INA241x-Q1 AEC-Q100, –5 V to 110 V, Bidirectional, Ultra-Precise Current Sense Amplifier With Enhanced PWM Rejection

1 Features

- AEC-Q100 qualified for automotive applications:
  - Temperature grade 1: −40°C to +125°C, T_A
- Functional Safety-Capable
  - Documentation available to aid functional safety system design
- Enhanced PWM rejection optimized for systems subject to switching common-mode voltages
  - Supports switching frequencies up to 125 kHz
- Wide common-mode voltage:
  - Operational voltage: −5 V to +110 V
  - Survival voltage: −20 V to +120 V
- Bidirectional operation
- High small signal bandwidth: 1.1 MHz (at all gains)
- Slew rate: 8 V/µs
- Step response settling time to 1%: 1 µs
- Excellent CMRR
  - 166 dB DC-CMRR
  - 104 dB AC-CMRR at 100 kHz
  - 89 dB AC-CMRR at 1 MHz
- Accuracy:
  - Gain error (maximum)
    - Version A: ±0.01%, ±1 ppm/°C drift
    - Version B: ±0.1%, ±5 ppm/°C drift
  - Offset voltage (maximum)
    - Version A: ±10 µV, ±0.1 µV/°C drift
    - Version B: ±150 µV, ±0.5 µV/°C drift
- Available gains:
  - INA241A1-Q1 : 10 V/V
  - INA241A2-Q1 : 20 V/V
  - INA241A3-Q1 : 50 V/V
  - INA241A4-Q1 : 100 V/V
  - INA241A5-Q1 : 200 V/V
- Package options: SOT23-8, VSSOP-8, SOIC-8

2 Applications

- eTurbo/charger
- Electric power steering (EPS)
- Starter/generator
- Regenerative breaking
- Brake system

3 Description

The INA241x-Q1 is an ultra-precise, bidirectional current sense amplifier than can measure voltage drops across shunt resistors over a wide common-mode range from –5 V to 110 V, independent of the supply voltage. The high-precision current measurement is achieved through a combination of low offset voltage (±10 µV, maximum), small gain error (±0.01%, maximum) and a high DC CMRR (typical 166 dB). The INA241x-Q1 is designed for high voltage, bidirectional measurements in switching systems that see large common-mode voltage transients at the device's inputs. The enhanced PWM rejection circuitry inside the INA241x-Q1 ensures minimal signal disturbance at the output due to the common-mode voltage transitions at the input.

The INA241x-Q1 operates from a single 2.7 V to 20 V supply, drawing 2.5 mA of supply current. The INA241x-Q1 is available in five gain options: 10 V/V, 20 V/V, 50 V/V, 100 V/V, and 200 V/V. Multiple gain options allow for optimization between available shunt resistor values and wide output dynamic range requirements.
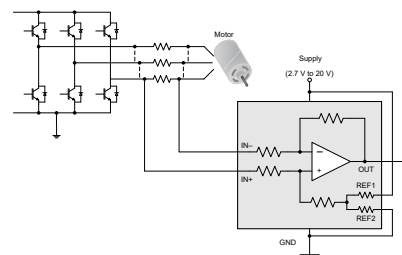
The INA241x-Q1 is specified over operating temperature range of −40°C to +125°C and is offered in a space-saving 8-pin SOT-23 and 8-pin VSSOP package.

Package Information[1]

PART NUMBER	PACKAGE	BODY SIZE (NOM)
INA241A-Q1 INA241B-Q1	SOT-23 (8)	2.90 mm × 1.60 mm
	VSSOP (8)[2]	3.00 mm × 3.00 mm
	SOIC (8)[2]	4.90 mm × 3.91 mm

(1) For all available packages, see the package option addendum at the end of the data sheet.
(2) Package is preview only

Typical Application - Inline Motor Control

Table of Contents

4 Revision History

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

DATE	REVISION	NOTES
February 2023	*	Initial Release

5 Device Comparison

Table 5-1. Device Comparison

DEVICE NAME	GAIN
INA241A1-Q1, INA241B1-Q1	10 V/V
INA241A2-Q1, INA241B2-Q1	20 V/V
INA241A3-Q1, INA241B3-Q1	50 V/V
INA241A4-Q1, INA241B4-Q1	100 V/V
INA241A5-Q1, INA241B5-Q1	200 V/V

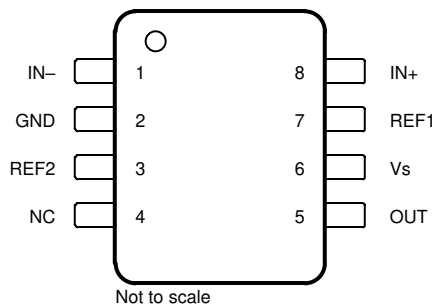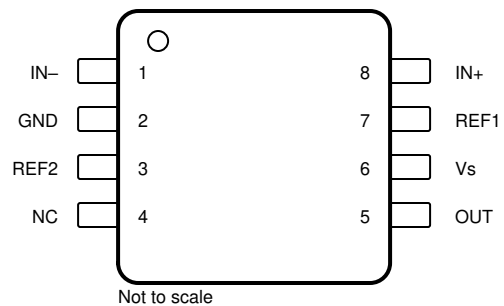## 6 Pin Configuration and Functions

Figure 6-1. INA241x-Q1: DDF Package 8-Pin SOT-23 Top View

1. This package is preview only.

Figure 6-2. INA241x-Q1: D and DGK Package 8-Pin SOIC and 8-Pin VSSOP Top View

Table 6-1. Pin Functions: D, DDF and DGK Packages

PIN NAME	PIN NO.	TYPE	DESCRIPTION
GND	2	Ground	Ground
IN+	8	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–	1	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.
NC	4	Ground	Reserved. Connect to ground.
OUT	5	Output	Output voltage
REF1	7	Input	Reference 1 voltage. Connect to voltage potential from 0 V to V_S; see *Adjusting the Output With the Reference Pins* for connection options.
REF2	3	Input	Reference 2 voltage. Connect to voltage potential from 0 V to V_S; see *Adjusting the Output With the Reference Pins* for connection options.
V_S	6	Power	Power supply, 2.7 V to 20 V

7 Specifications

7.1 Absolute Maximum Ratings

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

			MIN	MAX	UNIT
V_S	Supply voltage			22	V
	Analog inputs, V_{IN+}, V_{IN-} [2]	Differential (V_{IN+}) − (V_{IN-})	−30	30	V
		Common-mode	−20	120	V
	REF1, REF2, NC inputs		GND − 0.3	V_S + 0.3	V
Output	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) 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_{IN+} and V_{IN-} are the voltages at the IN+ and IN– pins, respectively.

7.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per AEC Q100-002[1] HBM ESD classification level 2	±2000	V
		Charged device model (CDM), per AEC Q100-011 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.

7.3 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
V_{CM}	Common-mode input range	−5	48	110	V
V_S	Operating supply range	2.7	5	20	V
T_A	Ambient temperature	−40		125	°C

7.4 Thermal Information

THERMAL METRIC[1]		INA241x -Q1			UNIT
		DDF (SOT23) 8 PINS	DGK (VSSOP)[2] 8 PINS	D (SOIC)[2] 8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	129.7	TBD	TBD	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	58	TBD	TBD	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	52.6	TBD	TBD	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	2.3	TBD	TBD	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	52.3	TBD	TBD	°C/W

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

(2) This package is preview only.

Product Folder Links: *INA241A-Q1 INA241B-Q1*

7.5 Electrical Characteristics

at T_A = 25°C, V_S = 5 V, V_{SENSE} = V_{IN+} – $V_{IN–}$, V_{CM} = $V_{IN–}$ = 48 V, and V_{REF1} = V_{REF2} = V_S / 2 (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
INPUT						
V_{CM}	Common-mode input range[1]	V_{IN+}, $V_{IN–}$ = –5 V to 110 V, V_{SENSE} = 0 mV T_A = –40°C to 125°C	–5		110	V
CMRR	Common-mode rejection ratio, input-referred	V_{IN+}, $V_{IN–}$ = –5 V to 110 V, V_{SENSE} = 0 mV T_A = –40°C to 125°C, INA241A-Q1	150	166		dB
		V_{IN+}, $V_{IN–}$ = –5 V to 110 V, V_{SENSE} = 0 mV T_A = –40°C to 125°C, INA241B-Q1	120	130		
		f = 50 kHz		105		
V_{os}	Offset voltage, input-referred	V_{SENSE} = 0 mV, INA241A1-Q1		±5	±20	µV
		V_{SENSE} = 0 mV, INA241A2-Q1		±3	±15	
		V_{SENSE} = 0 mV, INA241A3-Q1, INA241A4-Q1		±3	±10	
		V_{SENSE} = 0 mV, INA241A5-Q1		±2	±8	
		V_{SENSE} = 0 mV, INA241B-Q1		±25	±150	
dV_{os}/dT	Offset voltage drift, input-referred	T_A = –40°C to 125°C, INA241A1-Q1		±50	±250	nV/°C
		T_A = –40°C to 125°C, INA241A2-Q1		±30	±150	
		T_A = –40°C to 125°C, INA241A3-Q1, INA241A4-Q1, INA241A5-Q1		±20	±100	
		T_A = –40°C to 125°C, INA241B-Q1		±100	±500	
PSRR	Power-supply rejection ratio, input-referred	V_S = 2.7 V to 20 V, V_{SENSE} = 0 mV, V_{REF1} = V_{REF2} = 1V, T_A = –40°C to 125°C, INA241A1-Q1		±0.2	±1	µV/V
		V_S = 2.7 V to 20 V, V_{SENSE} = 0 mV, V_{REF1} = V_{REF2} = 1V, T_A = –40°C to 125°C, INA241A2-Q1		±0.1	±0.75	
		V_S = 2.7 V to 20 V, V_{SENSE} = 0 mV, V_{REF1} = V_{REF2} = 1V, T_A = –40°C to 125°C, INA241A3-Q1, INA241A4-Q1, INA241A5-Q1		±0.06	±0.5	
		V_S = 2.7 V to 20 V, V_{SENSE} = 0 mV, V_{REF1} = V_{REF2} = 1V, T_A = –40°C to 125°C, INA241B-Q1		±1	±10	
I_B	Input bias current	I_{B+}, $I_{B–}$, V_{SENSE} = 0 mV	25	35	45	uA
	Reference input range		0		V_S	V
OUTPUT						
G	Gain	A1, B1 devices		10		V/V
		A2, B2 devices		20		V/V
		A3, B3 devices		50		V/V
		A4, B4 devices		100		V/V
		A5, B5 devices		200		V/V

Product Folder Links: *INA241A-Q1 INA241B-Q1*

at T_A = 25°C, V_S = 5 V, V_{SENSE} = V_{IN+} – V_{IN-}, V_{CM} = V_{IN-} = 48 V, and V_{REF1} = V_{REF2} = V_S / 2 (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
G_{ERR}	Gain error	(GND + 50 mV) < V_{OUT} < (V_S - 200 mV), INA241A1-Q1, INA241A2-Q1, INA241A3-Q1		±0.002	±0.01	%
		(GND + 50 mV) < V_{OUT} < (V_S - 200 mV), INA241A4-Q1, INA241A5-Q1		±0.003	±0.015	
		(GND + 50 mV) < V_{OUT} < (V_S - 200 mV), INA241B-Q1		±0.02	±0.1	
	Gain error drift	T_A = –40°C to +125°C, INA241A1-Q1, INA241A2-Q1, INA241A3-Q1		±0.05	±1	ppm/°C
		T_A = –40°C to +125°C, INA241A4-Q1, INA241A5-Q1		±0.1	±2	
		T_A = –40°C to +125°C, INA241B-Q1		±0.2	±5	
	Non-linearity error			±0.001		%
	Maximum capacitive load	No sustained oscillations, no isolation resistor		1		nF
VOLTAGE OUTPUT						
	Swing to V_S power supply rail	R_L = 10 kΩ to GND, T_A = –40°C to +125°C		V_S – 0.07	V_S – 0.2	V
	Swing to ground	R_L = 10 kΩ to GND, V_{SENSE} = 0 mV, V_{REF1} = V_{REF2} = 0 V, T_A = –40°C to +125°C		8	20	mV
REFERENCE INPUT						
RVRR	Reference voltage rejection ratio, input-referred	V_{REF1} = V_{REF2} = 0.5 V to 4.5 V, T_A = –40°C to +125°C, INA241A1-Q1		±1	±2.5	µV/V
		V_{REF1} = V_{REF2} = 0.5 V to 4.5 V, T_A = –40°C to +125°C, INA241A2-Q1, INA241A3-Q1, INA241A4-Q1, INA241A5-Q1		±0.5	±1.5	
		V_{REF1} = V_{REF2} = 0.5 V to 4.5 V, T_A = –40°C to +125°C, INA241B-Q1,		±10	±20	
	Reference divider accuracy	V_{OUT} = |(V_{REF1} + V_{REF2})| / 2 at V_{SENSE} =0 mV, V_{REF1} = V_S, V_{REF2} = GND V_{REF1} = GND, V_{REF2} = V_S T_A = –40°C to +125°C, INA241A1-Q1, INA241A2-Q1		±0.002	±0.005	%
		V_{OUT} = |(V_{REF1} + V_{REF2})| / 2 at V_{SENSE} =0 mV, V_{REF1} = V_S, V_{REF2} = GND V_{REF1} = GND, V_{REF2} = V_S T_A = –40°C to +125°C, INA241A3-Q1, INA241A4-Q1, INA241A5-Q1		±0.002	±0.01	
		V_{OUT} = |(V_{REF1} + V_{REF2})| / 2 at V_{SENSE} =0 mV, V_{REF1} = V_S, V_{REF2} = GND V_{REF1} = GND, V_{REF2} = V_S T_A = –40°C to +125°C, , INA241B-Q1		±0.02	±0.15	
FREQUENCY RESPONSE						
BW	Bandwidth	All gains, −3dB Bandwidth		1.1		MHz

