

REF35-Q1 超低消費電力、高精度の基準電圧

1 特長

- 以下の結果で AEC-Q100 認定済み:
 - デバイス温度グレード 1: 動作時周囲温度範囲: $-40^{\circ}\text{C} \sim 125^{\circ}\text{C}$
- 非常に小さい静止電流:
 - 650nA (代表値)
- 初期精度: $\pm 0.05\%$ (最大値)
- 温度ドリフト係数:
 - 15ppm/ $^{\circ}\text{C}$ (最大値、 $-40^{\circ}\text{C} \sim 125^{\circ}\text{C}$)
- 出力 1/f ノイズ (0.1Hz \sim 10Hz): 3.3ppm_{p-p}
- ノイズ低減用に NR ピンを搭載
- シャットダウン時の消費電流の低減用に EN ピンを搭載
- 長期安定性: 1000 時間で 30ppm
- 仕様温度範囲: $-40^{\circ}\text{C} \sim +125^{\circ}\text{C}$
- 動作温度範囲: $-55^{\circ}\text{C} \sim +125^{\circ}\text{C}$
- 出力電流: +10mA、-5mA
- 入力電圧: $V_{\text{REF}} + V_{\text{DO}} \sim 6\text{V}$
- 出力電圧オプション:
 - 1.2V、1.25V、1.8V、2.048V、2.5V、3.0V、3.3V、4.096V、5.0V
- 小型の 6 ピン SOT-23 パッケージ

2 アプリケーション

- 車載用フロント・カメラ
- ドライバー監視
- バッテリー制御ユニット
- 電動パワー・ステアリング

3 概要

REF35-Q1 は、ナノパワー、低ドリフト、高精度を備えた一連のリファレンス・デバイスのファミリです。REF35-Q1 ファミリは、 $\pm 0.05\%$ の初期精度と 650nA (代表値) の消費電力を特長としています。このデバイスの温度ドリフト係数 (15ppm/ $^{\circ}\text{C}$) と長期安定性 (1000 時間で 30ppm) は、システムの安定性と信頼性の向上に役立ちます。低消費電力と高精度の仕様を組み合わせ、広範な低電流アプリケーション向けに設計されています。

REF35-Q1 は、3.3ppm_{p-p} ノイズおよび 20ppm/mA の負荷レギュレーションで、最大 10mA の電流を供給します。この機能セットにより、REF35-Q1 は高精度センサと 12 \sim 16 ビット・データ・コンバータ向けの強力な低ノイズで高精度の電源を実現します。

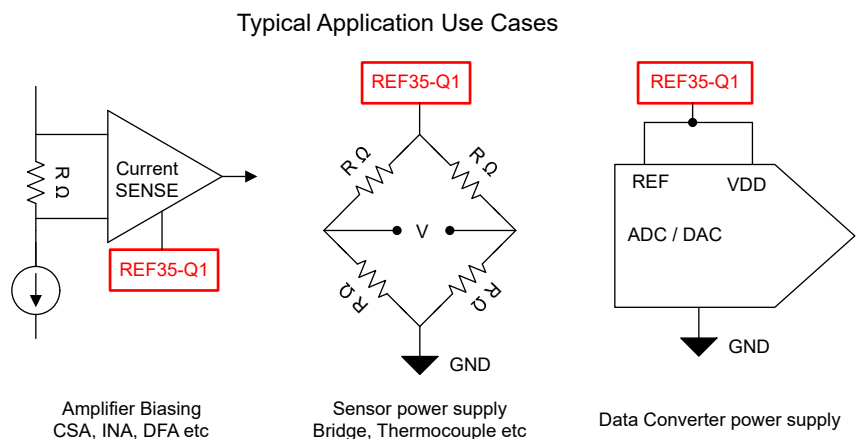
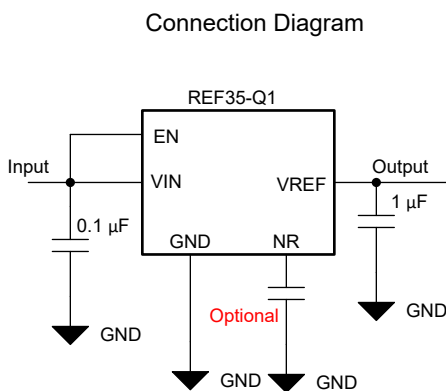
このファミリは $-40^{\circ}\text{C} \sim 125^{\circ}\text{C}$ 向けに完全に動作が規定されており、 $-55^{\circ}\text{C} \sim 125^{\circ}\text{C}$ で動作します。

REF35-Q1 は、1.20V \sim 5.0V の幅広い出力電圧範囲のバリエーションで利用可能です。このデバイスは、省スペースの SOT23-6 ピン・パッケージで供給されます。使用可能な電圧オプションについては、テキサス・インスツルメンツの営業担当者にお問い合わせください。

製品情報

部品番号	パッケージ ⁽¹⁾	本体サイズ (公称)
REF35xxx-Q1	SOT-23 (6)	2.90mm × 1.60mm

- (1) 利用可能なすべての電圧バリエーションおよびパッケージについては、データシートの末尾にある注文情報を参照してください。



REF35-Q1 のユースケース



Table of Contents

1 特長	1	9.1 Overview.....	17
2 アプリケーション	1	9.2 Functional Block Diagram.....	17
3 概要	1	9.3 Feature Description.....	17
4 Revision History	2	9.4 Device Functional Modes	18
5 Device Comparison	3	10 Application and Implementation	20
6 Pin Configuration and Functions	3	10.1 Application Information.....	20
7 Specifications	4	10.2 Typical Application: Negative Reference Voltage... ..	20
7.1 Absolute Maximum Ratings.....	4	10.3 Typical Application: Precision Power Supply and Reference.....	21
7.2 ESD Ratings.....	4	10.4 Power Supply Recommendations.....	22
7.3 Recommended Operating Conditions.....	4	10.5 Layout.....	22
7.4 Thermal Information.....	4	11 Device and Documentation Support	24
7.5 Electrical Characteristics.....	5	11.1 Documentation Support.....	24
7.6 Typical Characteristics.....	6	11.2 ドキュメントの更新通知を受け取る方法.....	24
8 Parameter Measurement Information	11	11.3 サポート・リソース.....	24
8.1 Solder Heat Shift.....	11	11.4 Trademarks.....	24
8.2 Temperature Coefficient.....	12	11.5 静電気放電に関する注意事項.....	24
8.3 Long-Term Stability.....	12	11.6 用語集.....	24
8.4 Thermal Hysteresis.....	13	12 Mechanical, Packaging, and Orderable Information	24
8.5 Noise Performance.....	14		
8.6 Power Dissipation.....	16		
9 Detailed Description	17		

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。

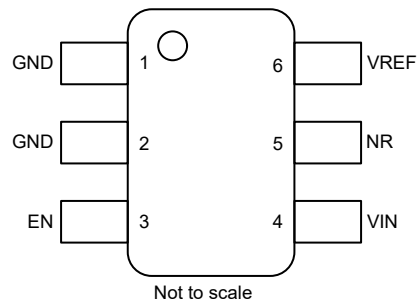
DATE	REVISION	NOTES
August 2023	*	Initial Release

5 Device Comparison

PRODUCT	V _{REF}
REF35120QDBVRQ1 ⁽¹⁾	1.2 V
REF35125QDBVRQ1 ⁽¹⁾	1.25 V
REF35180QDBVRQ1	1.8 V
REF35205QDBVRQ1 ⁽¹⁾	2.048 V
REF35250QDBVRQ1 ⁽¹⁾	2.5 V
REF35300QDBVRQ1	3.0 V
REF35330QDBVRQ1 ⁽¹⁾	3.3 V
REF35409QDBVRQ1 ⁽¹⁾	4.096 V
REF35500QDBVRQ1 ⁽¹⁾	5.0 V

(1) Product preview. Contact local TI support for samples.

6 Pin Configuration and Functions



**图 6-1. Package
6-Pin DBV
Top View**

表 6-1. Pin Functions

PIN		TYPE	DESCRIPTION
NAME	DBV		
GND	1	Ground	Device ground connection
GND	2	Ground	Device ground connection
EN	3	Input	Enable connection. Enables or disables the device.
VIN	4	Power	Input supply voltage connection
NR	5	Output	Noise reduction pin. Connect a capacitor to reduce noise.
VREF	6	Output	Reference voltage output

7 Specifications

7.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
Input voltage	V _{IN}	-0.3	6.5	V
Enable voltage	EN	-0.3	V _{IN} + 0.3 ⁽²⁾	V
Output voltage	V _{REF}	-0.3	V _{IN} + 0.3 ⁽²⁾	V
Output short circuit current	I _{SC}		20	mA
Operating temperature range	T _A	-55	125	°C
Storage temperature range	T _{stg}	-65	170	°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) I_N + 0.3 V or 6.5 V, whichever is lower

7.2 ESD Ratings

		VALUE	UNIT
V _(ESD)	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins ⁽¹⁾	±2000
		Charged device model (CDM), per ANSI/ESDA/JEDEC JS-002, all pins ⁽²⁾	±750

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

7.3 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
V _{IN}	Input voltage ⁽¹⁾	V _{REF} + V _{DO} ⁽²⁾		6	V
EN	Enable voltage	0		V _{IN}	V
I _L	Output current	-5		10	mA
T _A	Operating temperature	-40	25	125	°C

- (1) For V_{REF} = 1.2 V and 1.25 V, minimum V_{IN} = 1.7 V
- (2) V_{DO} = Dropout voltage

7.4 Thermal Information

THERMAL METRIC ⁽¹⁾		REF35-Q1	UNIT
		DBV (SOT-23)	
		6 PINS	
R _{θJA}	Junction-to-ambient thermal resistance	164.4	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	102.5	°C/W
R _{θJB}	Junction-to-board thermal resistance	59.6	°C/W
Ψ _{JT}	Junction-to-top characterization parameter	44.0	°C/W
Ψ _{JB}	Junction-to-board characterization parameter	59.4	°C/W
R _{θJC(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.

7.5 Electrical Characteristics

At $V_{IN} = V_{REF} + 0.5\text{ V}$, $V_{EN} = V_{IN}$, $C_L = 10\ \mu\text{F}$, $C_{IN} = 0.1\ \mu\text{F}$, $I_L = 0\ \text{mA}$, minimum and maximum specifications at $T_A = -40^\circ\text{C}$ to 125°C , typical specifications $T_A = 25^\circ\text{C}$; unless otherwise noted

