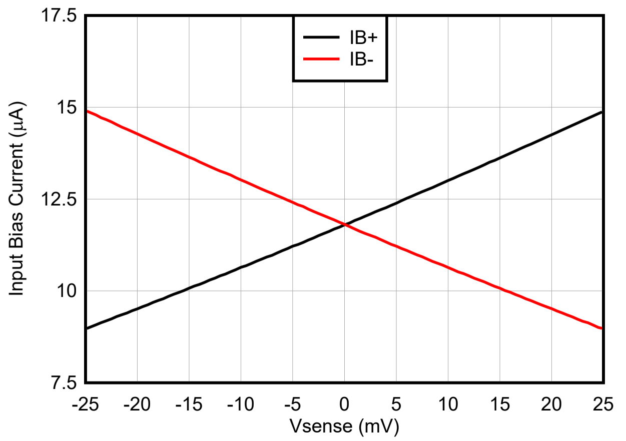
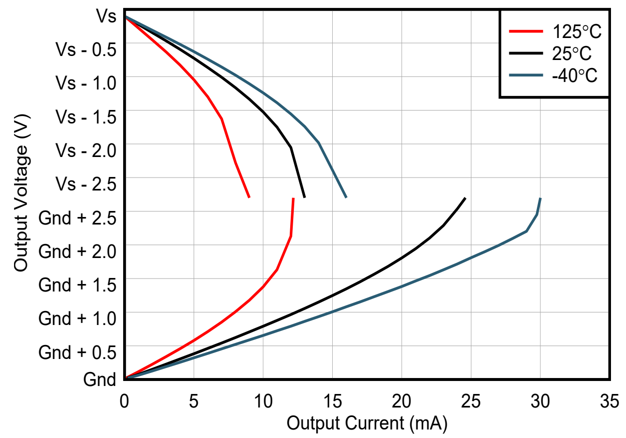
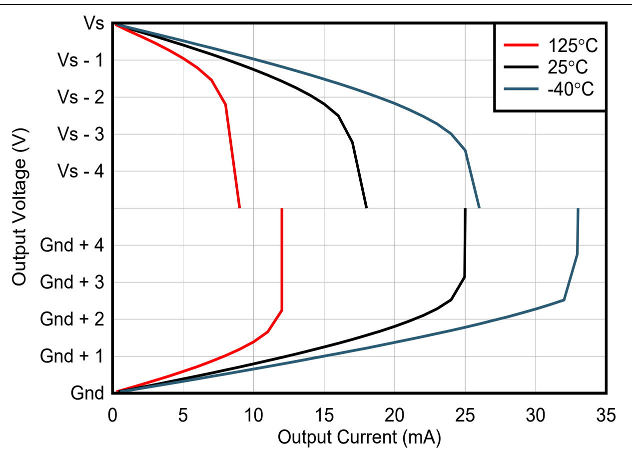


Figure 5-15. INA187 Gain = 100V/V Input Bias Current vs V_{SENSE}



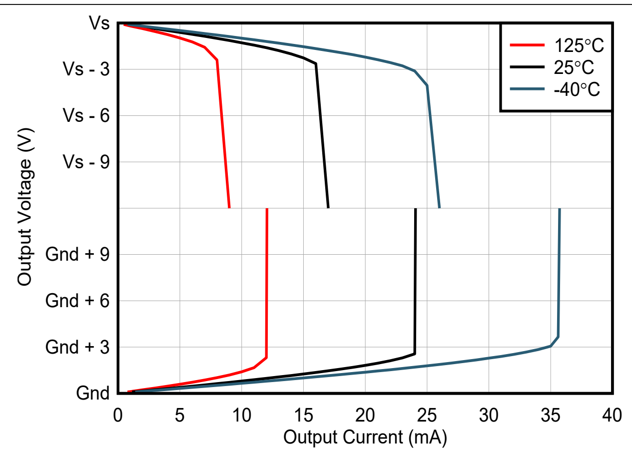
V_S = 2.7V Gain = 20V/V

Figure 5-16. Output Voltage vs Output Current



V_S = 5V Gain = 20V/V

Figure 5-17. Output Voltage vs Output Current



V_S = 12V Gain = 20V/V

Figure 5-18. Output Voltage vs Output Current

5.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5V, V_{SENSE} = V_{IN+} – $V_{IN–}$ = 0V, V_{CM} = $V_{IN–}$ = 24V, and V_{REF} = V_S / 2 (unless otherwise noted)

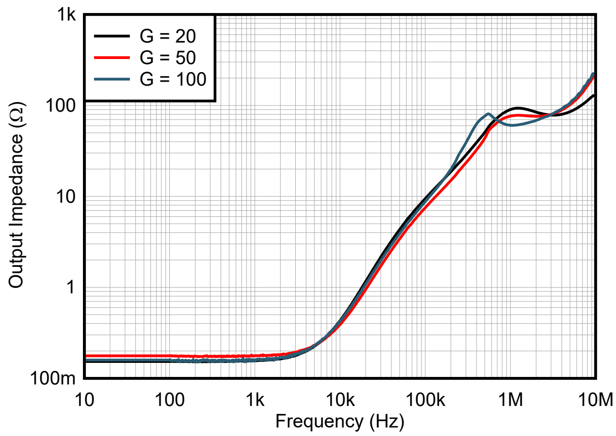
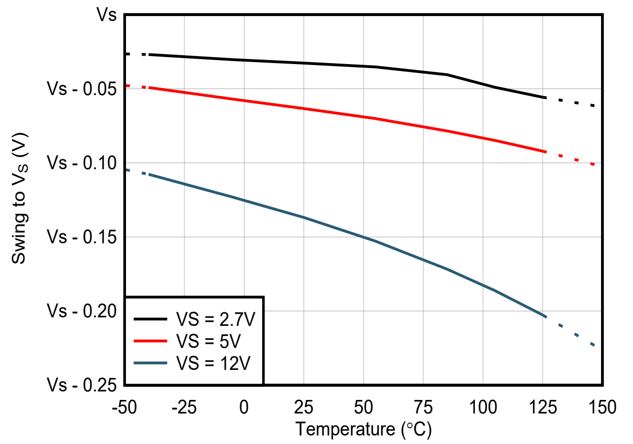
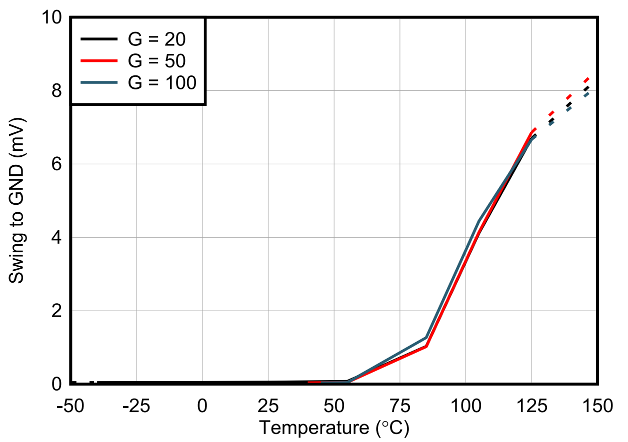