Product Folder Links: *INA241A-Q1 INA241B-Q1*

at T_A = 25°C, V_S = 5 V, V_{SENSE} = V_{IN+} – V_{IN-}, V_{CM} = V_{IN-} = 48 V, and V_{REF1} = V_{REF2} = V_S / 2 (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
	Settling time	V_{IN+}, V_{IN-} = 48 V, V_{OUT} = 0.5 V to 4.5 V, Output settles to 0.5%		1.5		µs
		V_{IN+}, V_{IN-} = 48 V, V_{OUT} = 0.5 V to 4.5 V, Output settles to 1%		1		µs
		V_{IN+}, V_{IN-} = 48 V, V_{OUT} = 0.5 V to 4.5 V, Output settles to 5%		0.5		µs
SR	Slew rate	Rising		8		V/µs
NOISE (INPUT-REFERRED)						
	Voltage noise density	A1, B1 devices		62		nV/√Hz
		A2, B2 devices		49		
		A3, B3 devices		39		
		A4, B4 devices		36		
		A5, B5 devices		28		
POWER SUPPLY						
V_S	Supply voltage		2.7		20	V
I_Q	Quiescent current	V_{SENSE} = 0 mV		2.5	3	mA
		V_{SENSE} = 0 mV, T_A = –40°C to+125°C			3.2	mA
TEMPERATURE						
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.

7.6 Typical Characteristics

at T_A = 25°C, V_S = 5 V, V_{SENSE} = V_{IN+} – $V_{IN–}$, V_{CM} = $V_{IN–}$ = 48 V, and V_{REF1} = V_{REF2} = V_S / 2 (unless otherwise noted)
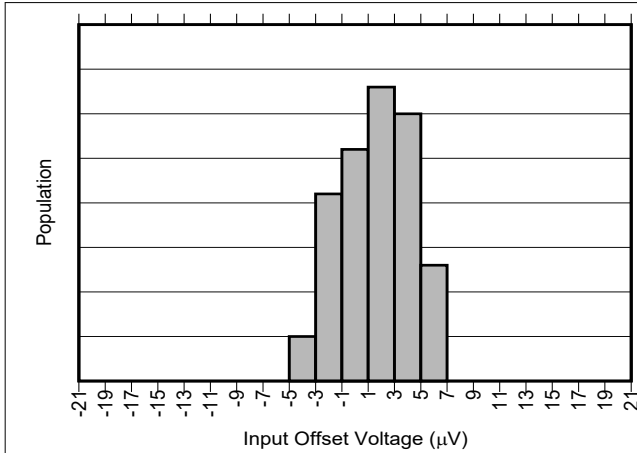

Figure 7-1. INA241A1-Q1 Input Offset Production Distribution
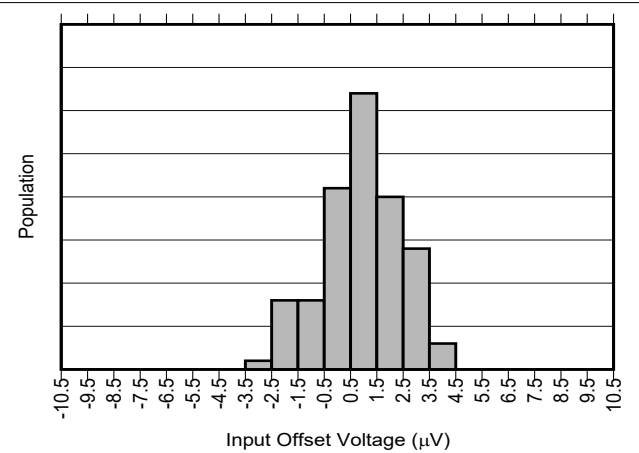

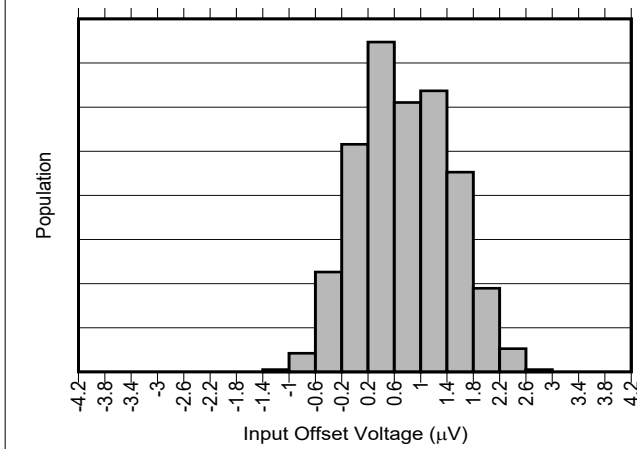Figure 7-2. INA241A2-Q1 Input Offset Production Distribution

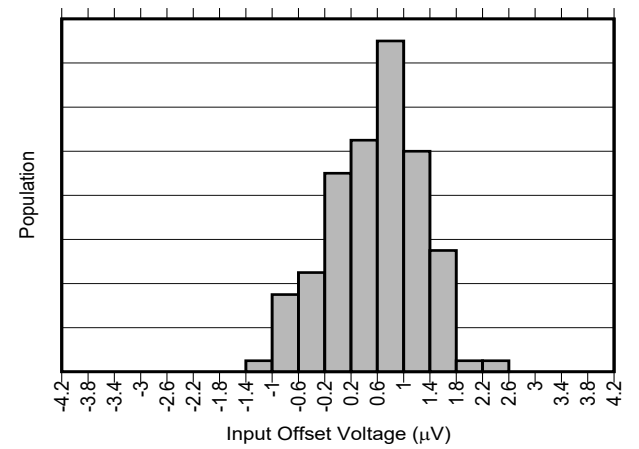Figure 7-3. INA241A3-Q1 and INA241A4-Q1 Input Offset Production Distribution

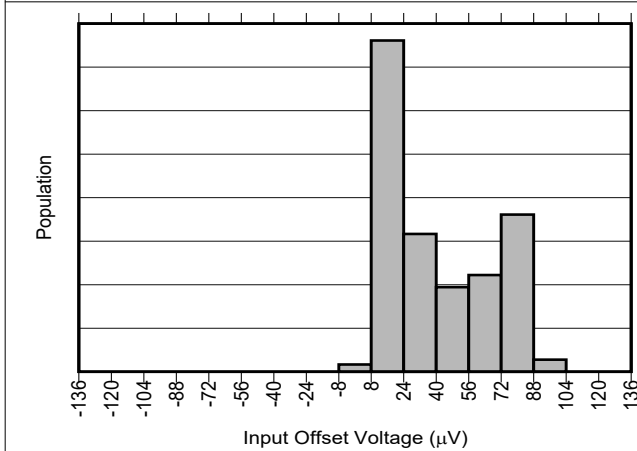Figure 7-4. INA241A5-Q1 Input Offset Production Distribution

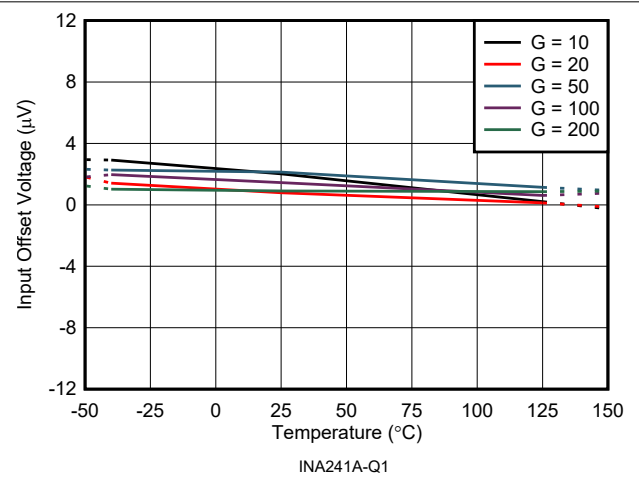Figure 7-5. All Gains INA241B-Q1 Input Offset Production Distribution

Figure 7-6. Input Offset Voltage vs Temperature

Product Folder Links: *INA241A-Q1 INA241B-Q1*

7.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5 V, V_{SENSE} = V_{IN+} – V_{IN-}, V_{CM} = V_{IN-} = 48 V, and V_{REF1} = V_{REF2} = V_S / 2 (unless otherwise noted)
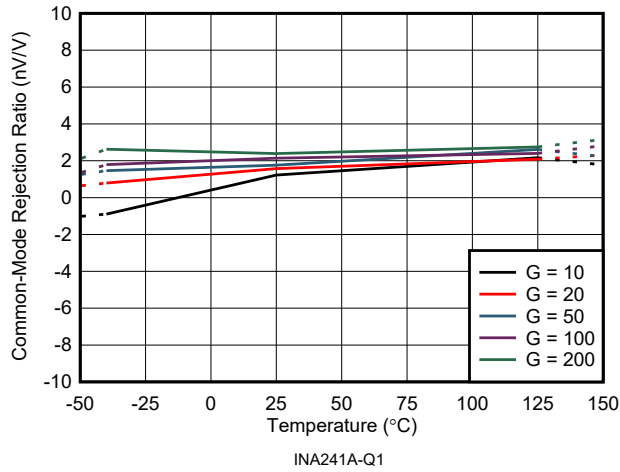

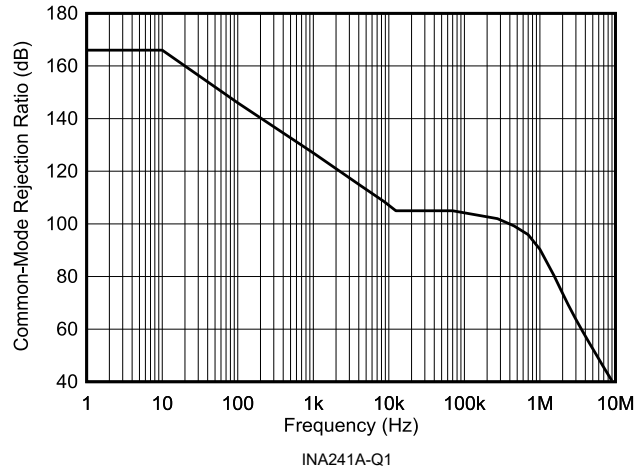**Figure 7-7. Common-Mode Rejection Ratio vs Temperature**

