

# TLVx365-Q1 車載用、50MHz、ゼロクロスオーバー、低歪み、高 CMRR、RRI/O、単一電源オペアンプ

## 1 特長

- AEC-Q100 認定済み
  - 温度グレード 1:  $-40^{\circ}\text{C} \sim +125^{\circ}\text{C}$
- ゲイン帯域幅: 50 MHz
- ゼロクロスオーバー歪みトポロジ:
  - CMRR: 115dB (標準値)
  - レールツーレール入出力
    - 電源レールを 100mV 超える入力
- ノイズ:  $4.5\text{nV}/\sqrt{\text{Hz}}$
- スルーレート:  $27\text{V}/\mu\text{s}$
- 高速セトリング: 0.01% まで  $0.2\mu\text{s}$
- 精度:
  - オフセットドリフト:  $2.6\mu\text{V}/^{\circ}\text{C}$  (最大値)
  - 入力バイアス電流:  $20\text{pA}$  (最大値)
- 動作電圧  $2.2\text{V} \sim 5.5\text{V}$

## 2 アプリケーション

- HV/EV の DC/DC コンバータ
- HEV/EV のインバータおよびモータ制御
- HV/EV (ハイブリッド車と電気自動車) のオンボード充電器 (OBC) とワイヤレス充電器
- eTurbo / 充電器
- 車載用 HVAC (エアコン) コンプレッサ・モジュール
- ジェスチャ

## 3 概要

TLV365-Q1 および TLV2365-Q1 (TLVx365-Q1) デバイスは、ゼロクロスオーバー、レール ツー レール入出力の CMOS オペアンプのファミリーで、低電圧およびコスト重視のアプリケーション向けに最適化されています。低ノイズ ( $4.5\text{nV}/\sqrt{\text{Hz}}$ ) および高速動作 (50MHz のゲイン帯域幅) であることから、これらのデバイスはローサイド電流センシング、オーディオ、シグナル コンディショニング、センサ増幅などのアプリケーションのサンプリング A/D コンバータ (ADC) を駆動するのに最適です。

特長として、優れた同相除去比 (CMRR)、クロスオーバー歪みがない入力段、高い入力インピーダンス、およびレール ツー レールの入出力スイング能力が挙げられます。入力同相範囲には、負と正の電源の両方が含まれています。出力電圧のスイングは、レールの  $12\text{mV}$  の範囲内です。

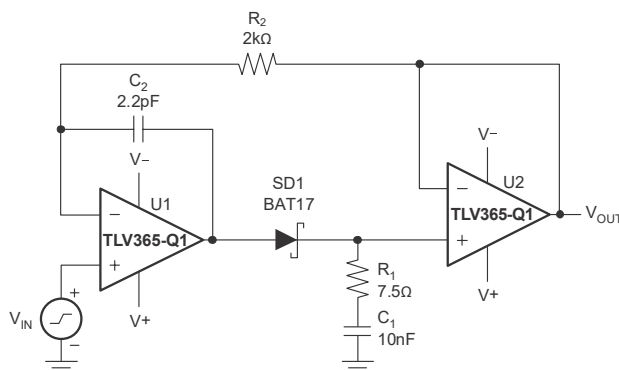
TLVx365-Q1 は、 $-40^{\circ}\text{C} \sim +125^{\circ}\text{C}$ での動作が規定されています。

### 製品情報

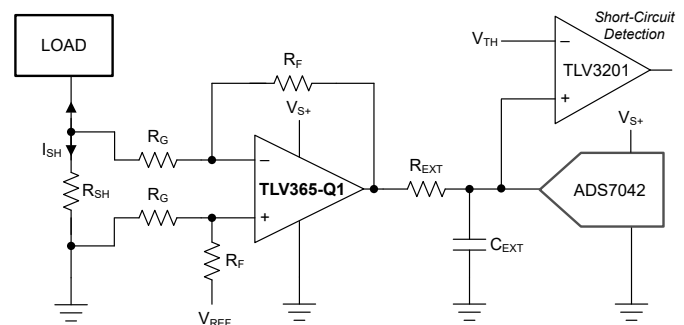
部品番号	チャンネル数	パッケージ (1)
TLV365-Q1	シングル	DBV (SOT-23, 5)
TLV2365-Q1 (2)	デュアル	D (SOIC, 8)
		DGK (VSSOP, 8)