Figure 5-19. Output Impedance vs Frequency



R_L = 10kΩ to GND

Figure 5-20. Swing to Supply vs Temperature



R_L = 10kΩ to GND

Figure 5-21. Swing to GND vs Temperature

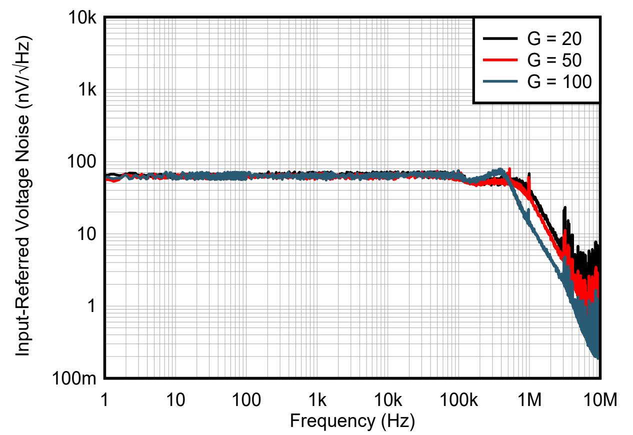


Figure 5-22. Input Referred Noise vs Frequency

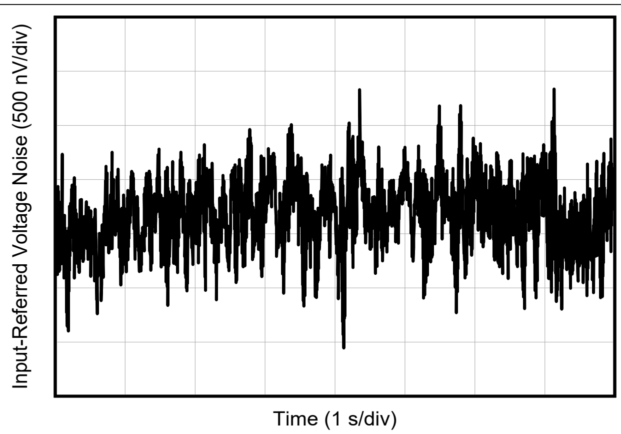
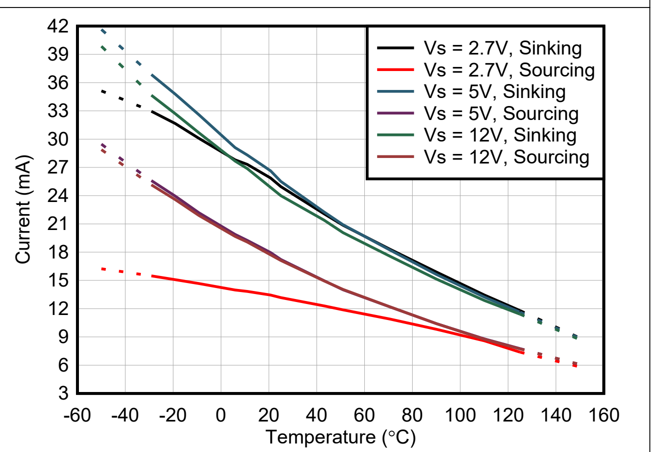


Figure 5-23. 0.1Hz to 10Hz Voltage Noise

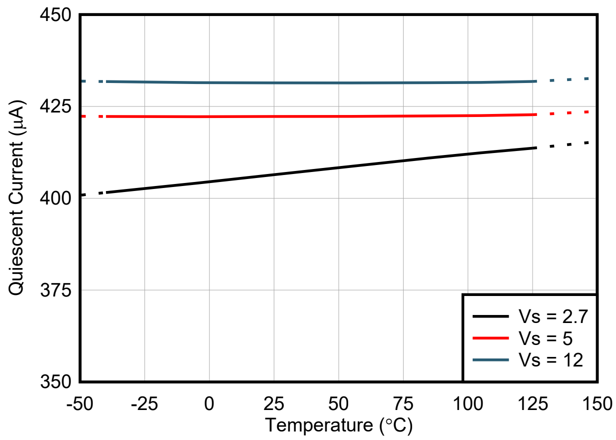


V_{CM} = 12V Gain = 20V/V

Figure 5-24. Short-Circuit Current vs Temperature

5.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5V, V_{SENSE} = V_{IN+} – $V_{IN–}$ = 0V, V_{CM} = $V_{IN–}$ = 24V, and V_{REF} = V_S / 2 (unless otherwise noted)