PARAMETER		TEST CONDITION		MIN	TYP	MAX	UNIT
ACCURACY AND DRIFT							
	Output voltage accuracy	$T_A = 25^\circ\text{C}$		-0.05		0.05	%
	Output voltage temperature coefficient	$-40^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$				15	ppm/ $^\circ\text{C}$
LINE AND LOAD REGULATION							
$\Delta V_{REF}/\Delta V_{IN}$	Line regulation	$V_{REF} < 2.5\ \text{V}$; $V_{IN} = V_{REF} + V_{DO}$ to V_{INMAX}			40	160	ppm/V
		$V_{REF} \geq 2.5\ \text{V}$; $V_{IN} = V_{REF} + V_{DO}$ to V_{INMAX}			40	120	ppm/V
$\Delta V_{REF}/\Delta I_L$	Load regulation	$I_L = 0\ \text{mA}$ to $10\ \text{mA}$, $V_{IN} = V_{REF} + V_{DO}$	Source		20	60	ppm/mA
		$I_L = 0\ \text{mA}$ to $5\ \text{mA}$, $V_{IN} = V_{REF} + V_{DO}$	Sink		40	350	ppm/mA
POWER SUPPLY							
V_{IN}	Input voltage ⁽¹⁾			$V_{REF} + V_{DO}$		6	V
I_Q	Quiescent current	Active mode	$T_A = 25^\circ\text{C}$		0.65	0.9	μA
			$-40^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$			2.6	
		Shutdown mode	$T_A = 25^\circ\text{C}$			0.1	
			$-40^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$			0.5	
V_{EN}	Enable pin voltage	Active mode (EN = 1 or Float)		$0.7 \times V_{IN}$			V
		Shutdown mode (EN = 0)		$0.3 \times V_{IN}$			
I_{EN}	Enable pin current	$V_{EN} = V_{IN}$			0.05	0.1	μA
V_{DO}	Dropout voltage	$I_L = 5\ \text{mA}$				120	mV
		$I_L = 10\ \text{mA}$				250	
I_{SC}	Short circuit current, Sourcing	$V_{REF} = 0\ \text{V}$, $T_A = 25^\circ\text{C}$			33		mA
I_{SC}	Short circuit current, Sinking	$V_{REF} = V_{IN}\ \text{V}$, $T_A = 25^\circ\text{C}$			21		mA
TURN-ON TIME							
t_{ON}	Turn-on time ⁽²⁾	0.1% settling, $C_L = 1\ \mu\text{F}$, $V_{REF} = 2.5\ \text{V}$			2		ms
NOISE							
e_n	Output voltage noise	$f = 10\ \text{Hz}$ to $1\ \text{kHz}$, $C_L = 1\ \mu\text{F}$			0.7		ppm _{rms}
e_{np-p}	Low-frequency noise	$f = 0.1\ \text{Hz}$ to $10\ \text{Hz}$, $V_{REF} \geq 2.5\ \text{V}$			3.8		ppm _{p-p}
		$f = 0.1\ \text{Hz}$ to $10\ \text{Hz}$, $V_{REF} < 2.5\ \text{V}$			3.3		ppm _{p-p}
HYSTERESIS AND LONG-TERM STABILITY							
	Long-term stability	0 to 1000h at 35°C			30		ppm
	Output voltage hysteresis	25°C , -40°C , 125°C , 25°C (cycle 1)			90		ppm
	Output voltage hysteresis	25°C , -40°C , 125°C , 25°C (cycle 2)			70		ppm
STABLE CAPACITANCE RANGE							
	Input capacitor range				0.1		μF
	Output capacitor range ⁽³⁾				0.1	10	μF

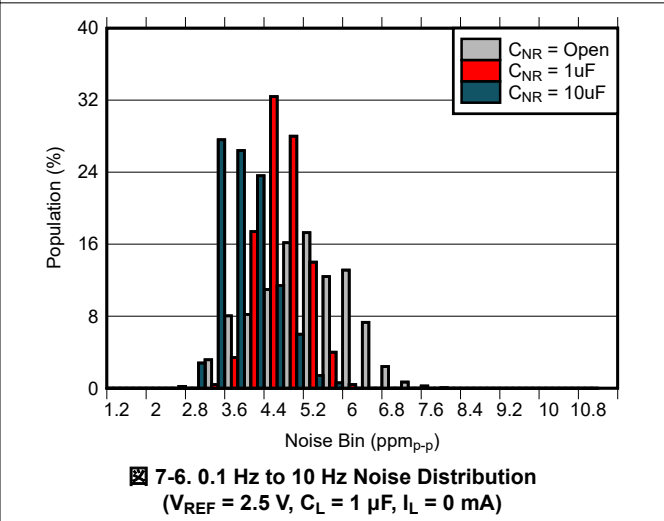
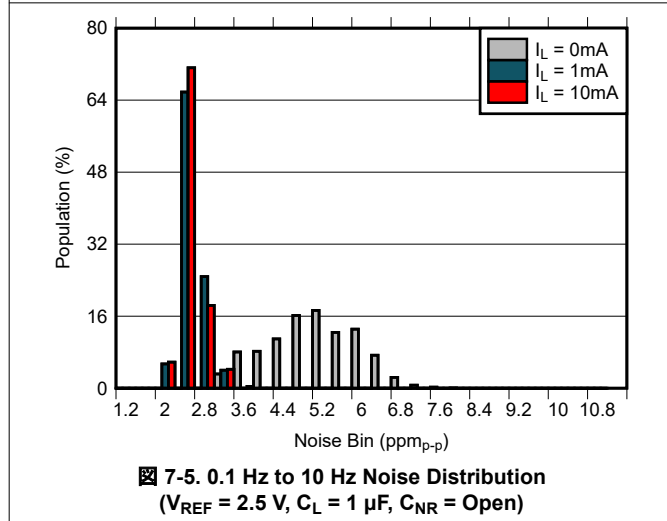
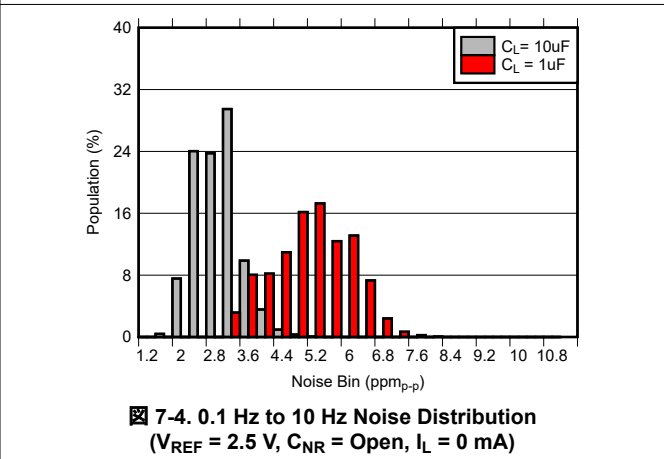
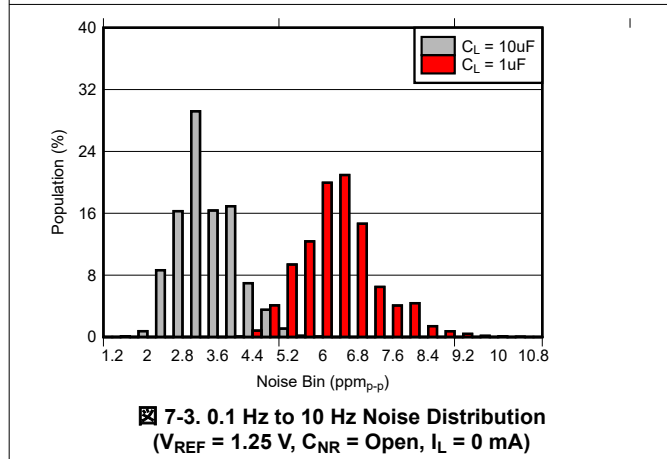
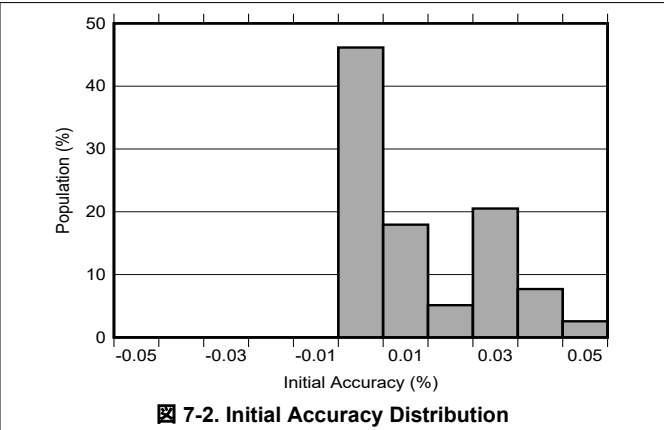
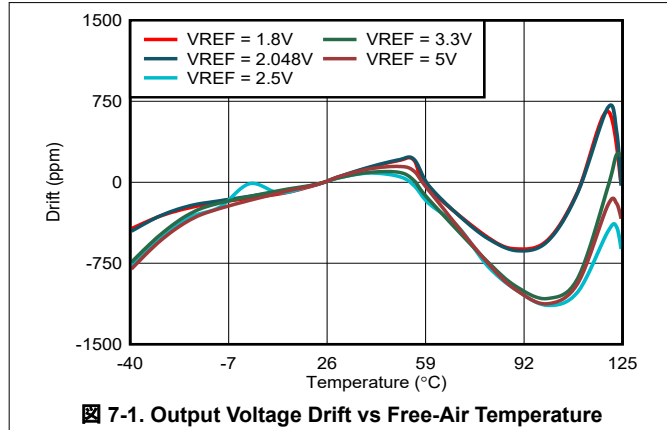
(1) For $V_{REF} = 1.2\ \text{V}$ and $1.25\ \text{V}$, minimum $V_{IN} = 1.7\ \text{V}$

(2) Scales linearly with V_{REF} .

(3) ESR for the capacitor $\leq 400\ \text{m}\Omega$

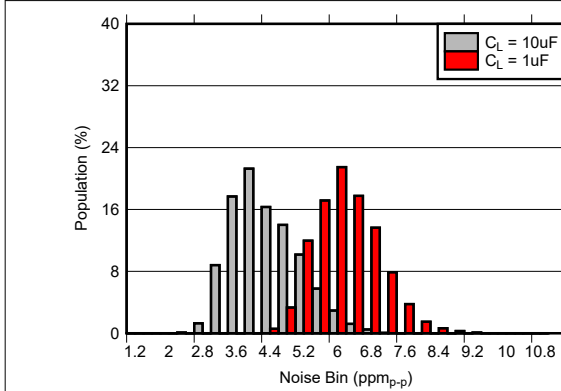
7.6 Typical Characteristics

at $T_A = 25^\circ\text{C}$, $V_{IN} = V_{EN} = V_{REF} + 0.3\text{ V}$, $I_L = 0\text{ mA}$, $C_L = 10\ \mu\text{F}$, $C_{IN} = 0.1\ \mu\text{F}$ (unless otherwise noted)

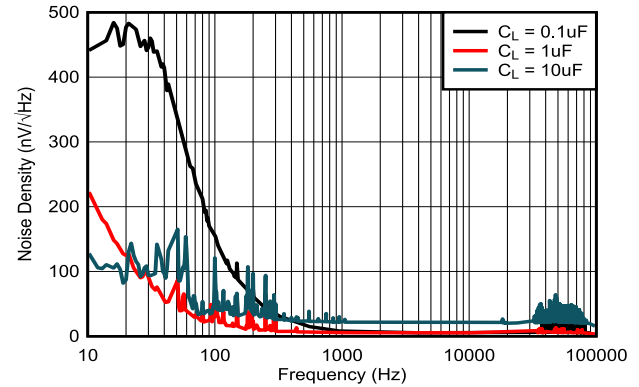


7.6 Typical Characteristics (continued)

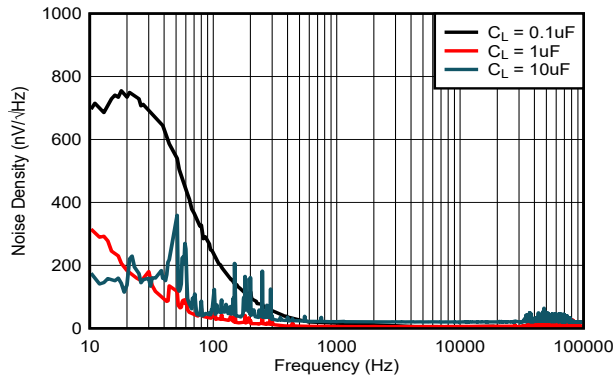
at $T_A = 25^\circ\text{C}$, $V_{IN} = V_{EN} = V_{REF} + 0.3\text{ V}$, $I_L = 0\text{ mA}$, $C_L = 10\text{ }\mu\text{F}$, $C_{IN} = 0.1\text{ }\mu\text{F}$ (unless otherwise noted)