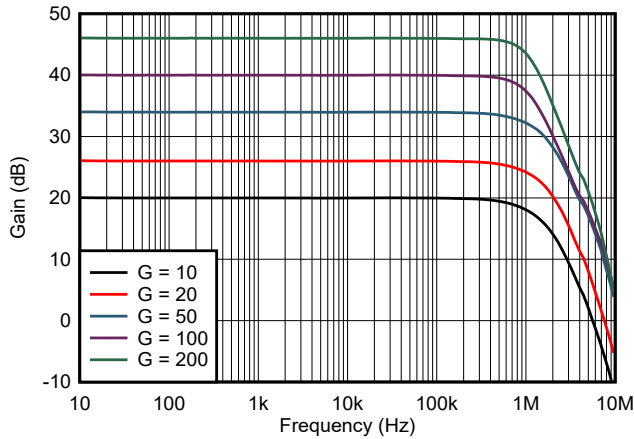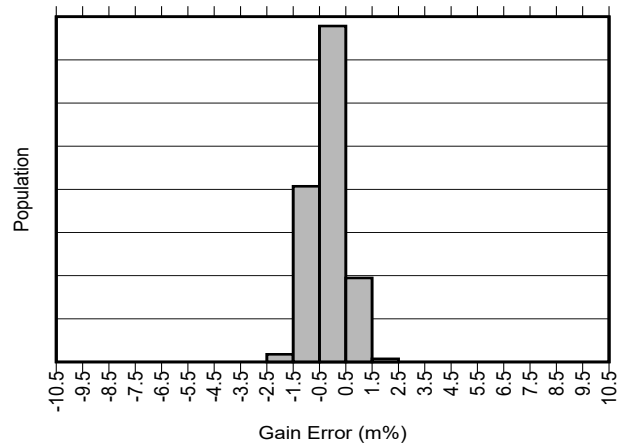**Figure 7-8. Common-Mode Rejection Ratio vs Frequency**

Figure 7-9. Gain vs Frequency

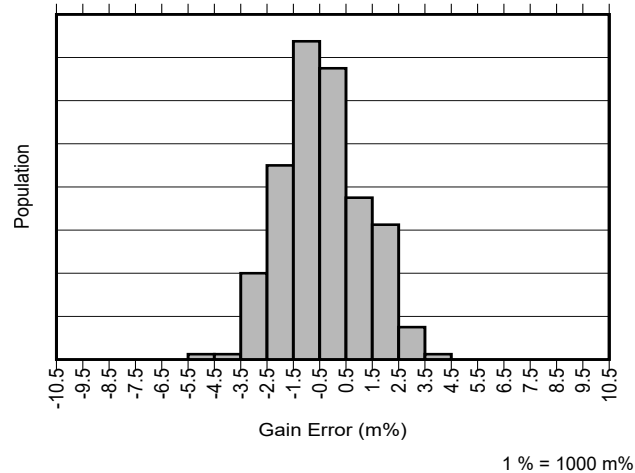**Figure 7-10. INA241A1-Q1, INA241A2-Q1 and INA241A3-Q1 Gain Error Production Distribution**

Figure 7-11. INA241A4-Q1 and INA241A5-Q1 Gain Error Production Distribution

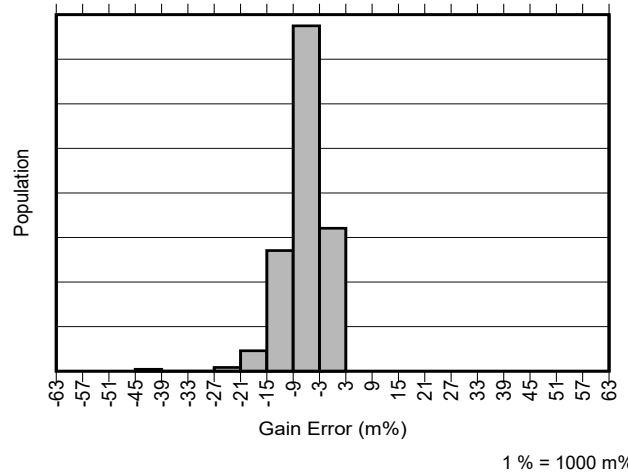**Figure 7-12. All Gains INA241B-Q1 Gain Error Production Distribution**

Product Folder Links: *INA241A-Q1 INA241B-Q1*

7.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5 V, V_{SENSE} = V_{IN+} – V_{IN-}, V_{CM} = V_{IN-} = 48 V, and V_{REF1} = V_{REF2} = V_S / 2 (unless otherwise noted)

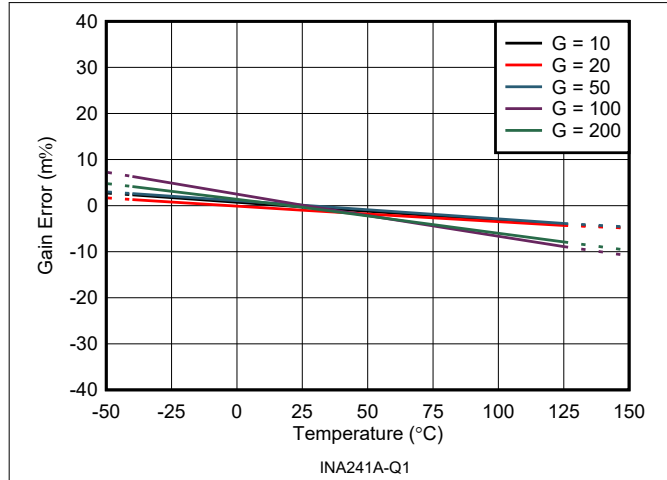**Figure 7-13. Gain Error vs Temperature**
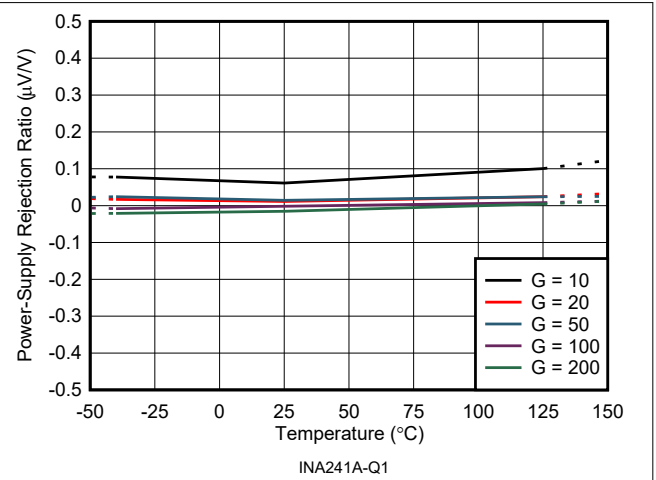
Figure 7-14. Power-Supply Rejection Ratio vs Temperature
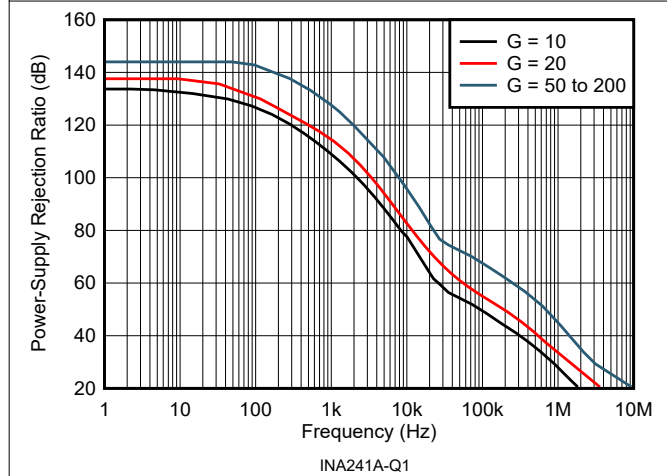
Figure 7-15. Power-Supply Rejection Ratio vs Frequency
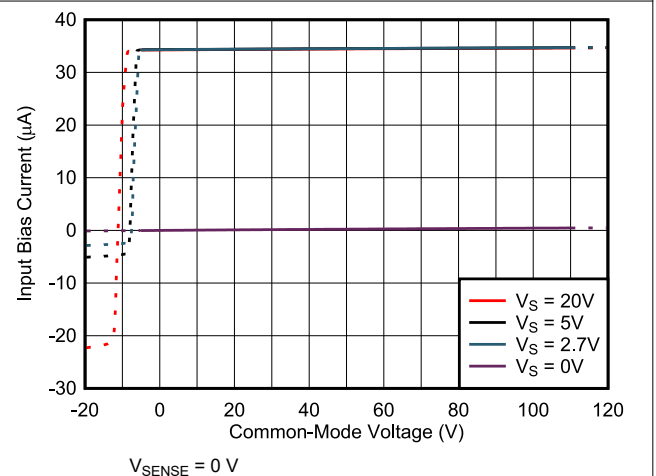
V_{SENSE} = 0 V

Figure 7-16. Input Bias Current vs Common-Mode Voltage
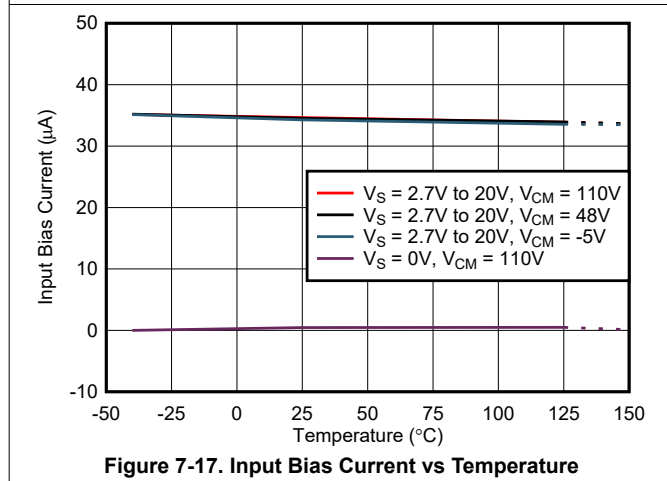
Figure 7-17. Input Bias Current vs Temperature
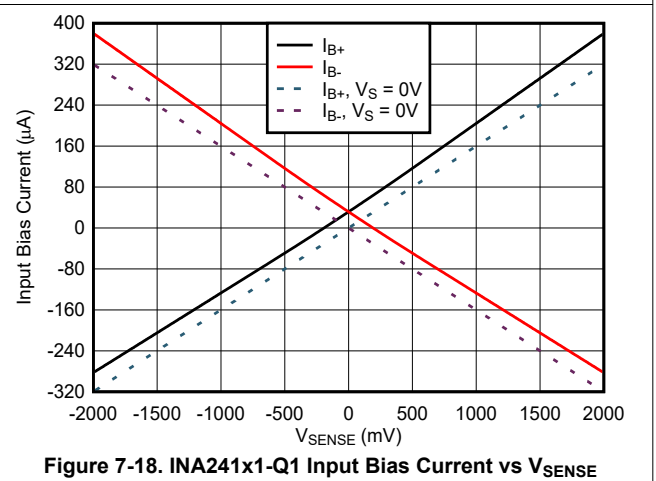
Figure 7-18. INA241x1-Q1 Input Bias Current vs V_{SENSE}

Product Folder Links: *INA241A-Q1 INA241B-Q1*

7.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5 V, V_{SENSE} = V_{IN+} − $V_{IN−}$, V_{CM} = $V_{IN−}$ = 48 V, and V_{REF1} = V_{REF2} = V_S / 2 (unless otherwise noted)
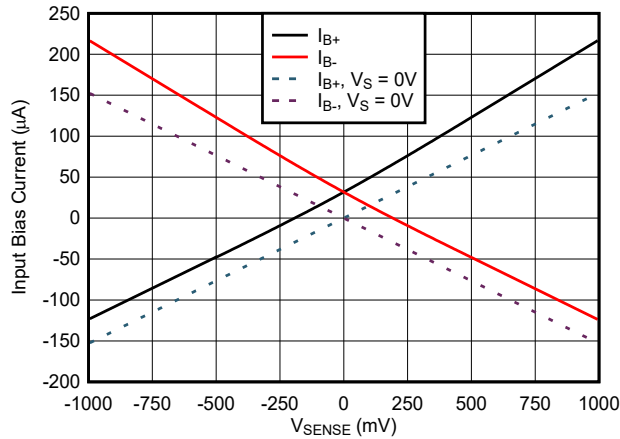
Figure 7-19. INA241x2-Q1 Input Bias Current vs V_{SENSE}
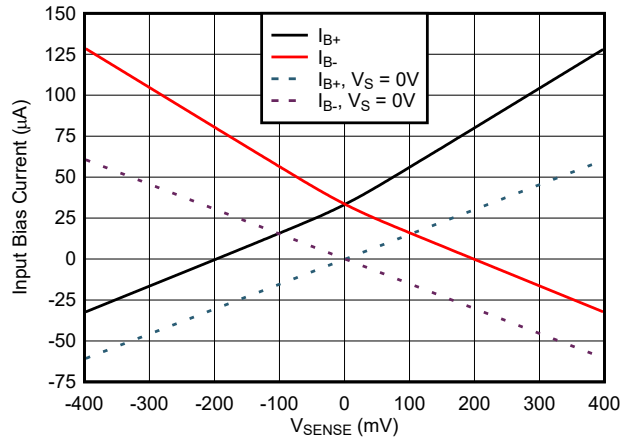
Figure 7-20. INA241x3-Q1 and INA241x4-Q1 Input Bias Current vs V_{SENSE}
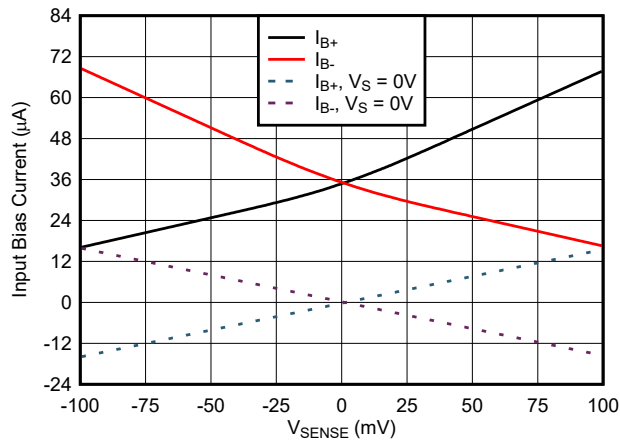
Figure 7-21. INA241x5-Q1 Input Bias Current vs V_{SENSE}