(1) 詳細については、[セクション 11](#) を参照してください。

(2) プレビュー情報 (量産データではありません)。



高速セトリング ピーク検出器



電流センシング用の TLVx365-Q1



## Table of Contents

<b>1 特長</b> .....	<b>1</b>	<b>8 Application and Implementation</b> .....	<b>14</b>
<b>2 アプリケーション</b> .....	<b>1</b>	8.1 Application Information.....	14
<b>3 概要</b> .....	<b>1</b>	8.2 Typical Applications.....	16
<b>4 Device Comparison Table</b> .....	<b>2</b>	8.3 Power Supply Recommendations.....	18
<b>5 Pin Configuration and Functions</b> .....	<b>3</b>	8.4 Layout.....	19
<b>6 Specifications</b> .....	<b>4</b>	<b>9 Device and Documentation Support</b> .....	<b>20</b>
6.1 Absolute Maximum Ratings.....	4	9.1 Device Support.....	20
6.2 ESD Ratings.....	4	9.2 Documentation Support.....	21
6.3 Recommended Operating Conditions.....	4	9.3 ドキュメントの更新通知を受け取る方法.....	21
6.4 Thermal Information.....	4	9.4 サポート・リソース.....	21
6.5 Electrical Characteristics.....	5	9.5 Trademarks.....	21
6.6 Typical Characteristics.....	6	9.6 静電気放電に関する注意事項.....	21
<b>7 Detailed Description</b> .....	<b>10</b>	9.7 用語集.....	21
7.1 Overview.....	10	<b>10 Revision History</b> .....	<b>21</b>
7.2 Functional Block Diagram.....	10	<b>11 Mechanical, Packaging, and Orderable Information</b> .....	<b>22</b>
7.3 Feature Description.....	11		
7.4 Device Functional Modes.....	13		

## 4 Device Comparison Table

DEVICE	INPUT TYPE	OFFSET DRIFT TYPICAL ( $\mu\text{V}/\text{C}$ )	MINIMUM GAIN STABLE (V/V)	$I_{\text{Q}}$ /CHANNEL TYPICAL (mA)	GAIN BANDWIDTH (MHz)	SLEW RATE (V/ $\mu\text{s}$ )	VOLTAGE NOISE (nV/ $\sqrt{\text{Hz}}$ )
TLVx365-Q1	CMOS	0.5	1	4.6	50	27	4.5
OPAx607-Q1	CMOS	0.3	6	0.9	50	24	3.8
OPAx365-Q1	CMOS	1	1	4.6	50	25	4.5

## 5 Pin Configuration and Functions

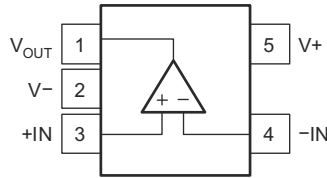


図 5-1. TLV365-Q1 DBV Package, 5-Pin SOT-23 (Top View)

表 5-1. Pin Functions: TLV365-Q1

PIN		TYPE	DESCRIPTION
NAME	NO.		
-IN	4	Input	Negative (inverting) input signal
+IN	3	Input	Positive (noninverting) input signal
V-	2	—	Negative (lowest) power supply
V+	5	—	Positive (highest) power supply
V <sub>OUT</sub>	1	Output	Output

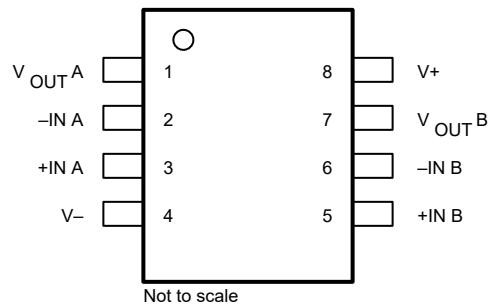


図 5-2. TLV2365-Q1 D (Preview) Package, 8-Pin SOIC and DGK (Preview) Package, 8-Pin VSSOP (Top View)

表 5-2. Pin Functions: TLV2365-Q1

PIN		TYPE	DESCRIPTION
NAME	NO.		
-IN A	2	Input	Negative (inverting) input signal, channel A
-IN B	6	Input	Negative (inverting) input signal, channel B
+IN A	3	Input	Positive (noninverting) input signal, channel A
+IN B	5	Input	Positive (noninverting) input signal, channel B
V-	4	—	Negative (lowest) power supply
V+	8	—	Positive (highest) power supply
V <sub>OUTA</sub>	1	Output	Output, channel A
V <sub>OUTB</sub>	7	Output	Output, channel B

## 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, V <sub>S</sub> = (V+) – (V–)		6	V
V <sub>I</sub>	Input voltage	(V–) – 0.5	(V+) + 0.5	V
V <sub>ID</sub>	Differential input voltage		±5	V
I <sub>I</sub>	Continuous input current <sup>(2)</sup>		±10	mA
I <sub>SC</sub>	Output short-circuit <sup>(3)</sup>	Continuous		
T <sub>A</sub>	Operating temperature	–40	125	°C
T <sub>J</sub>	Junction temperature		150	°C
T <sub>stg</sub>	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) Input pins are diode-clamped to the power-supply rails. Limit the current of input signals that can swing more than 0.5 V beyond the supply rails to 10 mA or less.
- (3) 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 <sup>(1)</sup>	±2000	V
		Charged device model (CDM), per AEC Q100-011	±1000	

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

### 6.3 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
V <sub>S</sub>	Supply voltage, V <sub>S</sub> = (V+) – (V–)	2.2		5.5	V
T <sub>A</sub>	Specified temperature	–40	25	125	°C

