INA290-Q1 AEC-Q100、2.7V～120V、1.1MHz、超高精度電流検出アンプ

1 特長

- 車載アプリケーション用に AEC-Q100 認定取得済み：
  - 温度グレード 1：-40℃～+125℃、T_A
- 機能安全対応
  - 機能安全システムの設計に役立つ資料を利用可能
- 広い同相電圧範囲：
  - 動作電圧：2.7V～120V
  - 残存電圧：-20V～+122V
- 非常に優れた CMRR：
  - 160dB (DC)
  - 85dB (AC、50kHz)
- 精度
  - ゲイン：
    - ゲイン誤差：±0.1% 以下
    - ゲイン・ドリフト：±5ppm/℃以下
  - オフセット
    - オフセット電圧：±12μV 以下
    - オフセット・ドリフト：±0.2μV/℃以下
- 利用可能なゲイン
  - A1 デバイス：20V/V
  - A2 デバイス：50V/V
  - A3 デバイス：100V/V
  - A4 デバイス：200V/V
  - A5 デバイス：500 V/V
- 広帯域幅：1.1MHz
- スルーレート：2V/μs
- 静止電流：370μA

2 アプリケーション

- 半導体 LiDAR
- 車載用 HVAC (エアコン) コンプレッサ・モジュール
- 車載ヒーター・モジュール
- 車載パーキング・ヒーター・モジュール
- 車載用ポンプ

3 概要

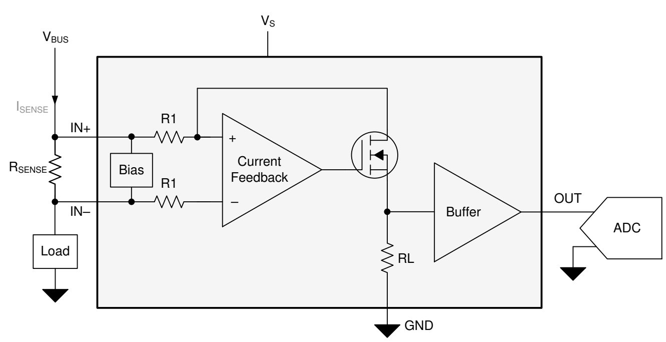
INA290-Q1 は、2.7V～120V の広い同相範囲にわたってシャント抵抗の電圧降下を測定できる超高精度電流センスアンプです。この製品は、PCB フットプリントがわずか 2.0mm × 2.1mm のスペース効率の高い SC-70 パッケージに搭載されています。±12μV 以下の極めて低いオフセット電圧、±0.1% 以下の小さいゲイン誤差、160dB (標準値) の高い DC CMRR により、超高精度の電流測定を実現します。INA290-Q1 は DC 電流測定だけでなく、高速アプリケーション (高速過電流保護など) にも対応するように設計されており、1.1MHz の広い帯域幅 (ゲイン 20V/V 時) と 85dB の AC CMRR (50kHz 時) を特長としています。

INA290-Q1 を使用すると、2.7V～120V の広い同相範囲にわたってシャント抵抗の電圧降下を検出することにより超高精度で電流を測定できます。INA290-Q1 は SC-70 パッケージで供給され、ソリューションの面積を最小化できます。

製品情報

部品番号	パッケージ(1)	本体サイズ (公称)
INA290-Q1	SC-70 (5)	2.00mm × 1.25mm

(1) 提供されているすべてのパッケージについては、データシートの末尾にあるパッケージ・オプションについての付録を参照してください。



代表的なアプリケーション

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4 Revision History

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

Changes from Revision * (October 2019) to Revision A (November 2020)	Page
• データシートのステータスを「事前情報」から「量産データ」に変更	1
• 文書全体にわたって表、図、相互参照の採番方法を更新	1

5 Pin Configuration and Functions

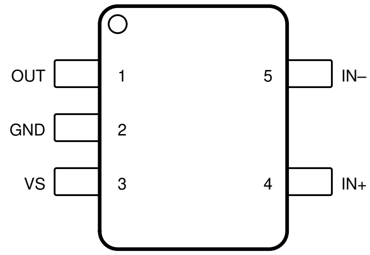


図 5-1. DCK Package 5-Pin SC-70 Top View

表 5-1. Pin Functions

PIN		TYPE	DESCRIPTION
NAME	NO.		
GND	2	Ground	Ground
IN–	5	Input	Connect to load side of shunt resistor
IN+	4	Input	Connect to supply side of shunt resistor
OUT	1	Output	Output voltage
VS	3	Power	Power supply

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)[(1)]

		MIN	MAX	UNIT
V_s	Supply Voltage	–0.3	22	V
Analog Inputs, V_{IN+}, $V_{IN–}$ [(2)]	Differential (V_{IN+}) – ($V_{IN–}$)	–30	30	V
	Common - mode	–20	122	V
Output		GND – 0.3	Vs + 0.3	V
T_A	Operating Temperature	–55	150	°C
T_J	Junction temperature		150	°C
T_{stg}	Storage temperature	–65	150	°C

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) VIN+ and VIN– are the voltages at the VIN+ and VIN– pins, respectively.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per AEC Q100-002, all pins[(1)] HBM ESD Classification Level 2	±2000	V
		Charged device model (CDM), per AEC Q100-011, all pins CDM ESD Classification Level C6	±1000	

(1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

6.3 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
V_{CM}	Common-mode input range[(1)]	V_S	48	120	V
V_S	Operating supply range	2.7	5	20	V
T_A	Ambient temperature	–40		125	°C

(1) Common-mode voltage can go below V_S under certain conditions. See 図 7-1 for additional information on operating range.

6.4 Thermal Information

THERMAL METRIC[(1)]		INA290-Q1 DCK (SC-70) 5 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	191.6	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	144.4	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	69.2	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	46.2	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	69.0	°C/W
$R_{\theta JC(bot)}$	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 report.

6.5 Electrical Characteristics

at T_A = 25 °C, V_S = 5 V, V_{SENSE} = V_{IN+} – $V_{IN–}$ = 0.5 V / Gain, V_{CM} = $V_{IN–}$ = 48 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
INPUT						
CMRR	Common-mode rejection ratio	V_{CM} = 2.7 V to 120 V, T_A = –40 °C to +125 °C	140	160		dB
		f = 50 kHz		85		
V_{os}	Offset voltage, input referred	A1 devices		5	±25	µV
		A2 devices		3	±20	
		A3 devices		3	±15	
		A4, A5 devices		2	±12	
dV_{os}/dT	Offset voltage drift	T_A = –40 °C to +125 °C			0.2	µV/°C
PSRR	Power supply rejection ratio, input referred	V_S = 2.7 V to 20 V, T_A = –40 °C to +125 °C		0.05	±0.5	µV/V
I_B	Input bias current	I_{B+}, V_{SENSE} = 0 mV	10	20	30	µA
		$I_{B–}$, V_{SENSE} = 0 mV	10	20	30	
OUTPUT						
G	Gain	A1 devices		20		V/V
		A2 devices		50		
		A3 devices		100		
		A4 devices		200		
		A5 devices		500		
	Gain error	A1, A2, A3 devices, GND + 50 mV ≤ V_{OUT} ≤ V_S – 200 mV		0.02	±0.1	%
		A4, A5 devices, GND + 50 mV ≤ V_{OUT} ≤ V_S – 200 mV		0.02	±0.15	
	Gain error drift	T_A = –40 °C to +125 °C		1.5	5	ppm/°C
	Nonlinearity error			0.01		%
	Maximum capacitive load	No sustained oscillations, no isolation resistor		500		pF
VOLTAGE OUTPUT						
	Swing to V_S power supply rail	R_{LOAD} = 10 kΩ, T_A = –40 °C to +125 °C		V_S – 0.07	V_S – 0.2	V
	Swing to ground	R_{LOAD} = 10 kΩ, V_{SENSE} = 0 V, T_A = –40 °C to +125 °C		0.005	0.025	V
FREQUENCY RESPONSE						
BW	Bandwidth	A1 devices, C_{LOAD} = 5 pF, V_{SENSE} = 200 mV		1100		kHz
		A2 devices, C_{LOAD} = 5 pF, V_{SENSE} = 80 mV		1100		
		A3 devices, C_{LOAD} = 5 pF, V_{SENSE} = 40 mV		900		
		A4 devices, C_{LOAD} = 5 pF, V_{SENSE} = 20 mV		850		
		A5 devices, C_{LOAD} = 5 pF, V_{SENSE} = 8 mV		800		
SR	Slew rate			2		V/µs
	Settling time	V_{OUT} =4 V ± 0.1 V step, output settles to 0.5%		9		µs
		V_{OUT} =4 V ± 0.1 V step, output settles to 1%		5		
NOISE						
Ve_n	Voltage noise density			50		nV/√Hz
POWER SUPPLY						
V_S	Supply voltage	T_A = –40 °C to +125 °C	2.7		20	V
I_Q	Quiescent current, INA290			370	500	µA
		T_A = –40 °C to +125 °C			600	

6.6 Typical Characteristics

All specifications at T_A = 25 °C, V_S = 5 V, V_{SENSE} = V_{IN+} – $V_{IN–}$ = 0.5 V / Gain, and V_{CM} = $V_{IN–}$ = 48 V, unless otherwise noted.