V_S = 2.7 V
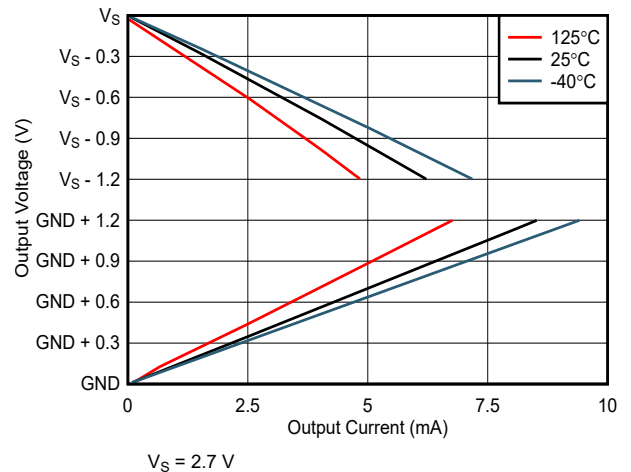
Figure 7-22. Output Voltage vs Output Current

V_S = 5 V to 20 V
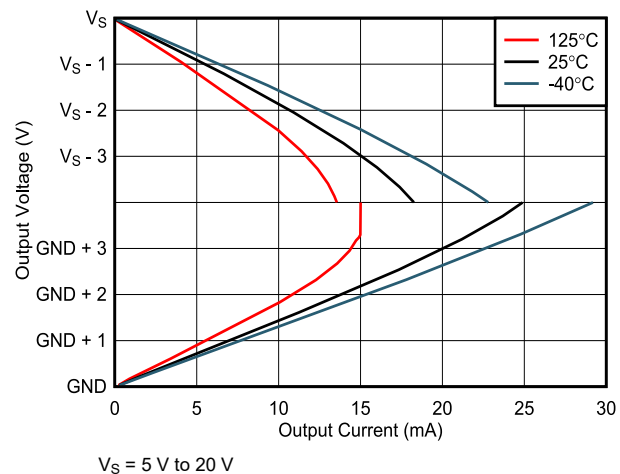
Figure 7-23. Output Voltage vs Output Current
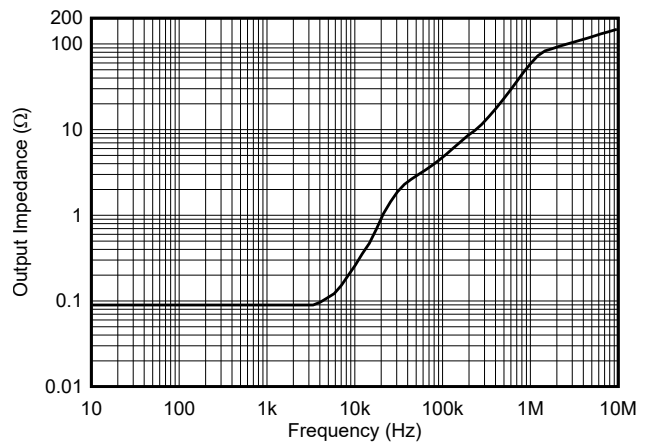
Figure 7-24. Output Impedance vs Frequency

7.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5 V, V_{SENSE} = V_{IN+} – V_{IN-}, V_{CM} = V_{IN-} = 48 V, and V_{REF1} = V_{REF2} = V_S / 2 (unless otherwise noted)

R_L = 10 kΩ to GND
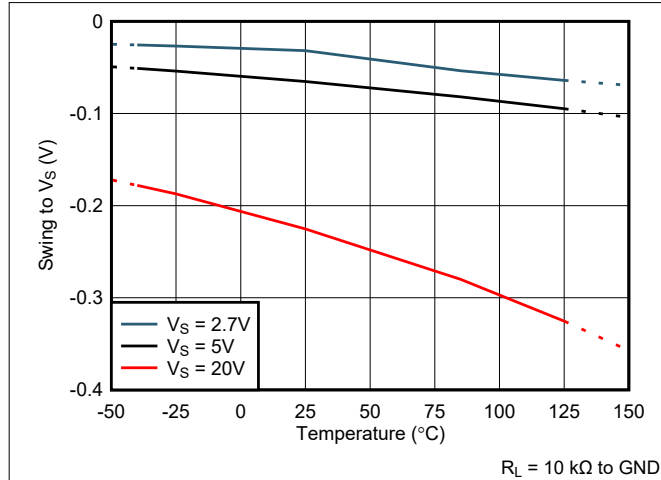
Figure 7-25. Swing to Supply vs Temperature

VREF1 = VREF2 = 0 V,

V_{SENSE} = 0 V

R_L = 10 kΩ to GND
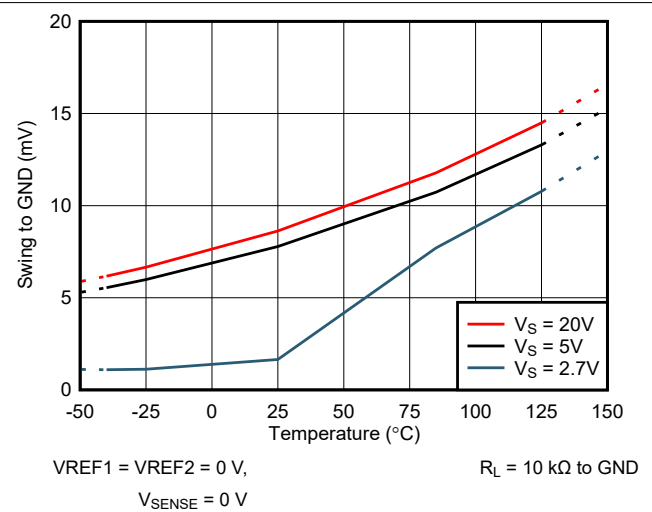
Figure 7-26. Swing to GND vs Temperature
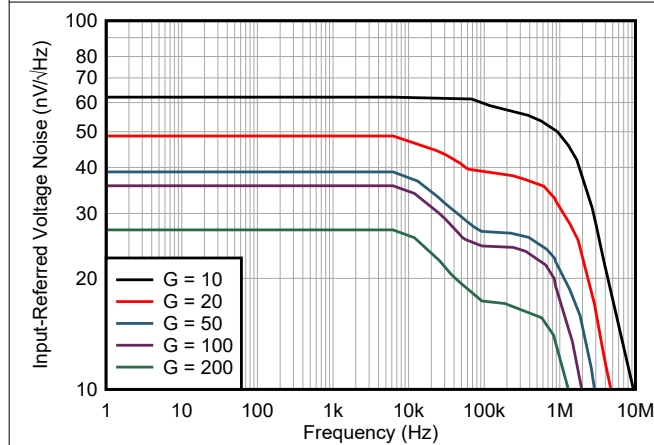
Figure 7-27. Input Referred Noise vs Frequency
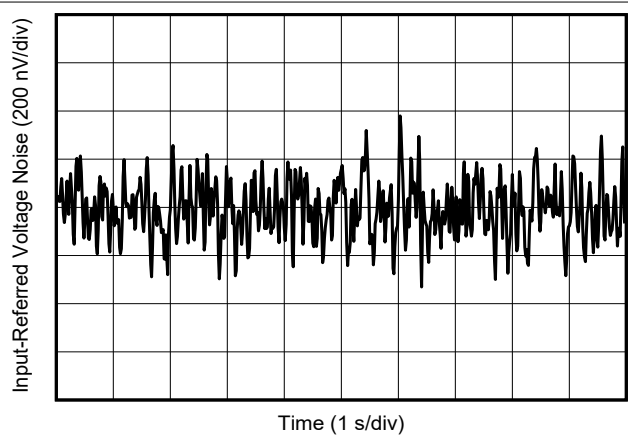
Figure 7-28. 0.1 Hz to 10 Hz Voltage Noise
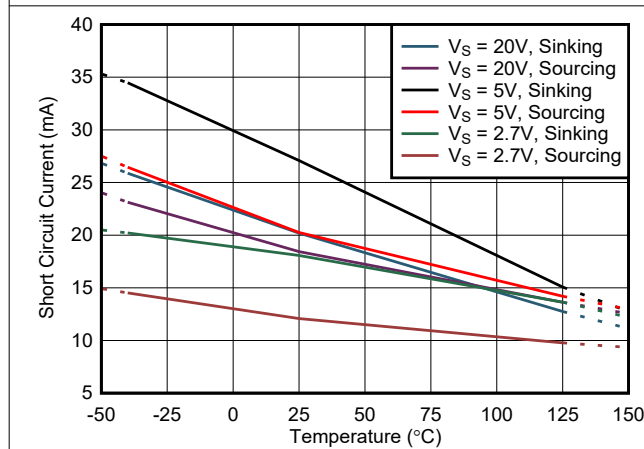
Figure 7-29. Short-Circuit Current vs Temperature
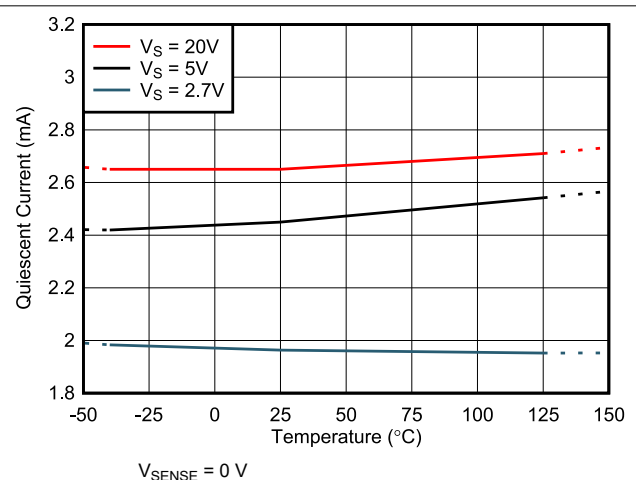
V_{SENSE} = 0 V

Figure 7-30. Quiescent Current vs Temperature

Product Folder Links: *INA241A-Q1 INA241B-Q1*

7.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5 V, V_{SENSE} = V_{IN+} – V_{IN-}, V_{CM} = V_{IN-} = 48 V, and V_{REF1} = V_{REF2} = V_S / 2 (unless otherwise noted)

VREF1 = VREF2 = 0 V,
V_{SENSE} = 0 V
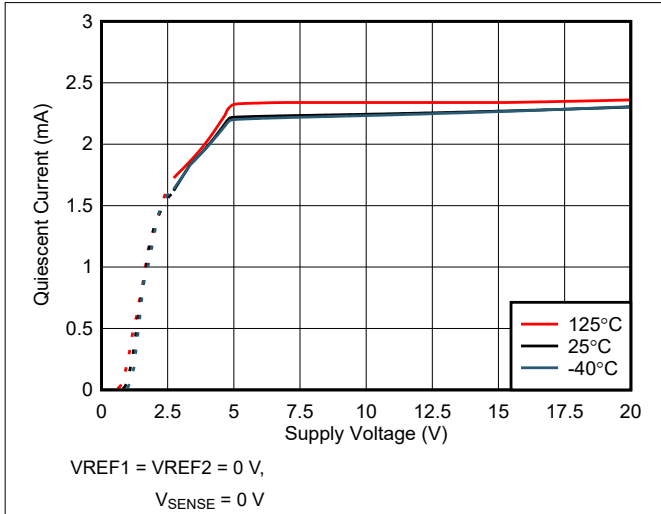
Figure 7-31. Quiescent Current vs Supply Voltage
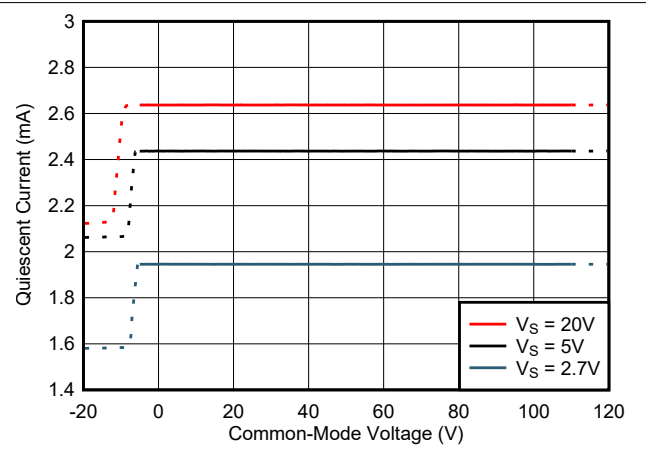
Figure 7-32. Quiescent Current vs Common-Mode Voltage