Gain = 20V/V

Figure 5-25. Quiescent Current vs Temperature

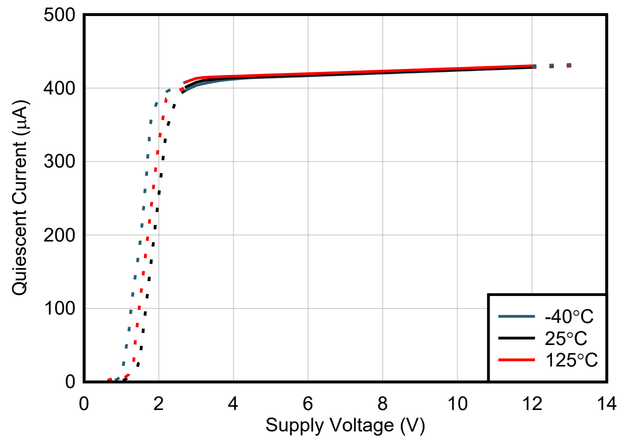
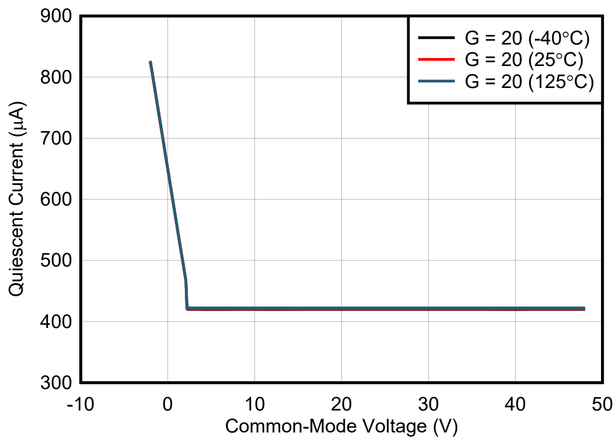


Figure 5-26. Quiescent Current vs Supply Voltage



Gain = 20V/V

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

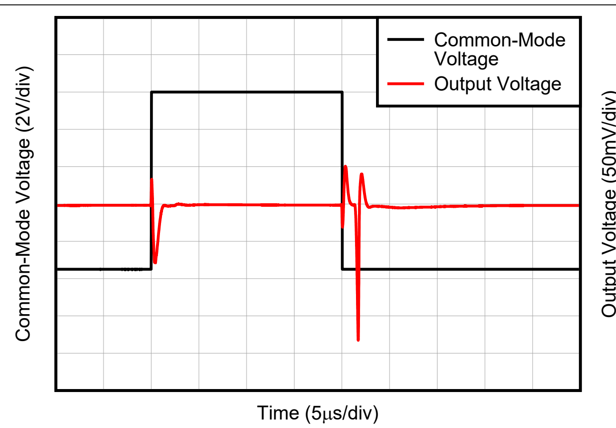
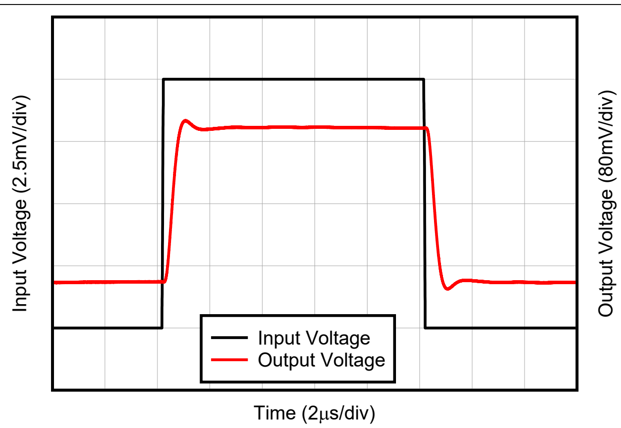
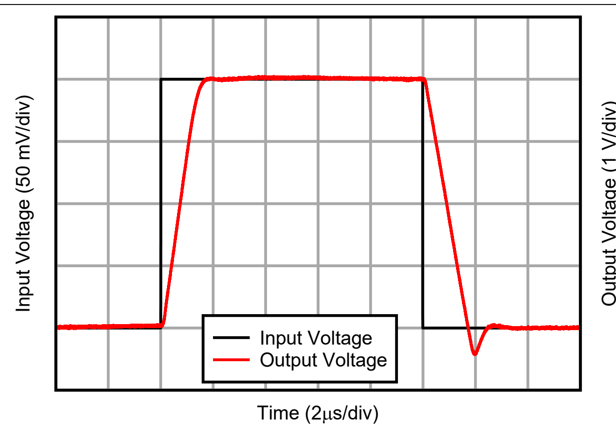


Figure 5-28. Common-Mode Voltage Fast Transient Pulse



V_{CM} = 12V Gain = 20V/V

Figure 5-29. Small Step Response



V_{CM} = 12V Gain = 20V/V

Figure 5-30. Large Step Response

5.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5V, $V_{SENSE} = V_{IN+} – V_{IN–}$ = 0V, $V_{CM} = V_{IN–}$ = 24V, and $V_{REF} = V_S$ / 2 (unless otherwise noted)