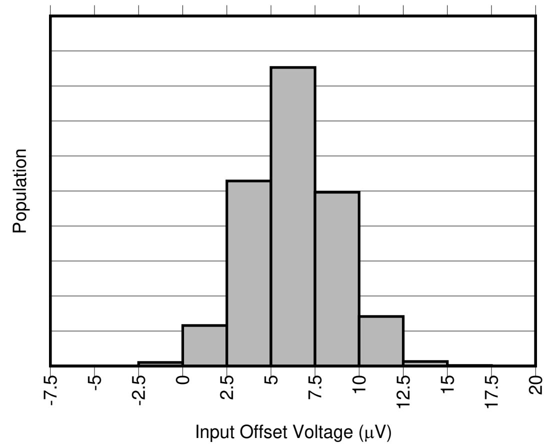


図 6-1. Input Offset Production Distribution, A1 Devices

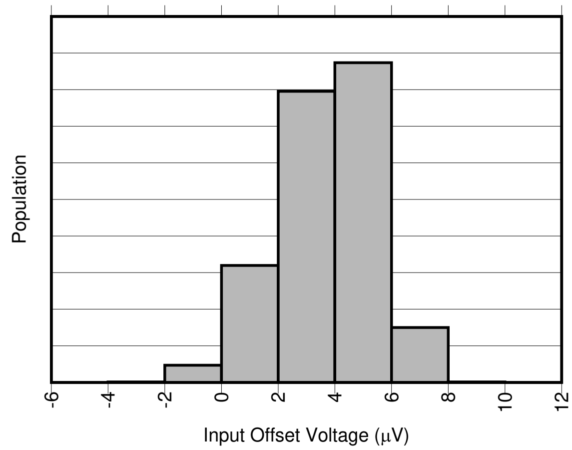


図 6-2. Input Offset Production Distribution, A2 Devices

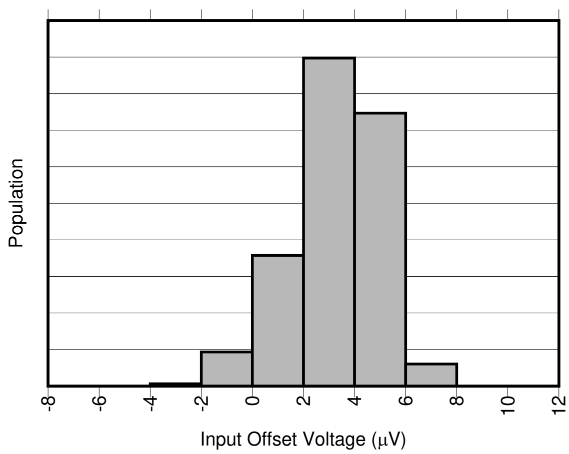


図 6-3. Input Offset Production Distribution, A3 Devices

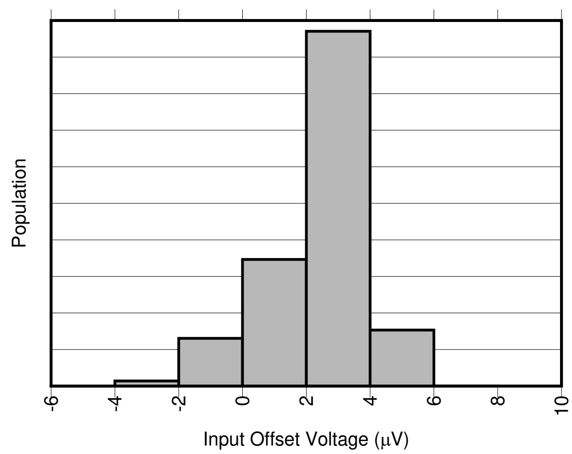


図 6-4. Input Offset Production Distribution, A4 Devices

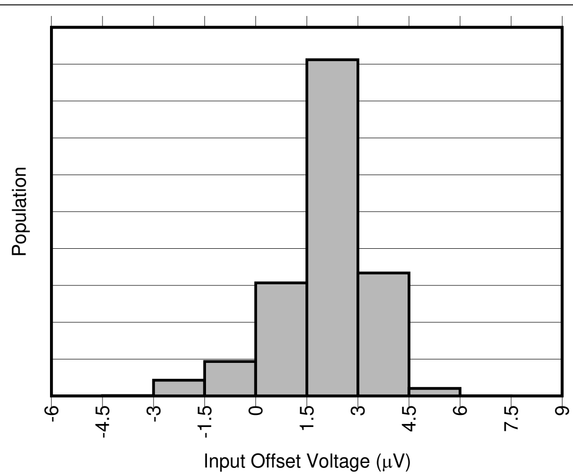


図 6-5. Input Offset Production Distribution, A5 Devices

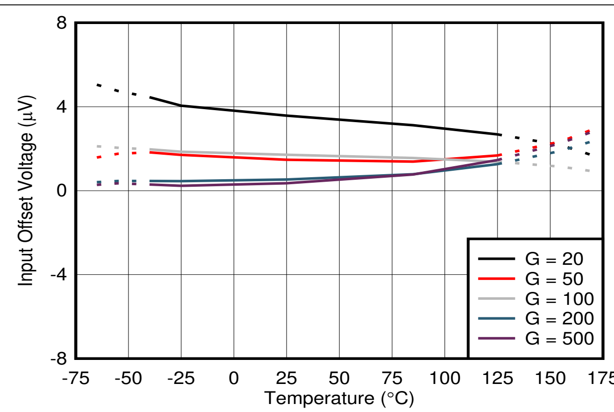


図 6-6. Input Offset Voltage vs Temperature

6.6 Typical Characteristics (continued)

All specifications at T_A = 25 °C, V_S = 5 V, V_{SENSE} = V_{IN+} – $V_{IN–}$ = 0.5 V / Gain, and V_{CM} = $V_{IN–}$ = 48 V, unless otherwise noted.

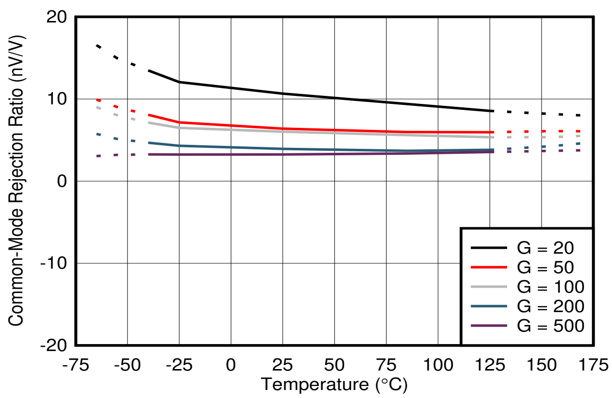


図 6-7. Common-Mode Rejection Ratio vs Temperature

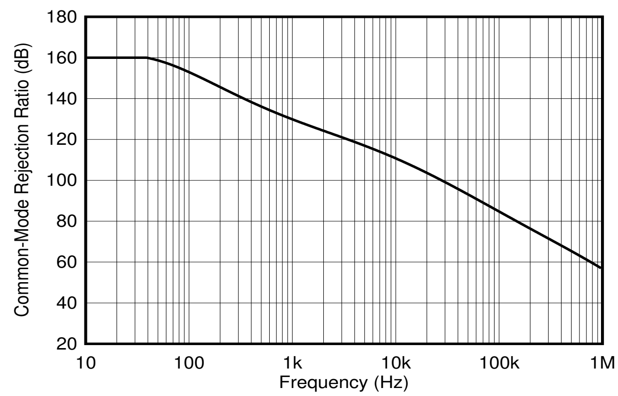
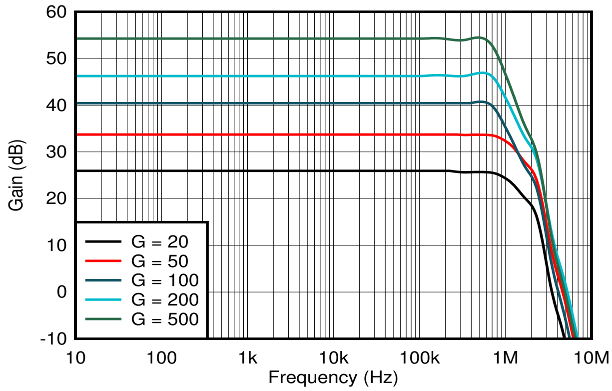


図 6-8. Common-Mode Rejection Ratio vs Frequency



V_{SENSE} = 4 V / Gain

図 6-9. Gain vs Frequency

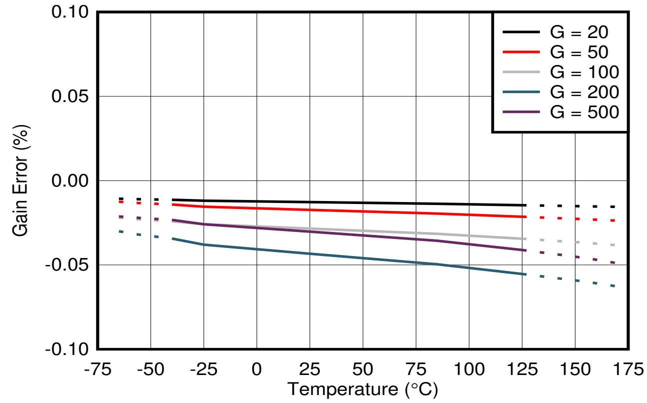


図 6-10. Gain Error vs Temperature

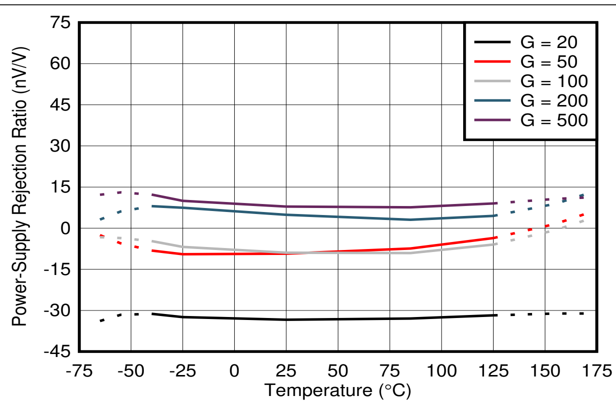


図 6-11. Power-Supply Rejection Ratio vs Temperature

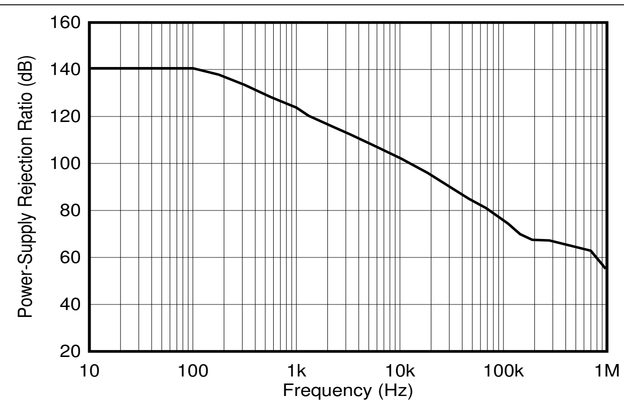
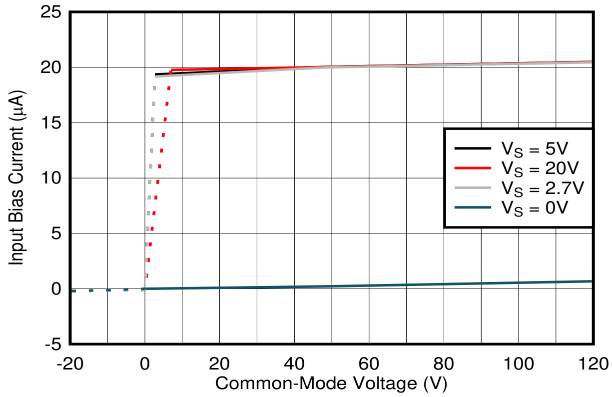


図 6-12. Power-Supply Rejection Ratio vs Frequency

6.6 Typical Characteristics (continued)

All specifications at T_A = 25 °C, V_S = 5 V, V_{SENSE} = V_{IN+} – $V_{IN–}$ = 0.5 V / Gain, and V_{CM} = $V_{IN–}$ = 48 V, unless otherwise noted.