V_{CM} = -5 V to 110 V,
V_{SENSE} = 0 V
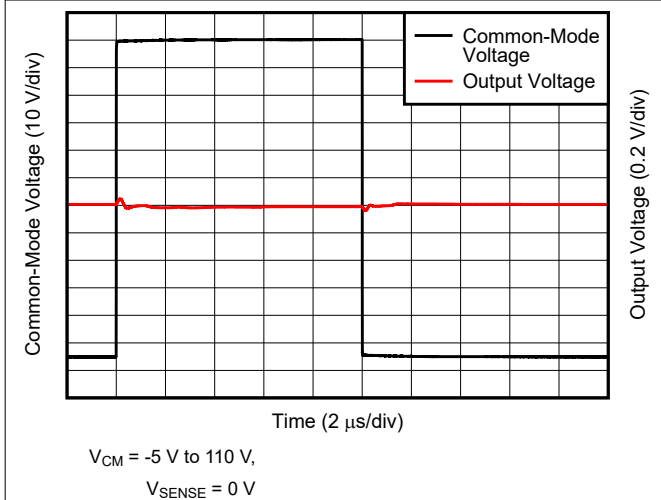
Figure 7-33. Common-Mode Voltage Fast Transient Pulse

INA241A4-Q1
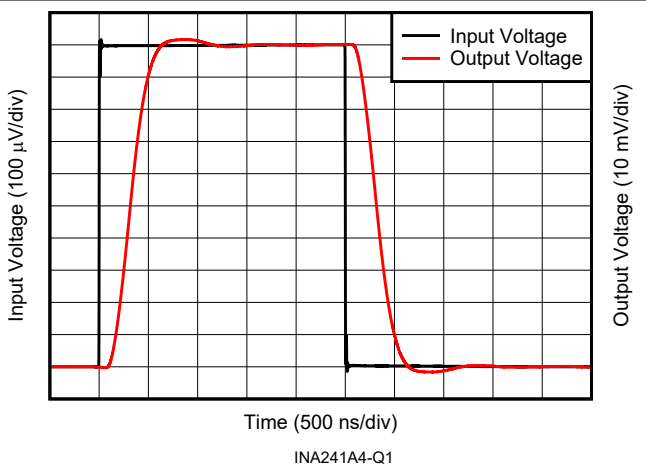
Figure 7-34. Small Step Response

INA241A4-Q1
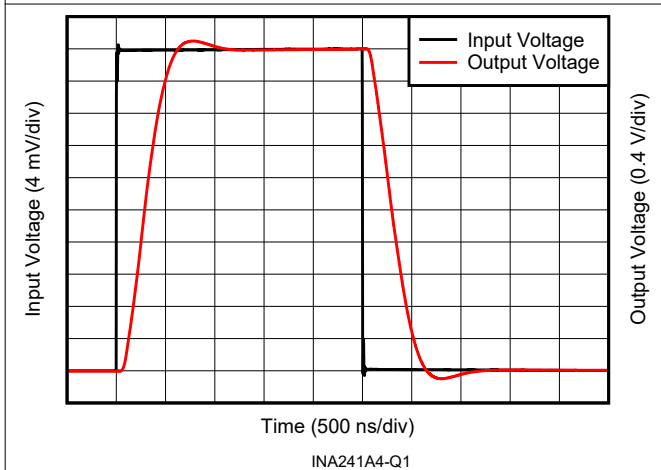
Figure 7-35. Large Step Response
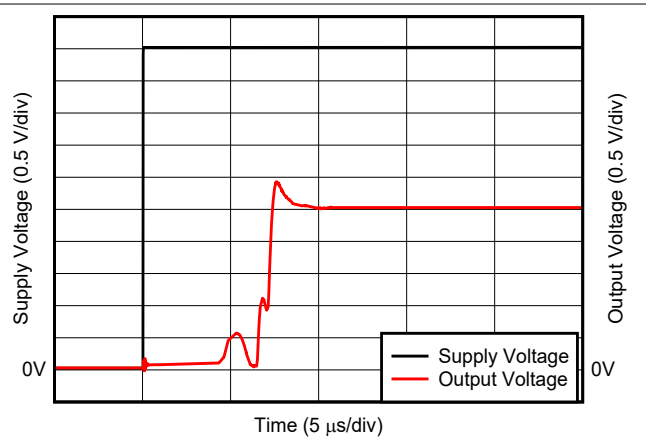
Figure 7-36. Start-Up Response

Texas
Instruments

7.6 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5 V, V_{SENSE} = V_{IN+} − $V_{IN−}$, V_{CM} = $V_{IN−}$ = 48 V, and V_{REF1} = V_{REF2} = V_S / 2 (unless otherwise noted)

Figure 7-37. Brownout Recovery

Product Folder Links: *INA241A-Q1 INA241B-Q1*
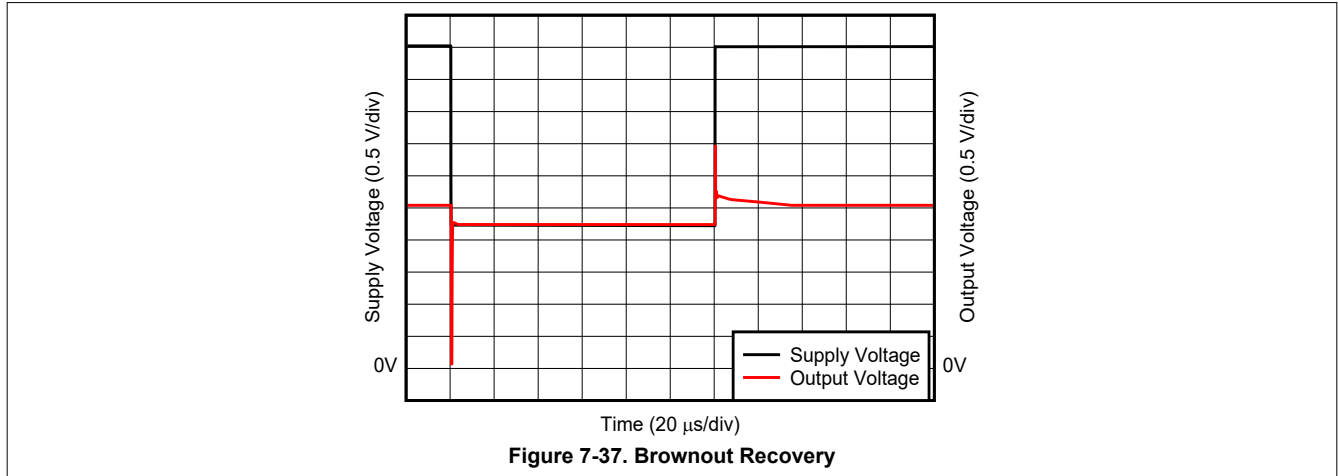
8 Detailed Description

8.1 Overview

The INA241x-Q1 is a high-side, inline, or low-side bidirectional, high-speed current-sense amplifier that offers a wide common-mode range, precision, zero-drift topology, excellent common-mode rejection ratio (CMRR), and features enhanced pulse width modulation (PWM) rejection at the inputs of the device. Enhanced PWM rejection reduces the effect of common-mode transients that can propagate to the output signal that are associated with PWM input signals. Multiple gain versions are available to allow for the optimization of the desired full-scale output voltage based on the target current range expected in the application.

8.2 Functional Block Diagram
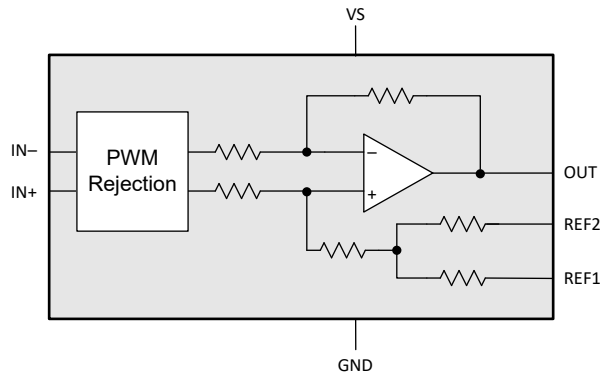
8.3 Feature Description

8.3.1 Amplifier Input Common-Mode Signal

The INA241x-Q1 supports large input common-mode voltages from –5 V to +110 V. The internal topology of the INA241x-Q1 allows the common-mode range to exceed the power-supply voltage (V_S). This allows for the INA241x-Q1 to be used for low-side, inline, and high-side current-sensing applications that extend beyond the supply range of 2.7 V to 20 V.

8.3.1.1 Enhanced PWM Rejection Operation

The enhanced PWM rejection feature of the INA241x-Q1 provides increased attenuation of large common-mode ΔV/Δt transients. Large ΔV/Δt common-mode transients associated with PWM signals are employed in applications such as motor or solenoid drive and switching power supplies. The disturbances that can occur at the output of a current sense amplifier from common-mode transients causes erroneous measurements and impose limitations when the output is valid. The INA241x-Q1 is designed with high common-mode rejection techniques to reduce large ΔV/Δt transients before the system is disturbed. As a result, this makes system design simple with INA241x-Q1. The high AC CMRR, in conjunction with signal bandwidth, allows the INA241x-Q1 to minimize output disturbances and ringing during common-mode transitions when compared against traditional current-sensing amplifiers.
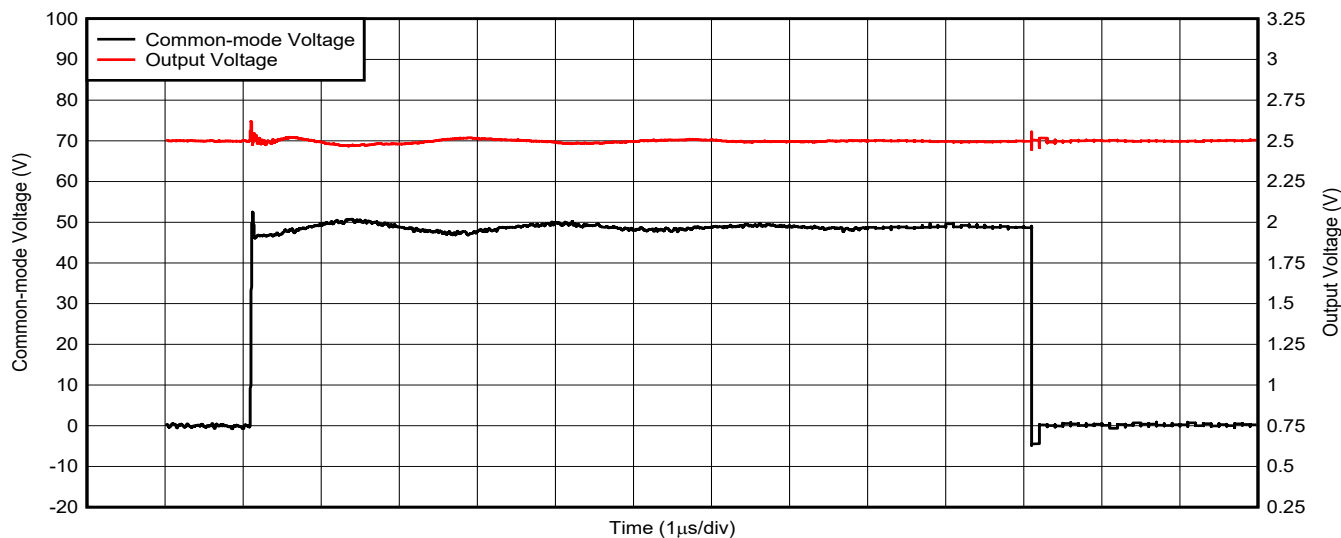
Figure 8-1. Enhanced PWM Rejection Performance

Figure 8-1 shows the INA241x-Q1 PWM enhancement performance. When INA241x-Q1 senses the large common-mode ΔV/Δt transients, it holds the output for 1 µs, thereby preventing the common-mode disturbance from propagating to the output. If another common-mode transient occurs during the following 3 µs, INA241x-Q1 relies on high BW and AC CMMR to attenuate the effect of common-mode transient. The enhanced PWM rejection is achieved up to a PWM frequency of 125 kHz or if common-mode transient edges are separated by a 3 µs interval or more.