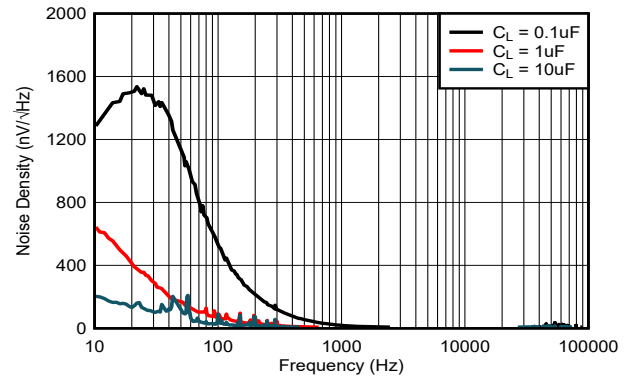
7-7. 0.1 Hz to 10 Hz Noise Distribution
($V_{REF} = 5\text{ V}$, $C_{NR} = \text{Open}$, $I_L = 0\text{ mA}$)



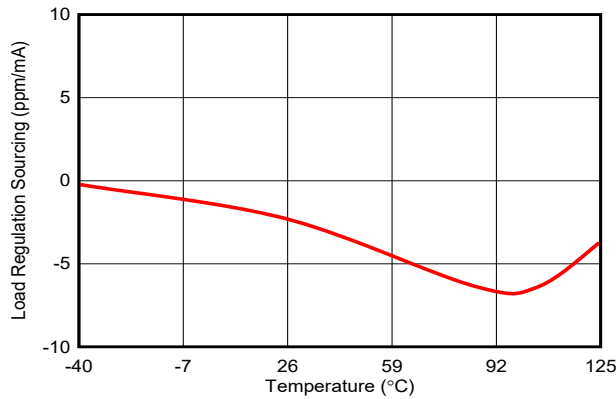
7-8. Noise Density vs Frequency
($V_{REF} = 1.25\text{ V}$, $I_L = 0\text{ mA}$)



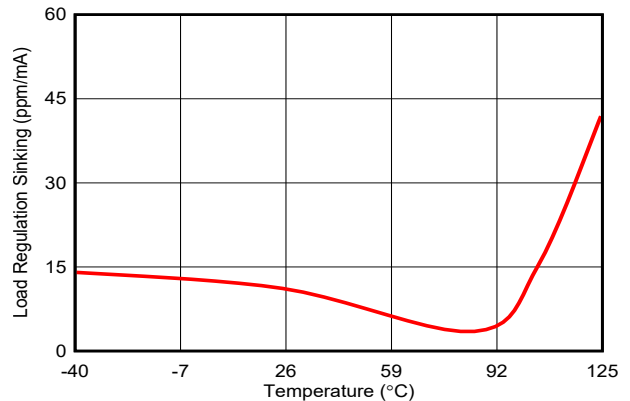
7-9. Noise Density vs Frequency
($V_{REF} = 2.5\text{ V}$, $I_L = 0\text{ mA}$)



7-10. Noise Density vs Frequency
($V_{REF} = 5\text{ V}$, $I_L = 0\text{ mA}$)



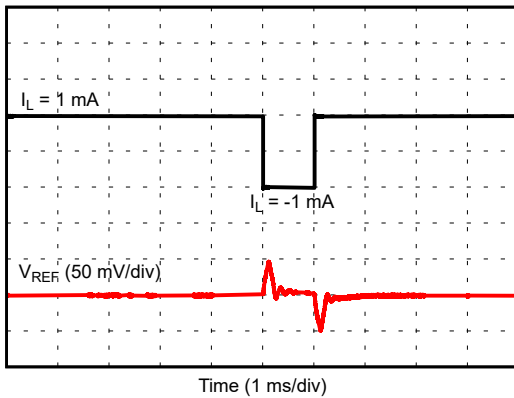
7-11. Load Regulation (Sourcing 10 mA) vs Free-Air Temperature



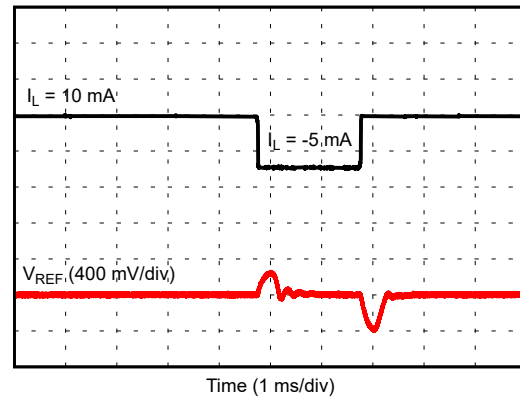
7-12. Load Regulation (Sinking 5 mA) vs Free-Air Temperature

7.6 Typical Characteristics (continued)

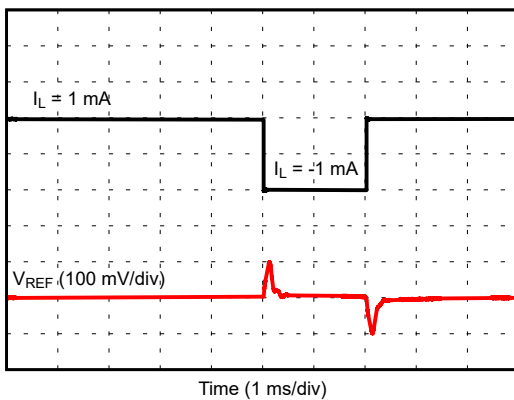
at $T_A = 25^\circ\text{C}$, $V_{IN} = V_{EN} = V_{REF} + 0.3\text{ V}$, $I_L = 0\text{ mA}$, $C_L = 10\text{ }\mu\text{F}$, $C_{IN} = 0.1\text{ }\mu\text{F}$ (unless otherwise noted)



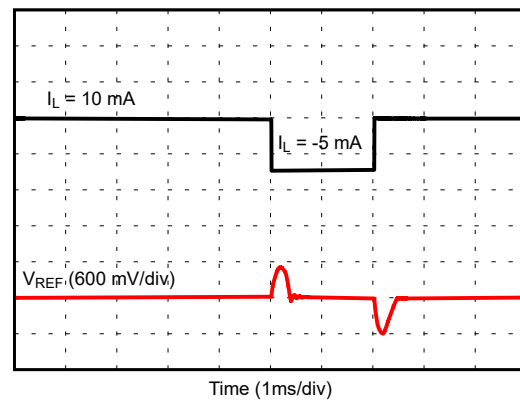
7-13. Load Transient Response
 ($V_{REF} = 2.5\text{ V}$, $C_L = 10\text{ }\mu\text{F}$)



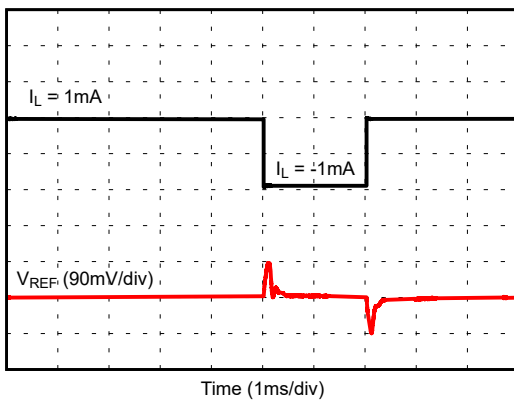
7-14. Load Transient Response
 ($V_{REF} = 2.5\text{ V}$, $C_L = 10\text{ }\mu\text{F}$)



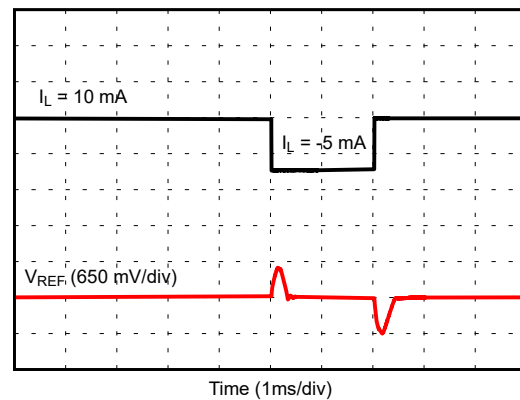
7-15. Load Transient Response
 ($V_{REF} = 2.5\text{ V}$, $C_L = 1\text{ }\mu\text{F}$)



7-16. Load Transient Response
 ($V_{REF} = 2.5\text{ V}$, $C_L = 1\text{ }\mu\text{F}$)



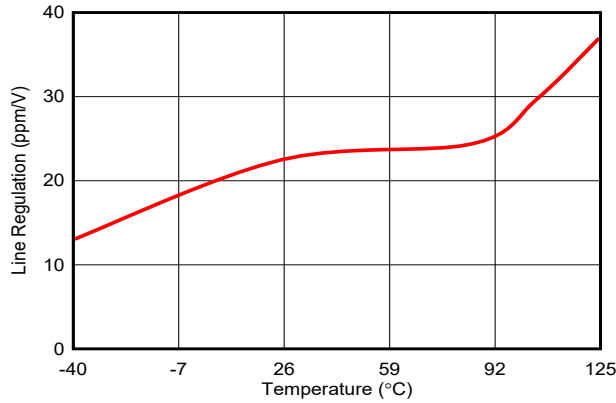
7-17. Load Transient Response
 ($V_{REF} = 1.25\text{ V}$, $C_L = 1\text{ }\mu\text{F}$)



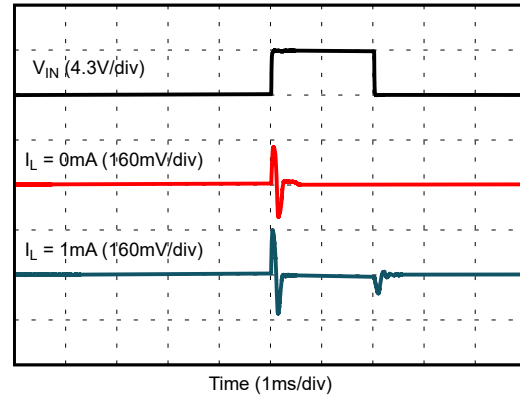
7-18. Load Transient Response
 ($V_{REF} = 1.25\text{ V}$, $C_L = 1\text{ }\mu\text{F}$)

7.6 Typical Characteristics (continued)

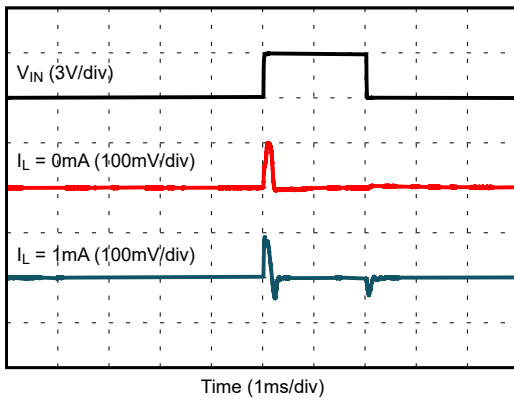
at $T_A = 25^\circ\text{C}$, $V_{IN} = V_{EN} = V_{REF} + 0.3\text{ V}$, $I_L = 0\text{ mA}$, $C_L = 10\ \mu\text{F}$, $C_{IN} = 0.1\ \mu\text{F}$ (unless otherwise noted)



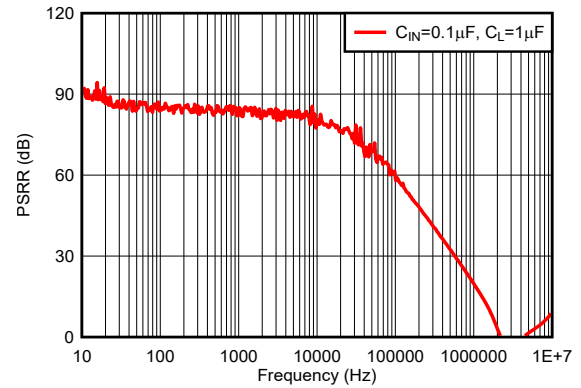
7-19. Line Regulation vs Free-Air Temperature