### 6.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		TLV365-Q1	TLV2365-Q1		UNIT
		DBV (SOT-23)	D (SOIC)	DGK (VSSOP)	
		5 PINS	8 PINS	8 PINS	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	179	140	179	°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	78	89	71	°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	46	80	101	°C/W
ψ <sub>JT</sub>	Junction-to-top characterization parameter	19	28	13	°C/W
ψ <sub>JB</sub>	Junction-to-board characterization parameter	46	80	100	°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  $V_S = 2.2\text{ V to }5.5\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$ ,  $V_{CM} = V_{OUT} = \text{mid-supply}$ , and gain = 1 V/V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>OFFSET VOLTAGE</b>						
$V_{OS}$	Input offset voltage			$\pm 0.4$	$\pm 1.9$	mV
$dV_{OS}/dT$	Input offset voltage drift	$T_A = -40^\circ\text{C to }+125^\circ\text{C}$		$\pm 0.5$	$\pm 2.6$	$\mu\text{V}/^\circ\text{C}$
PSRR	Power-supply rejection ratio	$V_S = 2.2\text{ V to }5.5\text{ V}$ , $T_A = -40\text{ to }+125^\circ\text{C}$		100		dB
<b>INPUT BIAS CURRENT</b>						
$I_B$	Input bias current			$\pm 5$	$\pm 20$	pA
		$T_A = -40^\circ\text{C to }+125^\circ\text{C}$		See <a href="#">6-5</a>		
<b>NOISE</b>						
	Input voltage noise (peak-to-peak)	$f = 0.1\text{ Hz to }10\text{ Hz}$		5.4		$\mu\text{V}_{PP}$
$e_N$	Input voltage noise density	$f = 500\text{ kHz}$		4.5		$\text{nV}/\sqrt{\text{Hz}}$
$i_n$	Input current noise density	$f = 1\text{ kHz}$		5.8		$\text{fA}/\sqrt{\text{Hz}}$
<b>INPUT VOLTAGE</b>						
$V_{CM}$	Common-mode voltage		$(V_-) - 0.1$		$(V_+) + 0.1$	V
CMRR	Common-mode rejection ratio	$(V_-) - 100\text{ mV} < V_{CM} < (V_+) + 100\text{ mV}$ $T_A = -40^\circ\text{C to }+125^\circ\text{C}$	100	115		dB
				110		
<b>INPUT IMPEDANCE</b>						
$C_{IN}$	Differential			5		pF
	Common-mode			1		
<b>OPEN-LOOP GAIN</b>						
$A_{OL}$	Open-loop voltage gain	$R_L = 10\text{ k}\Omega$ , $(V_-) + 0.1\text{ V} < V_{OUT} < (V_+) - 0.1\text{ V}$	100	120		dB
		$R_L = 10\text{ k}\Omega$ , $T_A = -40\text{ to }+125^\circ\text{C}$		113		
		$R_L = 600\ \Omega$ , $(V_-) + 0.2\text{ V} < V_{OUT} < (V_+) - 0.2\text{ V}$	100	120		
		$R_L = 600\ \Omega$ , $T_A = -40\text{ to }+125^\circ\text{C}$		110		
	Phase margin			56		$^\circ$
<b>FREQUENCY RESPONSE (<math>V_S = 5\text{ V}</math>)</b>						
GBW	Gain-bandwidth product			50		MHz
SR	Slew rate			27		V/ $\mu\text{s}$
$t_s$	Settling time	0.1%, 4-V step		0.15		$\mu\text{s}$
		0.01%, 4-V step		0.2		
	Overdrive recovery time	$V_{IN+} \times \text{gain} > V_S$		< 0.1		$\mu\text{s}$
THD + N	Total harmonic distortion + noise <sup>(1)</sup>	$V_{OUT} = 4\text{ V}_{PP}$ , $f = 1\text{ kHz}$ , $R_L = 600\ \Omega$		0.00025		%
	Channel-to-channel crosstalk (TLV2365-Q1 only)	$V_{OUT} = 2\text{ V}_{PP}$ , $f = 100\text{ kHz}$		108		dBc
<b>OUTPUT</b>						
	Output voltage swing from supply rails				12	mV
		$T_A = -40^\circ\text{C to }+125^\circ\text{C}$				
$I_{SC}$	Short-circuit current			$\pm 85$		mA
	Capacitive load drive			See <a href="#">6-16</a>		
$Z_O$	Open-loop output impedance	$f = 1\text{ MHz}$ , $I_O = 0\text{ mA}$		40		$\Omega$
<b>POWER SUPPLY</b>						
$I_Q$	Quiescent current per amplifier	$I_O = 0\text{ mA}$		4.6	5.8	mA
		$I_O = 0\text{ mA}$ , $T_A = -40^\circ\text{C to }+125^\circ\text{C}$			6.3	

(1) Low-pass-filter bandwidth is 20 kHz for  $f = 1\text{ kHz}$ .