8.3.1.2 Input-Signal Bandwidth

The INA241x-Q1 is available with several gain options including 10 V/V, 20 V/V, 50 V/V, 100 V/V, and 200 V/V. The unique multistage design enables the amplifier to achieve high bandwidth of 1.1 MHz at all gains. This high bandwidth provides the throughput and fast response that is required for the rapid detection and processing of over-current events.

8.3.1.3 Low Input Bias Current

The INA241x-Q1 inputs draw 35 µA (typical) bias current per input pin at common-mode voltages as high as 110 V, which enables precision current sensing on applications that require lower current leakage. Unlike many high voltage current sense amplifiers whose input bias currents are proportional to the common-mode voltage, the input bias current of the INA241x-Q1 remains constant over the entire common-mode voltage range.

8.3.1.4 Low V_{SENSE} Operation

The INA241x-Q1 features high performance operation across the entire valid V_{SENSE} range. The zero-drift input architecture of the INA241x-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. 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.

8.3.1.5 Wide Fixed Gain Output

The INA241x-Q1 maximum gain error is ±0.01% at room temperature, with a maximum drift of ±1 ppm/°C over the full temperature range of –40°C to +125°C. The INA241x-Q1 is available in multiple gain options of 10 V/V, 20 V/V, 50 V/V, 100 V/V, and 200 V/V, which the system designer should select based on their desired signal-to-noise ratio and other system requirements, such as the dynamic current range and full-scale output voltage target.

8.3.1.6 Wide Supply Range

The INA241x-Q1 operates with a wide supply range from 2.7 V to 20 V. While the input common-mode voltage range of the INA241x-Q1 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 20 mV to as high as 200 mV below the supply voltage.

8.4 Device Functional Modes

8.4.1 Adjusting the Output With the Reference Pins

Figure 8-2 shows a test circuit for reference-divider accuracy. The INA241x-Q1 output is configurable to allow for unidirectional or bidirectional operation.
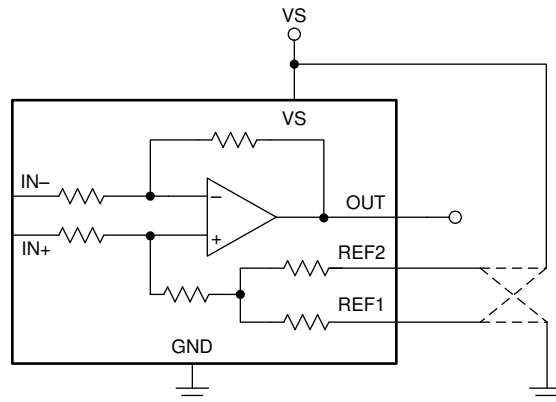
Figure 8-2. Test Circuit For Reference Divider Accuracy

The output voltage is set by applying a voltage or voltages to the reference voltage inputs, REF1 and REF2. The reference inputs are connected to an internal gain network. There is no operational difference between the two reference pins. The resistor network connected to the two reference pins are designed with ultra-precision and matching. Output is set accurately at the mid-point voltage between the voltages applied to reference voltage inputs, when current-sense input voltage is 0 V as shown in Equation 1 . In most bidirectional applications, one reference input is connected to the positive supply and the other reference input is connected to the negative supply (GND pin) to set the output voltage to mid-supply.

$$V_{OUT} = G \times (V_{IN+} - V_{IN-}) + \frac{V_{REF1} + V_{REF2}}{2} \tag{1}$$

8.4.2 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 pins together and then 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 pins are connected to the positive rail, then the input polarity must be negative to move the amplifier output down (towards ground). If the amplifier reference pins are 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.

8.4.2.1 Ground Referenced Output

When using the INA241x-Q1 in a unidirectional mode with a ground referenced output, both reference inputs are connected to ground. This configuration takes the output to ground when there is a 0 V differential at the input (see Figure 8-3).
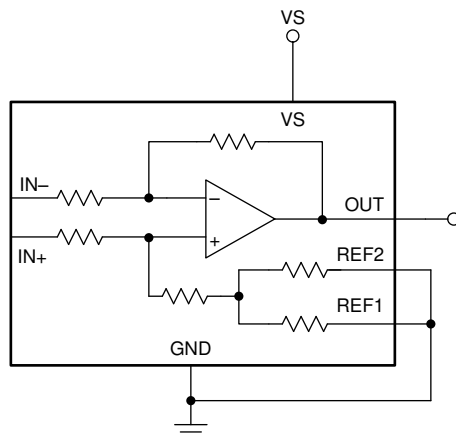
Figure 8-3. Ground Referenced Output

8.4.2.2 VS Referenced Output

Unidirectional mode with a VS referenced output is configured by connecting both reference pins to the positive supply. Use this configuration for circuits that require power up and stabilization of the amplifier output signal and other control circuitry before power is applied to the load (see Figure 8-4).
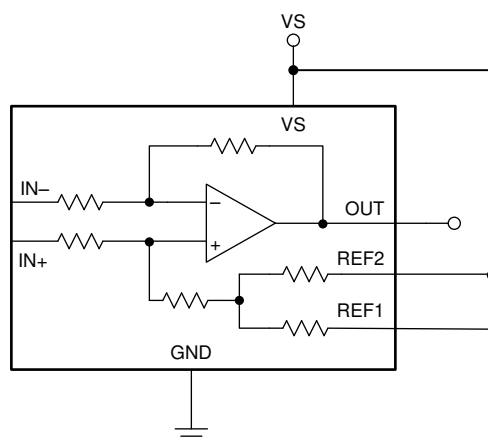
Figure 8-4. VS Referenced Output

8.4.3 Reference Pin Connections for Bidirectional Current Measurements

The INA241x-Q1 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 INA241x-Q1 can operate in either a unidirectional or bidirectional mode based on the voltage potential placed on the reference pins.

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 selection of the current-sensing resistor along with the current range to be measured, selection of the gain option, as well as the voltage applied to the reference pins should be chosen to keep the INA241x-Q1 within the linear region of operation.

8.4.3.1 Output Set to External Reference Voltage

Connecting both pins together and then to a reference voltage results in an output voltage equal to the reference voltage for the condition of shorted input pins or a 0 V differential input. Figure 8-5 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.
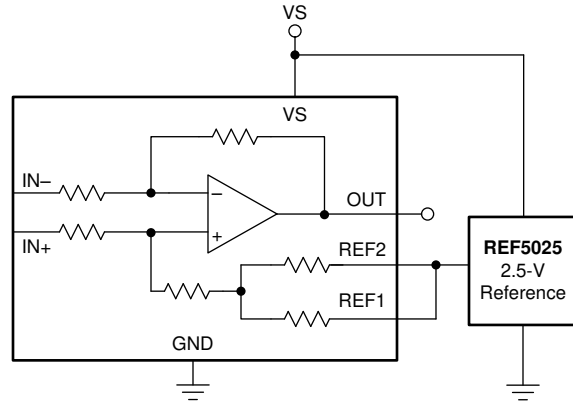
Copyright © 2016, Texas Instruments Incorporated

Figure 8-5. External Reference Output

8.4.3.2 Output Set to Mid-Supply Voltage

By connecting one reference pin to VS and the other to the GND pin, Figure 8-6 shows that the output is set 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 0 V applied to the inputs.
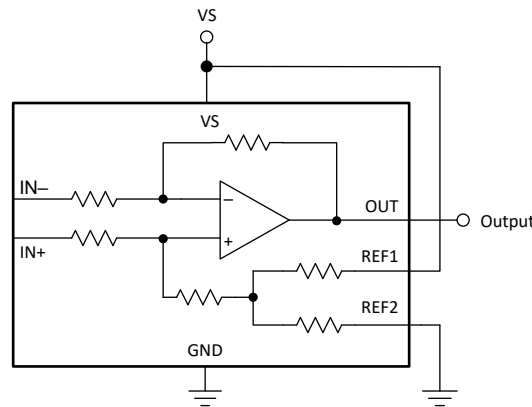
Figure 8-6. Mid-Supply Voltage Output

8.4.3.3 Output Set to Mid-External Reference

In this case, Figure 8-7 shows how an external reference can divided by two by connecting one REF pin to ground and the other REF pin to the reference.
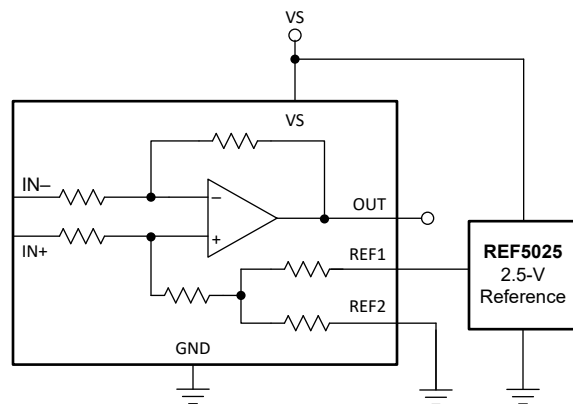
Figure 8-7. Mid-External Reference Output

Product Folder Links: *INA241A-Q1 INA241B-Q1*

8.4.3.4 Output Set Using Resistor Divider

The INA241x-Q1 reference pins allow for the mid-point of the output voltage to be adjusted for system circuitry connections to analog to digital converters (ADCs) or other amplifiers. The reference pins are designed to be connected directly to supply, ground, or a low-impedance reference voltage. The reference pins can be connected together and biased using a resistor divider to achieve a custom output voltage. If the amplifier is used in this configuration, as shown in Figure 8-8, use the output as a differential signal with respect to the resistor divider voltage. Use of the amplifier output as a single-ended signal in this configuration is not recommended because the internal impedance shifts can adversely affect device performance specifications. If single-ended measurement is required, TI recommends to use an external op amp to buffer the resistor divider voltage (see Figure 8-9).
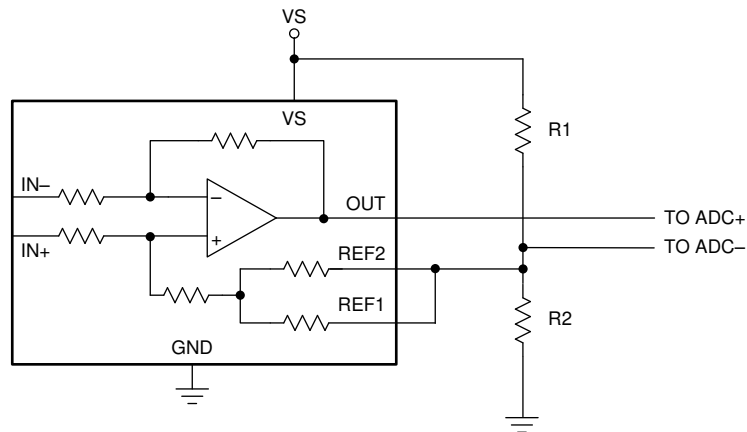
Figure 8-8. Setting the Reference Using a Resistor Divider
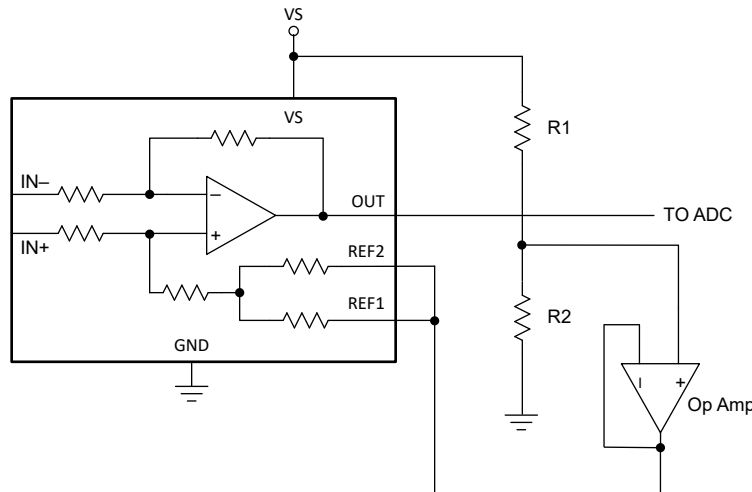
Figure 8-9. Setting the Reference Using a Resistor Divider and an Op Amp buffer

Product Folder Links: INA241A-Q1 INA241B-Q1

8.4.4 High Signal Throughput

With a bandwidth of 1.1 MHz at a gain of 20 V/V and a slew rate of 8 V/µs, the INA241x-Q1 is specifically designed for detecting and protecting applications from fast inrush currents. As shown in Table 8-1, the INA241x-Q1 responds in less than 1 µs for a system measuring a 75 A threshold on a 2 mΩ shunt.

