

## INA333-Q1 汽车类零温漂微功率仪表放大器

### 1 特性

- 符合面向汽车应用的 AEC-Q100 标准：
  - 温度等级 1：-40°C ≤ T<sub>A</sub> ≤ +125°C
- 功能安全型
  - 可提供用于功能安全系统设计的文档
- 低失调电压：25 μV (最大值)，G ≥ 100
- 低温漂：0.1 μV/°C，G ≥ 100
- 低噪声：50nV/√Hz，G ≥ 100
- 高 CMRR：96dB (最小值)，G ≥ 10
- 低输入偏置电流：280pA (最大值)
- 电源电压范围：1.8V 至 5.5V
- 输入电压：(V-) + 0.1V 至 (V+) - 0.1V
- 输出范围：(V-) + 0.05V 至 (V+) - 0.05V
- 低静态电流：50 μA
- 工作温度：-40°C 至 +125°C
- RFI 滤波输入
- 封装：8 引脚 VSSOP

### 2 应用

- 动力总成扭矩传感器
- 动力总成压力传感器
- 动力总成温度传感器
- 动力总成爆震传感器
- 车辆乘员检测传感器
- 驾驶员生命体征监测
- 控制面板，基于力传感器的开关

### 3 说明

INA333-Q1 是一款具备出色精度的低功耗精密仪表放大器。该器件具有三级运算放大器设计、小尺寸和低功耗，是需要漏电流检测等精密测量的汽车应用的理想选择。此 INA333-Q1 也是使用电阻式电桥传感器的应用的理想选择。

可通过单个外部电阻器在 1 到 1000 范围内设置增益。INA333-Q1 的设计适用业界通用的增益公式： $G = 1 + (100\text{k}\Omega/R_G)$ 。

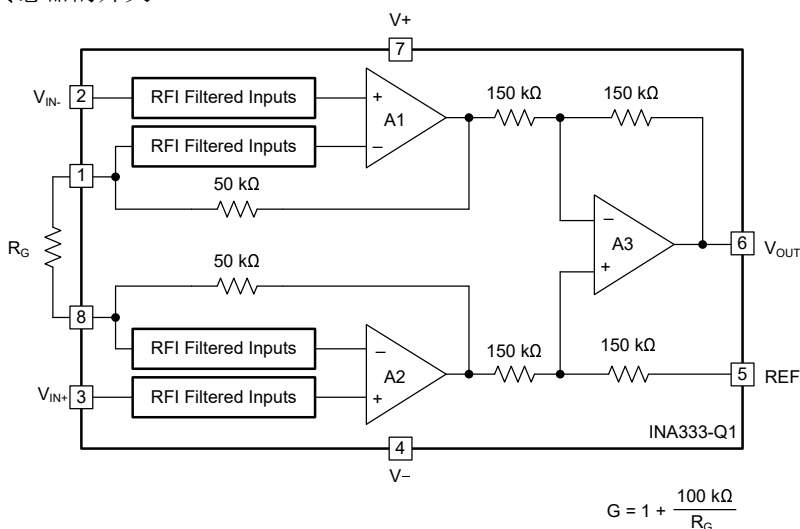
INA333-Q1 提供极低的失调电压 (25 μV，G ≥ 100)、出色的温漂 (0.1 μV/°C，G ≥ 100) 和高共模抑制 (G ≥ 10 时为 96dB)。该器件采用低至 1.8V (±0.9V) 的电源电压，静态电流仅为 50 μA。自动校准技术可在汽车温度范围内保持出色的精度。INA333-Q1 提供 1 μV 的极低峰峰值噪声。

INA333-Q1 器件采用 8 引脚 VSSOP 封装，额定温度范围为 T<sub>A</sub> = -40°C 至 +125°C。

#### 封装信息

器件型号	封装 <sup>(1)</sup>	封装尺寸 <sup>(2)</sup>
INA333-Q1	VSSOP (8)	3 mm × 4.9 mm

- 如需了解所有可用封装，请参阅数据表末尾的封装选项附录。
- 封装尺寸 (长 × 宽) 为标称值，并包括引脚 (如适用)。



简化原理图



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## 4 Revision History

注：以前版本的页码可能与当前版本的页码不同

<b>Changes from Revision A (May 2020) to Revision B (June 2023)</b>	<b>Page</b>
• 添加了“功能安全”特性要点.....	1
• 将首页图中的四个电阻器从 150 Ω 更改为 150k Ω.....	1
• Changed four resistors in functional block diagram from 150 Ω to 150 k Ω.....	13

<b>Changes from Revision * (October 2019) to Revision A (May 2020)</b>	<b>Page</b>
• 将器件状态从“预告信息 ( 预发布 )”更改为“量产数据 ( 正在供货 )”.....	1

## 5 Pin Configuration and Functions

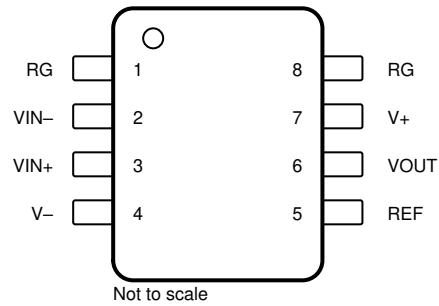


图 5-1. DGK Package, 8-Pin VSSOP (Top View)

表 5-1. Pin Functions

PIN		TYPE	DESCRIPTION
NAME	NO.		
REF	5	Input	Reference input. This pin must be driven by low impedance or connected to ground.
RG	1, 8	—	Gain setting pins. For gains greater than 1, place a gain resistor between pins 1 and 8.
V+	7	—	Positive supply
V-	4	—	Negative supply
VIN+	3	Input	Positive input
VIN-	2	Input	Negative input
VOUT	6	Output	Output

## 6 Specifications

### 6.1 Absolute Maximum Ratings

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

			MIN	MAX	UNIT
V <sub>S</sub>	Supply voltage	Single-supply, V <sub>S</sub> = (V <sub>+</sub> )		7	V
		Dual-supply, V <sub>S</sub> = (V <sub>+</sub> ) - (V <sub>-</sub> )		±3.5	
	Input voltage	Common-mode	(V <sub>-</sub> ) - 0.3	(V <sub>+</sub> ) + 0.3	V
		Differential	(V <sub>+</sub> ) - (V <sub>-</sub> ) + 0.2		
	Input current		±10		mA
	Output short circuit <sup>(2)</sup>		Continuous	Continuous	
T <sub>A</sub>	Operating temperature		- 55	150	°C
T <sub>J</sub>	Junction temperature			150	°C
T <sub>stg</sub>	Storage temperature		- 65	150	°C

- (1) Operation outside of *Absolute Maximum Ratings* may cause permanent damage to the device. *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) Short-circuit to ground, one amplifier per package.

### 6.2 ESD Ratings

			VALUE	UNIT
V <sub>(ESD)</sub>	Electrostatic discharge	Human-body model (HBM), per AEC Q100-002 HBM ESD classification level 2 <sup>(1)</sup>	±2000	V
		Charge device model (CDM), per AEC Q100-011 CDM ESD classification level C5	±750	

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

### 6.3 Recommended Operating Conditions

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

			MIN	MAX	UNIT
V <sub>S</sub>	Supply voltage		1.8	5.5	V
T <sub>A</sub>	Operating temperature		- 40	125	°C

### 6.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		INA333-Q1		UNIT
		DGK (VSSOP)		
		8 PINS		
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	169.5		°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	62.7		°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	90.3		°C/W
ψ <sub>JT</sub>	Junction-to-top characterization parameter	7.6		°C/W
ψ <sub>JB</sub>	Junction-to-board characterization parameter	88.7		°C/W
R <sub>θJC(bot)</sub>	Junction-to-case (bottom) thermal resistance	N/A		°C/W