## 6.6 Typical Characteristics

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

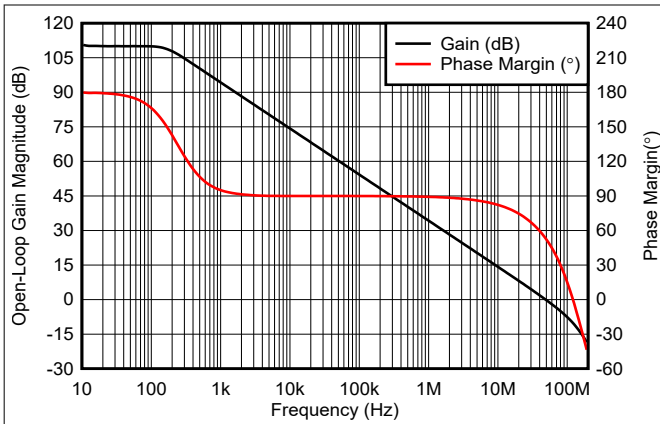


图 6-1. Open-Loop Gain and Phase vs Frequency

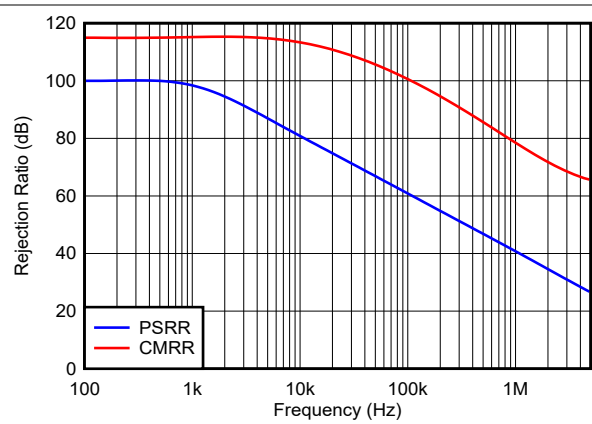


图 6-2. Power-Supply and Common-Mode Rejection Ratio

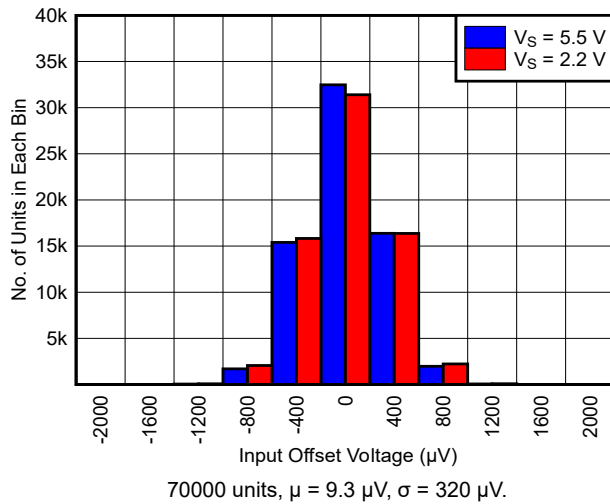


图 6-3. Offset Voltage Production Distribution

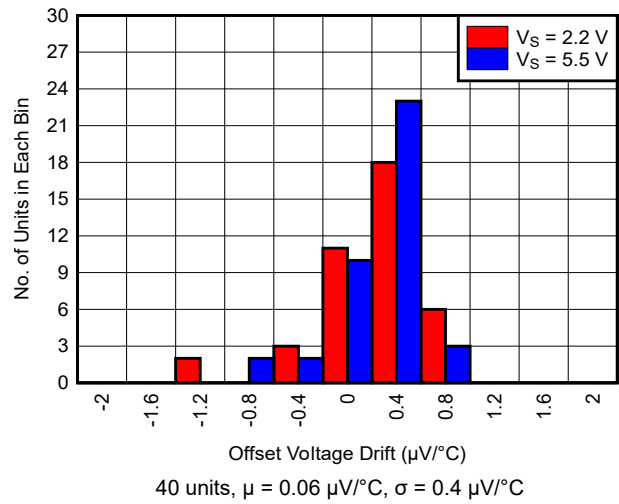