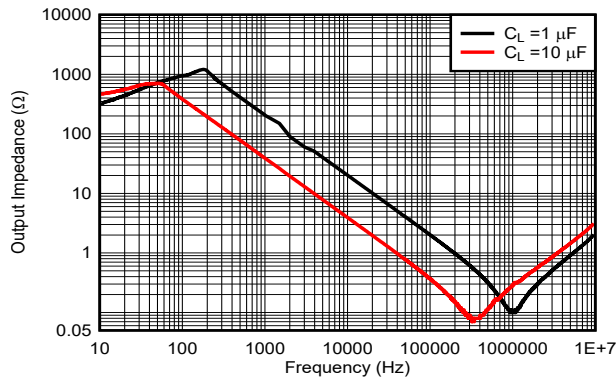
7-20. Line Transient Response
($V_{REF} = 1.25\text{ V}$, $C_L = 1\ \mu\text{F}$)



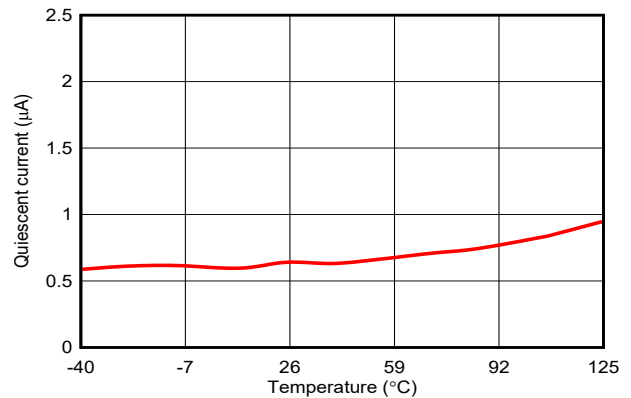
7-21. Line Transient Response
($V_{REF} = 2.5\text{ V}$, $C_L = 1\ \mu\text{F}$)



7-22. Power Supply Rejection Ratio
($V_{REF} = 2.5\text{ V}$, $I_L = 0\text{ mA}$)



7-23. Output Impedance



7-24. Quiescent Current vs Free-Air Temperature

7.6 Typical Characteristics (continued)

at $T_A = 25^\circ\text{C}$, $V_{IN} = V_{EN} = V_{REF} + 0.3\text{ V}$, $I_L = 0\text{ mA}$, $C_L = 10\text{ }\mu\text{F}$, $C_{IN} = 0.1\text{ }\mu\text{F}$ (unless otherwise noted)

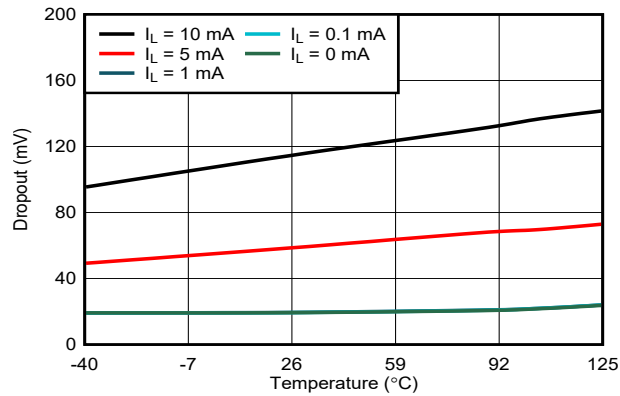


Figure 7-25. Dropout Voltage vs Free-Air Temperature

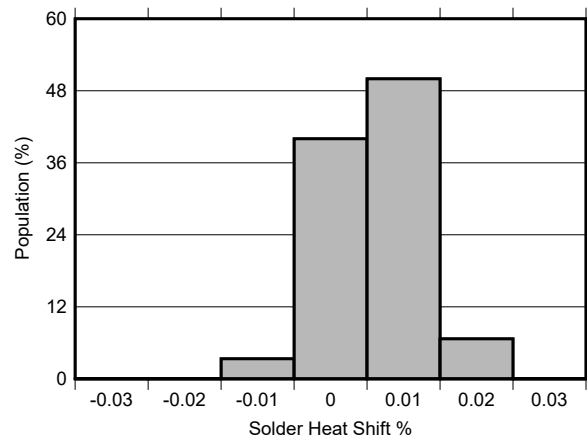


Figure 7-26. Solder Heat Shift Distribution

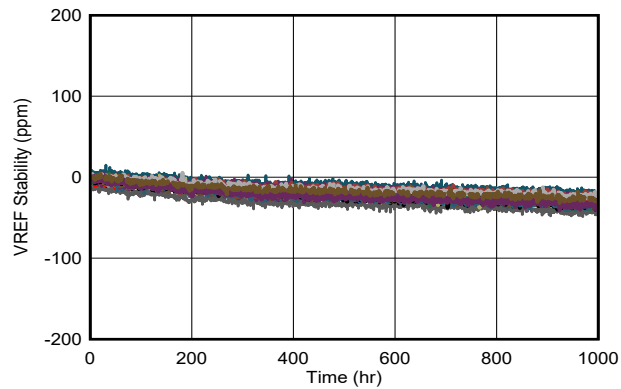


Figure 7-27. Long Term Stability - 1000 hours (V_{REF})

8 Parameter Measurement Information

8.1 Solder Heat Shift

The materials used in the manufacture of the REF35-Q1 have differing coefficients of thermal expansion, resulting in stress on the device die when the part is heated. Mechanical and thermal stress on the device die can cause the output voltages to shift, degrading the initial accuracy specifications of the product. Reflow soldering is a common cause of this error.

To illustrate this effect, a total of 32 devices were soldered on one printed circuit board using lead-free solder paste and the paste manufacturer suggested reflow profile. [Figure 8-1](#) shows the reflow profile. The printed circuit board is comprised of FR4 material. The board thickness is 1.66 mm and the area is 174 mm × 135 mm.

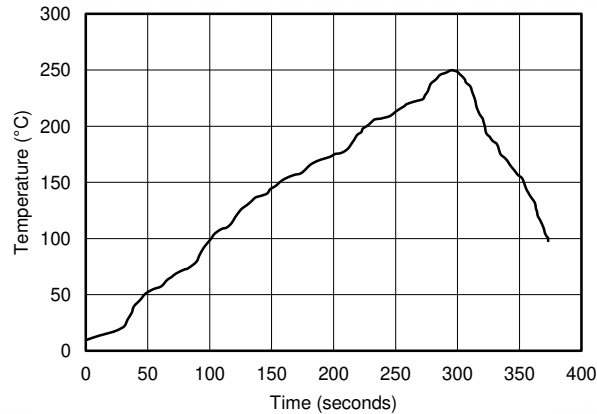


Figure 8-1. Reflow Profile

The reference output voltage is measured before and after the reflow process; [Figure 8-2](#) shows the typical shift. Although all tested units exhibit very low shifts (< 0.03%), higher shifts are also possible depending on the size, thickness, and material of the printed circuit board (PCB). An important note is that the histograms display the typical shift for exposure to a single reflow profile. Exposure to multiple reflows, as is common on PCBs with surface-mount components on both sides, causes additional shifts in the output bias voltage. If the PCB is exposed to multiple reflows, the device must be soldered in the last pass to minimize its exposure to thermal stress.

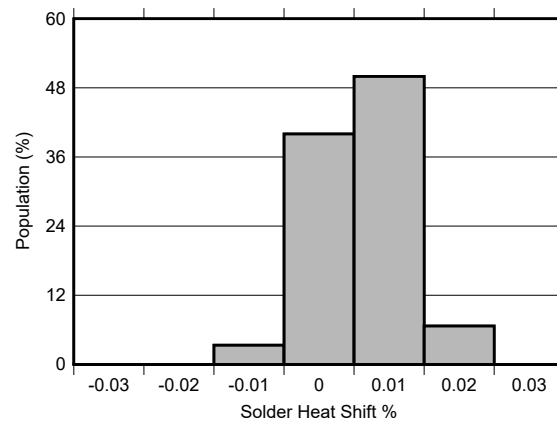


Figure 8-2. Solder Heat Shift Distribution, V_{REF} (%)

8.2 Temperature Coefficient

The REF35-Q1 is designed and tested for a low output voltage temperature coefficient, which is defined as the change in output voltage over temperature. The temperature coefficient is calculated using the box method in which a box is formed by the minimum/maximum limits for the nominal output voltage over the operating temperature range. REF35-Q1 has a low maximum temperature coefficient of 15 ppm/°C from –40°C to +125°C. The box method specifies limits for the temperature error but does not specify the exact shape and slope of the device under test. Due to temperature curvature correction to achieve low-temperature drift, the temperature drift is expected to be non-linear. See TI's Analog Design Journal, [Precision voltage references](#), for more information on the box method. Use 式 1 for the box method.

$$\text{Drift} = \left(\frac{V_{\text{REF(MAX)}} - V_{\text{REF(MIN)}}}{V_{\text{REF(25°C)}} \times \text{Temperature Range}} \right) \times 10^6 \quad (1)$$

Figure 8-3 shows a typical voltage versus temperature curves for various reference voltages.

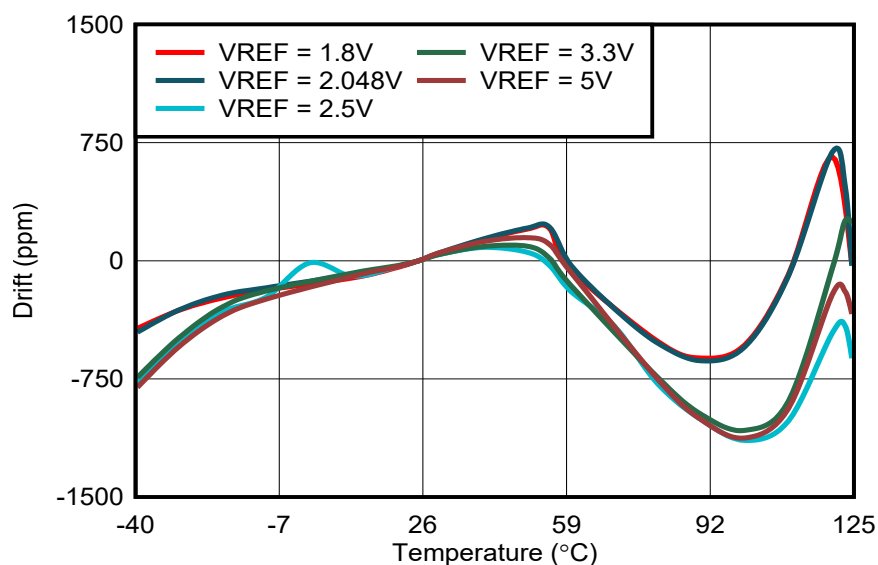


Figure 8-3. Output Voltage Drift Vs Free-Air Temperature

8.3 Long-Term Stability

One of the key performance parameters of the REF35-Q1 references is long-term stability also known as long-term drift. The long-term stability value is tested in a typical setup that reflects standard PCB board manufacturing practices. The boards are made of standard FR4 material and the board does not have special cuts or grooves around the devices to relieve the mechanical stress of the PCB. The devices and boards in this test do not undergo high temperature burn in post-soldering prior to testing. These conditions reflect a real world use case scenario and common manufacturing techniques.

During the long-term stability testing, precautions are taken to ensure that only the long-term stability drift is being measured. The boards are maintained at 35°C in an oil bath. The oil bath ensures that the temperature is constant across the device over time compared to an air oven. The measurements are captured every 30 minutes with a calibrated 8.5 digit multimeter.

The typical long-term stability characteristic is expressed as a deviation of the reference voltage output over time.