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

## 6.5 Electrical Characteristics

at  $V_S = 1.8\text{ V}$  to  $5.5\text{ V}$  at  $T_A = 25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$ ,  $V_{REF} = V_S / 2$ , and  $G = 1$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
<b>INPUT<sup>(1)</sup></b>							
$V_{OSI}$	Input stage offset voltage <sup>(2)</sup>				$\pm 10$	$\pm 25$	$\mu\text{V}$
		vs temperature, $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$				$\pm 0.1$	$\mu\text{V}/^\circ\text{C}$
$V_{OSO}$	Output stage offset voltage <sup>(2)</sup>				$\pm 25$	$\pm 110$	$\mu\text{V}$
		vs temperature, $T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$				$\pm 0.5$	$\mu\text{V}/^\circ\text{C}$
PSRR	Power-supply rejection ratio			90	102		dB
$Z_{id}$	Differential impedance			100    3			$\text{G}\Omega$    $\text{pF}$
$Z_{ic}$	Common-mode impedance			100    3			$\text{G}\Omega$    $\text{pF}$
$V_{CM}$	Common-mode voltage	$V_O = 0\text{ V}$		$(V^-) + 0.1$		$(V^+) - 0.1$	V
CMRR	Common-mode rejection ratio	DC to 60 Hz, $V_S = 5.5\text{ V}$ , $V_{CM} = (V^-) + 0.1\text{ V}$ to $(V^+) - 0.1\text{ V}$	$G = 1$	78	90		dB
			$G = 10$	96	110		
			$G = 100$	96	115		
			$G = 1000$	96	115		
<b>INPUT BIAS CURRENT</b>							
$I_B$	Input bias current				$\pm 70$	$\pm 280$	$\text{pA}$
		$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			See <a href="#">Fig 6-26</a>		$\text{pA}/^\circ\text{C}$
$I_{OS}$	Input offset current				$\pm 50$	$\pm 280$	$\text{pA}$
		$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$			See <a href="#">Fig 6-28</a>		$\text{pA}/^\circ\text{C}$
<b>INPUT VOLTAGE NOISE</b>							
$e_{NI}$	Input voltage noise	$G = 100$ , $R_S = 0\ \Omega$	$f = 10\text{ Hz}$	50			$\text{nV}/\sqrt{\text{Hz}}$
			$f = 100\text{ Hz}$	50			
			$f = 1\text{ kHz}$	50			
			$f = 0.1\text{ Hz}$ to $10\text{ Hz}$	1		$\mu\text{V}_{PP}$	
$I_n$	Input current noise	$f = 10\text{ Hz}$		100		$\text{fA}/\sqrt{\text{Hz}}$	
		$f = 0.1\text{ Hz}$ to $10\text{ Hz}$		2		$\text{pA}_{PP}$	
<b>GAIN</b>							
	Gain equation			$1 + (100\text{ k}\Omega / R_G)$			V/V
G	Gain			1		1000	V/V
GE	Gain error	$V_S = 5.5\text{ V}$ , $(V^-) + 100\text{ mV} \leq V_O \leq (V^+) - 100\text{ mV}$	$G = 1$	$\pm 0.01$	$\pm 0.1$		%
			$G = 10$	$\pm 0.05$	$\pm 0.25$		
			$G = 100$	$\pm 0.07$	$\pm 0.25$		
			$G = 1000$	$\pm 0.25$	$\pm 0.5$		
	Gain vs temperature	$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$		$\pm 1$	$\pm 5$		$\text{ppm}/^\circ\text{C}$
			$G > 1$ <sup>(3)</sup>	$\pm 15$	$\pm 50$		
	Gain nonlinearity	$G = 1$ to $1000$ $V_S = 5.5\text{ V}$ , $(V^-) + 100\text{ mV} \leq V_O \leq (V^+) - 100\text{ mV}$		10			ppm
<b>OUTPUT</b>							
	Output voltage swing from rail	$V_S = 5.5\text{ V}$		40	50		mV
	Capacitive load drive			500			pF
$I_{SC}$	Short-circuit current	Continuous to common		-40	+5		mA

### 6.5 Electrical Characteristics (continued)

at  $V_S = 1.8\text{ V to }5.5\text{ V}$  at  $T_A = 25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$ ,  $V_{REF} = V_S / 2$ , and  $G = 1$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
<b>FREQUENCY RESPONSE</b>							
BW	Bandwidth, - 3 dB	G = 1			150		kHz
		G = 10			35		
		G = 100			3.5		
		G = 1000			350		Hz
SR	Slew rate	$V_S = 5\text{ V}$ , $V_O = 4\text{-V step}$		G = 1	0.16		V/ $\mu\text{s}$
				G = 100	0.05		
$t_s$	Settling time to 0.01%	$V_{STEP} = 4\text{ V}$		G = 1	50		$\mu\text{s}$
				G = 100	400		
	Settling time to 0.001%	$V_{STEP} = 4\text{ V}$		G = 1	60		
				G = 100	500		
	Overload recovery	50% overdrive			75		$\mu\text{s}$
<b>REFERENCE INPUT</b>							
$R_{IN}$	Input impedance				300		k $\Omega$
	Voltage range			V -		V+	V
<b>POWER SUPPLY</b>							
$I_Q$	Quiescent current	$V_{IN} = V_S / 2$			50	75	$\mu\text{A}$
		$T_A = -40^\circ\text{C to }+125^\circ\text{C}$				80	

- (1) Total  $V_{OS}$ , referred-to-input =  $(V_{OSI}) + (V_{OSO} / G)$ .
- (2) RTI = Referred-to-input.
- (3) Does not include effects of external resistor  $R_G$ .

## 6.6 Typical Characteristics

at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $R_L = 10\text{ k}\Omega$ ,  $V_{REF} = \text{mid supply}$ , and  $G = 1$  (unless otherwise noted)

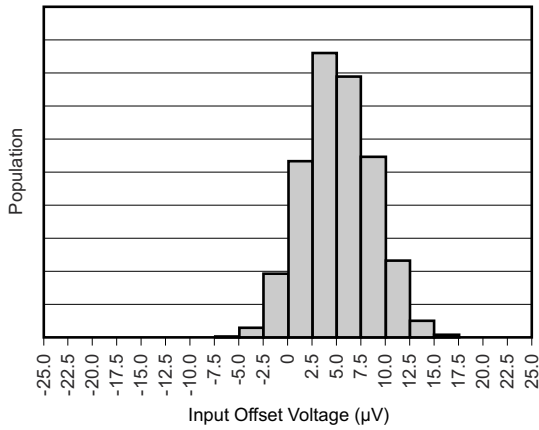


图 6-1. Input Offset Voltage

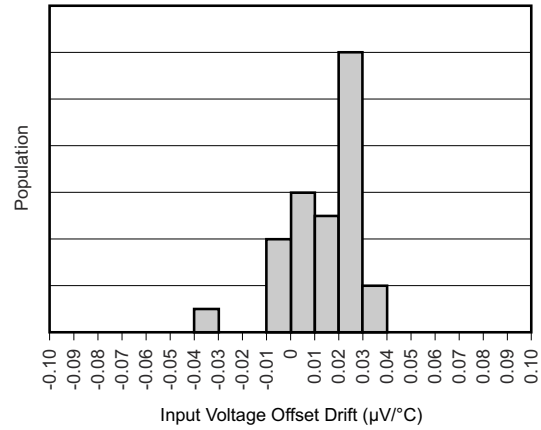


图 6-2. Input Voltage Offset Drift ( - 40°C to 125°C)

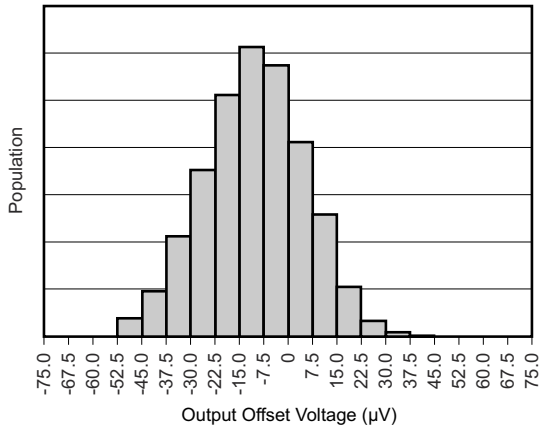


图 6-3. Output Offset Voltage

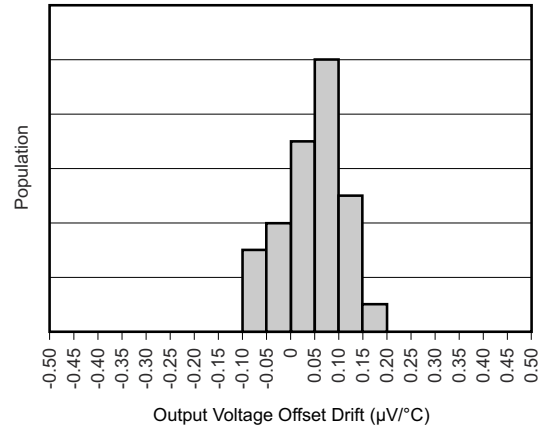


图 6-4. Output Voltage Offset Drift ( - 40°C to 125°C)