图 6-4. Offset Voltage Drift Distribution

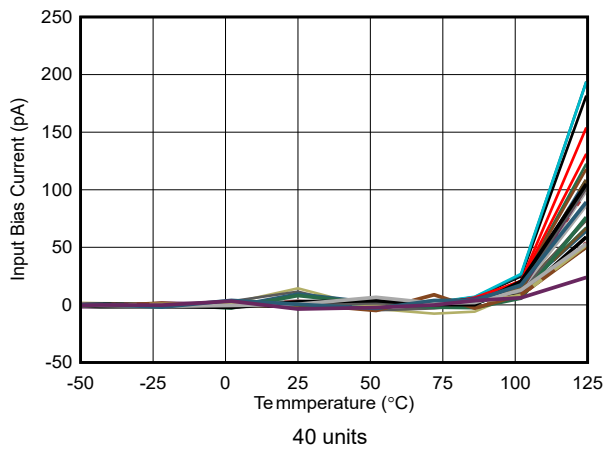


图 6-5. Input Bias Current vs Temperature

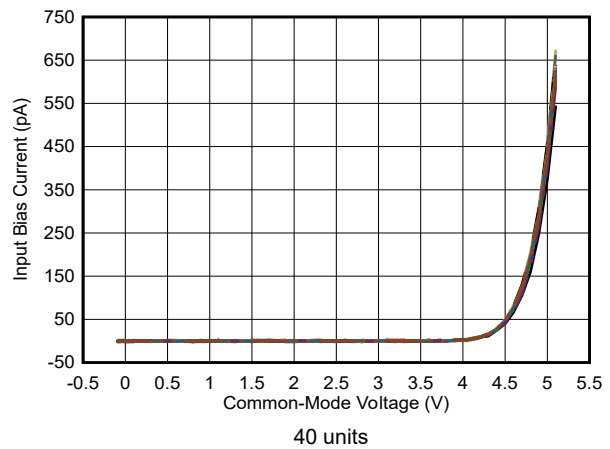
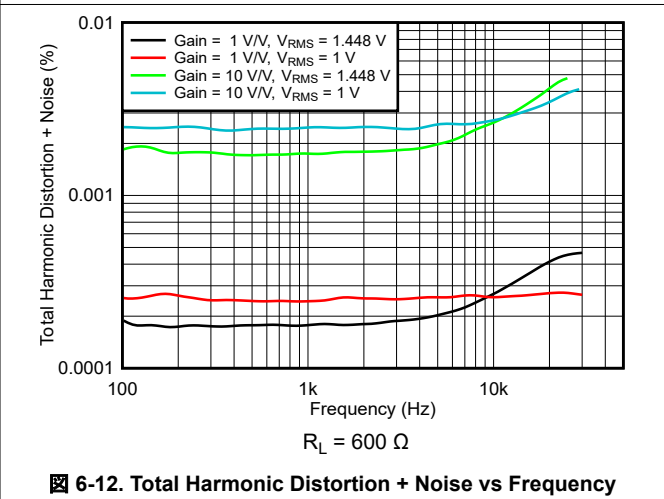
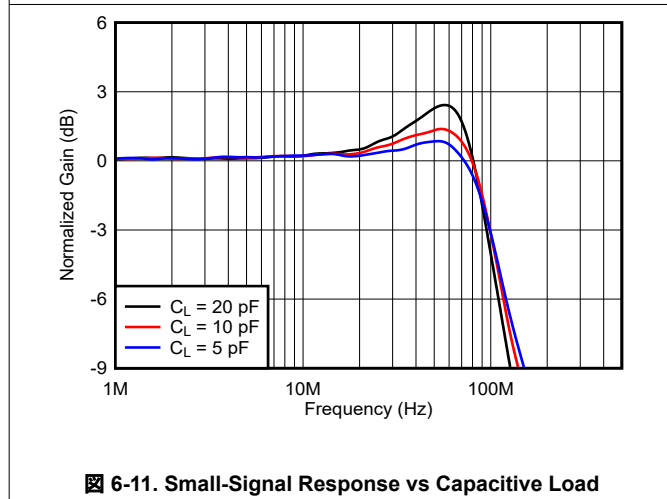
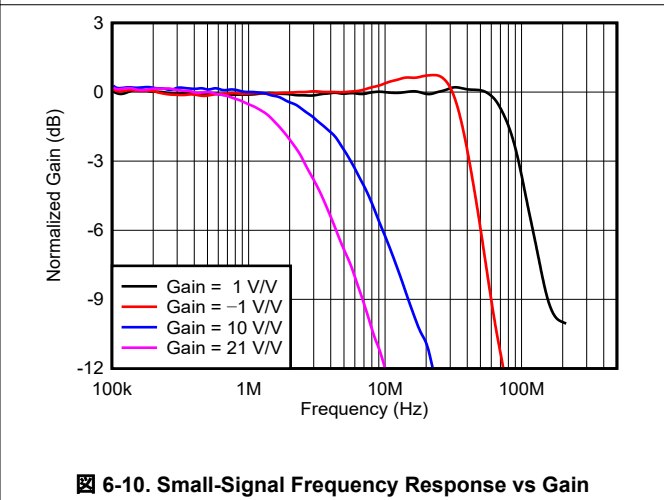
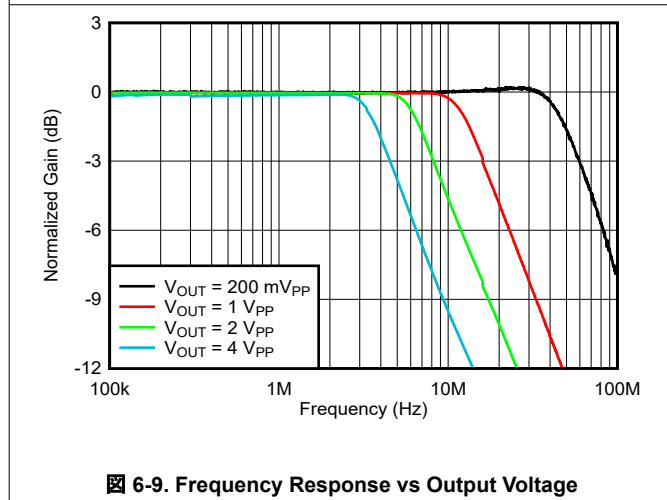
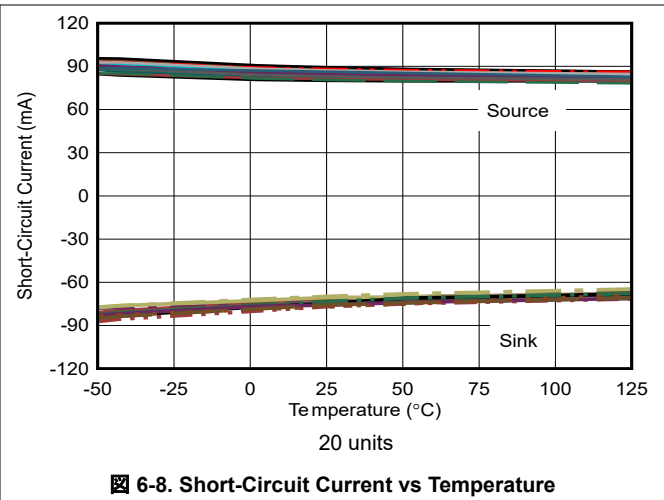
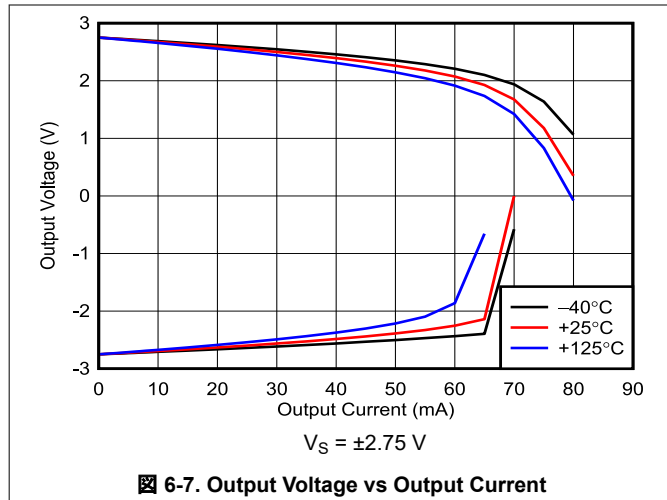