Figure 8-4 shows the typical drift value for the REF35-Q1 in 6-pin SOT-23 package is 30 ppm from 0 to 1000 hours. It is important to understand that long-term stability is not ensured by design and that the value is typical. The

REF35-Q1 will experience the highest drift in the initial 1000 hr. Subsequent deviation is typically lower than first 1000 hr.

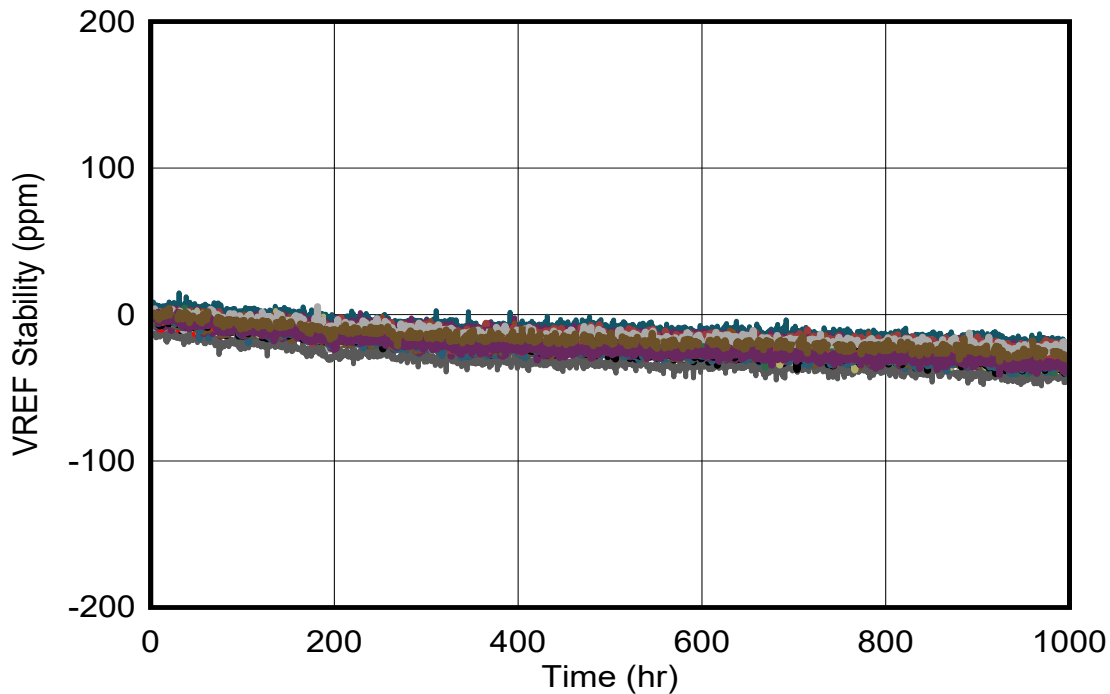


图 8-4. Long Term Stability - 1000 hours (V_{REF})

8.4 Thermal Hysteresis

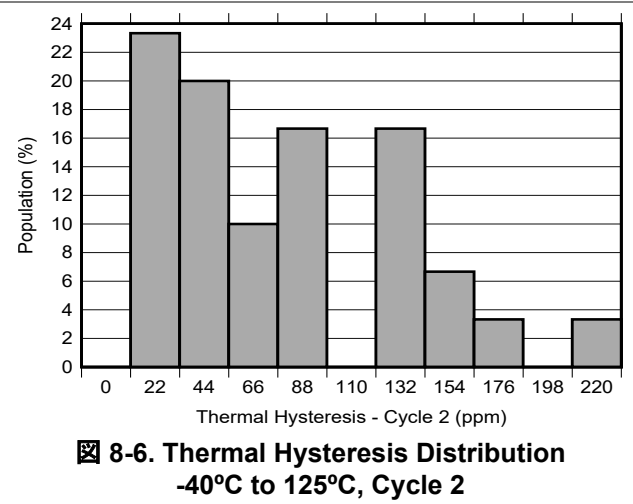
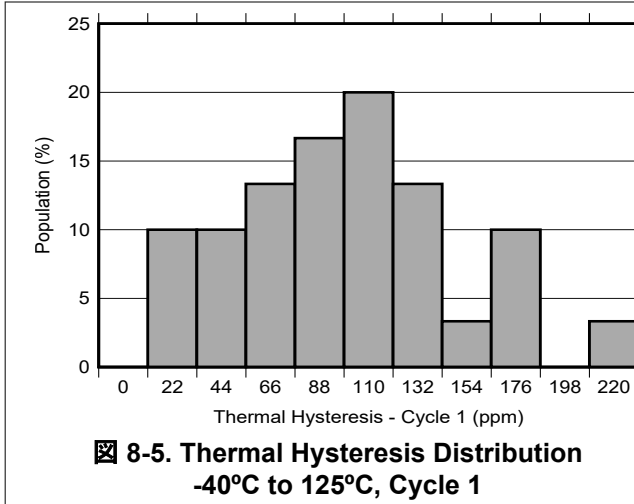
Thermal hysteresis is measured with the REF35-Q1 soldered to a PCB, similar to a real-world application. Thermal hysteresis for the device is defined as the change in output voltage after operating the device at 25°C, cycling the device through the specified temperature range, and returning to 25°C. The PCB was baked at 150°C for 30 minutes before thermal hysteresis was measured. Use 式 2 to calculate the thermal hysteresis.

$$V_{HYST} = \left(\frac{|V_{PRE} - V_{POST}|}{V_{NOM}} \right) \times 10^6 \text{ (ppm)} \quad (2)$$

where

- V_{HYST} = thermal hysteresis (in units of ppm)
- V_{NOM} = the specified output voltage
- V_{PRE} = output voltage measured at 25°C pre-temperature cycling
- V_{POST} = output voltage measured after the device has cycled from 25°C through the specified temperature range of -40°C to +125°C and returns to 25°C.

图 8-5 and 图 8-6 show the typical thermal hysteresis distribution across various temperature ranges in two cycles.

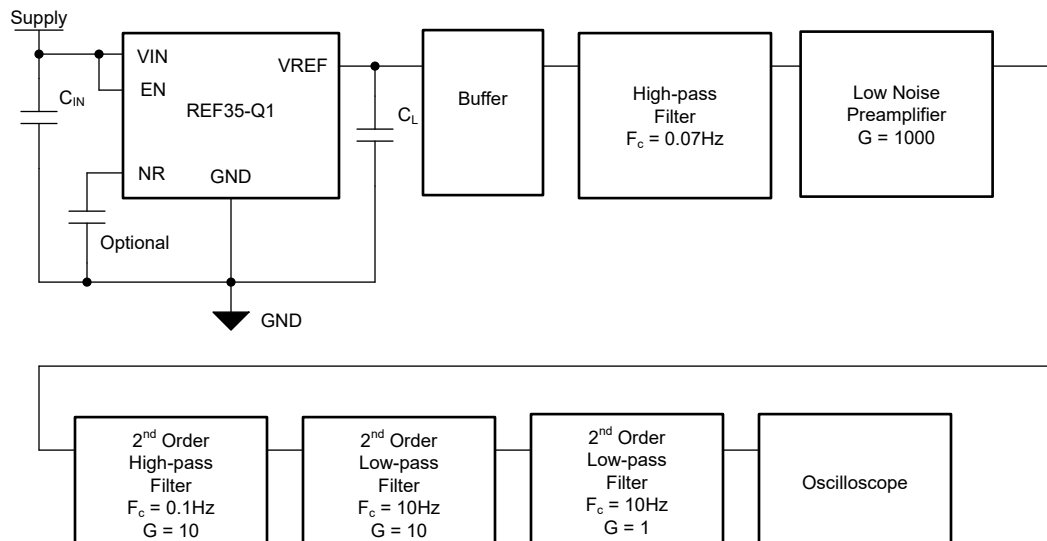


8.5 Noise Performance

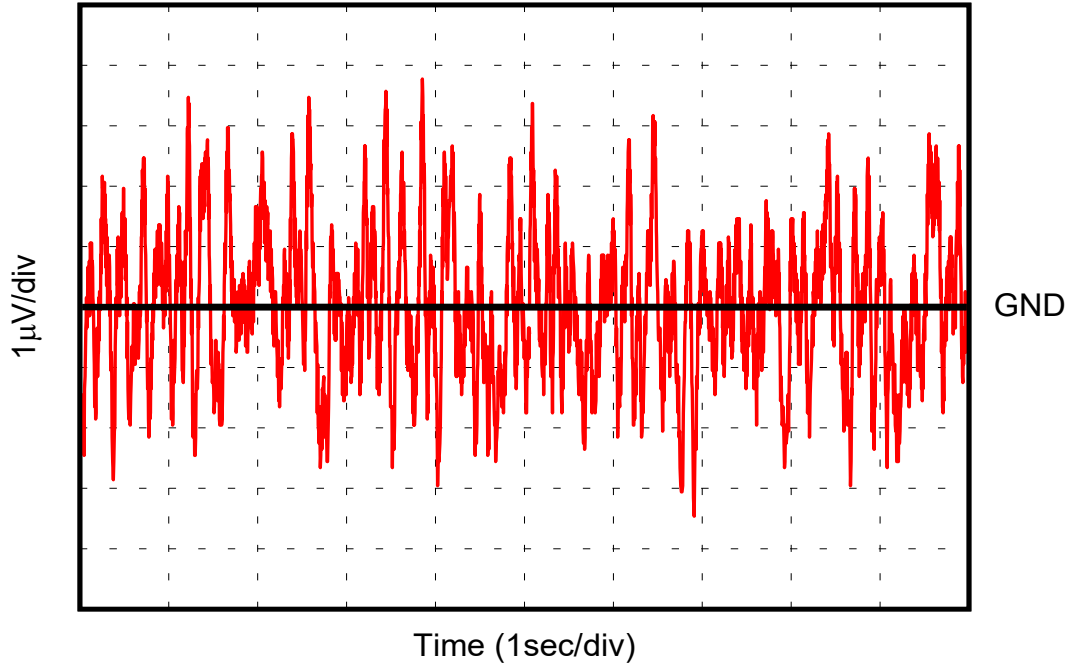
The reference pin output noise is categorized as low frequency and broadband noise. The following sections describe these categories in detail.

8.5.1 Low-Frequency (1/f) Noise

Flicker noise, also known as 1/f noise, is a low-frequency noise that affects the device output voltage which can affect precision measurements in ADCs. This noise increases proportionally with output voltage and operating temperature. The noise is measured by filtering the output from 0.1 Hz to 10 Hz. The 1/f noise is an extremely low value, therefore the frequency of interest must be amplified and band-pass filtered. This is done by using a high-pass filter to block the DC voltage. The resulting noise is then amplified by a gain of 1000. The bandpass filter is created by a series of high-pass and low-pass filter that adds additional gain to make it more visible on an oscilloscope as shown in [8-7](#). [8-8](#) shows the effect of flicker noise over 10 second. Flicker noise must be tested in a Faraday cage enclosure to block environmental noise.