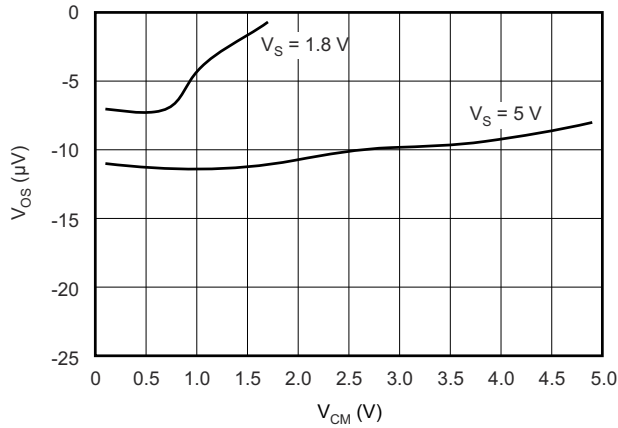


图 6-5. Offset Voltage vs Common-Mode Voltage

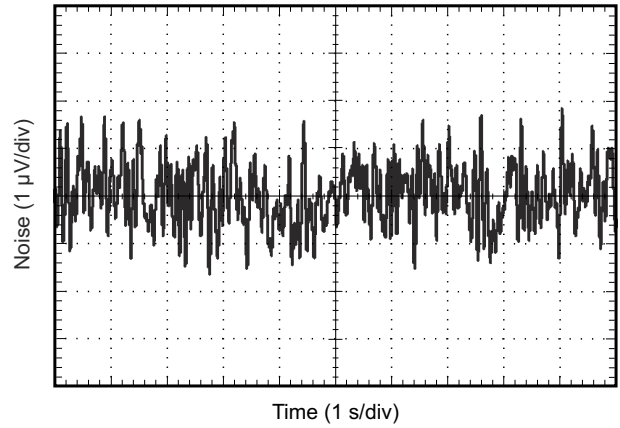
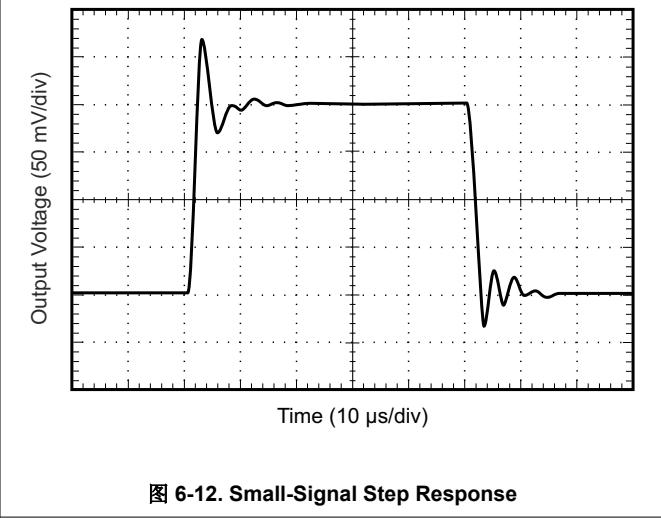
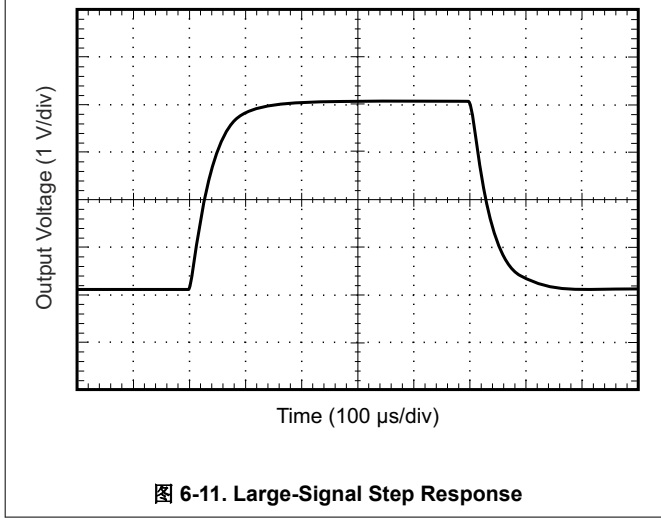
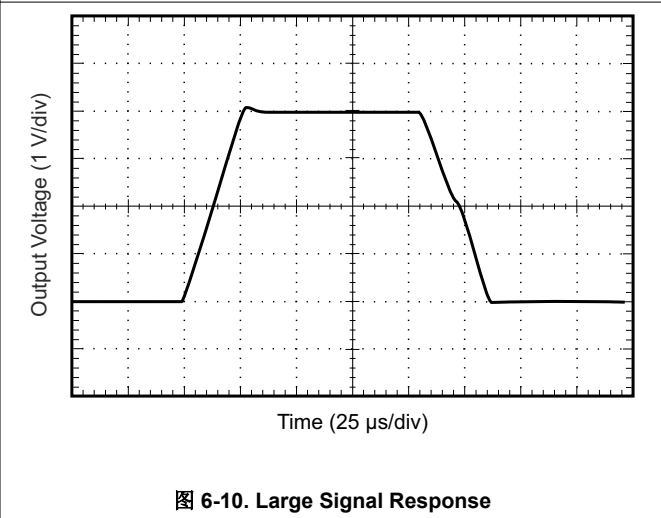
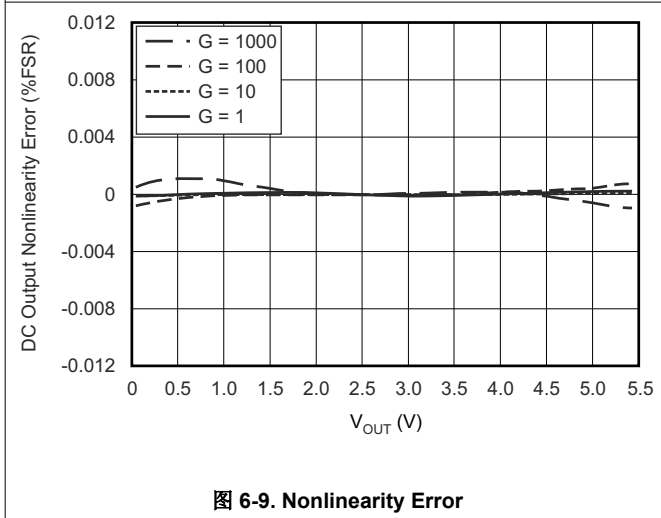
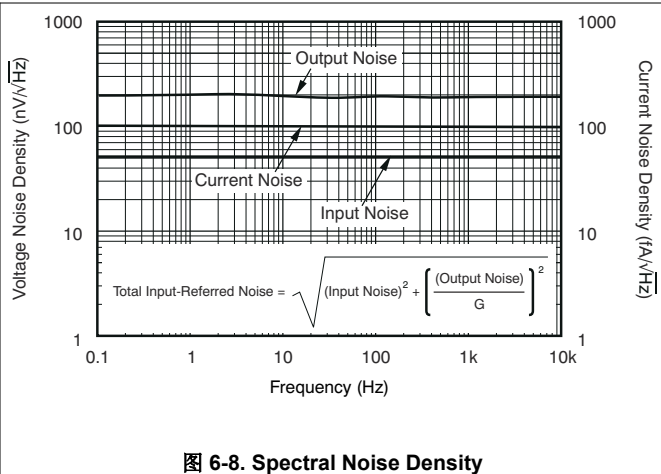
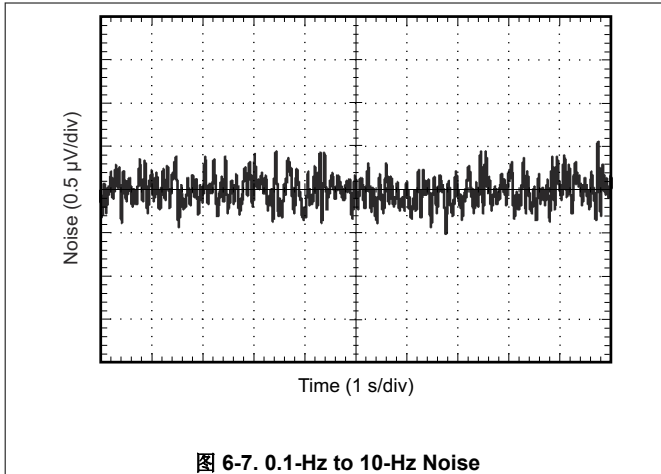


图 6-6. 0.1-Hz to 10-Hz Noise

## 6.6 Typical Characteristics (continued)

at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $R_L = 10\text{ k}\Omega$ ,  $V_{REF} = \text{midsupply}$ , and  $G = 1$  (unless otherwise noted)





## 6.6 Typical Characteristics (continued)

at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $R_L = 10\text{ k}\Omega$ ,  $V_{REF} = \text{midsupply}$ , and  $G = 1$  (unless otherwise noted)