V_{SENSE} = 0 V

図 6-13. Input Bias Current vs Common-Mode Voltage

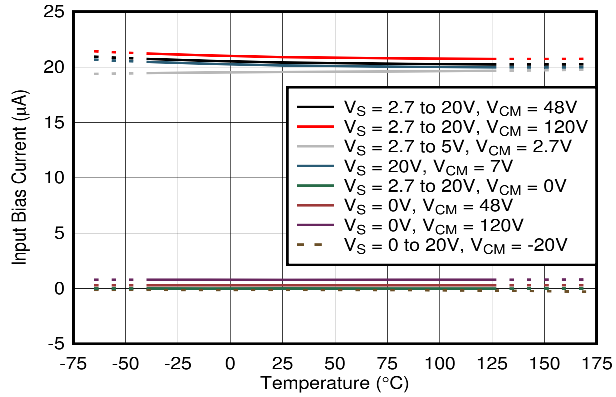


図 6-14. Input Bias Current vs Temperature

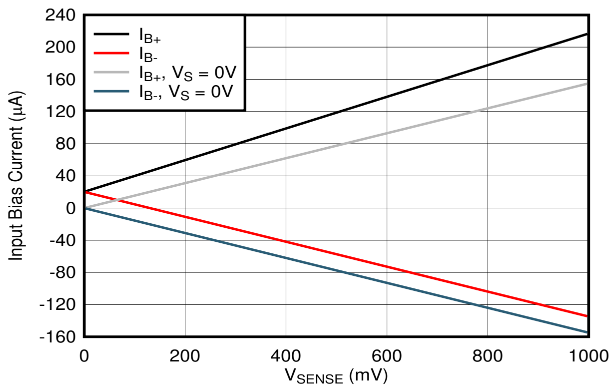


図 6-15. Input Bias Current vs V_{SENSE}, A1 Devices

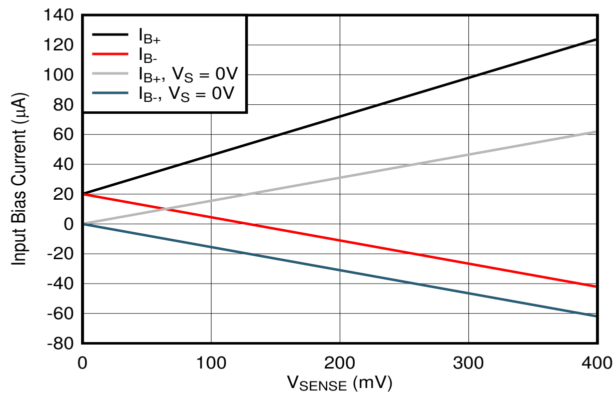


図 6-16. Input Bias Current vs V_{SENSE}, A2 and A3 Devices

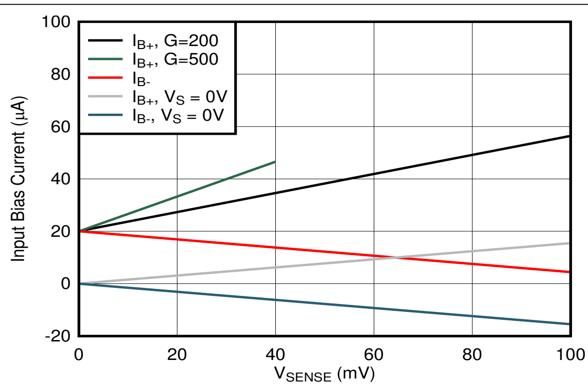
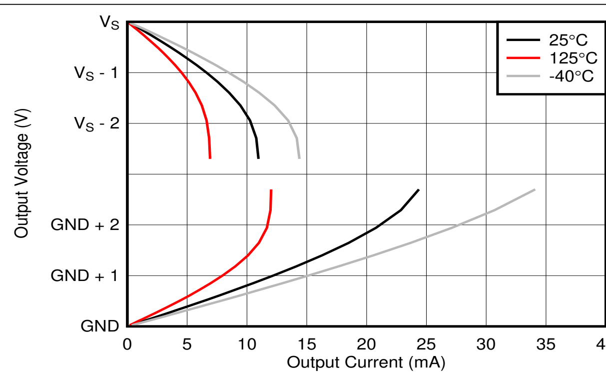


図 6-17. Input Bias Current vs V_{SENSE}, A4 and A5 Devices

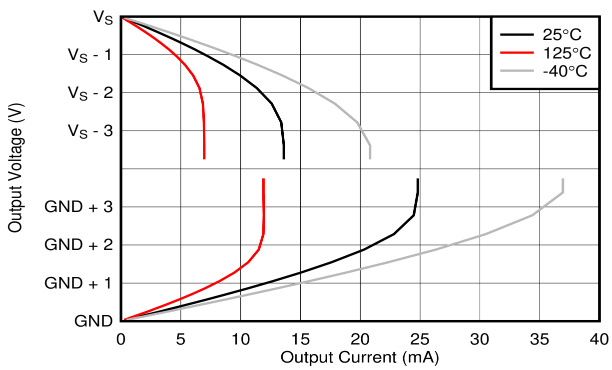


V_S = 2.7 V

図 6-18. Output Voltage vs Output Current

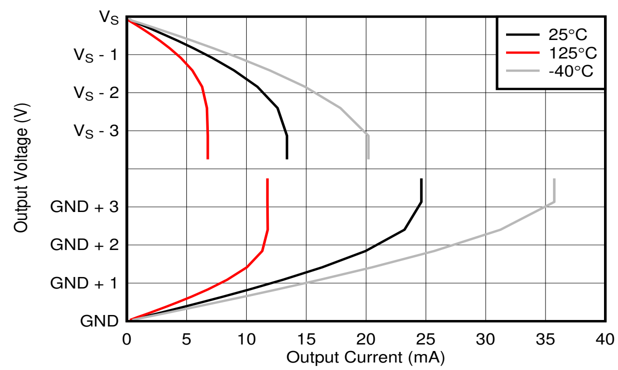
6.6 Typical Characteristics (continued)

All specifications at T_A = 25 °C, V_S = 5 V, V_{SENSE} = V_{IN+} – $V_{IN–}$ = 0.5 V / Gain, and V_{CM} = $V_{IN–}$ = 48 V, unless otherwise noted.



V_S = 5 V

図 6-19. Output Voltage vs Output Current



V_S = 20 V

図 6-20. Output Voltage vs Output Current

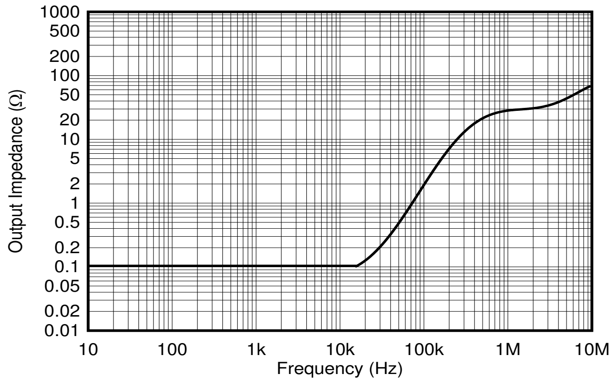
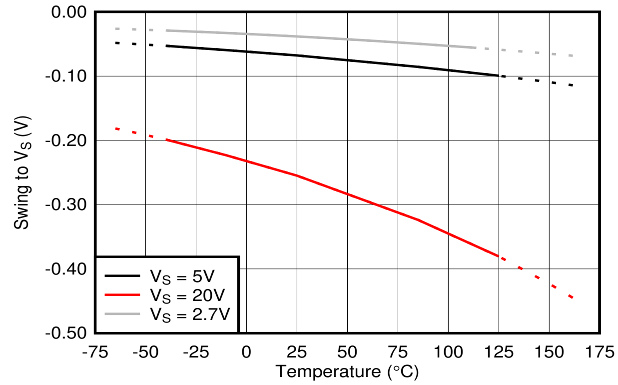
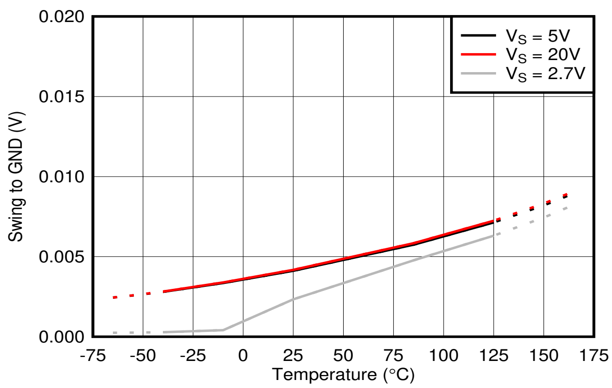