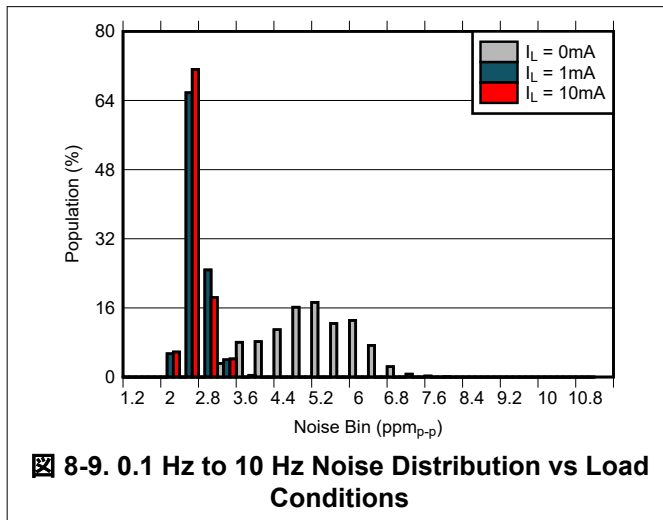
8-7. Low-Frequency (1/f) Noise Test Setup



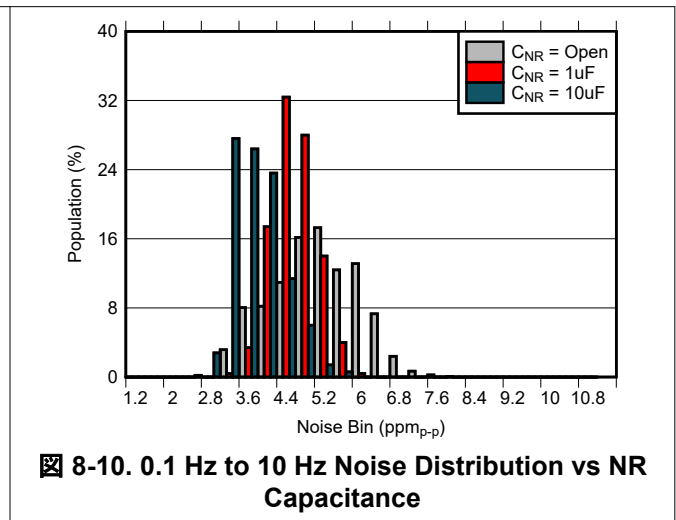
8-8. 0.1 Hz to 10 Hz Voltage Noise

8-9 shows the typical $1/f$ noise (0.1 Hz to 10 Hz) distribution across various load conditions. The REF35-Q1 device also offers noise reduction functionality by adding an optional capacitor between NR (pin 5) and ground pins.

8-10 shows the typical $1/f$ noise (0.1 Hz to 10 Hz) distribution across REF35-Q1 devices with various capacitance between NR pin and GND.



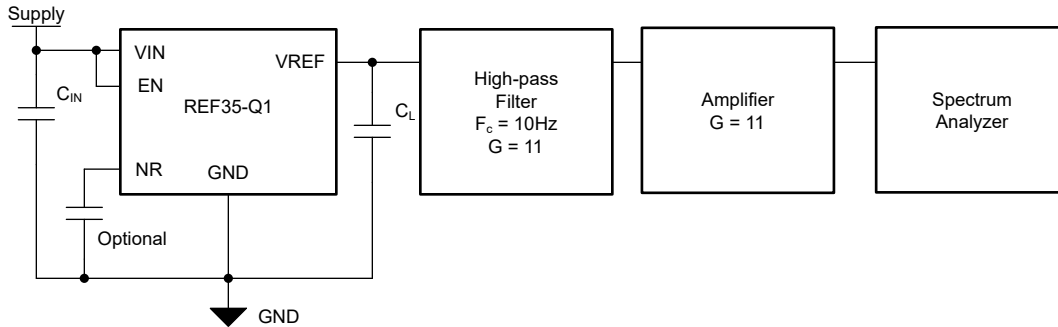
8-9. 0.1 Hz to 10 Hz Noise Distribution vs Load Conditions



8-10. 0.1 Hz to 10 Hz Noise Distribution vs NR Capacitance

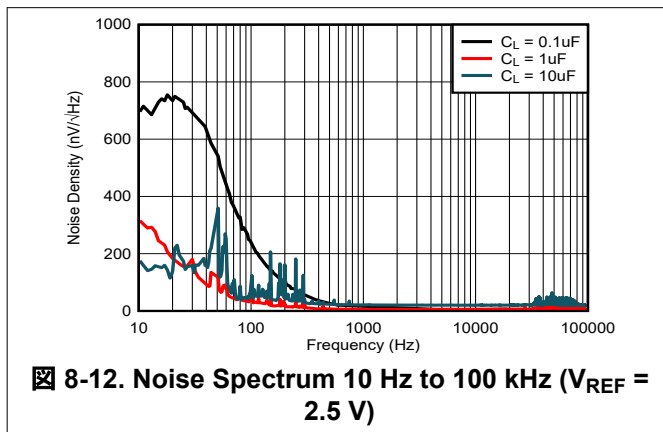
8.5.2 Broadband Noise

Broadband noise is a noise that appears at higher frequency compared to $1/f$ noise. The broadband noise is measured by high-pass filtering the output of the reference device, followed by a gain stage and measuring the result on a spectrum analyzer as shown in 8-11

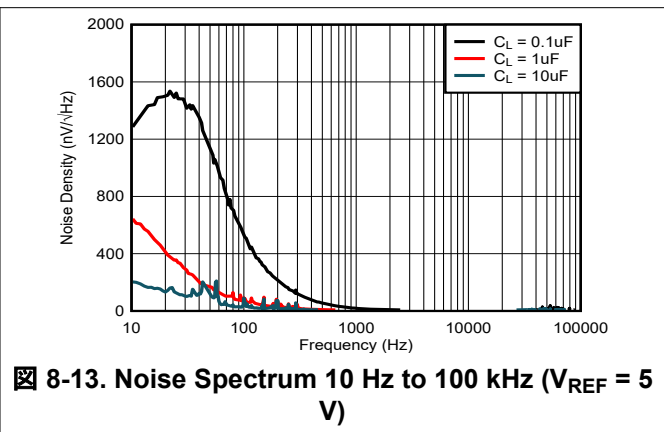


8-11. Broadband Noise Test Setup

For noise sensitive designs, a low-pass filter can be used to reduce broadband noise output noise levels by removing the high frequency components. When designing a low-pass filter, take special care to make sure the output impedance of the filter does not degrade AC performance. This can occur in RC low-pass filters where a large series resistance can impact the load transients due to output current fluctuations. The REF35-Q1 device also offers noise reduction functionality by adding an optional capacitor between NR (pin 5) and ground pins. [8-12](#) and [8-13](#) show the noise spectrum for REF35250 and REF35500 devices respectively across various NR pin capacitance.



8-12. Noise Spectrum 10 Hz to 100 kHz ($V_{REF} = 2.5\text{ V}$)



8-13. Noise Spectrum 10 Hz to 100 kHz ($V_{REF} = 5\text{ V}$)

8.6 Power Dissipation

The REF35-Q1 voltage references are capable of source up to 10 mA and sink up to 5 mA of load current across the rated input voltage range. However, when used in applications subject to high ambient temperatures, the input voltage and load current must be carefully monitored to ensure that the device does not exceed its maximum power dissipation rating. The maximum power dissipation of the device can be calculated with [3](#):

$$T_J = T_A + P_D \times R_{\theta JA} \tag{3}$$

where

- P_D is the device power dissipation
- T_J is the device junction temperature
- T_A is the ambient temperature
- $R_{\theta JA}$ is the package (junction-to-air) thermal resistance

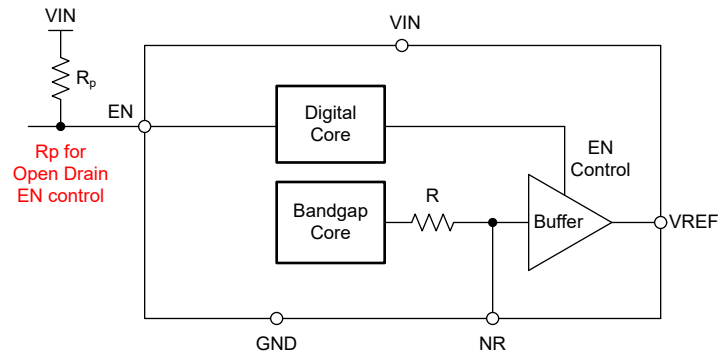
Because of this relationship, acceptable load current in high temperature conditions may be less than the maximum current-sourcing capability of the device. In no case should the device be operated outside of its maximum power rating because doing so can result in premature failure or permanent damage to the device.

9 Detailed Description

9.1 Overview

The REF35-Q1 is family of ultralow current, low-noise, precision band-gap voltage references that are specifically designed for excellent initial voltage accuracy and drift. The [Functional Block Diagram](#) is a simplified block diagram of the REF35-Q1 showing basic band-gap topology.

9.2 Functional Block Diagram



9.3 Feature Description

9.3.1 Supply Voltage

The REF35-Q1 family of references features an extremely low dropout voltage. For 10 mA loaded conditions, a maximum dropout voltage is 250 mV. [Figure 7-25](#) shows a typical dropout voltage (V_{DO}) versus load current. The device supports operation with input voltage range from $V_{REF} + V_{DO}$ to 6 V. The typical quiescent current is 680 nA and maximum quiescent current over temperature is only 2.6 μ A. The low dropout voltage coupled with ultralow current enable the operation across multiple battery powered applications.

9.3.2 EN Pin

The REF35-Q1 family supports device enable and disable functionality through logic level control on EN pin. The EN pin of REF35-Q1 does not use an internal pull-up resistor. Instead, the pin uses new 'clean EN' technology. This allows the EN pin to be in a no connect condition at start-up, and no extra current is drawn from the supply when the EN pin is pulled low in shutdown mode. When EN pin is pulled high or left unconnected, the device is in active mode. When EN pin is drive by an open-drain outputs, a pull-up resistor to VIN is required. The device must be in active mode for normal operation. The EN pin must not be pulled higher than VIN supply voltage.

The device can be placed in shutdown mode by pulling the EN pin low. When in shutdown mode, the output of the device becomes high impedance and the quiescent current of the device drops to 50 nA.

Also note that for applications where EN pin is no-connect, total parasitic capacitance on EN pin should be restricted within 30 pF.

See the [セクション 7.5](#) for logic high and logic low voltage levels.

9.3.3 NR Pin

The REF35-Q1 pin allows access to the band gap through the NR pin. Placing a capacitor from the NR pin to GND creates a low-pass filter in combination with the internal resistance of 60 k Ω . Leakage of the capacitance directly impacts the accuracy and temperature drift. If NR functionality is used, choose a low leakage capacitor. A capacitance of 1 μ F creates a low-pass filter with corner frequency around 2.7 Hz. Such a filter decreases the overall noise on the VREF pin. Higher capacitance results in a lower filter cut off frequency, further reducing output noise. Please note, using the capacitor on NR pin also increases start-up time.

9.4 Device Functional Modes

9.4.1 Basic Connections

Figure 9-1 shows the typical connections for the REF35-Q1. TI recommends a supply bypass capacitor (C_{IN}) ranging from 0.1 μF to 10 μF . A 0.1 μF to 10 μF output capacitor (C_L) must be connected from REF to GND. The equivalent series resistance (ESR) value of C_L must be lower than 400 m Ω to ensure output stability.

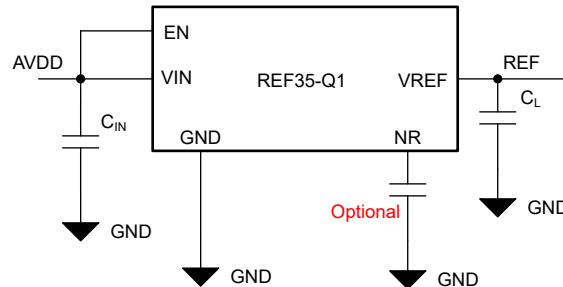


Figure 9-1. Basic Connections

9.4.2 Start-Up

Figure 9-2 shows the start-up behavior of REF35250 device with 1 μF load capacitance. REF35-Q1 device ensures the output voltage settles to the expected output voltage within specified accuracy without oscillations. The start-up time is dependent on the output voltage variant, output capacitance and NR pin capacitance. Higher capacitance leads to longer start-up time.