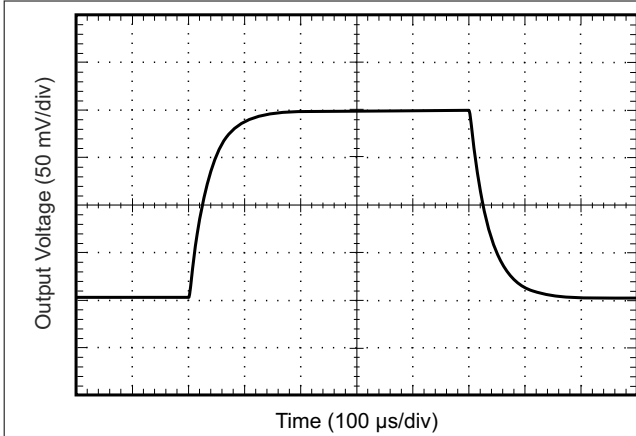


图 6-13. Small-Signal Step Response

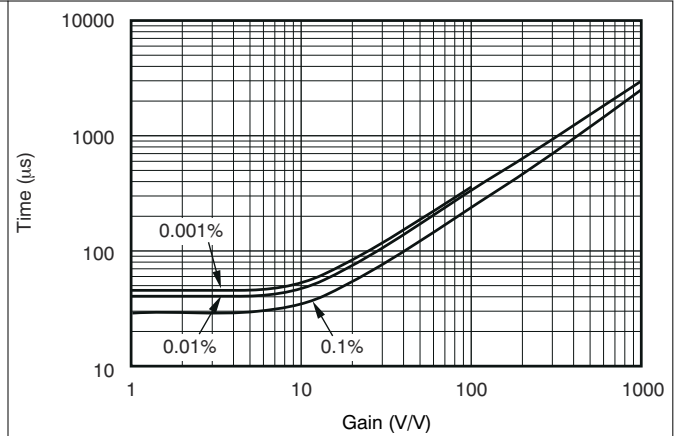


图 6-14. Settling Time vs Gain

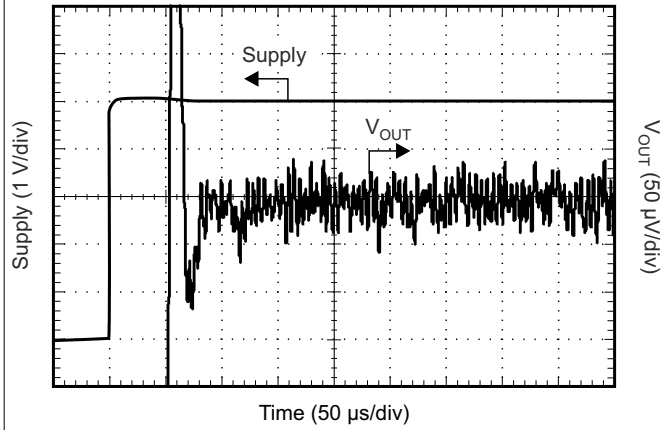


图 6-15. Start-Up Settling Time

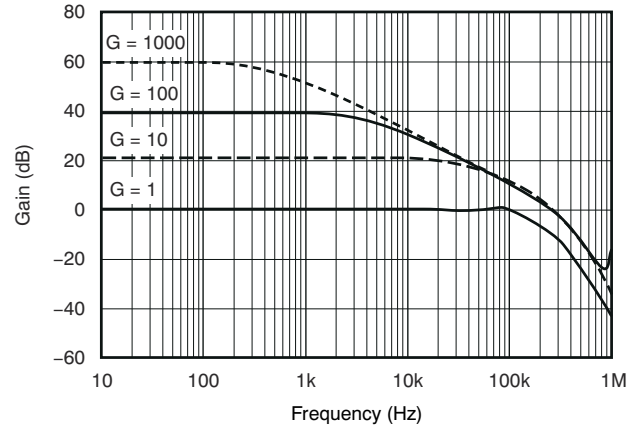


图 6-16. Gain vs Frequency

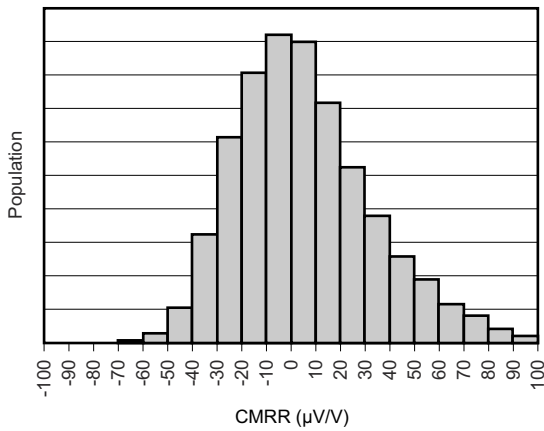


图 6-17. Common-Mode Rejection Ratio

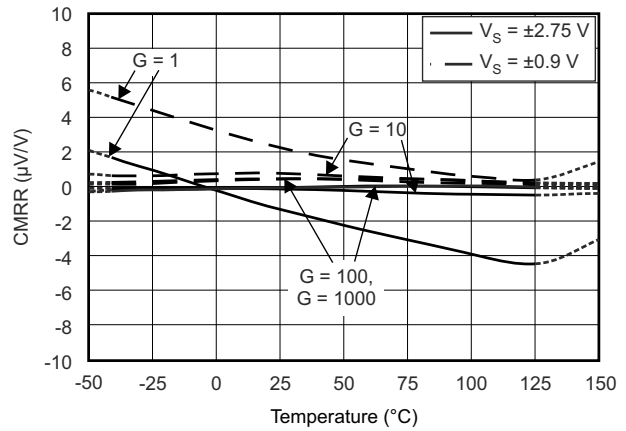


图 6-18. Common-Mode Rejection Ratio vs Temperature

## 6.6 Typical Characteristics (continued)

at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $R_L = 10\text{ k}\Omega$ ,  $V_{REF} = \text{midsupply}$ , and  $G = 1$  (unless otherwise noted)

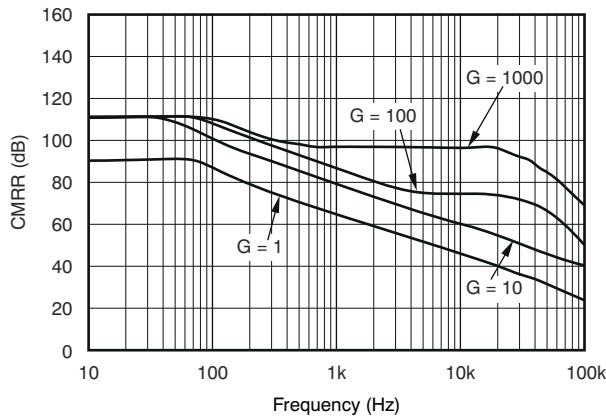


图 6-19. Common-Mode Rejection Ratio vs Frequency

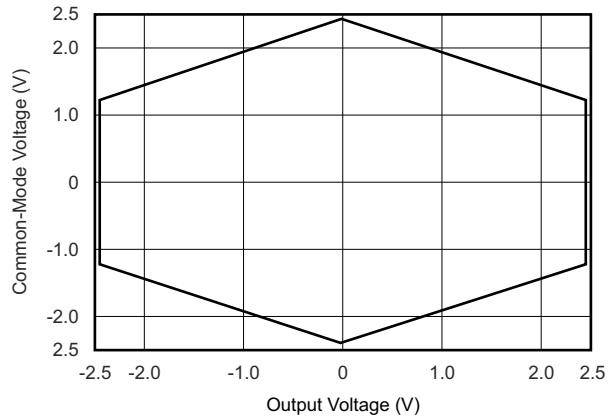


图 6-20. Typical Common-Mode Range vs Output Voltage

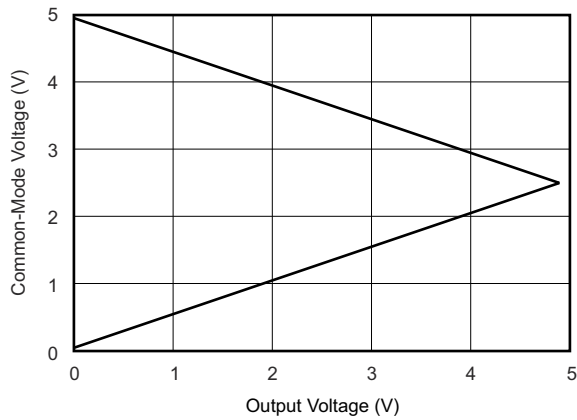


图 6-21. Typical Common-Mode Range vs Output Voltage

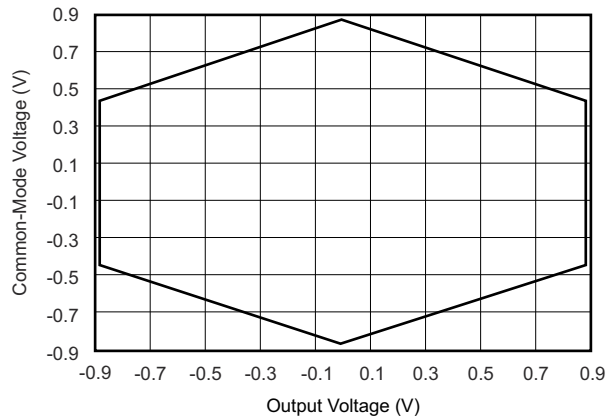


图 6-22. Typical Common-Mode Range vs Output Voltage

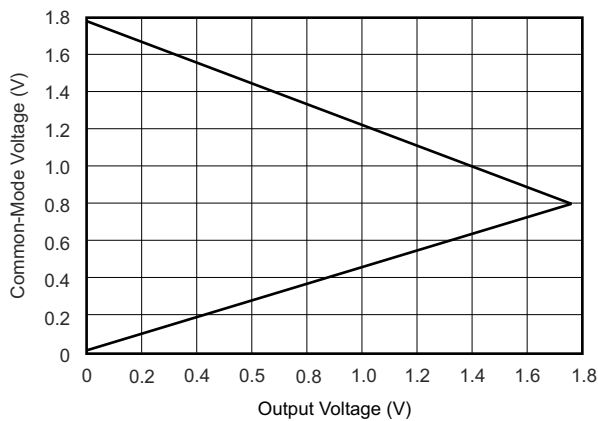


图 6-23. Typical Common-Mode Range vs Output Voltage

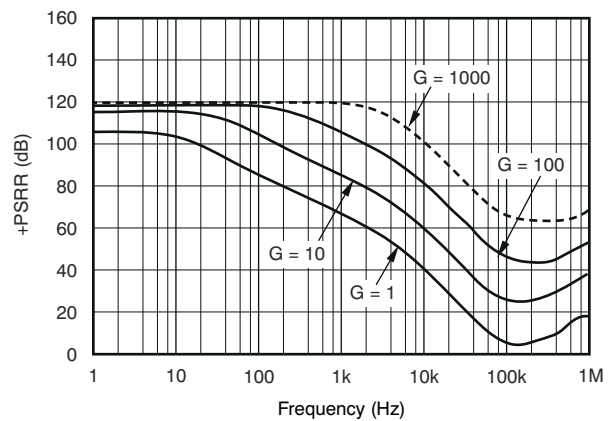


图 6-24. Positive Power-Supply Rejection Ratio

### 6.6 Typical Characteristics (continued)

at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $R_L = 10\text{ k}\Omega$ ,  $V_{REF} = \text{midsupply}$ , and  $G = 1$  (unless otherwise noted)