图 6-6. Input Bias Current vs Common-Mode Voltage

## 6.6 Typical Characteristics (continued)

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



## 6.6 Typical Characteristics (continued)

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

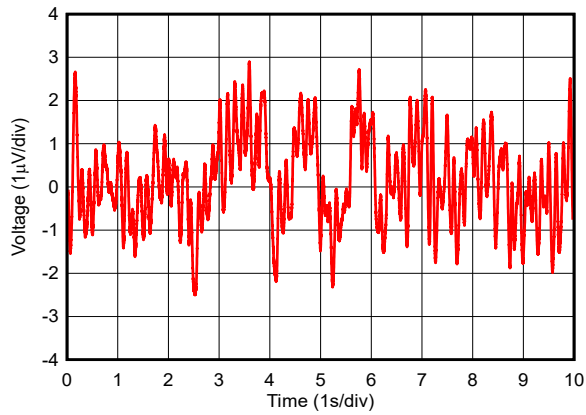


Figure 6-13. 0.1-Hz to 10-Hz Input Voltage Noise

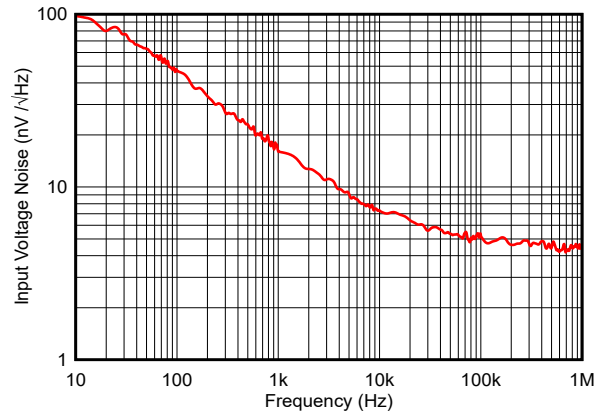


Figure 6-14. Input Voltage Noise Spectral Density

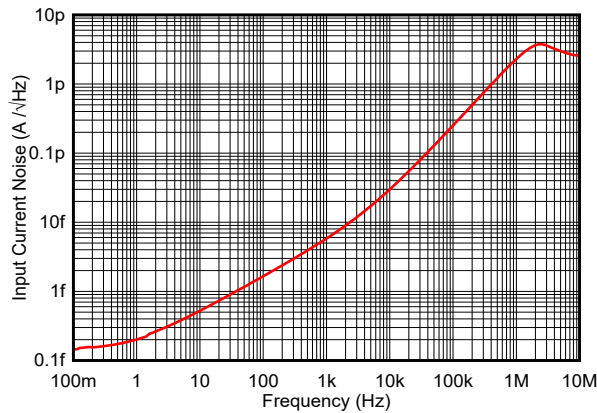
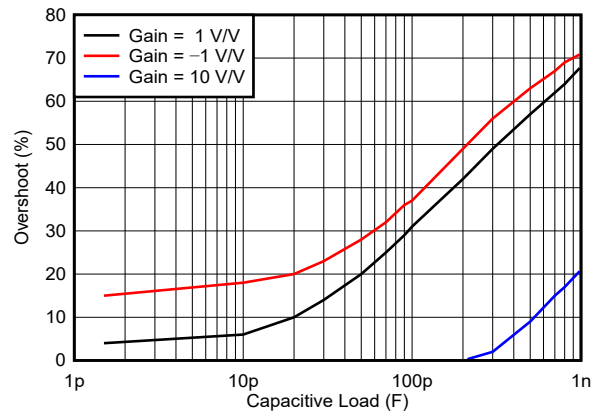