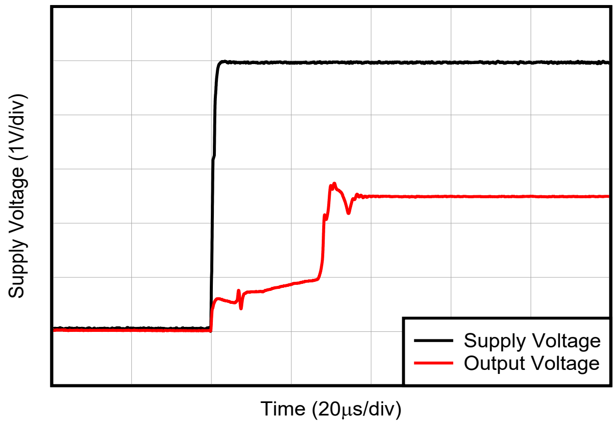


Figure 5-31. Start-Up Response

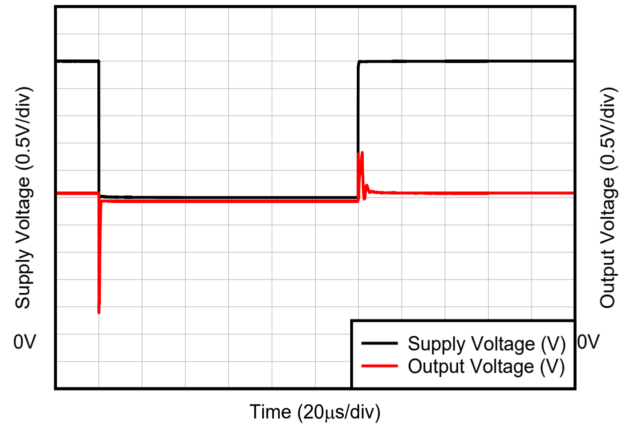


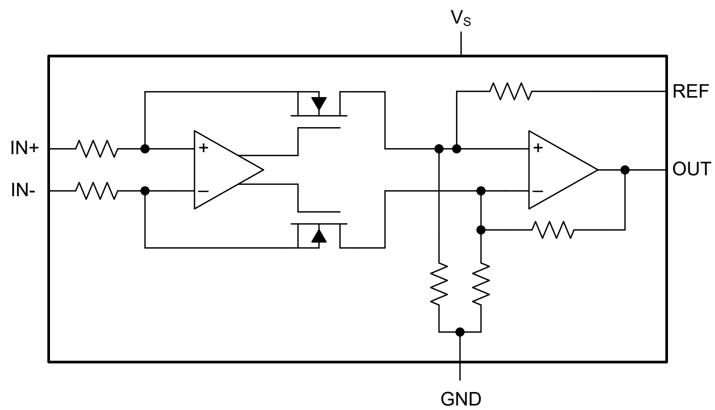
Figure 5-32. Brownout Recovery

6 Detailed Description

6.1 Overview

The INA187 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 INA187 is designed using an architecture that enables low bias currents of 13µA with a specified common-mode voltage range from –2V to 42V with signal bandwidths up to 650kHz.

6.2 Functional Block Diagram



6.3 Feature Description

6.3.1 Amplifier Input Common-Mode Signal

The INA187 supports large input common-mode voltages from –2V to +42V. The internal topology of the INA187 allows the common-mode range to exceed the power-supply voltage (V_S). This allows for the INA187 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 INA187 inputs draw 13µA (typical) bias current per input pin at common-mode voltages as high as 42V, which enables precision current sensing on applications that require lower current leakage. The input bias current is proportional to the common-mode voltage at -2V to 2.5V, after that the input bias current of the INA187 remains constant over the entire common-mode voltage range.

6.3.3 Low V_{SENSE} Operation

The INA187 features high performance operation across the entire valid V_{SENSE} range. The zero-drift input architecture of the INA187 provides the low offset voltage and low offset drift needed to measure low V_{SENSE} levels accurately across the wide operating temperature of –40°C to +125°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 INA187 maximum gain error is ±0.25% at room temperature, with a maximum drift of ±10ppm/°C over the full temperature range of –40°C to +125°C. The INA187 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 INA187 operates with a wide supply range from 2.7V to 12V. While the input common-mode voltage range of the INA187 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 INA187 output is configurable to allow for unidirectional or bidirectional operation.

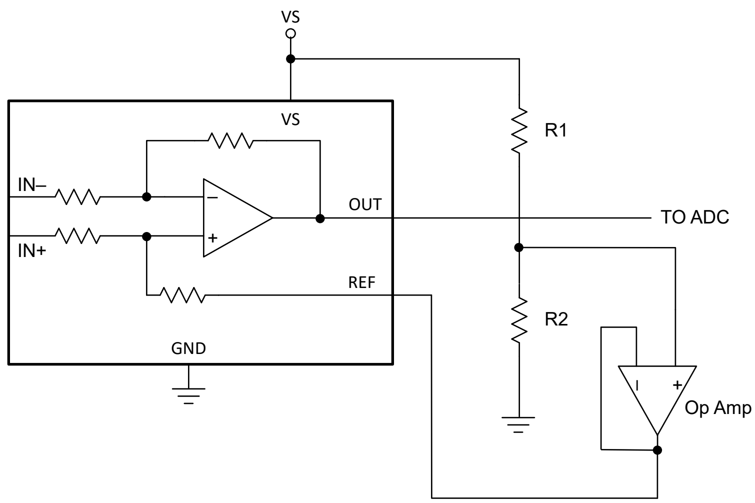


Figure 6-1. Reference Pin Adjusting the Output

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.

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

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 INA187 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).

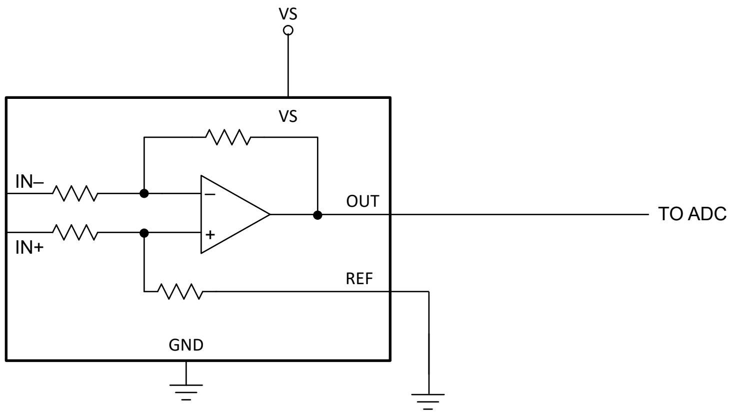


Figure 6-2. Ground Referenced Output

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).