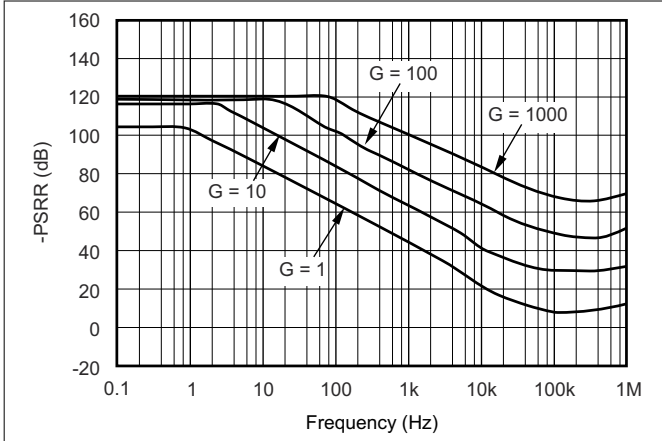


图 6-25. Negative Power-Supply Rejection Ratio

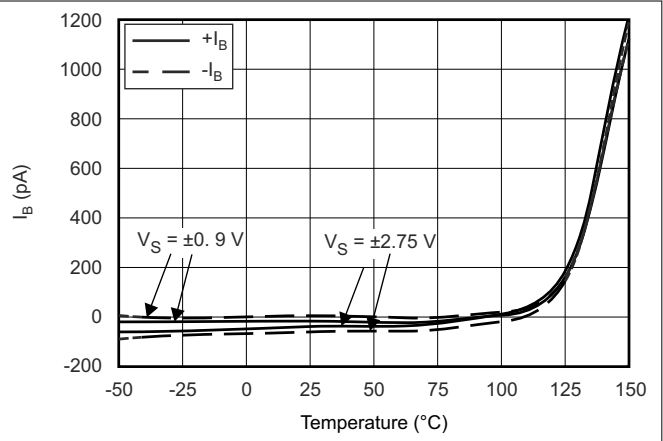


图 6-26. Input Bias Current vs Temperature

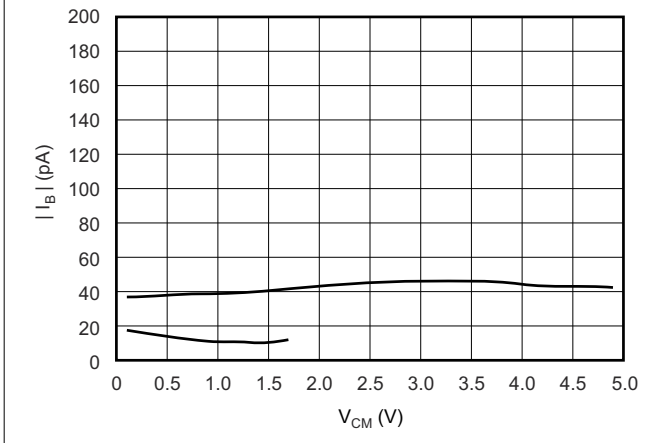


图 6-27. Input Bias Current vs Common-Mode Voltage

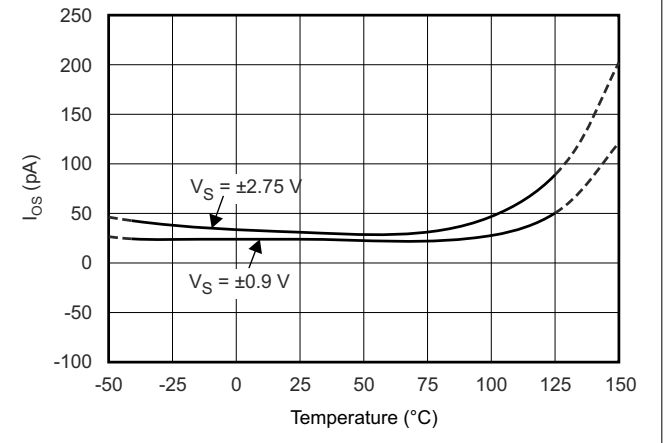


图 6-28. Input Offset Current vs Temperature

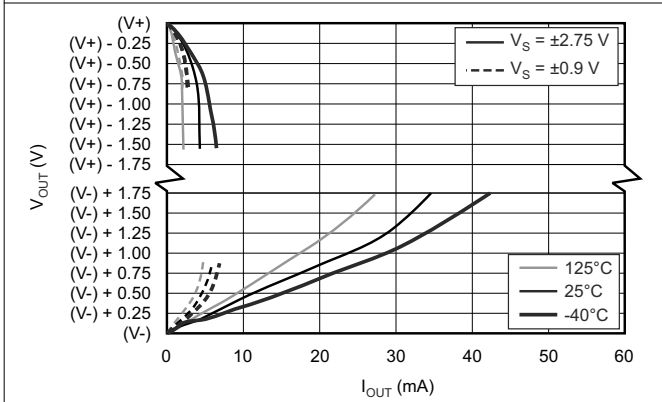


图 6-29. Output Voltage Swing vs Output Current

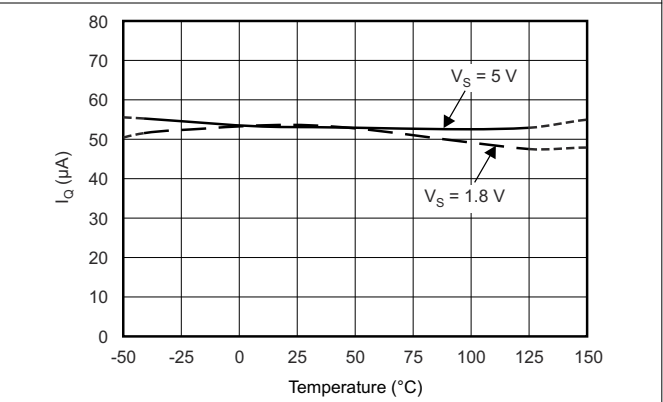


图 6-30. Quiescent Current vs Temperature

### 6.6 Typical Characteristics (continued)

at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $R_L = 10\text{ k}\Omega$ ,  $V_{REF} = \text{midsupply}$ , and  $G = 1$  (unless otherwise noted)

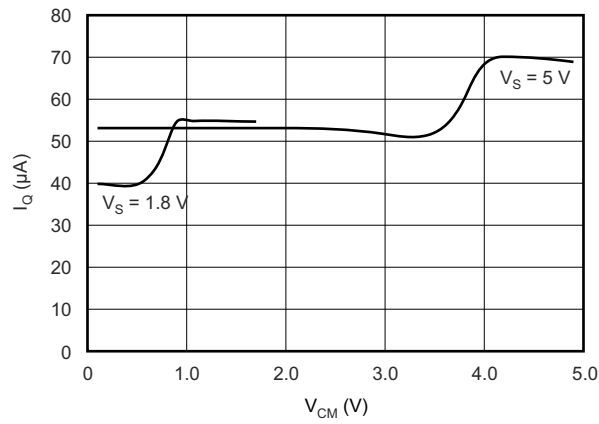


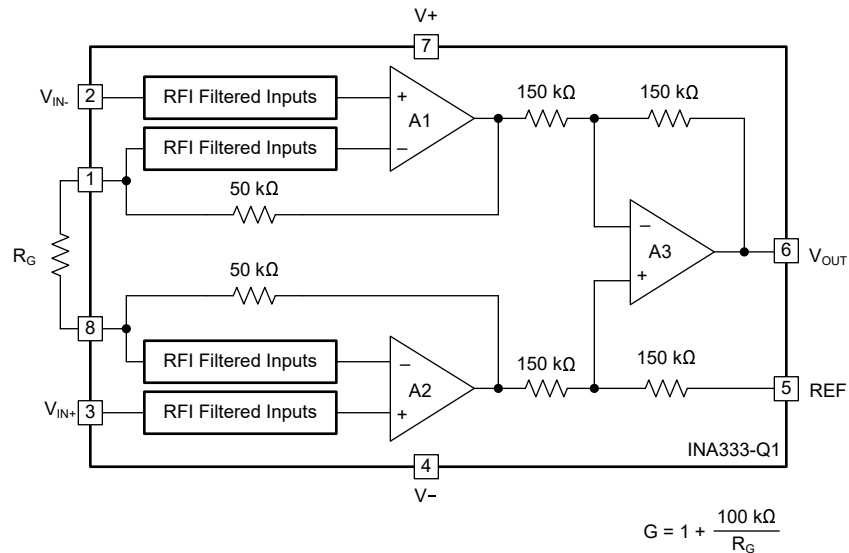
图 6-31. Quiescent Current vs Common-Mode Voltage

## 7 Detailed Description

### 7.1 Overview

The INA333-Q1 is a monolithic instrumentation amplifier (INA) based on the precision zero-drift INA333-Q1 (operational amplifier) core. The INA333-Q1 also integrates laser-trimmed resistors to maintain excellent common-mode rejection and low gain error. The combination of the zero-drift amplifier core and the precision resistors allows this device to achieve outstanding dc precision, and makes the INA333-Q1 an excellent choice for many 3.3-V and 5-V automotive applications.