図 6-21. Output Impedance vs Frequency



R_L = 10 kΩ

図 6-22. Swing to Supply vs Temperature



R_L = 10 kΩ

図 6-23. Swing to GND vs Temperature

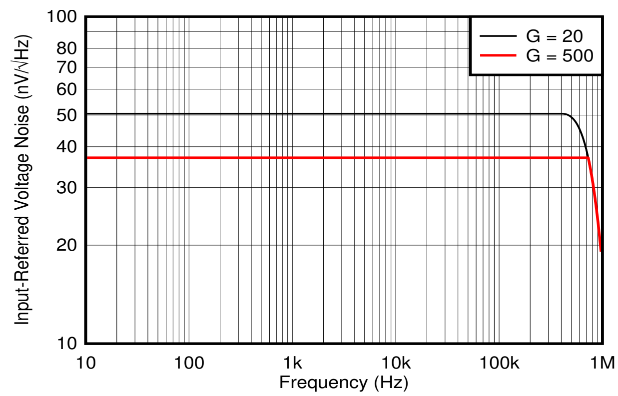


図 6-24. Input Referred Noise vs Frequency

6.6 Typical Characteristics (continued)

All specifications at T_A = 25 °C, V_S = 5 V, V_{SENSE} = V_{IN+} – $V_{IN–}$ = 0.5 V / Gain, and V_{CM} = $V_{IN–}$ = 48 V, unless otherwise noted.

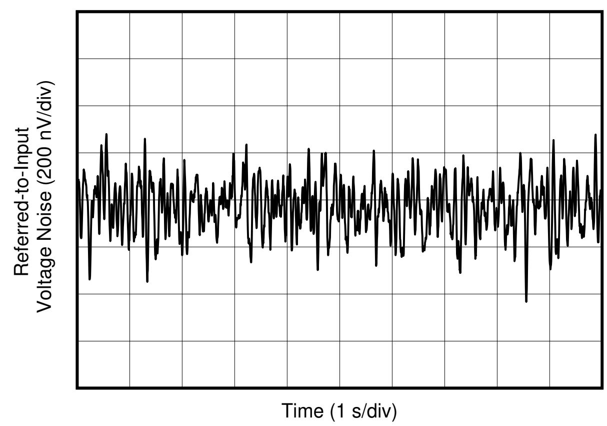


図 6-25. Input Referred Noise

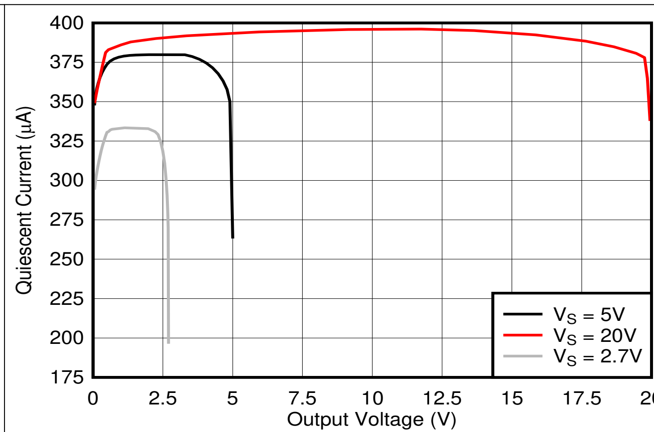


図 6-26. Quiescent Current vs Output Voltage, INA290

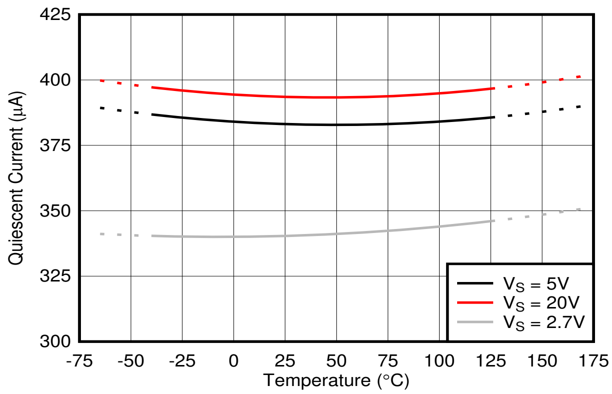


図 6-27. Quiescent Current vs Temperature, INA290

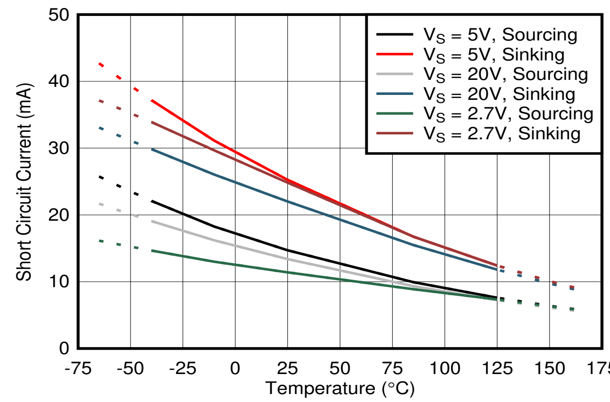


図 6-28. Short-Circuit Current vs Temperature

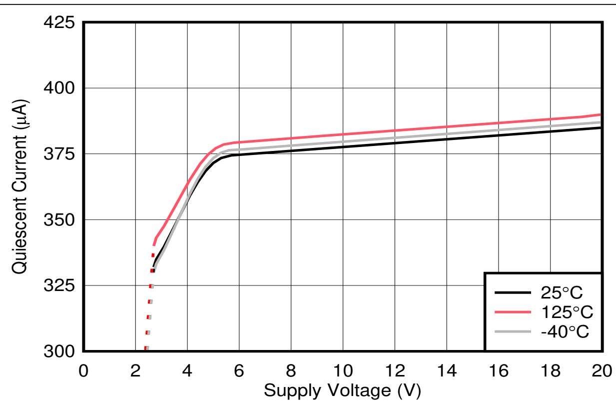


図 6-29. Quiescent Current vs Supply Voltage, INA290

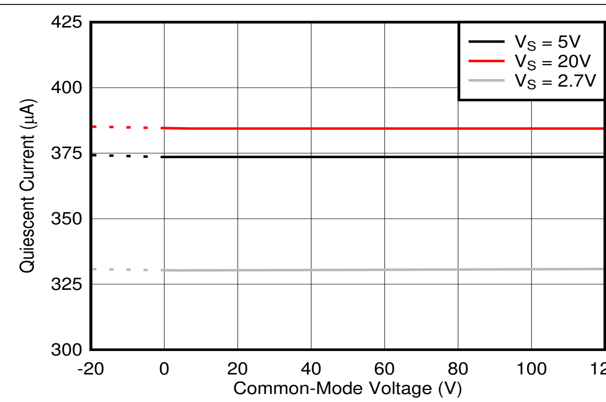
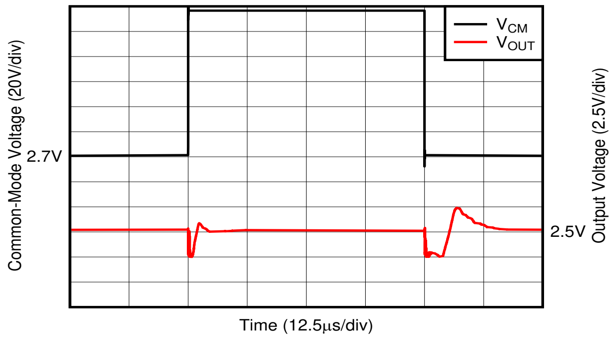


図 6-30. Quiescent Current vs Common-Mode Voltage, INA290

6.6 Typical Characteristics (continued)

All specifications at T_A = 25 °C, V_S = 5 V, V_{SENSE} = V_{IN+} – $V_{IN–}$ = 0.5 V / Gain, and V_{CM} = $V_{IN–}$ = 48 V, unless otherwise noted.



R_L = 10 kΩ V_{SENSE} = 5 mV

図 6-31. Common-Mode Voltage Fast Transient Pulse, A5 DeviceAs

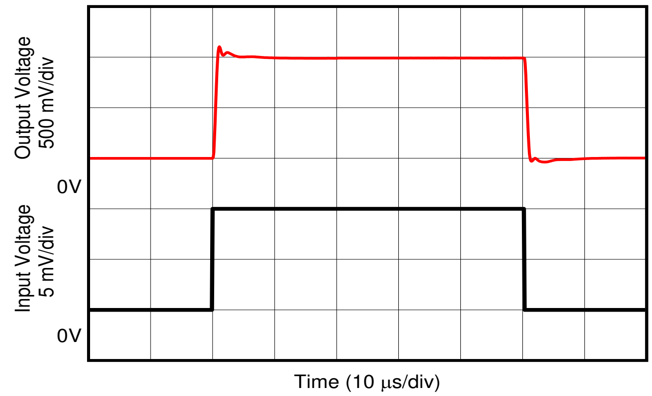
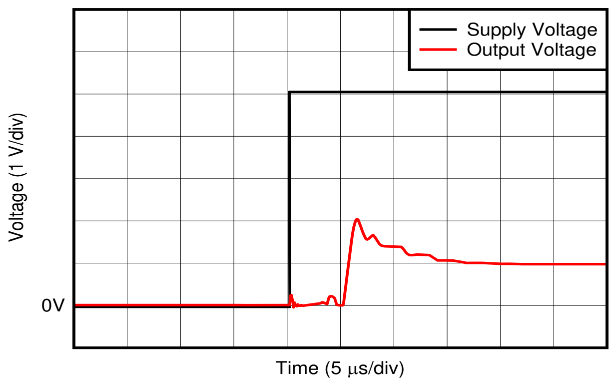
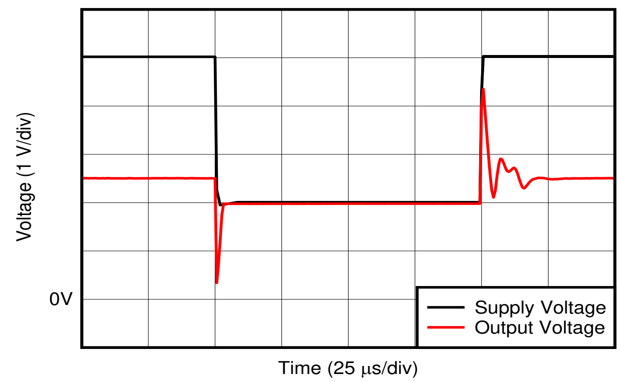