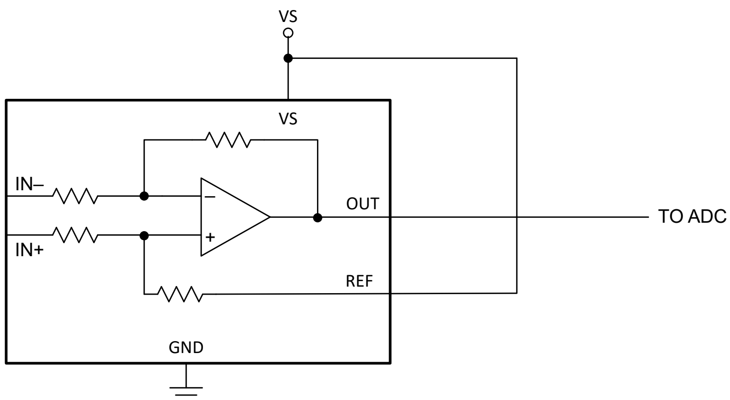


Figure 6-3. VS Referenced Output

6.4.3 Reference Pin Connections for Bidirectional Current Measurements

The INA187 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 INA187 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 INA187 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.

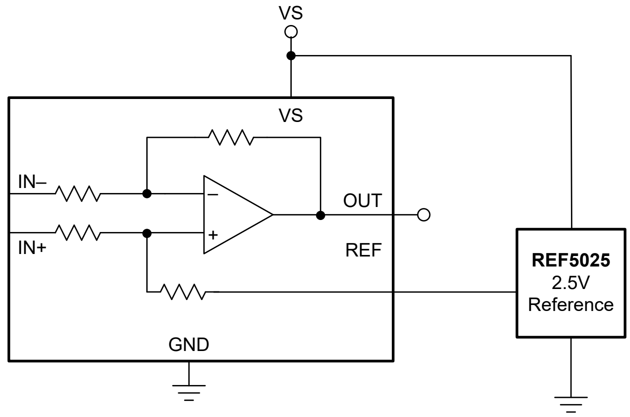


Figure 6-4. External Reference Output

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.

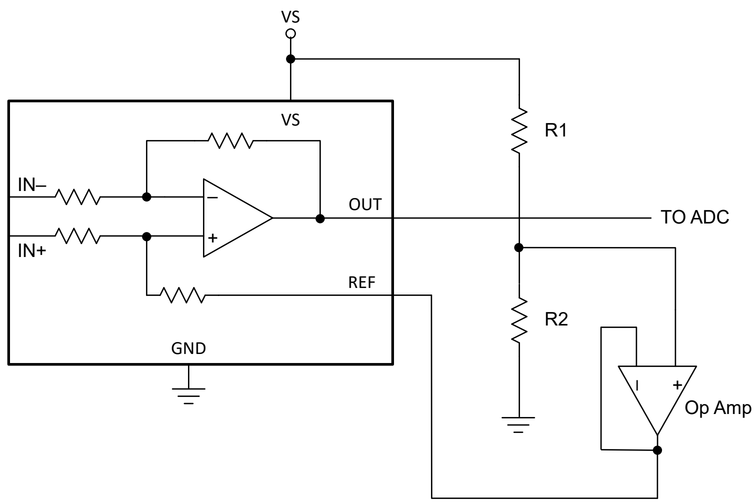


Figure 6-5. Mid-Supply Voltage Output

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 INA187 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 INA187 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:

$$R_{SENSE} < \frac{PD_{MAX}}{I_{MAX}^2} \tag{2}$$

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.

$$I_{MAX} \times R_{SENSE} \times GAIN < V_{SP} \tag{3}$$

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.

$$I_{MIN} \times R_{SENSE} \times GAIN > V_{SN} \tag{4}$$

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 INA187 . 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 (1)

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 INA187 is a bidirectional, current-sense amplifier capable of measuring currents through a resistive shunt with common-mode voltages from –2V to +42V.

7.2.1 Low-side Current Sensing in Motor Application

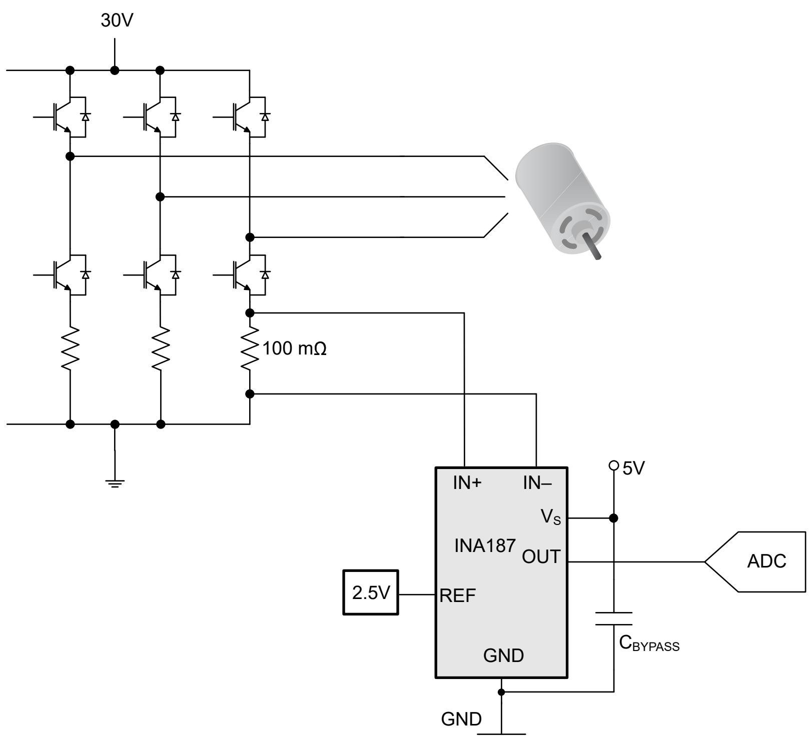


Figure 7-1. Low-Side Motor Current-Sense Application Circuit

7.2.1.1 Design Requirements

In this example application for low-side current sensing in motor application at common-mode voltage close to the ground. The maximum sense current is 0.5A, and a 5V supply is available for the INA187 . 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. The *Design Parameters* table lists the design setup for this application.