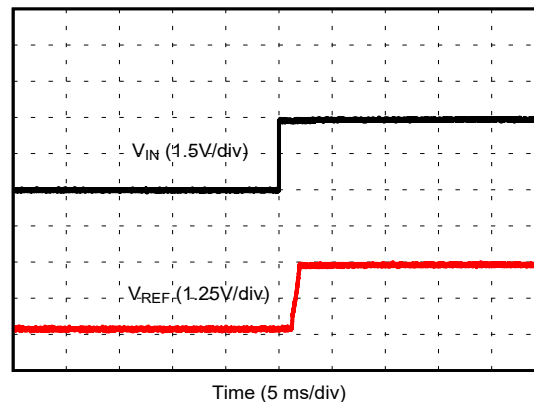
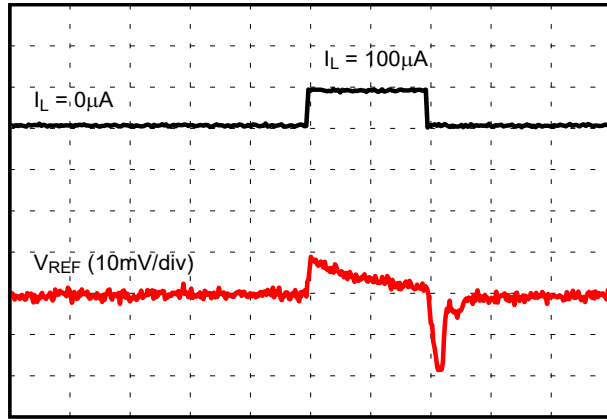


Figure 9-2. REF35250 Start-Up Behavior, $C_L = 1 \mu\text{F}$

9.4.3 Output Transient Behavior

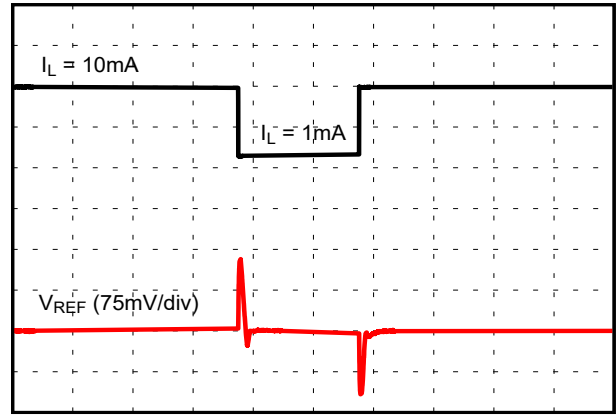
The REF35-Q1 output buffer is capable of sourcing 10 mA load current as well as sink 5 mA of load current. The output stage is designed using class AB architecture with ultra-low quiescent current. This architecture avoids the dead zone around the no load condition. The output buffer uses a fast start-up implementation to achieve 2ms typical turn-on time at $C_L = 1 \mu\text{F}$ and no-load current condition.

Figure 9-3 and Figure 9-4 show the output settling behavior for light load transient and high load transient respectively.



Time (1ms/div)

**9-3. Load Transient Response 0 μ A to 100 μ A,
 $C_{REF} = 1 \mu$ F**



Time (1ms/div)

**9-4. Load Transient Response 1 mA to 10 mA,
 $C_{REF} = 1 \mu$ F**

10 Application and Implementation

注

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

10.1 Application Information

REF35-Q1 with low current consumption and class leading performance specifications is suitable reference for multiple applications. The device can also be used as a precision low noise power supply to sensor or data converter instead of traditional LDO or DC/DC based power supply. Basic applications includes positive/negative voltage reference and data acquisition.

10.2 Typical Application: Negative Reference Voltage

For applications requiring a negative and positive reference voltage, the REF35-Q1 and OPA188-Q1 can be used to provide a dual-supply reference from a 5 V supply. [Figure 10-1](#) shows the REF35250 used to provide a 2.5 V supply reference voltage. The low drift performance of the REF35250-Q1 complements the low offset voltage and low-drift of the OPA188-Q1 to provide an accurate solution for split-supply applications. Take care to match the temperature coefficients of R1 and R2.

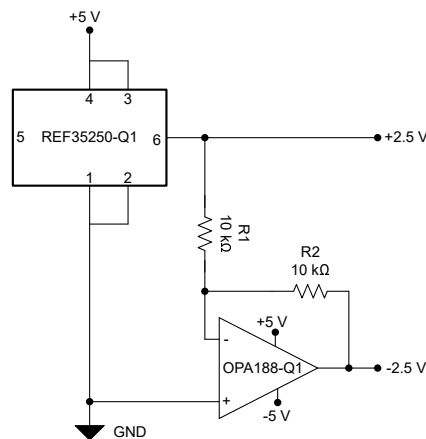
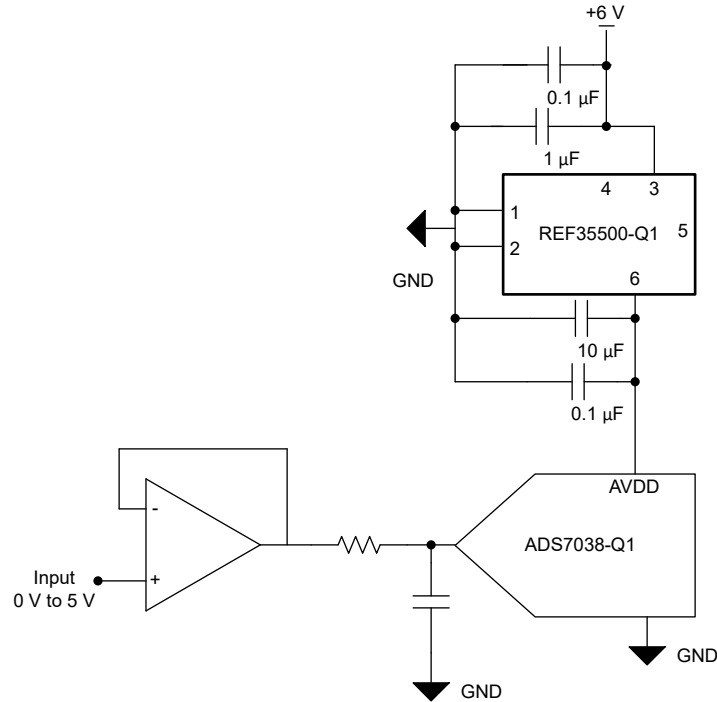


Figure 10-1. REF35-Q1 and OPA188-Q1 Create Positive and Negative Reference Voltages

10.3 Typical Application: Precision Power Supply and Reference

10-2 shows the basic configuration for the REF35-Q1 device as precision power supply to ADS7038-Q1 data converter which uses its power supply AVDD as reference. Connect bypass capacitors according to the guidelines in セクション 10.3.2.2 section.



10-2. Basic Reference Connection

10.3.1 Design Requirements

A detailed design procedure is described based on a design example. For this design example, use the parameters listed in 表 10-1 as the input parameters.

表 10-1. Design Example Parameters

DESIGN PARAMETER	VALUE
Input voltage range V_{IN}	0 V - 5 V
Output resolution	12-bit
REF input capacitor	1 μ F
REF output capacitor	10 μ F

10.3.2 Detailed Design Procedure

10.3.2.1 Selection of Reference

The REF35500-Q1 reference is selected for this design. The REF35500-Q1 device operates of very low quiescent current while offering ± 0.05 % initial accuracy and very low noise. These parameters help improve system accuracy as compared to external LDO based power supply. The 5 V reference voltage supports the 0 V to 5 V input range specification.

10.3.2.2 Input and Output Capacitors

A 1 μ F to 10 μ F electrolytic or ceramic capacitor can be connected to the input to improve transient response in applications where the supply voltage may fluctuate.

A ceramic capacitor of at least a 0.1 μF must be connected to the output to improve stability and help filter out high frequency noise. Add an additional 10 μF capacitor in parallel to improve transient performance in response to sudden changes in load current; however, keep in mind that doing so increases the start-up time of the device.

Best performance and stability is attained with low-ESR, low-inductance ceramic chip-type output capacitors (X5R, X7R, or similar). If using an electrolytic capacitor on the output, place a 0.1 μF ceramic capacitor in parallel to reduce overall ESR on the output. Place the input and output capacitors as close as possible to the device.

10.3.2.3 Selection of ADC

[ADS7038-Q1](#) 12-bit 8 channel multiplexed ADC is chosen for this application. The ADC offers low current operation with averaging mode to increase the resolution to 16-bit with internal averaging modes while operating with slow sampling speed.

10.3.3 Application Curves

表 10-2 shows the captured measurement results for various DC inputs. The ADC output is captured and analyzed for output accuracy, code spread and sigma with REF35500-Q1 as power supply vs LDO as power supply.

REF35-Q1 offers better accuracy and lower noise than the LDO device at lower quiescent current. This results in lower error in measurement as well as lower ADC output code variation across various OSR settings.

表 10-2. DC Input Performance Test Results

INPUT V	ADC OSR SETTING	REF35500		LDO	
		ERROR	CODE SPREAD	ERROR	CODE SPREAD
1.0 V	0	0.01 mV	32 LSB	8.9 mV	48 LSB
	8	0.3 mV	10 LSB	9.21 mV	16 LSB
	128	0.38 mV	6 LSB	9.26 mV	6 LSB
2.5 V	0	0.69 mV	32 LSB	22.89 mV	64 LSB
	8	1.44 mV	10 LSB	23.63 mV	18 LSB
	128	1.17 mV	3 LSB	23.41 mV	5 LSB
4 V	0	2.27 mV	32 LSB	37.84 mV	48 LSB
	8	3.01 mV	24 LSB	38.62 mV	24 LSB
	128	2.46 mV	3 LSB	38.09 mV	17 LSB

10.4 Power Supply Recommendations


The REF35 family of references feature an extremely low-dropout voltage. These references can be operated with a supply of only 50 mV above the output voltage at no load. TI recommends a supply bypass capacitor ranging between 0.1 μF to 10 μF .

10.5 Layout

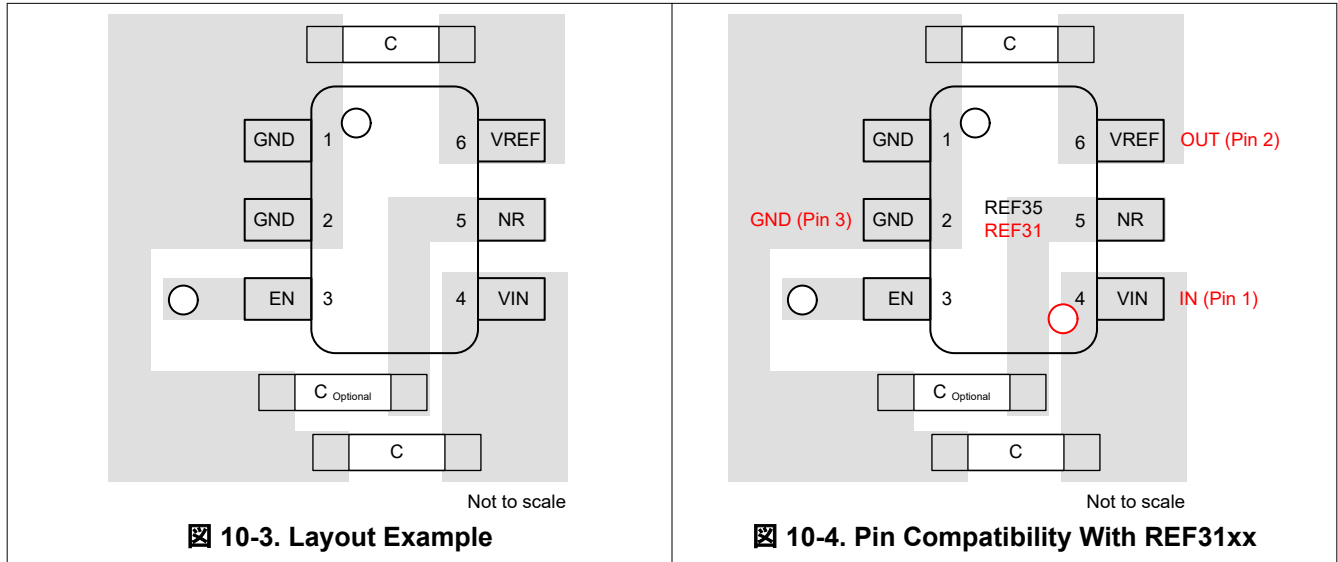
10.5.1 Layout Guidelines

☒ 10-3 shows an example of a PCB layout for a data acquisition system using the REF35-Q1. Some key considerations are:

- Connect low-ESR, 0.1 μF ceramic bypass capacitors at V_{IN} , V_{REF} of the REF35-Q1.
- Decouple other active devices in the system per the device specifications.
- Using a solid ground plane helps distribute heat and reduces electromagnetic interference (EMI) noise pickup.
- Place the external components as close to the device as possible.
- Do not run sensitive analog traces in parallel with digital traces. Avoid crossing digital and analog traces if possible, and only make perpendicular crossings when absolutely necessary.