図 6-32. Step Response, A3 Devices



V_{SENSE} = 0 mV

図 6-33. Start-Up Response



V_{SENSE} = 5 mV

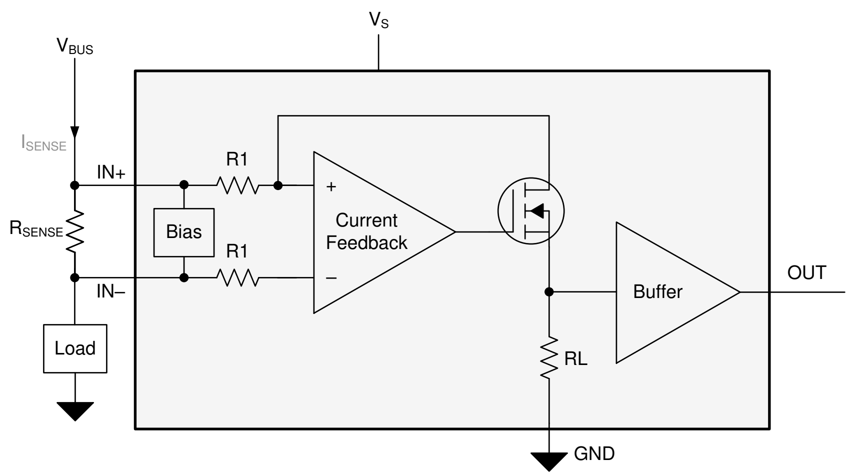
図 6-34. Supply Transient Response, A5 Devices

7 Detailed Description

7.1 Overview

The INA290-Q1 is a high-side only current-sense amplifier that offers a wide common-mode range, precision zero-drift topology, excellent common-mode rejection ratio (CMRR), high bandwidth, and fast slew rate. Different gain versions are available to optimize the output dynamic range based on the application. The INA290-Q1 is designed using a transconductance architecture with a current-feedback amplifier that enables low bias currents of 20 µA and a common-mode voltage of 120 V.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Amplifier Input Common-Mode Range

The INA290-Q1 supports large input common-mode voltages from 2.7 V to 120 V and features a high DC CMRR of 160 dB (typical) and a 85-dB AC CMRR at 50 kHz. The minimum common-mode voltage is restricted by the supply voltage as shown in 図 7-1. The topology of the internal amplifiers INA290-Q1 restricts operation to high-side, current-sensing applications.

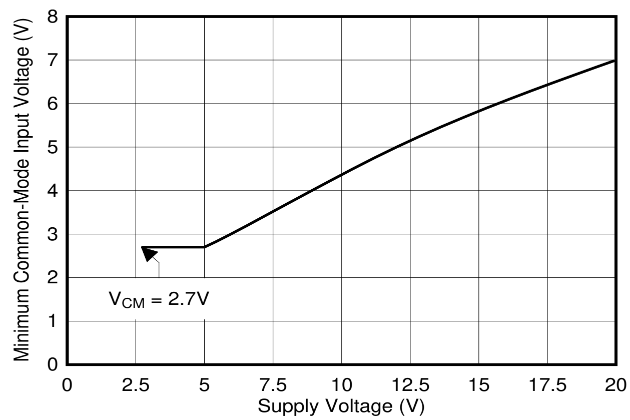


図 7-1. Minimum Common-Mode Voltage vs Supply

7.3.1.1 Input-Signal Bandwidth

The INA290-Q1 –3-dB bandwidth is gain dependent with several gain options of 20 V/V, 50 V/V, 100 V/V, 200 V/V, and 500 V/V as shown in 図 6-8. The unique multistage design enables the amplifier to achieve high bandwidth at all gains. This high bandwidth provides the throughput and fast response that is required for the rapid detection and processing of overcurrent events.

The bandwidth of the device also depends on the applied V_{SENSE} voltage. 図 7-2 shows the bandwidth performance profile of the device over frequency as output voltage increases for each gain variation. As shown in 図 7-2, the device exhibits the highest bandwidth with higher V_{SENSE} voltages, and the bandwidth is higher with lower device gain options. Individual requirements determine the acceptable limits of error for high-frequency, current-sensing applications. Testing and evaluation in the end application or circuit is required to determine the acceptance criteria and validate whether or not the performance levels meet the system specifications.

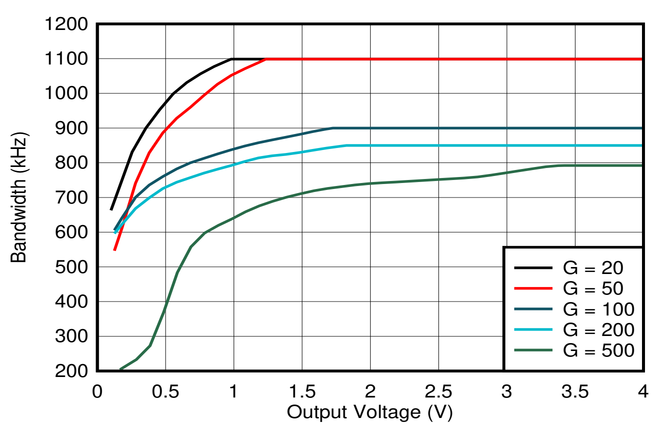


図 7-2. Bandwidth vs Output Voltage

7.3.1.2 Low Input Bias Current

The INA290-Q1 input bias current draws 20 µA (typical) even with common-mode voltages as high as 120 V. This enables precision current sensing in applications where the sensed current is small or applications that require lower input leakage current.

7.3.1.3 Low V_{SENSE} Operation

The INA290-Q1 enables accurate current measurement across the entire valid V_{SENSE} range. The zero-drift input architecture of the INA290-Q1 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. The capability to measure low sense voltages enables accurate measurements at lower load currents, and also allows reduction of the sense resistor value for a given operating current, which minimizes the power loss in the current sensing element.

7.3.1.4 Wide Fixed Gain Output

The INA290-Q1 gain error is < 0.1% at room temperature for most gain options, with a maximum drift of 5 ppm/°C over the full temperature range of –40 °C to +125 °C. The INA290-Q1 is available in multiple gain options of 20 V/V, 50 V/V, 100 V/V, 200 V/V, and 500 V/V, which the system designer should select based on their desired signal-to-noise ratio and other system requirements.

The INA290-Q1 closed-loop gain is set by a precision, low-drift internal resistor network. The ratio of these resistors are excellently matched, while the absolute values may vary significantly. TI does not recommend adding additional resistance around the INA290-Q1 to change the effective gain because of this variation, however. The typical values of the gain resistors are described in 表 7-1.

表 7-1. Fixed Gain Resistor

GAIN	R1	RL
20 (V/V)	25 kΩ	500 kΩ
50 (V/V)	10 kΩ	500 kΩ
100 (V/V)	10 kΩ	1000 kΩ
200 (V/V)	5 kΩ	1000 kΩ
500 (V/V)	2 kΩ	1000 kΩ

7.3.1.5 Wide Supply Range

The INA290-Q1 operates with a wide supply range from a 2.7 V to 20 V. The output stage supports a full-scale output voltage range of up to V_S. Wide output range can enable very-wide dynamic range current measurements. For a gain of 20 V/V, the maximum differential input acceptable is 1 V.

The offset of the gain of INA290-Q1A1 device is ±25 µV, and the INA290-Q1A1 is capable of measuring a wide dynamic range of current up to 92 dB.

7.4 Device Functional Modes

7.4.1 Unidirectional Operation

The INA290-Q1 measures the differential voltage developed by current flowing through a resistor that is commonly referred to as a current-sensing resistor or a current-shunt resistor. The INA290-Q1 operates in unidirectional mode only, meaning it only senses current sourced from a power supply to a system load as shown in 図 7-3.

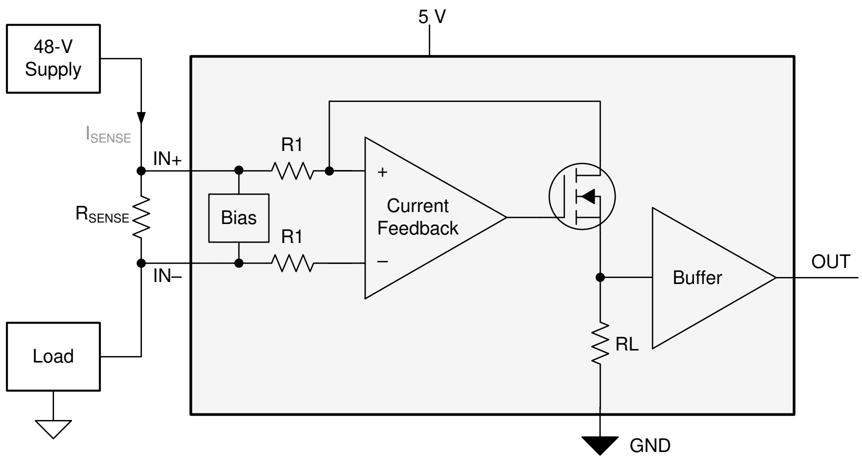


図 7-3. Unidirectional Application

The linear range of the output stage is limited to how close the output voltage can approach ground under zero-input conditions. The zero current output voltage of the INA290-Q1 is very small, with a maximum of GND + 25 mV. Make sure to apply a sense voltage of (25 mV / Gain) or greater to keep the INA290-Q1 output in the linear region of operation.