Table 7-2. Design Parameters

DESIGN PARAMETERS	EXAMPLE VALUE
Power supply voltage	5V
Common mode voltage range	-0.7V to 0.7V
Maximum sense current	0.5A
R_{SENSE} resistor	100mΩ
Gain option	50V/V

7.2.1.2 Detailed Design Procedure

The INA187 is designed to measure a typical high-side current in motor application but also can be used for low-side current measurement. The INA187 measures current across the 100mΩ shunt that is placed at ground in series with low-side FET of a half-bridge driving a motor. The INA187 measures the differential voltage across the shunt resistor, and the signal is internally amplified with a gain of 50V/V. The output of the INA187 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 the motor health and possible failure. The INA187 can operate down to -2V which is beneficial during the braking of the motor where shunt resistor voltage can go below the ground. The INA187 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 Performance Plots

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

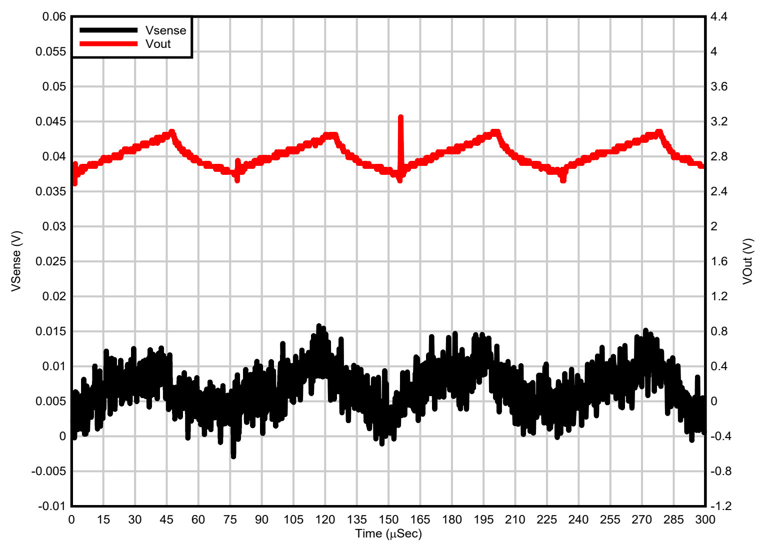


Figure 7-2. Low-Side Motor Current Measurement

7.3 Power Supply Recommendations

The INA187 makes accurate measurements beyond the connected power-supply voltage (V_S) because the inputs (IN+ and IN–) can operate anywhere between –2V and +42V 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 +42V.

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 0.1μF. Additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies.

7.4.2 Layout Examples

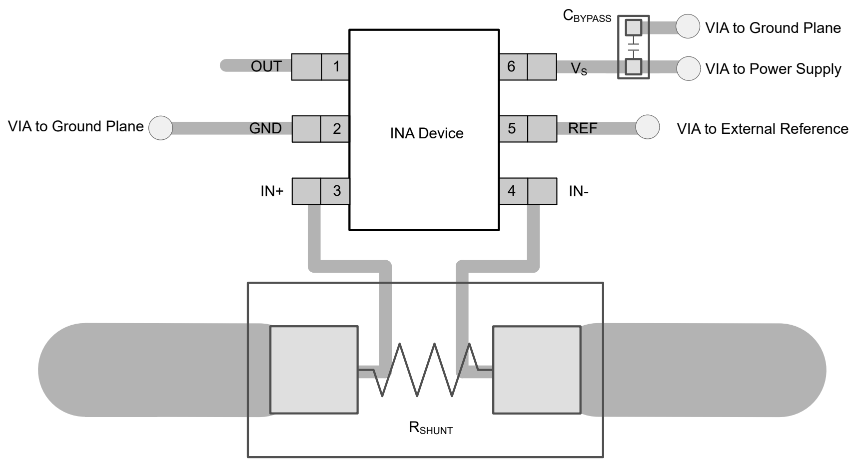


Figure 7-3. INA187 SOT-23 6-pin (DBV) Package Recommended Layout

8 Device and Documentation Support

8.1 Documentation Support

8.1.1 Related Documentation

For related documentation see the following: Texas Instruments,

- Texas Instruments, INA187xEVM, 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.

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8.4 Trademarks

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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.

Changes from Revision * (May 2025) to Revision A (September 2025) **Page**

- Updated the *Pin Configuration and Functions* section to change the package typo for DBV package.............. 2

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.