Table 8-1. Response Time

PARAMETER		EQUATION	INA241x-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	$V_{OUT\_MAX} = I_{MAX} \times R_{SENSE} \times G$	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		8 V/µs
$T_{response}$	Output response time	$T_{response} = V_{OUT\_THR} / SR$	< 1 µs

9 Application and Implementation

Note

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

9.1 Application Information

The INA241x-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 INA241x-Q1 make it usable over a wide range of voltage rails while still maintaining an accurate current measurement.

9.1.1 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:

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

(2)

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. Equation 3 provides the maximum values of R_{SENSE} and GAIN to keep the device from exceeding the positive swing limitation.

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

(3)

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 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 it is possible to select a lower gain device 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.

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

(4)

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 as specified in the *Specifications*.

Table 9-1 shows an example of the different results obtained from using five different gain versions of the INA241x-Q1. From the table data, the highest gain device allows a smaller current-shunt resistor and decreased power dissipation in the element.

Table 9-1. R_{SENSE} Selection and Power Dissipation[1]

PARAMETER		EQUATION	RESULTS AT V_S = 5 V				
			A1, B1 DEVICES	A2, B2 DEVICES	A3, B3 DEVICES	A4, B4 DEVICES	A5, B5 DEVICES
G	Gain		10 V/V	20 V/V	50 V/V	100 V/V	200 V/V
V_{SENSE}	Ideal differential input voltage	$V_{SENSE} = V_{OUT} / G$	500 mV	250 mV	100 mV	50 mV	25 mV
R_{SENSE}	Current sense resistor value	$R_{SENSE} = V_{SENSE} / I_{MAX}$	50 mΩ	25 mΩ	10 mΩ	5 mΩ	2.5 mΩ
P_{SENSE}	Current-sense resistor power dissipation	$R_{SENSE} \times I_{MAX}2$	5 W	2.5 W	1 W	0.5 W	0.25 W

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

9.2 Typical Application

The INA241x-Q1 is a bidirectional, current-sense amplifier capable of measuring currents through a resistive shunt with common-mode voltages from –5 V to +110 V.

9.2.1 Inline Motor Current-Sense Application
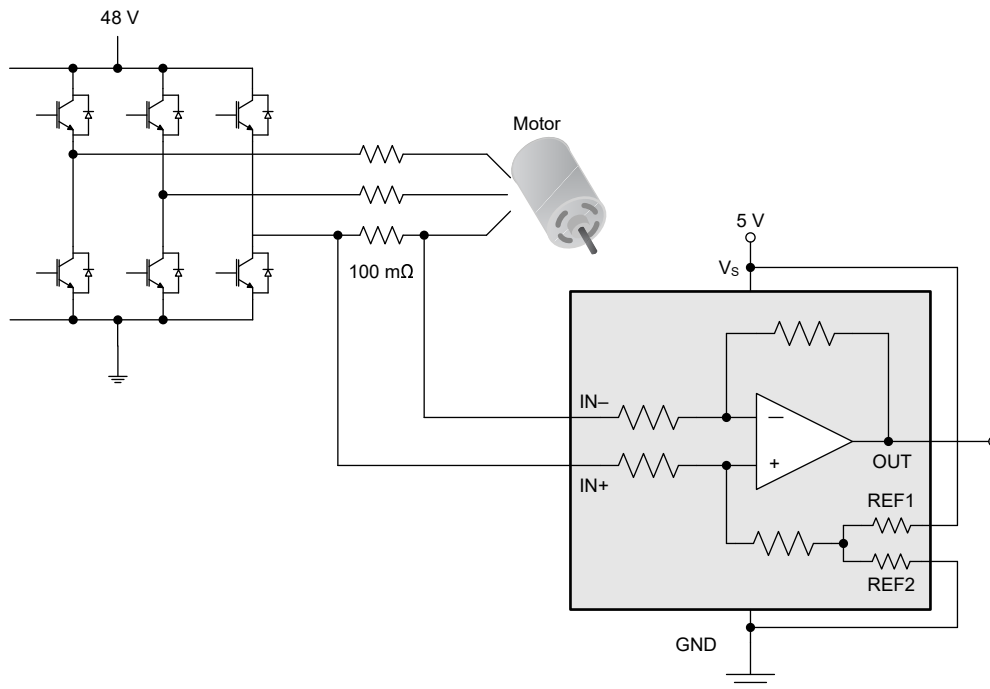
Figure 9-1. Inline Motor Application Circuit

9.2.1.1 Design Requirements

Inline current sensing has many advantages in motor control, from torque ripple reduction to real-time motor health monitoring. However, the full-scale PWM voltage requirements for inline current measurements provide challenges to accurately measure the current. Switching frequencies in the 50 kHz to 100 kHz range create higher ΔV/Δt signal transitions that must be addressed to obtain accurate inline current measurements.

With a superior common-mode rejection capability, high precision, and a high common-mode specification, the INA241x-Q1 provides performance for a wide range of common-mode voltages.

9.2.1.2 Detailed Design Procedure

For this application, the INA241x-Q1 measures current in the drive circuitry of a 48 V, 4000 RPM motor.

To demonstrate the performance of the device, the INA241A2-Q1 with a gain of 20 V/V was selected for this design and powered from a 5 V supply.

Using the information in the Section 8.4.3.2 section, the reference point is set to mid-scale by splitting the supply with REF1 connected to supply and REF2 connected to ground. This configuration allows for bipolar current measurements. Alternatively, the reference pins can be tied together and driven with an external precision reference.

The current-sensing resistor is sized so that the output of the INA241x-Q1 is not saturated. A value of 100 mΩ was selected to maintain the analog input within the device limits.

9.2.1.3 Application Curve
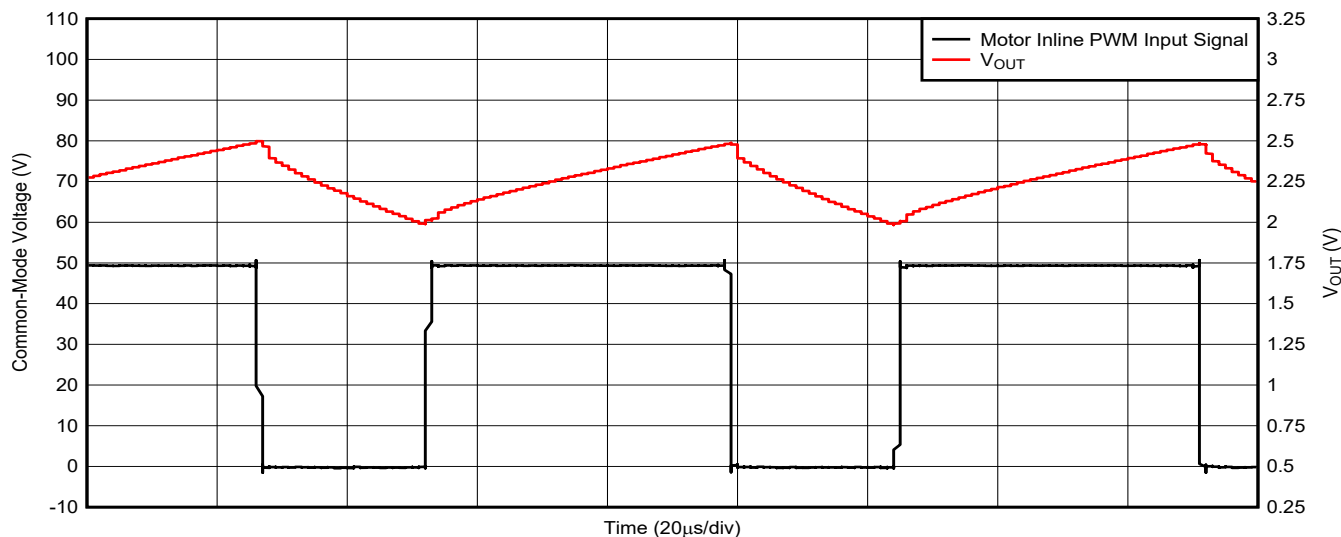
Figure 9-2. INA241A2-Q1 Inline Motor Current-Sense Input and Output Signals

9.3 Power Supply Recommendations

The INA241x-Q1 makes accurate measurements beyond the connected power-supply voltage (V_S) because the inputs (IN+ and IN–) can operate anywhere between –5 V and +110 V independent of V_S. For example, with the V_S power supply equal to 5 V, the common-mode voltage of the measured shunt can be as high as +110 V.

9.3.1 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 0.1 µF. Additional decoupling capacitance can be added to compensate for noisy or high-impedance power supplies.

9.4 Layout

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

9.4.2 Layout Example
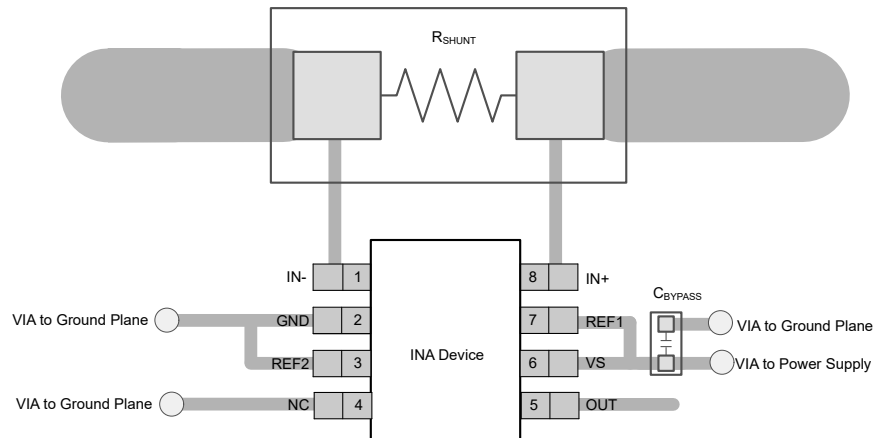
Figure 9-3. INA241x-Q1 SOT-23 (DDF) and VSSOP (DGK) Package Recommended Layout

10 Device and Documentation Support

10.1 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.

10.2 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.

10.3 Trademarks

TI E2E™ is a trademark of Texas Instruments.
All trademarks are the property of their respective owners.

10.4 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.