7.4.2 High Signal Throughput

With a bandwidth of 1.1 MHz at a gain of 20 V/V and a slew rate of 2 V/µs, the INA290-Q1 is specifically designed for detecting and protecting applications from fast inrush currents. As shown in 表 7-2, the INA290-Q1 responds in less than 2 µs for a system measuring a 75-A threshold on a 2-mΩ shunt.

表 7-2. Response Time

PARAMETER		EQUATION	INA290-Q1 AT V_S = 5 V
G	Gain		20 V/V
I_{MAX}	Maximum current		100 A
$I_{Threshold}$	Threshold current		75 A
R_{SENSE}	Current sense resistor value		2 mΩ
V_{OUT_MAX}	Output voltage at maximum current	$V_{OUT} = I_{MAX} \times R_{SENSE} \times G$	4 V
V_{OUT_THR}	Output voltage at threshold current	$V_{OUT\_THR} = I_{THR} \times R_{SENSE} \times G$	3 V
SR	Slew rate		2 V/µs
	Output response time	$T_{response} = V_{OUT\_THR} / SR$	< 2 µs

8 Application and Implementation

Note

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8.1 Application Information

The INA290-Q1 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 INA290-Q1 allows use over a wide range of voltage rails while still maintaining an accurate current measurement.

8.1.1 R_{SENSE} and Device Gain Selection

The accuracy of any current-sense amplifier is maximized by choosing the current-sense resistor to be as large as possible. A large 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 can be in a given application because of the resistor size and maximum allowable power dissipation. 式 1 gives the maximum value for the current-sense resistor for a given power dissipation budget:

$$R_{SENSE} < \frac{PD_{MAX}}{I_{MAX}^{2}} \tag{1}$$

where:

- PD_{MAX} is the maximum allowable power dissipation in R_{SENSE}.
- I_{MAX} is the maximum current that will flow 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 make sure that the current-sense signal is properly passed to the output, both positive and negative output swing limitations must be examined. 式 2 provides the maximum values of R_{SENSE} and GAIN to keep the device from exceeding the positive swing limitation.

$$I_{MAX} \times R_{SENSE} \times GAIN < V_{SP} \tag{2}$$

where:

- I_{MAX} is the maximum current that will flow through R_{SENSE}.
- GAIN is the gain of the current-sense amplifier.
- V_{SP} is the positive output swing as specified in the data sheet.

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 it is possible to select a lower-gain device in order 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. 式 3 provides the limit on the minimum value of the sense resistor.

$$I_{MIN} \times R_{SENSE} \times GAIN > V_{SN} \tag{3}$$

where:

- I_{MIN} is the minimum current that will flow through R_{SENSE}.
- GAIN is the gain of the current-sense amplifier.

- V_{SN} is the negative output swing of the device.

表 8-1 shows an example of the different results obtained from using five different gain versions of the INA290-Q1. From the table data, the highest gain device allows a smaller current-shunt resistor and decreased power dissipation in the element.

表 8-1. R_{SENSE} Selection and Power Dissipation

PARAMETER[1]		EQUATION	RESULTS AT V_S = 5 V				
			INA290A1Q	INA290A2Q	INA290A3Q	INA290A4Q	INA290A5Q
G	Gain		20 V/V	50 V/V	100 V/V	200 V/V	500 V/V
V_{SENSE}	Ideal differential input voltage (Ignores swing limitation and power supply variation.)	$V_{SENSE} = V_{OUT} / G$	250 mV	100 mV	50 mV	25 mV	10 mV
R_{SENSE}	Current sense resistor value	$R_{SENSE} = V_{SENSE} / I_{MAX}$	25 mΩ	10 mΩ	5 mΩ	2.5 mΩ	1 mΩ
P_{SENSE}	Current-sense resistor power dissipation	R_{SENSE} x $I_{MAX}2$	2.5 W	1 W	0.5W	0.25 W	0.1 W

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

8.1.2 Input Filtering

Note

Input filters are not required for accurate measurements using the INA290-Q1, and use of filters in this location is not recommended. If filter components are used on the input of the amplifier, follow the guidelines in this section to minimize the effects on performance.

Based strictly on user design requirements, external filtering of the current signal may be desired. The initial location that can be considered for the filter is at the output of the current-sense amplifier. Although placing the filter at the output satisfies the filtering requirements, this location changes the low output impedance measured by any circuitry connected to the output voltage pin. The other location for filter placement is at the current-sense amplifier input pins. This location also satisfies the filtering requirement, but the components must be carefully selected to minimally impact device performance. 図 8-1 shows a filter placed at the input pins.

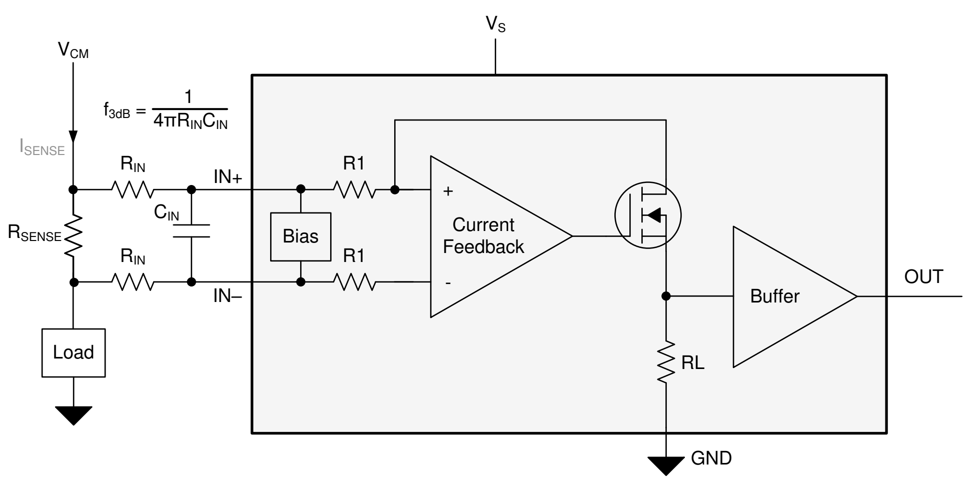

図 8-1. Filter at Input Pins

External series resistance provides a source of additional measurement error, so keep the value of these series resistors to 10 Ω or less to reduce loss of accuracy. The internal bias network shown in 図 8-1 creates a mismatch in input bias currents (see 図 6-15, 図 6-16, and 図 6-17) when a differential voltage is applied between the input pins. If additional external series filter resistors are added to the circuit, a mismatch is created in the voltage drop across the filter resistors. This voltage is a differential error voltage in the shunt resistor voltage. In addition to the absolute resistor value, mismatch resulting from resistor tolerance can significantly impact the error because this value is calculated based on the actual measured resistance.

The measurement error expected from the additional external filter resistors can be calculated using 式 4, where the gain error factor is calculated using 式 5.

$$\text{Gain Error (\%)} = 100 \times (\text{Gain Error Factor} - 1) \tag{4}$$

The gain error factor, shown in 式 4, can be calculated to determine the gain error introduced by the additional external series resistance. 式 4 calculates the deviation of the shunt voltage, resulting from the attenuation and imbalance created by the added external filter resistance. 表 8-2 provides the gain error factor and gain error for several resistor values.

$$\text{Gain Error Factor} = \frac{R_B \times R1}{(R_B \times R1) + (R_B \times R_{IN}) + (2 \times R_{IN} \times R1)} \tag{5}$$

Where:

- R_{IN} is the external filter resistance value.
- R1 is the INA290-Q1 input resistance value specified in 表 7-1.
- R_B in the internal bias resistance, which is 6600 Ω ± 20%.

表 8-2. Example Gain Error Factor and Gain Error for 10-Ω External Filter Input Resistors

DEVICE (GAIN)	GAIN ERROR FACTOR	GAIN ERROR (%)
A1 devices (20)	0.99658	–0.34185
A2 devices (50)	0.99598	–0.40141
A3 devices (100)	0.99598	–0.40141
A4 devices (200)	0.99499	–0.50051
A5 devices (500)	0.99203	–0.79663

8.2 Typical Application

The INA290-Q1 is a unidirectional, current-sense amplifier capable of measuring currents through a resistive shunt with shunt common-mode voltages from 2.7 V to 120 V. The circuit configuration for monitoring current in a high-side pump or motor is shown in 図 8-2 .

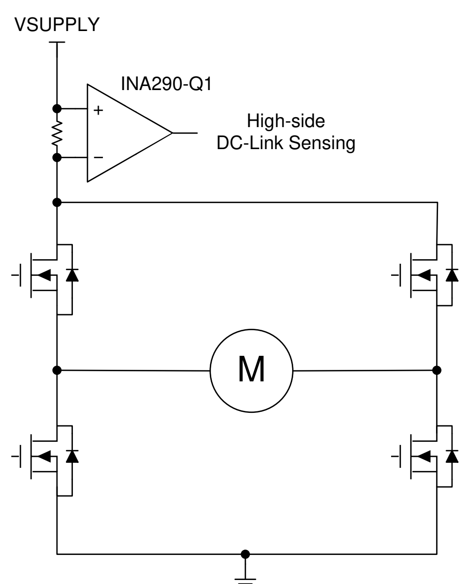

図 8-2. Current Sensing in a Automotive Pump

8.2.1 Design Requirements

V_{SUPPLY} is set to 5 V, and the common-mode voltage set to 48 V. 表 8-3 lists the design setup for this application.

表 8-3. Design Parameters

DESIGN PARAMETERS	EXAMPLE VALUE
INA290-Q1 supply voltage	5 V
High-side supply voltage	48 V
Maximum sense current (I_{MAX})	5 A
Gain option	50 V/V

8.2.2 Detailed Design Procedure

The maximum value of the current-sense resistor is calculated based choice of gain, value of the maximum current the be sensed (I_{MAX}), and the power-supply voltage (V_S). When operating at the maximum current, the output voltage must not exceed the positive output swing specification, V_{SP}. Under the given design parameters, 式 6 calculates the maximum value for R_{SENSE} as 19.2 mΩ.

$$R_{SENSE} < \frac{V_{SP}}{I_{MAX} \times GAIN} \tag{6}$$

For this design example, a value of 15 mΩ is selected because, while the 15 mΩ is less than the maximum value calculated, 15 mΩ is still large enough to give adequate signal at the current-sense amplifier output.