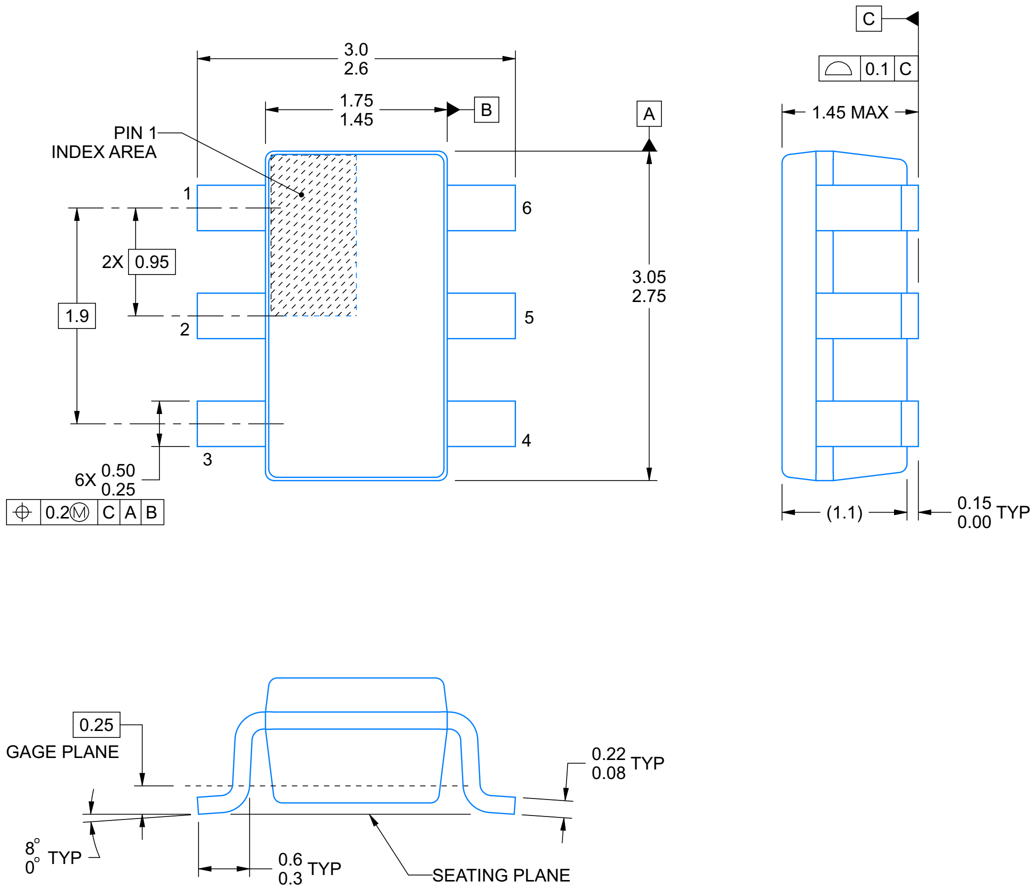
10.1 Mechanical Data

PACKAGE OUTLINE

DBV0006A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



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NOTES:

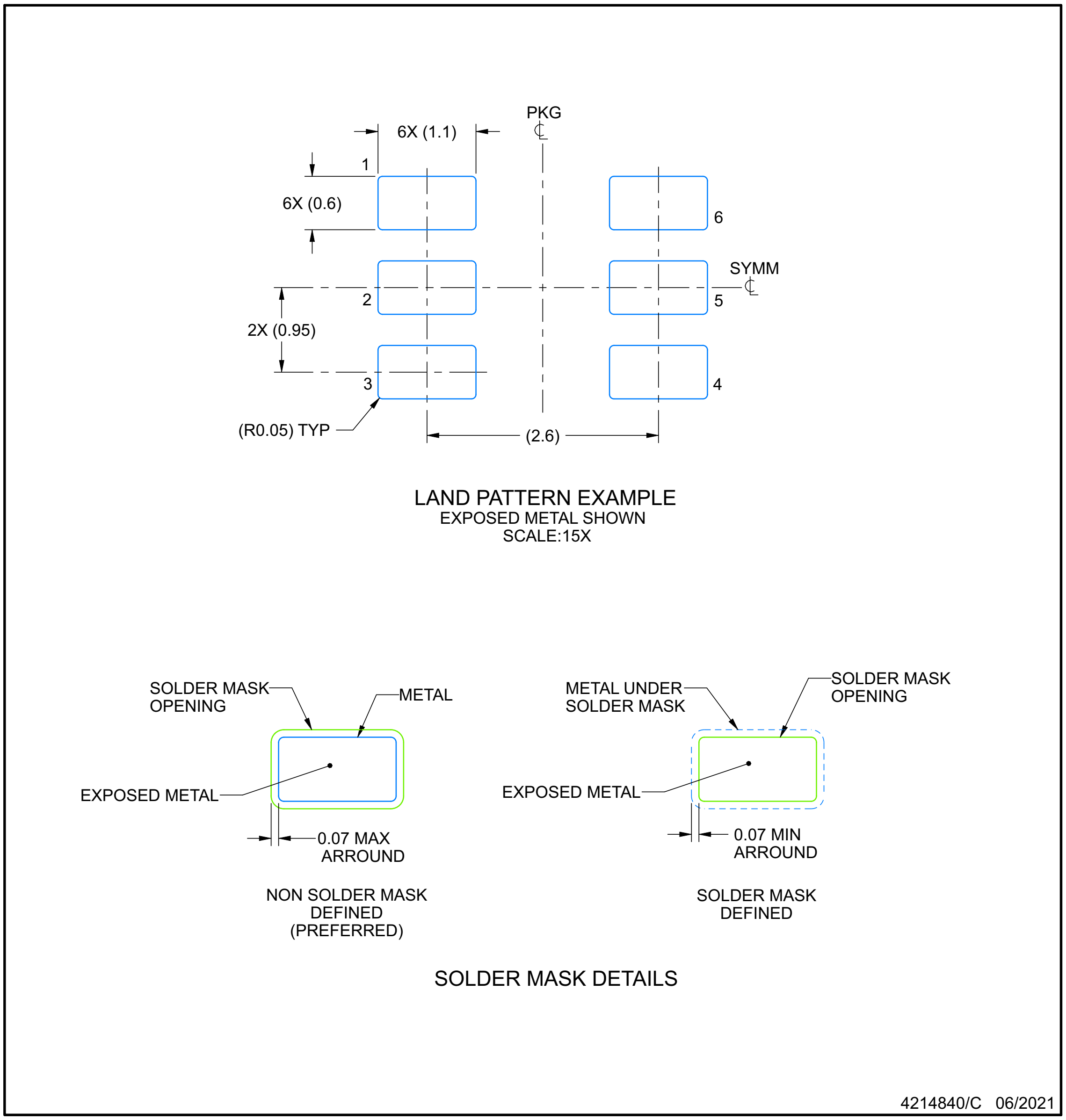
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed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