10.5 Glossary

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

11 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.
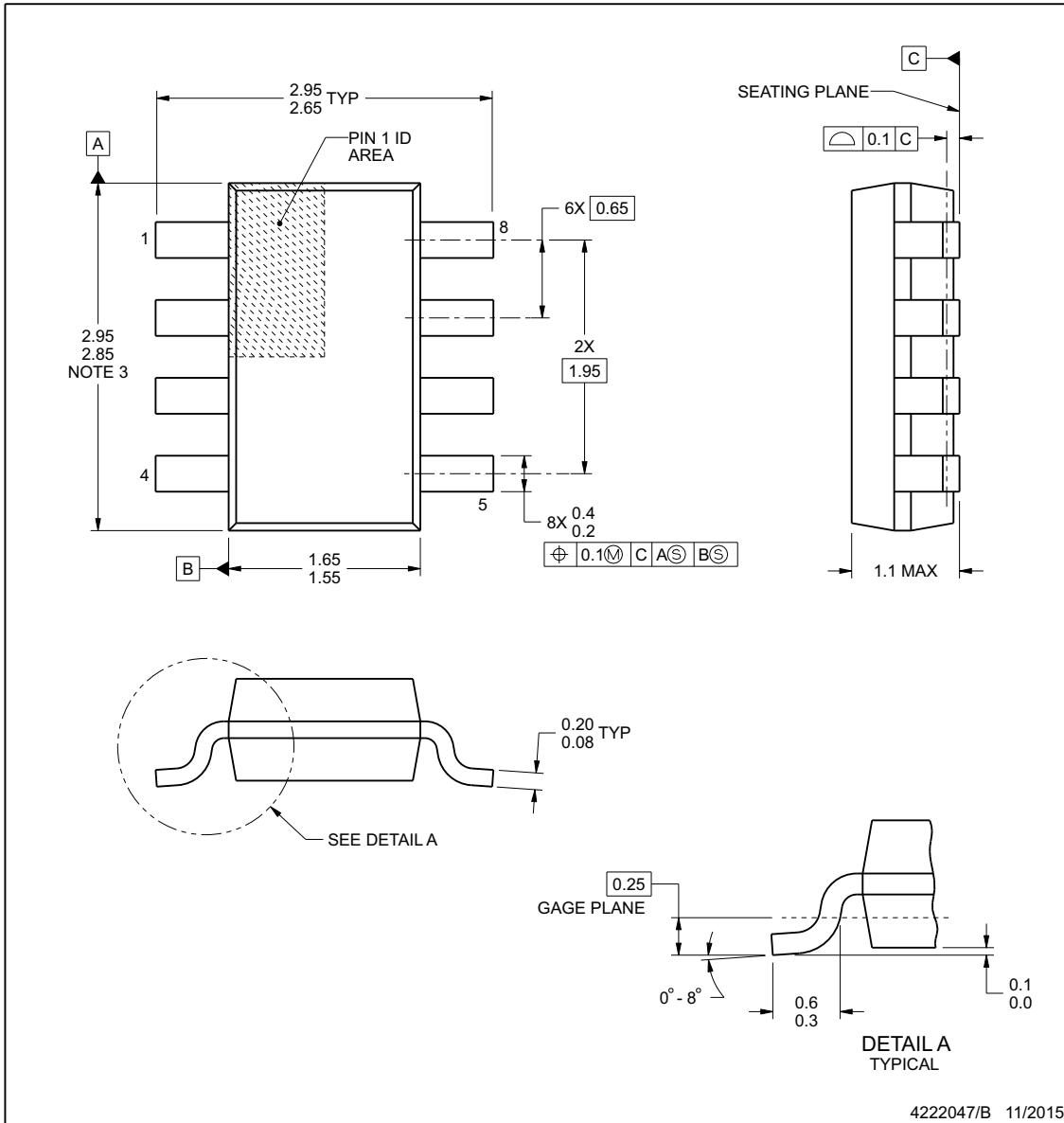
PACKAGE OUTLINE

DDF0008A

SOT-23 - 1.1 mm max height

PLASTIC SMALL OUTLINE

4222047/B   11/2015

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. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.

Product Folder Links: *INA241A-Q1 INA241B-Q1*

EXAMPLE BOARD LAYOUT

DDF0008A

SOT-23 - 1.1 mm max height
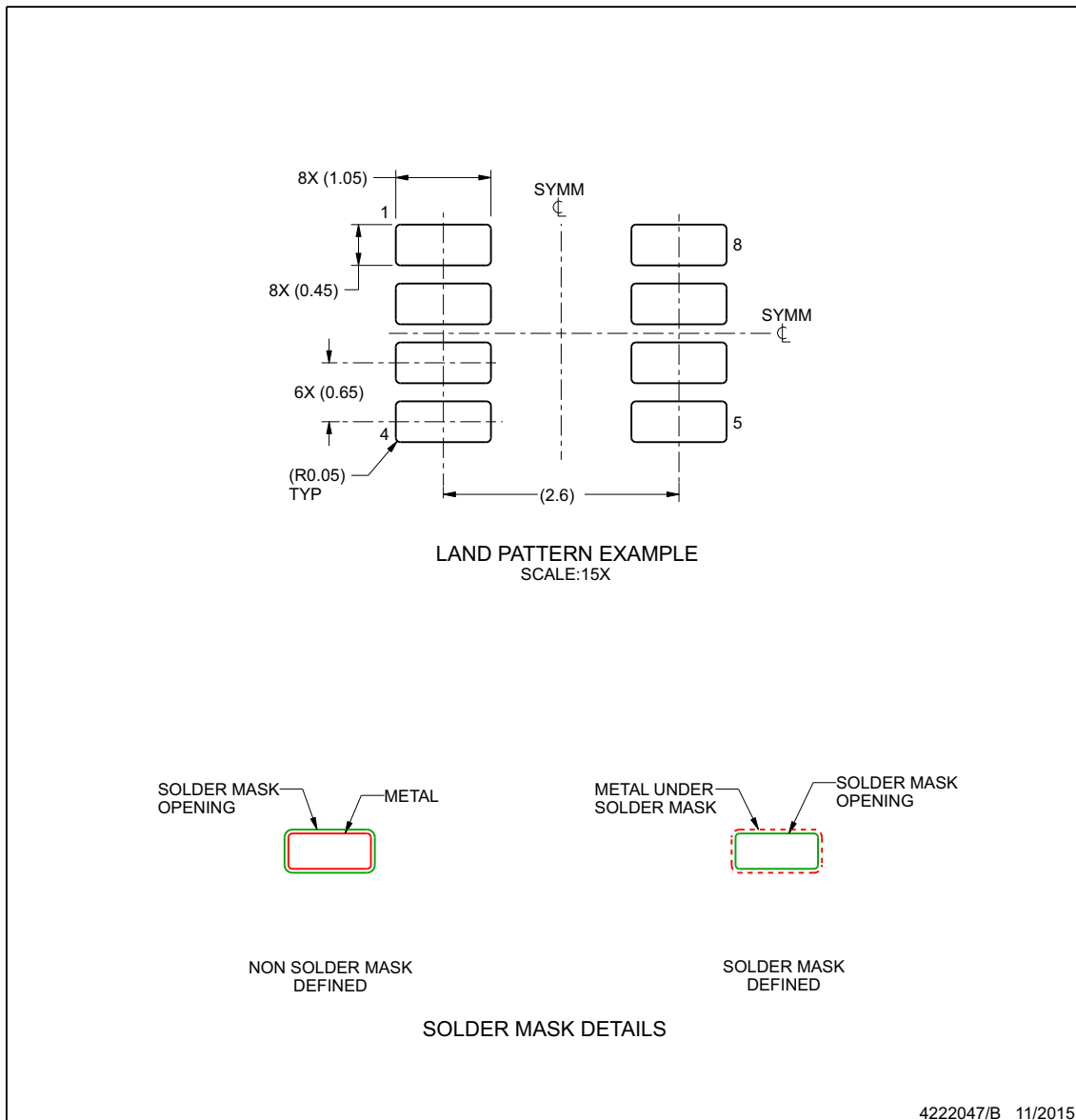
PLASTIC SMALL OUTLINE

8X (1.05)

SYMM

1

8

8X (0.45)

SYMM

6X (0.65)

4

5

(R0.05)
TYP

(2.6)

LAND PATTERN EXAMPLE
SCALE:15X

SOLDER MASK
OPENING

METAL

METAL UNDER
SOLDER MASK

SOLDER MASK
OPENING

NON SOLDER MASK
DEFINED

SOLDER MASK
DEFINED

SOLDER MASK DETAILS

4222047/B   11/2015

NOTES: (continued)

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

EXAMPLE STENCIL DESIGN

DDF0008A

SOT-23 - 1.1 mm max height

PLASTIC SMALL OUTLINE

8X (1.05)

1

8X (0.45)

(R0.05) TYP

8

SYMM

SYMM

6X (0.65)

4

5

(2.6)

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

4222047/B   11/2015

NOTES: (continued)

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

www.ti.com

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
INA241A1QDDFRQ1	ACTIVE	SOT-23-THIN	DDF	8	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2ZN3	Samples
INA241A2QDDFRQ1	ACTIVE	SOT-23-THIN	DDF	8	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2ZO3	Samples
INA241A3QDDFRQ1	ACTIVE	SOT-23-THIN	DDF	8	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2ZP3	Samples
INA241A4QDDFRQ1	ACTIVE	SOT-23-THIN	DDF	8	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2ZQ3	Samples
INA241A5QDDFRQ1	ACTIVE	SOT-23-THIN	DDF	8	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2ZR3	Samples
INA241B1QDDFRQ1	ACTIVE	SOT-23-THIN	DDF	8	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2ZS3	Samples
INA241B2QDDFRQ1	ACTIVE	SOT-23-THIN	DDF	8	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2ZT3	Samples
INA241B3QDDFRQ1	ACTIVE	SOT-23-THIN	DDF	8	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2ZU3	Samples
INA241B4QDDFRQ1	ACTIVE	SOT-23-THIN	DDF	8	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2ZV3	Samples
INA241B5QDDFRQ1	ACTIVE	SOT-23-THIN	DDF	8	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2ZW3	Samples

(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.

OTHER QUALIFIED VERSIONS OF INA241A-Q1, INA241B-Q1 :

● Catalog : INA241A, INA241B

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
INA241A1QDDFRQ1	SOT-23-THIN	DDF	8	3000	180.0	8.4	3.15	3.1	1.55	4.0	8.0	Q3
INA241A2QDDFRQ1	SOT-23-THIN	DDF	8	3000	180.0	8.4	3.15	3.1	1.55	4.0	8.0	Q3
INA241A3QDDFRQ1	SOT-23-THIN	DDF	8	3000	180.0	8.4	3.15	3.1	1.55	4.0	8.0	Q3
INA241A4QDDFRQ1	SOT-23-THIN	DDF	8	3000	180.0	8.4	3.15	3.1	1.55	4.0	8.0	Q3
INA241A5QDDFRQ1	SOT-23-THIN	DDF	8	3000	180.0	8.4	3.15	3.1	1.55	4.0	8.0	Q3
INA241B1QDDFRQ1	SOT-23-THIN	DDF	8	3000	180.0	8.4	3.15	3.1	1.55	4.0	8.0	Q3
INA241B2QDDFRQ1	SOT-23-THIN	DDF	8	3000	180.0	8.4	3.15	3.1	1.55	4.0	8.0	Q3
INA241B3QDDFRQ1	SOT-23-THIN	DDF	8	3000	180.0	8.4	3.15	3.1	1.55	4.0	8.0	Q3
INA241B4QDDFRQ1	SOT-23-THIN	DDF	8	3000	180.0	8.4	3.15	3.1	1.55	4.0	8.0	Q3

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
INA241B5QDDFRQ1	SOT-23-THIN	DDF	8	3000	180.0	8.4	3.15	3.1	1.55	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)
INA241A1QDDFRQ1	SOT-23-THIN	DDF	8	3000	210.0	185.0	35.0
INA241A2QDDFRQ1	SOT-23-THIN	DDF	8	3000	210.0	185.0	35.0
INA241A3QDDFRQ1	SOT-23-THIN	DDF	8	3000	210.0	185.0	35.0
INA241A4QDDFRQ1	SOT-23-THIN	DDF	8	3000	210.0	185.0	35.0
INA241A5QDDFRQ1	SOT-23-THIN	DDF	8	3000	210.0	185.0	35.0
INA241B1QDDFRQ1	SOT-23-THIN	DDF	8	3000	210.0	185.0	35.0
INA241B2QDDFRQ1	SOT-23-THIN	DDF	8	3000	210.0	185.0	35.0
INA241B3QDDFRQ1	SOT-23-THIN	DDF	8	3000	210.0	185.0	35.0
INA241B4QDDFRQ1	SOT-23-THIN	DDF	8	3000	210.0	185.0	35.0
INA241B5QDDFRQ1	SOT-23-THIN	DDF	8	3000	210.0	185.0	35.0

2.95 / 2.65 TYP

PIN 1 ID AREA

A

1

2.95 / 2.85 NOTE 3

4

B

1.65 / 1.55

6X 0.65

8

2X 1.95

5

8X 0.38 / 0.22

⊕ 0.1Ⓜ C A B

C

SEATING PLANE

◯ 0.1 C

1.1 MAX

0.20 / 0.08 TYP

SEE DETAIL A

0.25 GAGE PLANE

0° - 8°

0.6 / 0.3

0.1 / 0.0

DETAIL A TYPICAL

4222047/C 10/2022

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. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.

8X (1.05)

SYMM

1

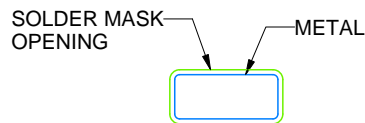8X (0.45)

6X (0.65)

4

(R0.05)
TYP

8

SYMM

5

(2.6)

LAND PATTERN EXAMPLE
SCALE:15X

SOLDER MASK
OPENING

METAL

METAL UNDER
SOLDER MASK

SOLDER MASK
OPENING

NON SOLDER MASK
DEFINED

SOLDER MASK
DEFINED

SOLDER MASK DETAILS

4222047/C   10/2022

NOTES: (continued)

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

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

4222047/C   10/2022

NOTES: (continued)

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

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 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.