### 7.2 Functional Block Diagram



### 7.3 Feature Description

#### 7.3.1 Internal Offset Correction

The INA333-Q1 internal operational amplifiers use an autocalibration technique with a time-continuous, 350-kHz operational amplifier in the signal path. The amplifier is zero-corrected every 8  $\mu\text{s}$  using a proprietary technique. At power up, the amplifier requires approximately 100  $\mu\text{s}$  to achieve the specified  $V_{OS}$  accuracy. This design has no aliasing or flicker noise.

#### 7.3.2 Input Protection

The input pins of the INA333-Q1 are protected with internal diodes connected to the power-supply rails. These diodes clamp and prevent the applied signal from damaging the input circuitry. If the input signal voltage exceeds the power supplies by greater than 0.3 V, limit the input signal current to less than 10 mA to protect the internal clamp diodes. This current limiting is generally done with a series input resistor. Some signal sources are inherently current-limited and do not require limiting resistors.

### 7.4 Device Functional Modes

The INA333-Q1 has a single functional mode, and is operational when the power-supply voltage is greater than 1.8 V. The recommended maximum specified power-supply voltage for the INA333-Q1 is 5.5 V.

## 8 Application and Implementation

---

### 备注

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.

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### 8.1 Application Information

The INA333-Q1 measures small differential voltages with high common-mode voltage developed between the noninverting and inverting input. The high input impedance makes the INA333-Q1 a great choice for a wide range of applications. The ability to set the reference pin to adjust the functionality of the output signal offers additional flexibility that is practical for multiple configurations.

#### 8.1.1 Input Common-Mode Range

The linear input voltage range of the input circuitry of the INA333-Q1 is from approximately 0.1 V below the positive supply voltage to 0.1 V above the negative supply. As a differential input voltage causes the output voltage to increase, however, the linear input range is limited by the output voltage swing of amplifiers A1 and A2. Thus, the linear common-mode input range is related to the output voltage of the complete amplifier. This behavior also depends on supply voltage; see [图 6-20](#) to [图 6-23](#) in [节 6.6](#).

Input overload conditions can produce an output voltage that appears normal. For example, if an input overload condition drives both input amplifiers to the respective positive output swing limit, the difference voltage measured by the output amplifier is near zero. The output of the INA333-Q1 is near 0 V even though both inputs are overloaded.

## 8.2 Typical Application

图 8-1 shows the basic connections required for operation of the INA333-Q1. Good layout practice mandates the use of bypass capacitors placed close to the device pins as shown.

The output of the INA333-Q1 is referred to the output reference (REF) pin, which is normally grounded. This connection must be low-impedance to maintain good common-mode rejection. Although 15 Ω or less of stray resistance can be tolerated while maintaining specified CMRR, small stray resistances of tens of ohms in series with the REF pin can cause noticeable degradation in CMRR.

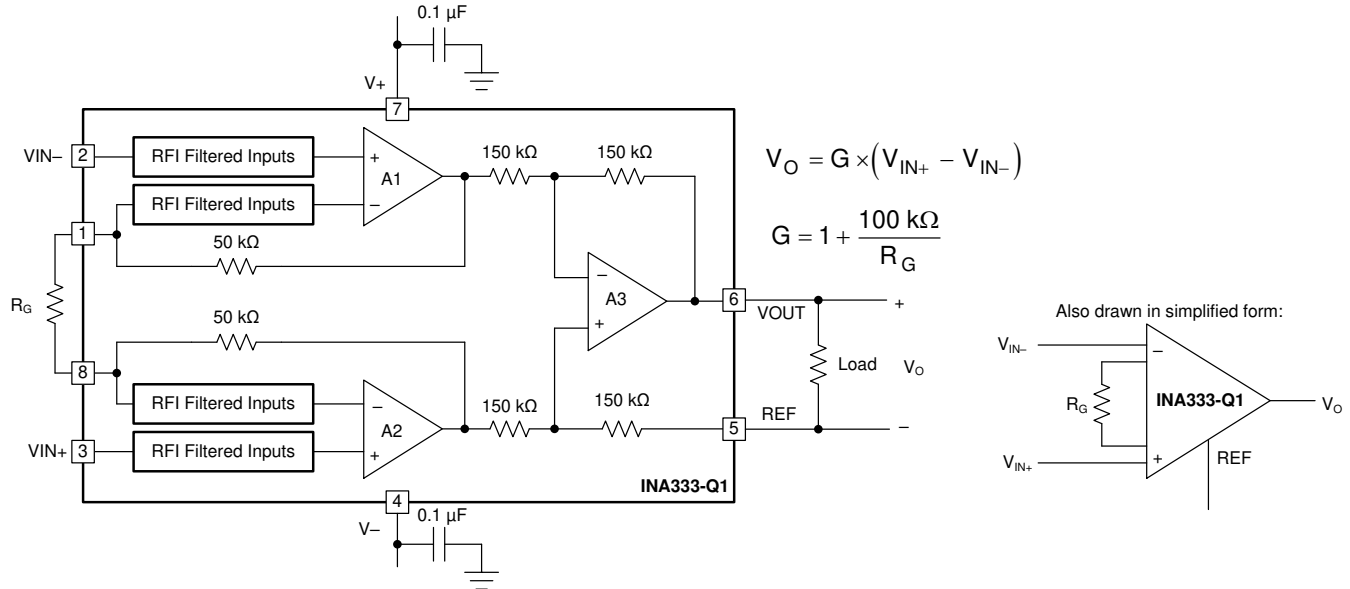


图 8-1. Basic Connections

### 8.2.1 Design Requirements

The device can be configured to monitor the input differential voltage when the gain of the input signal is set by external resistor RG. The output signal references to the REF pin. The most common application is where the output is referenced to ground when no input signal is present by connecting the REF pin to ground. When the input signal increases, the output voltage at the OUT pin also increases.

### 8.2.2 Detailed Design Procedure

#### 8.2.2.1 Setting the Gain

The gain of the INA333-Q1 is set by a single external resistor, RG, connected between pins 1 and 8. The value of RG is selected according to 方程式 1:

$$G = 1 + (100 \text{ k}\Omega / R_G) \quad (1)$$

表 8-1 lists several commonly-used gains and resistor values. The 100 kΩ in 方程式 1 comes from the sum of the two internal feedback resistors of A1 and A2. These on-chip resistors are laser trimmed to accurate absolute values. The accuracy and temperature coefficient of these resistors are included in the gain accuracy and drift specifications of the INA333-Q1.

The stability and temperature drift of the external gain setting resistor,  $R_G$ , also affects gain. The contribution of  $R_G$  to gain accuracy and drift can be directly inferred from 方程式 1. Low resistor values required for high gain can make wiring resistance important. Sockets add to the wiring resistance and contribute additional gain error (possibly an unstable gain error) in gains of approximately 100 or greater. To maintain stability, avoid parasitic capacitance greater than a few picofarads at the  $R_G$  connections. Careful matching of any parasitics on both  $R_G$  pins maintains optimal CMRR over frequency.

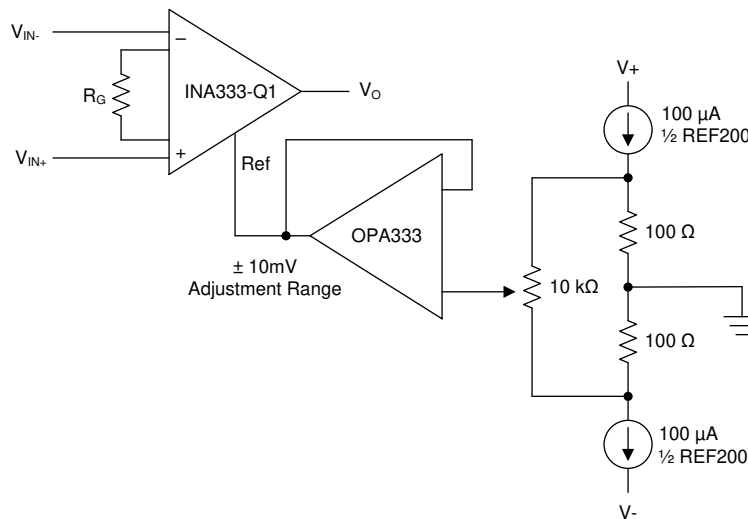
**表 8-1. Commonly Used Gains and Resistor Values**

DESIRED GAIN	$R_G$ ( $\Omega$ )	NEAREST 1% $R_G$ ( $\Omega$ )
1	NC <sup>(1)</sup>	NC
2	100k	100k
5	25k	24.9k
10	11.1k	11k
20	5.26k	5.23k
50	2.04k	2.05
100	1.01k	1k
200	502.5	499
500	200.4	200
1000	100.1	100

(1) NC denotes no connection. When using the SPICE model, the simulation does not converge unless a resistor is connected to the  $R_G$  pins; use a very large resistor value.