EXAMPLE BOARD LAYOUT

DBV0006A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



NOTES: (continued)

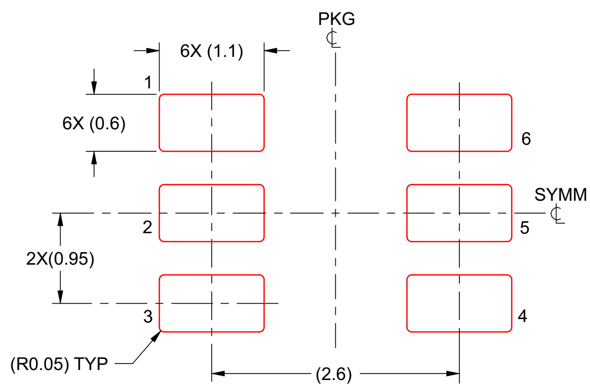
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

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

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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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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)
INA187A1IDBVR	Active	Production	SOT-23 (DBV) | 6	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	3OSF
INA187A2IDBVR	Active	Production	SOT-23 (DBV) | 6	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	3OTF
INA187A3IDBVR	Active	Production	SOT-23 (DBV) | 6	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	3OUF

(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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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.

OTHER QUALIFIED VERSIONS OF INA187 :

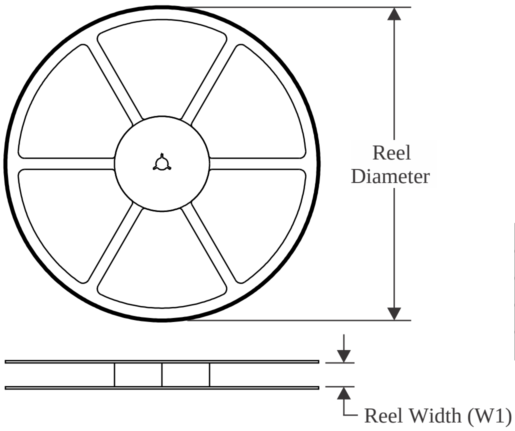
- Automotive : INA187-Q1

NOTE: Qualified Version Definitions:

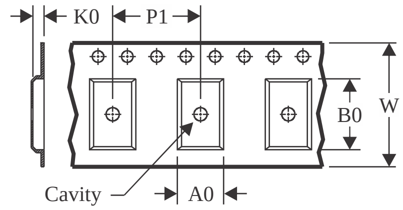
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

TAPE AND REEL INFORMATION

REEL DIMENSIONS

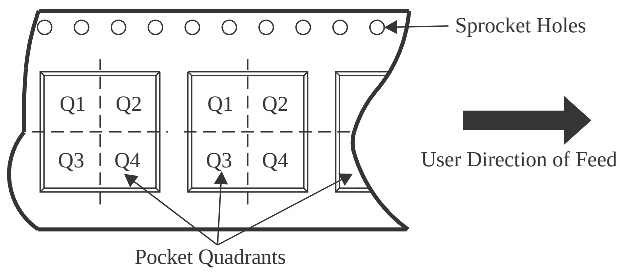


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

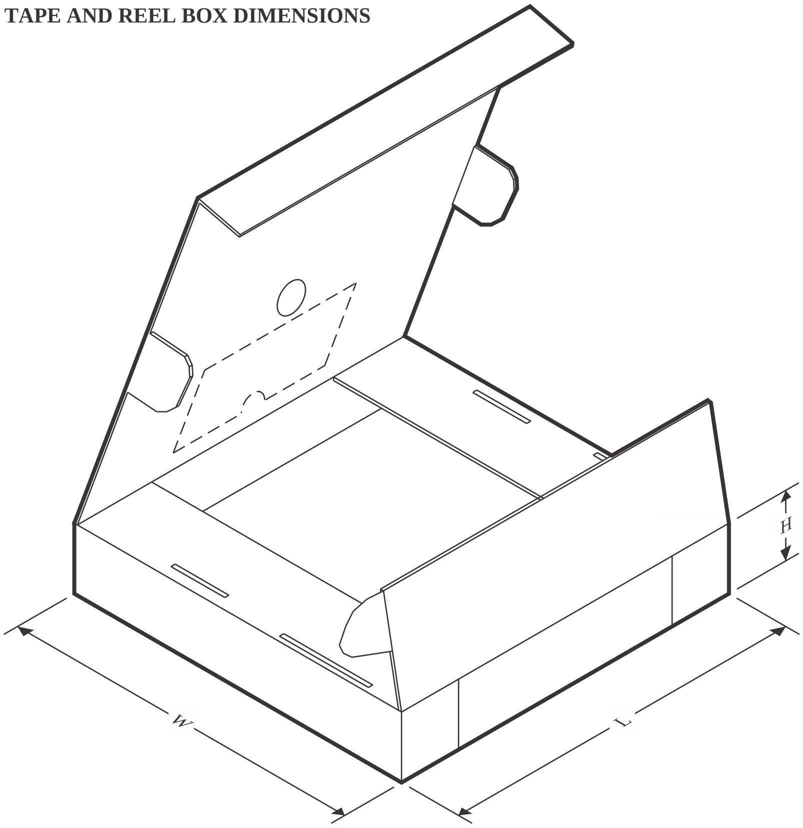
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
INA187A1IDBVR	SOT-23	DBV	6	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
INA187A2IDBVR	SOT-23	DBV	6	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
INA187A3IDBVR	SOT-23	DBV	6	3000	180.0	8.4	3.2	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)
INA187A1IDBVR	SOT-23	DBV	6	3000	210.0	185.0	35.0
INA187A2IDBVR	SOT-23	DBV	6	3000	210.0	185.0	35.0
INA187A3IDBVR	SOT-23	DBV	6	3000	210.0	185.0	35.0