8.2.2.1 Overload Recovery With Negative V_{SENSE}

The INA290-Q1 is a unidirectional current-sense amplifier that is meant to operate with a positive differential input voltage (V_{SENSE}). If negative V_{SENSE} is applied, the device is placed in an overload condition and requires time to recover once V_{SENSE} returns positive. The required overload recovery time increases with more negative V_{SENSE}.

8.2.3 Application Curve

図 8-3 shows the output response of the device to a high frequency sinusoidal current.

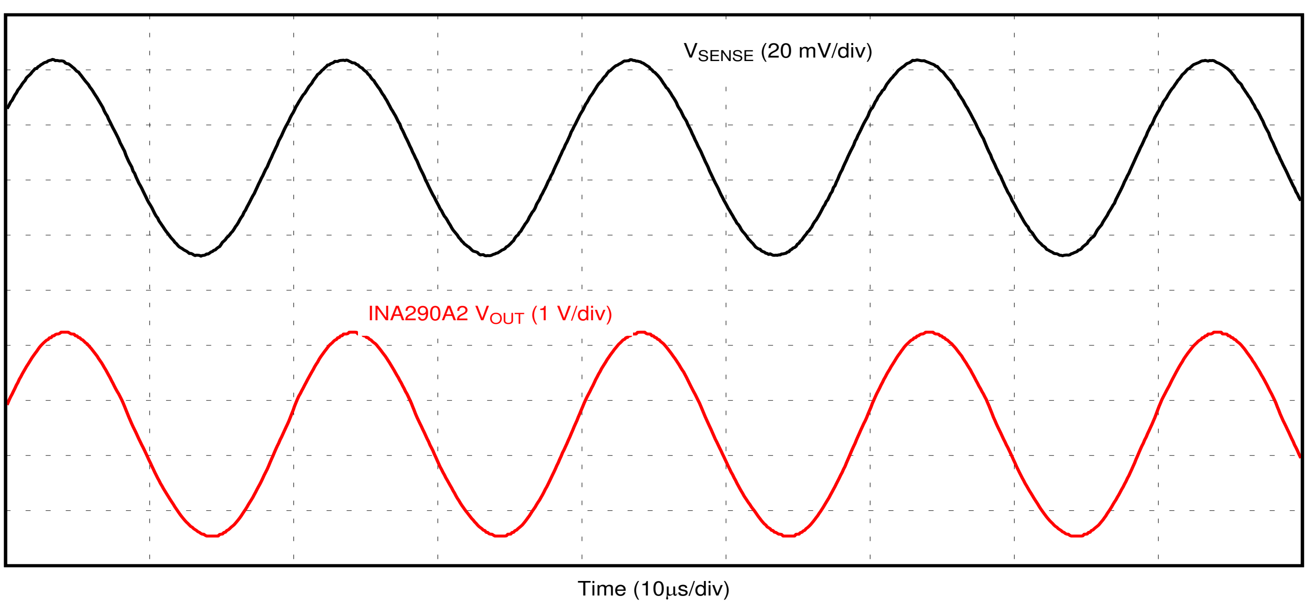

図 8-3. INA290-Q1 Output Response

9 Power Supply Recommendations

The input circuitry of the INA290-Q1 device can accurately measure beyond the power-supply voltage. The power supply can be 20 V, whereas the load power-supply voltage at IN+ and IN– can go up to 120 V. The output voltage range of the OUT pin is limited by the voltage on the V_S pin and the device swing to supply specification.

10 Layout

10.1 Layout Guidelines

TI always recommends to follow good layout practices:

- 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 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 µF. Additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies.
- When routing the connections from the current-sense resistor to the device, keep the trace lengths as short as possible.

10.2 Layout Example

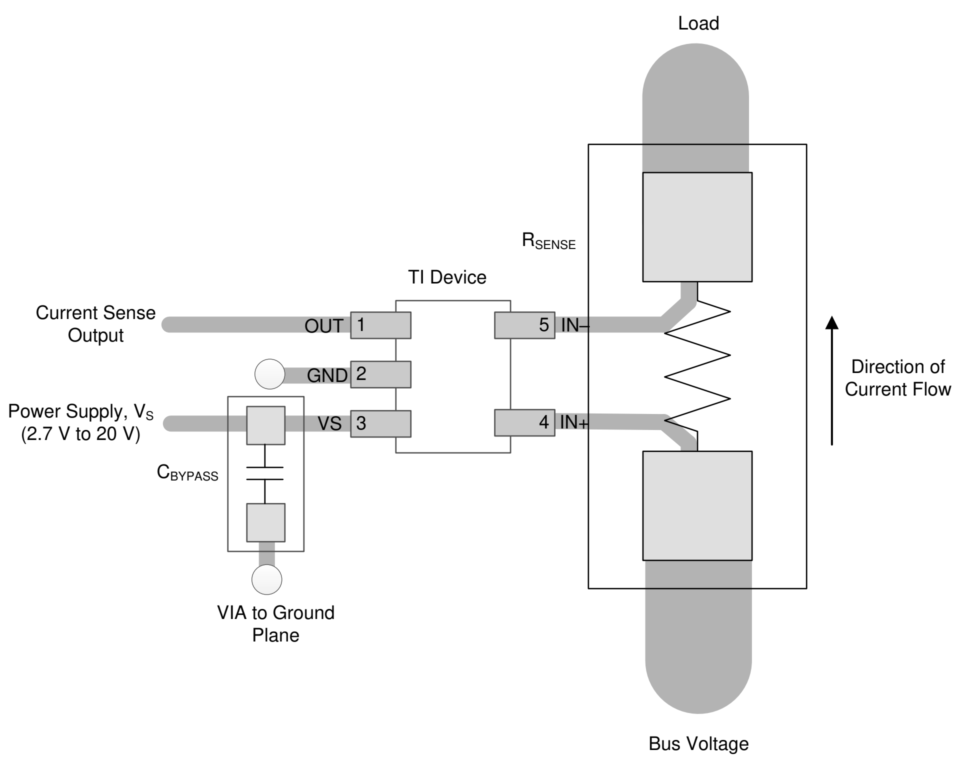

図 10-1. Recommended Layout for INA290-Q1

11 Device and Documentation Support

11.1 Documentation Support

11.1.1 Related Documentation

For related documentation, see the following:

Texas Instruments, *INA290EVM User's Guide*

11.2 ドキュメントの更新通知を受け取る方法

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11.6 用語集

TI 用語集　　この用語集には、用語や略語の一覧および定義が記載されています。

12 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.

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)
INA290A1QDCKRQ1	Active	Production	SC70 (DCK) | 5	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	1G6
INA290A1QDCKRQ1.B	Active	Production	SC70 (DCK) | 5	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	1G6
INA290A2QDCKRQ1	Active	Production	SC70 (DCK) | 5	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	1G8
INA290A2QDCKRQ1.B	Active	Production	SC70 (DCK) | 5	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	1G8
INA290A3QDCKRQ1	Active	Production	SC70 (DCK) | 5	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	1G7
INA290A3QDCKRQ1.B	Active	Production	SC70 (DCK) | 5	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	1G7
INA290A4QDCKRQ1	Active	Production	SC70 (DCK) | 5	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	1G9
INA290A4QDCKRQ1.B	Active	Production	SC70 (DCK) | 5	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	1G9
INA290A5QDCKRQ1	Active	Production	SC70 (DCK) | 5	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	1GA
INA290A5QDCKRQ1.B	Active	Production	SC70 (DCK) | 5	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	1GA

(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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OTHER QUALIFIED VERSIONS OF INA290-Q1 :

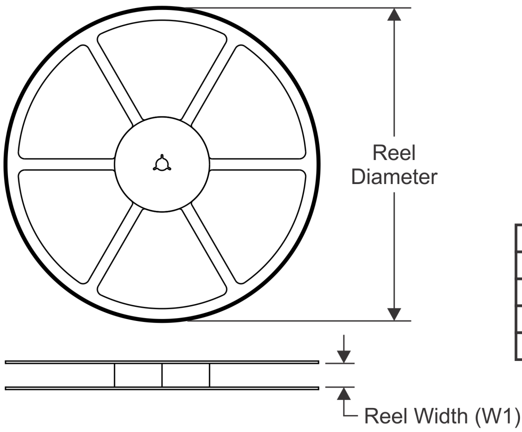
- Catalog : INA290

NOTE: Qualified Version Definitions:

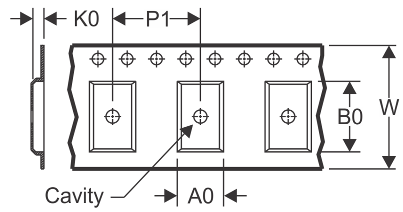
- Catalog - TI's standard catalog product