Figure 6-15. Input Current Noise Spectral Density



For gain  $\neq 1\text{ V/V}$ ,  $R_F = 1\text{ k}\Omega$   
For gain = 1 V/V,  $R_F = 0\ \Omega$

Figure 6-16. Overshoot vs Capacitive Load

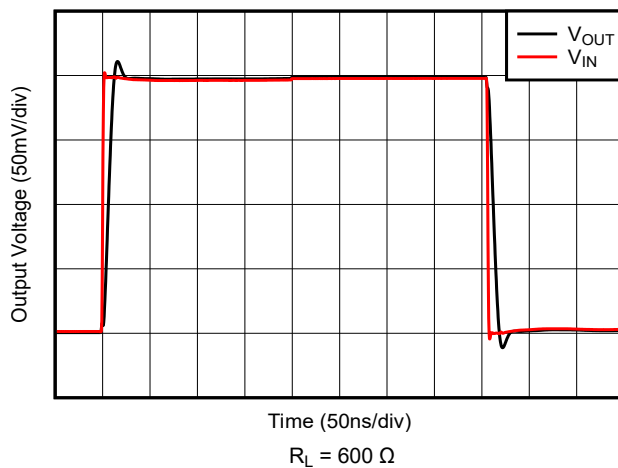


Figure 6-17. Small-Signal Step Response

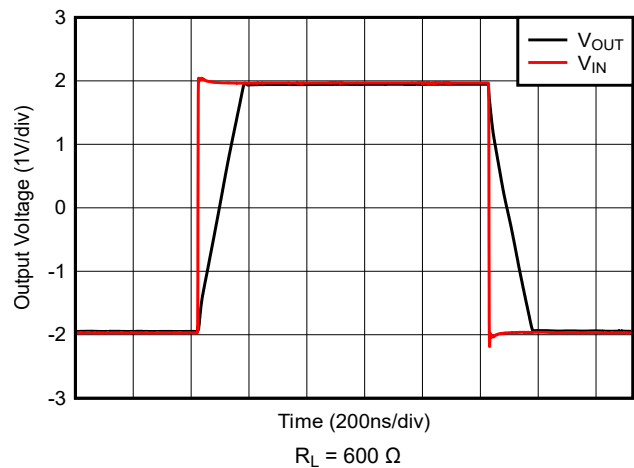
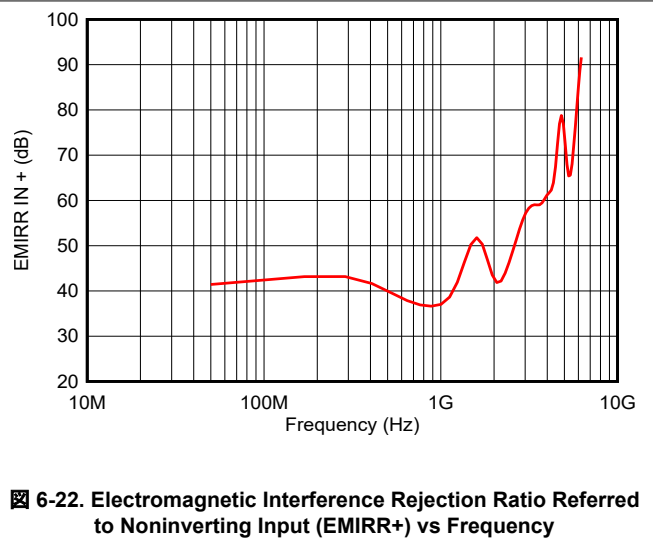
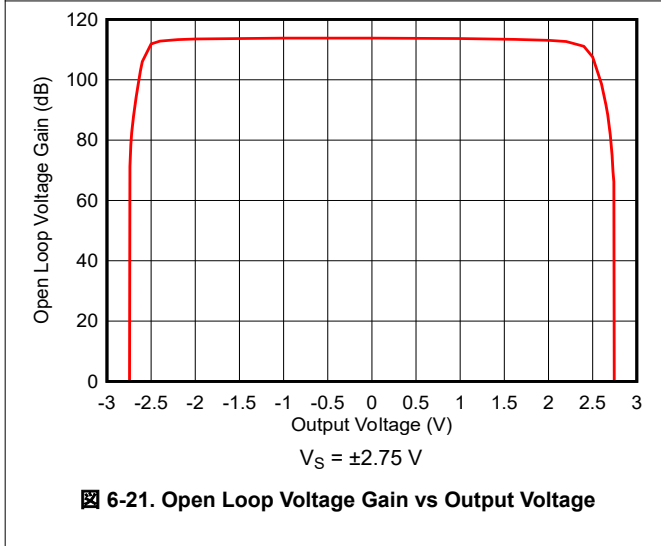
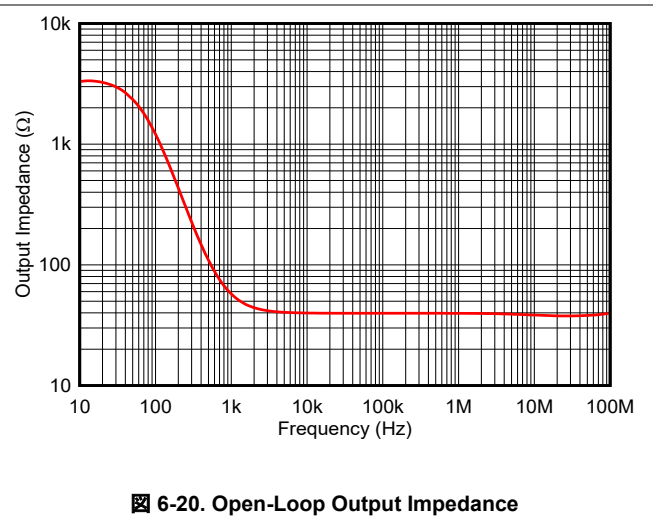
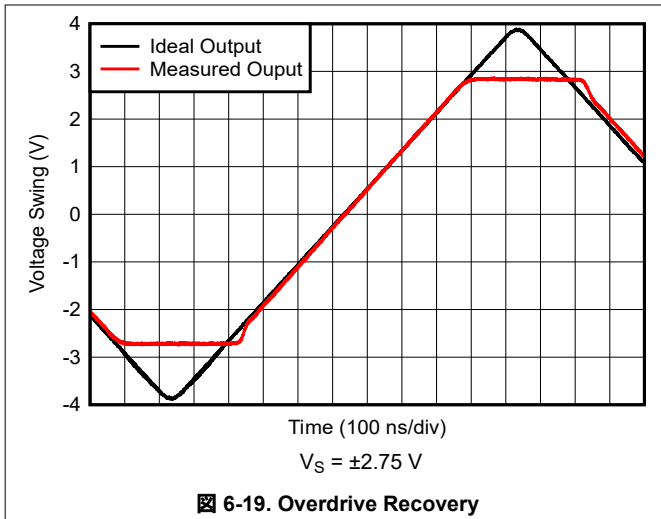