### 8.2.2.2 Offset Trimming

Most applications require no external offset adjustment. However, if necessary, adjustments can be made by applying a voltage to the REF pin. 图 8-2 shows an optional circuit for trimming the output offset voltage. The voltage applied to REF pin is summed at the output. The operational amplifier buffer provides low impedance at the REF pin to preserve good common-mode rejection.



**图 8-2. Optional Trimming of Output Offset Voltage**



### 8.2.2.3 Noise Performance

The autocalibration technique used by the INA333-Q1 results in reduced low frequency noise, typically only  $50 \text{ nV}/\sqrt{\text{Hz}}$  ( $G = 100$ ). The spectral noise density is shown in detail in 图 6-8. The low-frequency noise of the device is approximately  $1 \mu\text{V}_{\text{PP}}$  measured from 0.1 Hz to 10 Hz ( $G = 100$ ).

### 8.2.2.4 Input Bias Current Return Path

The input impedance of the INA333-Q1 is extremely high; approximately  $100 \text{ G}\Omega$ . However, a path must be provided for the input bias current of both inputs. This input bias current is typically  $\pm 70 \text{ pA}$ . High input impedance means that this input bias current changes very little with varying input voltage.

Input circuitry must provide a path for this input bias current for proper operation. 图 8-3 shows various provisions for an input bias current path. Without a bias current path, the inputs float to a potential that exceeds the common-mode range of the device, and the input amplifiers saturate. If the differential source resistance is low, the bias current return path can be connected to one input (see the thermocouple example in 图 8-3). With higher source impedance, use two equal resistors to provide a balanced input with the possible advantages of a lower input offset voltage as a result of bias current, and improved high-frequency common-mode rejection.

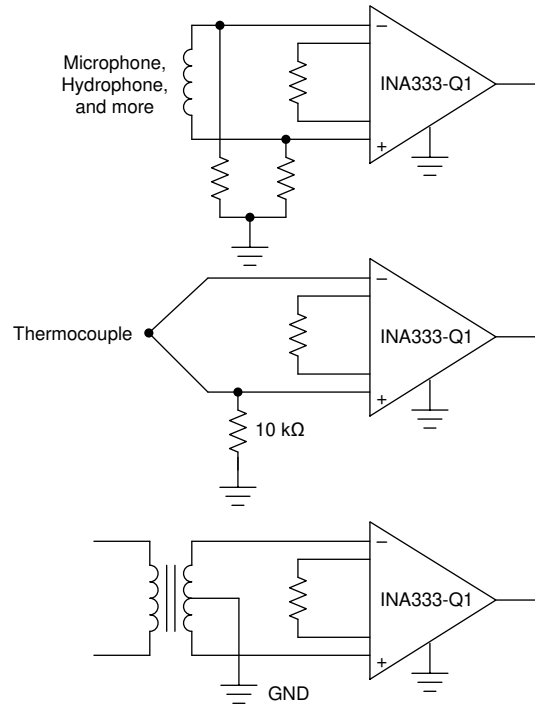


图 8-3. Providing an Input Common-Mode Current Path

### 8.2.2.5 Low Voltage Operation

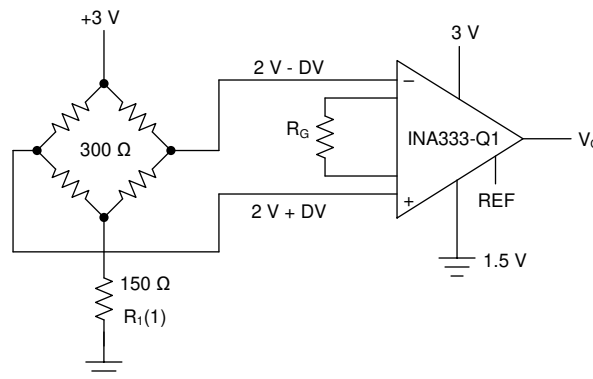
The INA333-Q1 can be operated on power supplies as low as  $\pm 0.9$  V. Most parameters vary only slightly throughout this supply voltage range; see ¶ 6.6. Operation at a very-low supply voltage requires careful attention to make sure that the input voltages remain within the linear range. Voltage swing requirements of internal nodes limit the input common-mode range with low power-supply voltage. 图 6-20 to 图 6-23 show the range of linear operation for various supply voltages and gains.

### 8.2.2.6 Single-Supply Operation

The INA333-Q1 can be used on single power supplies of 1.8 V to 5.5 V. 图 8-4 shows a basic single-supply circuit. The output REF pin is connected to midsupply. Zero differential input voltage demands an output voltage of midsupply. Actual output voltage swing is limited to approximately 50 mV more than ground, when the load is referred to ground as shown. 图 6-29 shows how the output voltage swing varies with output current.

With single-supply operation,  $V_{IN+}$  and  $V_{IN-}$  must both be 0.1 V greater than ground for linear operation. For instance, the inverting input cannot be connected to ground to measure a voltage connected to the noninverting input.

To show the issues affecting low-voltage operation, consider the circuit in 图 8-4 that shows the device operating from a single 3-V supply. A resistor in series with the low side of the bridge makes sure that the bridge output voltage is within the common-mode range of the amplifier inputs.



(1)  $R_1$  creates proper common-mode voltage, only for low-voltage operation; see ¶ 8.2.2.6.

图 8-4. Single-Supply Bridge Amplifier

### 8.2.3 Application Curves

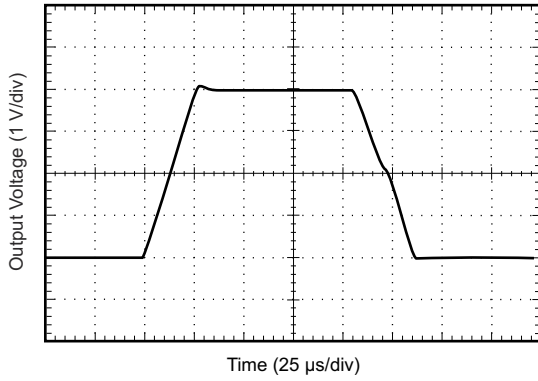


图 8-5. Large Signal Response

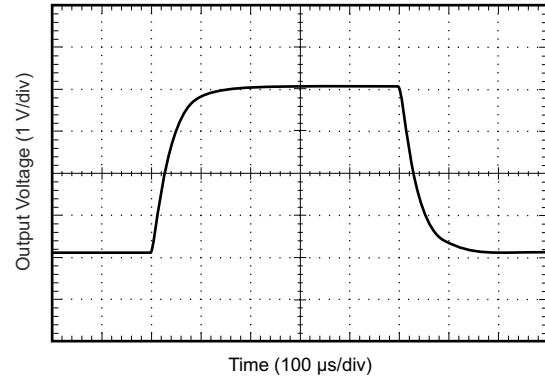


图 8-6. Large-Signal Step Response

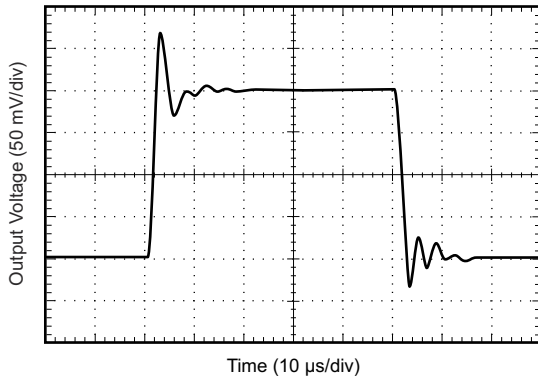


图 8-7. Small-Signal Step Response

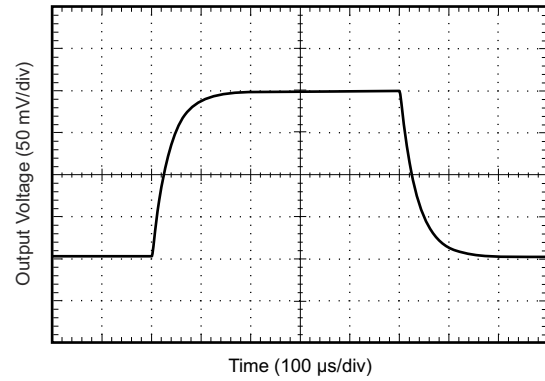


图 8-8. Small-Signal Step Response

### 8.3 Power Supply Recommendations

The minimum power supply voltage for the INA333-Q1 is 1.8 V, and the maximum power supply voltage is 5.5 V; for specified performance, 3.3 V to 5 V is recommended. Add a bypass capacitor at the input to compensate for the layout and power supply source impedance.

### 8.4 Layout

#### 8.4.1 Layout Guidelines

Attention to good layout practices is always recommended.