TAPE AND REEL INFORMATION

REEL DIMENSIONS

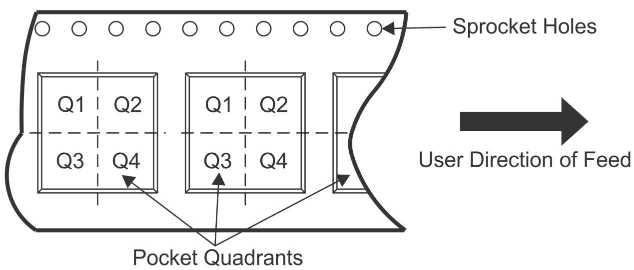


TAPE DIMENSIONS



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

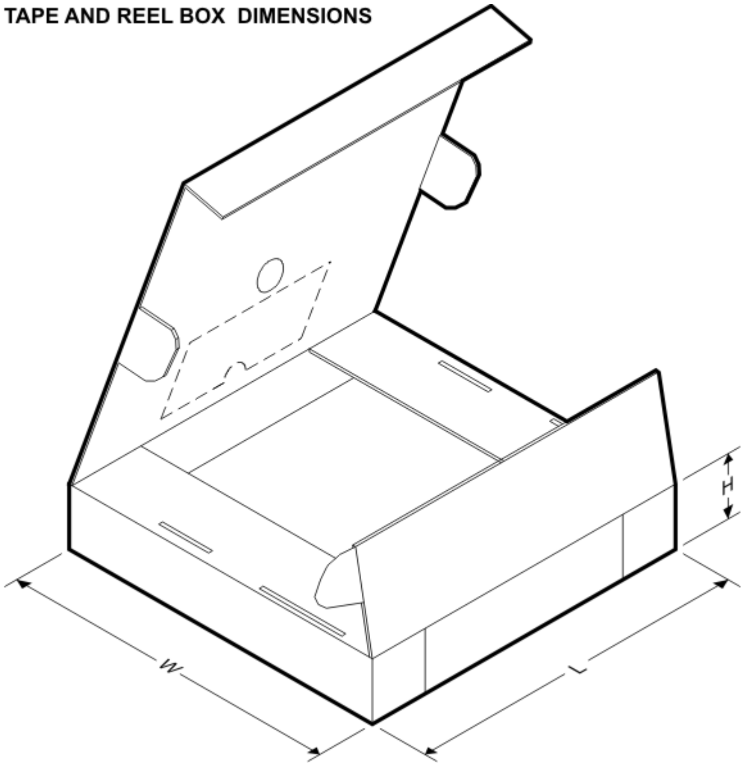
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

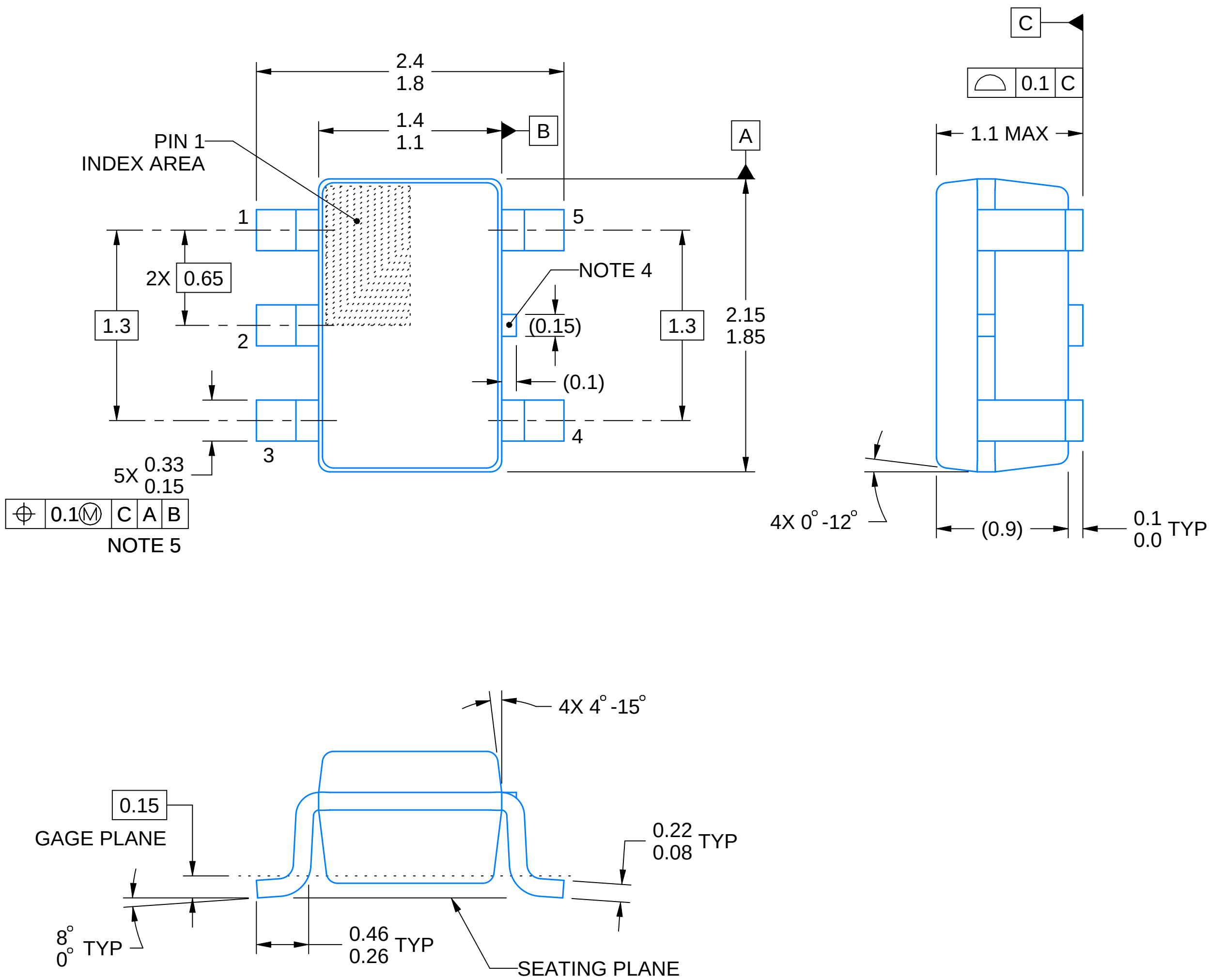
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
INA290A1QDCKRQ1	SC70	DCK	5	3000	180.0	8.4	2.47	2.3	1.25	4.0	8.0	Q3
INA290A2QDCKRQ1	SC70	DCK	5	3000	180.0	8.4	2.47	2.3	1.25	4.0	8.0	Q3
INA290A3QDCKRQ1	SC70	DCK	5	3000	180.0	8.4	2.47	2.3	1.25	4.0	8.0	Q3
INA290A4QDCKRQ1	SC70	DCK	5	3000	180.0	8.4	2.47	2.3	1.25	4.0	8.0	Q3
INA290A5QDCKRQ1	SC70	DCK	5	3000	180.0	8.4	2.47	2.3	1.25	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)
INA290A1QDCKRQ1	SC70	DCK	5	3000	183.0	183.0	20.0
INA290A2QDCKRQ1	SC70	DCK	5	3000	183.0	183.0	20.0
INA290A3QDCKRQ1	SC70	DCK	5	3000	183.0	183.0	20.0
INA290A4QDCKRQ1	SC70	DCK	5	3000	183.0	183.0	20.0
INA290A5QDCKRQ1	SC70	DCK	5	3000	183.0	183.0	20.0



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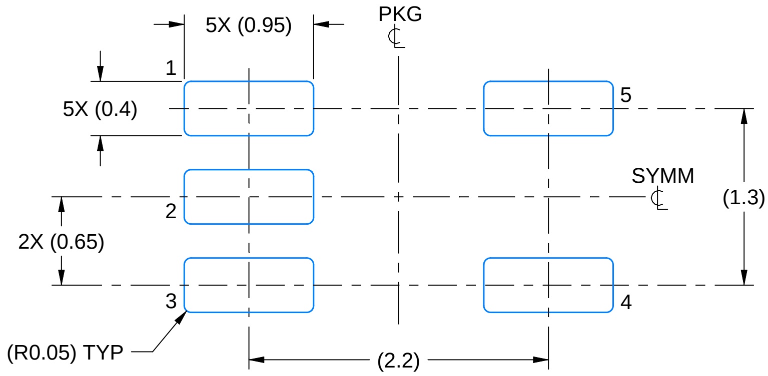
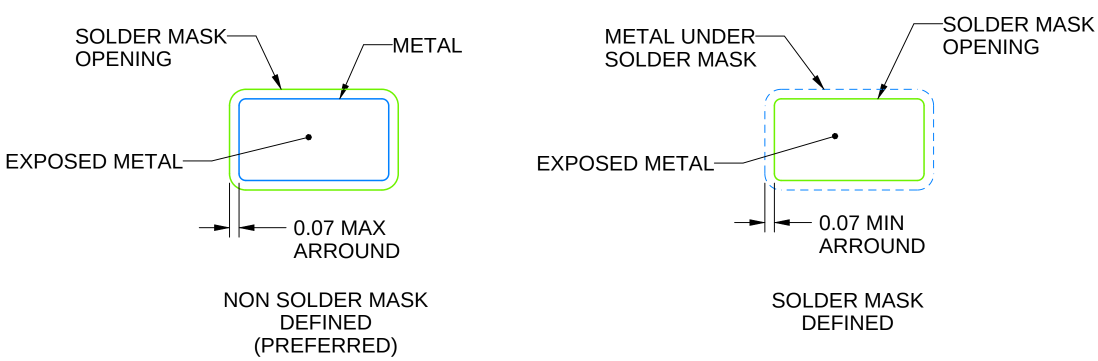
NOTES:

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. Refernce JEDEC MO-203.
4. Support pin may differ or may not be present.
5. Lead width does not comply with JEDEC.
6. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25mm per side



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:18X



SOLDER MASK DETAILS

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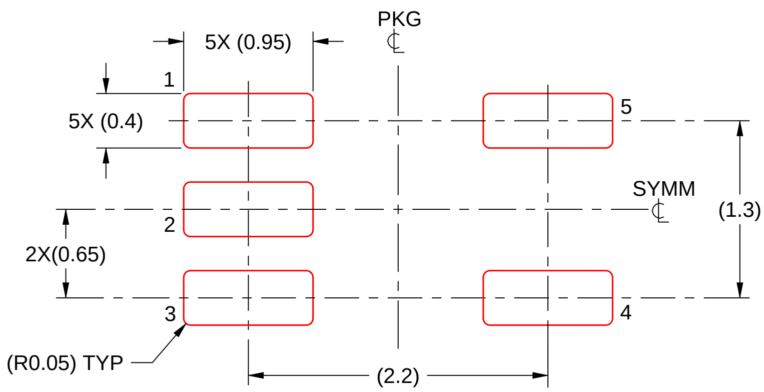
NOTES: (continued)

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



SOLDER PASTE EXAMPLE
BASED ON 0.125 THICK STENCIL
SCALE:18X

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NOTES: (continued)

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

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