 **10-4** shows the pin compatibility with TI REF31xx series reference in the 3-pin SOT-23 package when using the REF35xxx family footprint. You must rotate the REF31xx reference device by 180° before assembly.

10.5.2 Layout Examples



11 Device and Documentation Support

11.1 Documentation Support

11.1.1 Related Documentation

For related documentation see the following:

- [INA21x Voltage Output, Low- or High-Side Measurement, Bidirectional, Zero-Drift Series, Current-Shunt Monitors](#)
- [Low-Drift Bidirectional Single-Supply Low-Side Current Sensing Reference Design](#)

11.2 ドキュメントの更新通知を受け取る方法

ドキュメントの更新についての通知を受け取るには、ti.com のデバイス製品フォルダを開いてください。「更新の通知を受け取る」をクリックして登録すると、変更されたすべての製品情報に関するダイジェストを毎週受け取れます。変更の詳細については、修正されたドキュメントに含まれている改訂履歴をご覧ください。

11.3 サポート・リソース

[TI E2E™ サポート・フォーラム](#)は、エンジニアが検証済みの回答と設計に関するヒントをエキスパートから迅速かつ直接得ることができる場所です。既存の回答を検索したり、独自の質問をしたりすることで、設計に必要な支援を迅速に得ることができます。

リンクされているコンテンツは、該当する貢献者により、現状のまま提供されるものです。これらは TI の仕様を構成するものではなく、必ずしも TI の見解を反映したものではありません。TI の[使用条件](#)を参照してください。

11.4 Trademarks

TI E2E™ is a trademark of Texas Instruments.

すべての商標は、それぞれの所有者に帰属します。

11.5 静電気放電に関する注意事項



この IC は、ESD によって破損する可能性があります。テキサス・インスツルメンツは、IC を取り扱う際には常に適切な注意を払うことを推奨します。正しい取り扱いおよび設置手順に従わない場合、デバイスを破損するおそれがあります。

ESD による破損は、わずかな性能低下からデバイスの完全な故障まで多岐にわたります。精密な IC の場合、パラメータがわずかに変化するだけで公表されている仕様から外れる可能性があるため、破損が発生しやすくなっています。

11.6 用語集

[テキサス・インスツルメンツ用語集](#) 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)
REF35125QDBVRQ1	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	34BI
REF35125QDBVRQ1.A	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	34BI
REF35160QDBVRQ1	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	3SQI
REF35180QDBVRQ1	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	34AI
REF35180QDBVRQ1.A	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	34AI
REF35250QDBVRQ1	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	34CI
REF35250QDBVRQ1.A	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	34CI
REF35300QDBVRQ1	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	34DI
REF35300QDBVRQ1.A	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	34DI
REF35330QDBVRQ1	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	34EI
REF35500QDBVRQ1	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	34FI
REF35500QDBVRQ1.A	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	34FI

(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.

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 REF35-Q1 :

- Catalog : [REF35](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

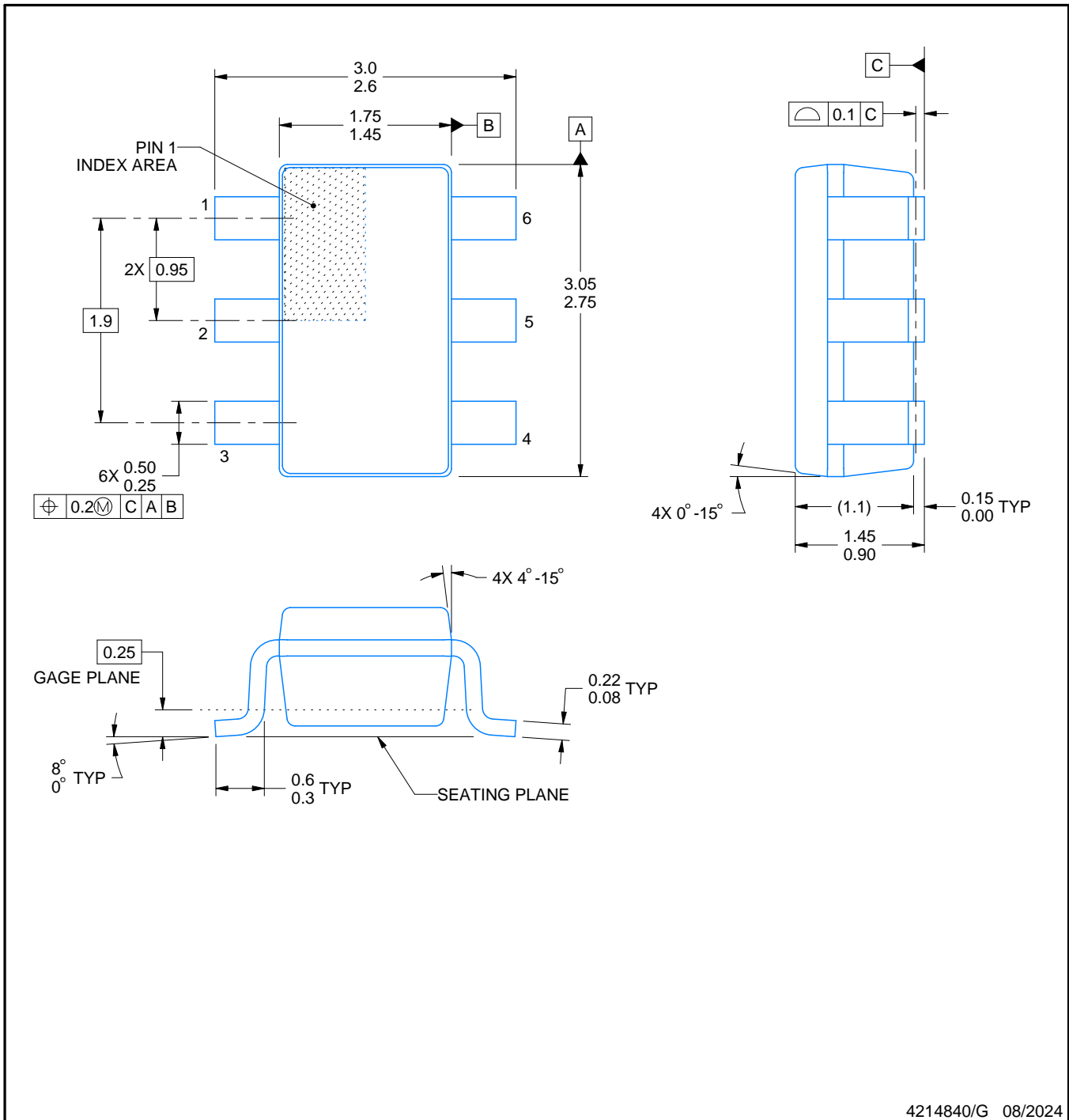


DBV0006A

PACKAGE OUTLINE

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



NOTES:

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

EXAMPLE BOARD LAYOUT

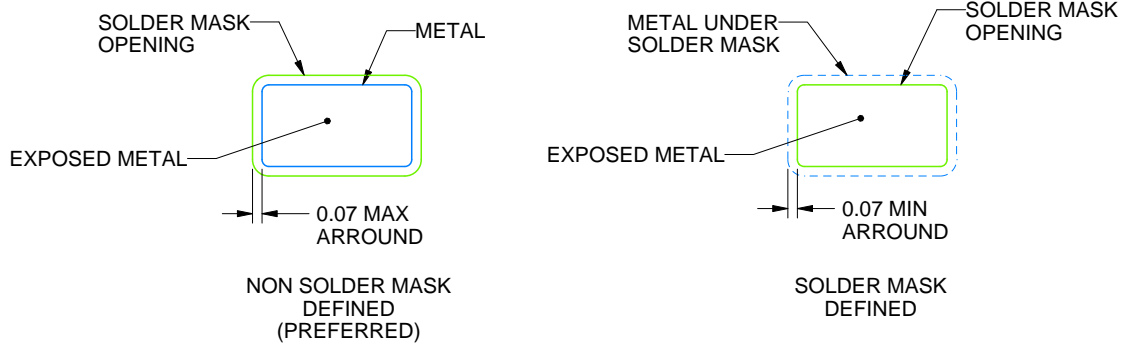
DBV0006A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X



SOLDER MASK DETAILS

4214840/G 08/2024

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

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

EXAMPLE STENCIL DESIGN

DBV0006A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



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

4214840/G 08/2024

NOTES: (continued)

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

重要なお知らせと免責事項

TI は、技術データと信頼性データ(データシートを含みます)、設計リソース(リファレンス デザインを含みます)、アプリケーションや設計に関する各種アドバイス、Web ツール、安全性情報、その他のリソースを、欠陥が存在する可能性のある「現状のまま」提供しており、商品性および特定目的に対する適合性の黙示保証、第三者の知的財産権の非侵害保証を含むいかなる保証も、明示的または黙示的にかかわらず拒否します。

これらのリソースは、TI 製品を使用する設計の経験を積んだ開発者への提供を意図したものです。(1) お客様のアプリケーションに適した TI 製品の選定、(2) お客様のアプリケーションの設計、検証、試験、(3) お客様のアプリケーションに該当する各種規格や、その他のあらゆる安全性、セキュリティ、規制、または他の要件への確実な適合に関する責任を、お客様のみが単独で負うものとし、

上記の各種リソースは、予告なく変更される可能性があります。これらのリソースは、リソースで説明されている TI 製品を使用するアプリケーションの開発の目的でのみ、TI はその使用をお客様に許諾します。これらのリソースに関して、他の目的で複製することや掲載することは禁止されています。TI や第三者の知的財産権のライセンスが付与されている訳ではありません。お客様は、これらのリソースを自身で使用した結果発生するあらゆる申し立て、損害、費用、損失、責任について、TI およびその代理人を完全に補償するものとし、TI は一切の責任を拒否します。

TI の製品は、[TI の販売条件](#)、[TI の総合的な品質ガイドライン](#)、[ti.com](#) または TI 製品などに関連して提供される他の適用条件に従い提供されます。TI がこれらのリソースを提供することは、適用される TI の保証または他の保証の放棄の拡大や変更を意味するものではありません。TI がカスタム、またはカスタマー仕様として明示的に指定していない限り、TI の製品は標準的なカタログに掲載される汎用機器です。

お客様がいかなる追加条項または代替条項を提案する場合も、TI はそれらに異議を唱え、拒否します。

Copyright © 2025, Texas Instruments Incorporated

最終更新日：2025 年 10 月