- Keep traces short.
- When possible, use a printed-circuit-board (PCB) ground plane with surface-mount components placed as close to the device pins as possible.
- Place a 0.1- $\mu$ F bypass capacitor closely across the supply pins.

Apply these guidelines throughout the analog circuit to improve performance and provide benefits such as reducing the electromagnetic-interference (EMI) susceptibility.

Instrumentation amplifiers vary in susceptibility to radio-frequency interference (RFI). RFI can generally be identified as a variation in offset voltage or dc signal levels with changes in the interfering RF signal. The INA333-Q1 has been specifically designed to minimize susceptibility to RFI by incorporating passive RC filters with an 8-MHz corner frequency at the  $V_{IN+}$  and  $V_{IN-}$  inputs. As a result, the INA333-Q1 demonstrates remarkably low sensitivity compared to previous-generation devices. Strong RF fields can continue to cause varying offset levels, however, and can require additional shielding.

#### 8.4.2 Layout Example

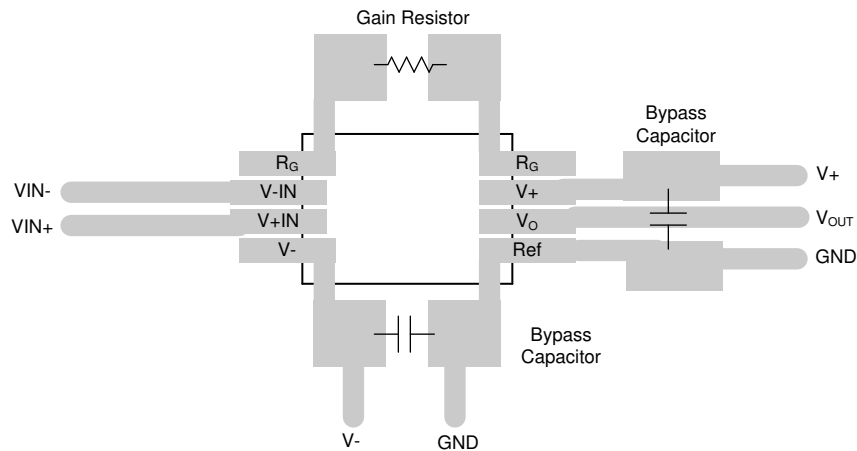


图 8-9. Layout Example

## 9 Device and Documentation Support

### 9.1 Device Support

#### 9.1.1 Development Support

##### 9.1.1.1 TINA-TI Simulation Software (Free Download)

TINA™ is a simple, powerful, and easy-to-use circuit simulation program based on a SPICE engine. TINA-TI™ is a free, fully functional version of the TINA software, preloaded with a library of macromodels in addition to a range of both passive and active models. TINA-TI provides all the conventional dc, transient, and frequency domain analysis of SPICE as well as additional design capabilities.

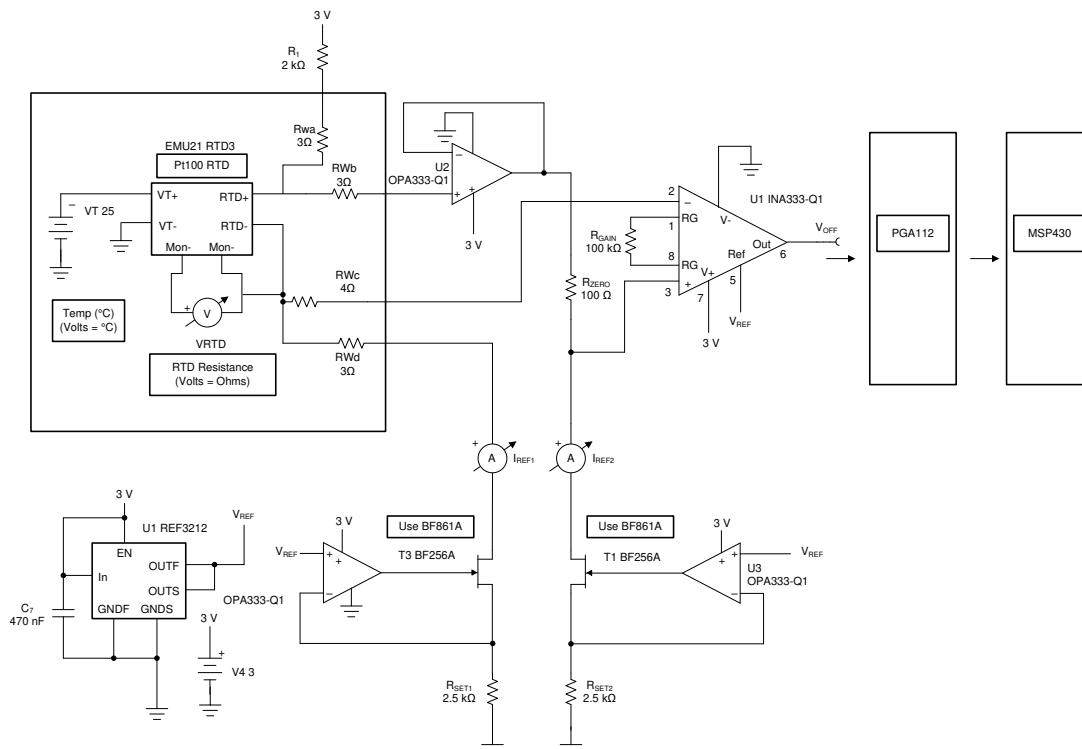
Available as a [free download](#) from the [Design tools and simulation](#) web page, TINA-TI simulation software offers extensive post-processing capability that allows users to format results in a variety of ways. Virtual instruments offer the ability to select input waveforms and probe circuit nodes, voltages, and waveforms, creating a dynamic quick-start tool.

Virtual instruments offer users the ability to select input waveforms and probe circuit nodes, voltages, and waveforms, creating a dynamic quick-start tool.

图 9-1 shows example TINA-TI circuits for the device that can be used to develop, modify, and assess the circuit design for specific applications. Links to download these simulation files are given below.

#### 备注

These files require that either the TINA software (from DesignSoft) or TINA-TI software be installed. Download the free TINA-TI software from the TINA-TI folder.



NOTE: Rwa, RWb, RWc, and RWd simulate wire resistance. These resistors are included to show the four-wire sense technique immunity to line mismatches. This method assumes the use of a four-wire RTD.

图 9-1. Four-Wire, 3-V Conditioner for a PT100 RTD With Programmable Gain Acquisition System

Download the TINA-TI simulation file for this circuit with the following link: [PT100 RTD](#).

## 9.2 Documentation Support

### 9.2.1 Related Documentation

For related documentation see the following:

- Texas Instruments, [OPA188-Q1 Precision, Low-Noise, Rail-to-Rail Output, 36-V, Zero-Drift, Automotive-Grade Operational Amplifier data sheet](#)
- Texas Instruments, [OPA333-Q1 1.8-V microPower CMOS Operational Amplifier Zero-Drift Series data sheet](#)
- Texas Instruments, [Circuit board layout techniques](#)

### 9.3 接收文档更新通知

要接收文档更新通知，请导航至 [ti.com](https://www.ti.com) 上的器件产品文件夹。点击 [订阅更新](#) 进行注册，即可每周接收产品信息更改摘要。有关更改的详细信息，请查看任何已修订文档中包含的修订历史记录。

### 9.4 支持资源

[TI E2E™ 支持论坛](#) 是工程师的重要参考资料，可直接从专家获得快速、经过验证的解答和设计帮助。搜索现有解答或提出自己的问题可获得所需的快速设计帮助。

链接的内容由各个贡献者“按原样”提供。这些内容并不构成 TI 技术规范，并且不一定反映 TI 的观点；请参阅 TI 的 [《使用条款》](#)。

### 9.5 Trademarks

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ESD 的损坏小至导致微小的性能降级，大至整个器件故障。精密的集成电路可能更容易受到损坏，这是因为非常细微的参数更改都可能会导致器件与其发布的规格不相符。

### 9.7 术语表

[TI 术语表](#) 本术语表列出并解释了术语、首字母缩略词和定义。

## 10 Mechanical, Packaging, and Orderable Information

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

**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
INA333QDGKRQ1	ACTIVE	VSSOP	DGK	8	2500	RoHS & Green	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	333Q	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.

**OBSELETE:** 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.

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**OTHER QUALIFIED VERSIONS OF INA333-Q1 :**

- Catalog : [INA333](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product



**TAPE AND REEL INFORMATION**

**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
INA333QDGKRQ1	VSSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
INA333QDGKRQ1	VSSOP	DGK	8	2500	366.0	364.0	50.0

DGK0008A



# PACKAGE OUTLINE

VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



NOTES:

PowerPAD is a trademark of Texas Instruments.

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.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-187.

# EXAMPLE BOARD LAYOUT

DGK0008A

™ VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 15X



SOLDER MASK DETAILS

4214862/A 04/2023

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.
8. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.
9. Size of metal pad may vary due to creepage requirement.

# EXAMPLE STENCIL DESIGN

DGK0008A

<sup>TM</sup> VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE  
SCALE: 15X

4214862/A 04/2023

NOTES: (continued)

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

## 重要声明和免责声明

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