Figure 6-18. Large-Signal Step Response



## 6.6 Typical Characteristics (continued)

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



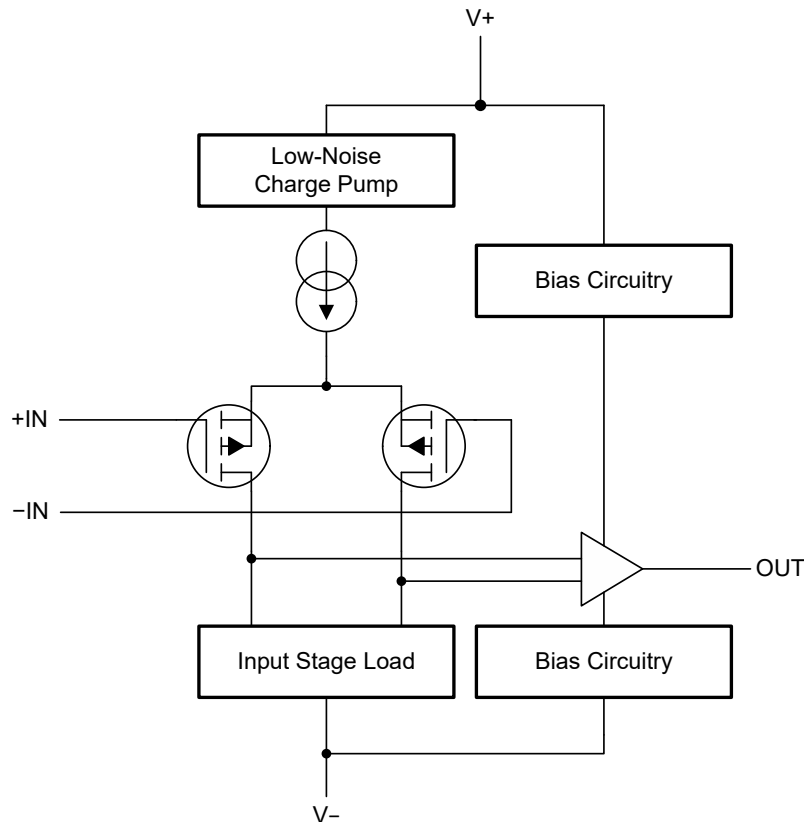
## 7 Detailed Description

### 7.1 Overview

The TLVx365-Q1 series of operational amplifiers feature rail-to-rail input and output, wide-bandwidth making these devices an excellent choice for driving ADCs. Other typical applications include signal conditioning, low-side current sensing, signal buffering and sensor amplification. The TLVx365-Q1 operates with either a single supply or dual supplies.

Furthermore, the TLVx365-Q1 amplifier parameters are fully specified from 2.2 V to 5.5 V. Many of the specifications apply from  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

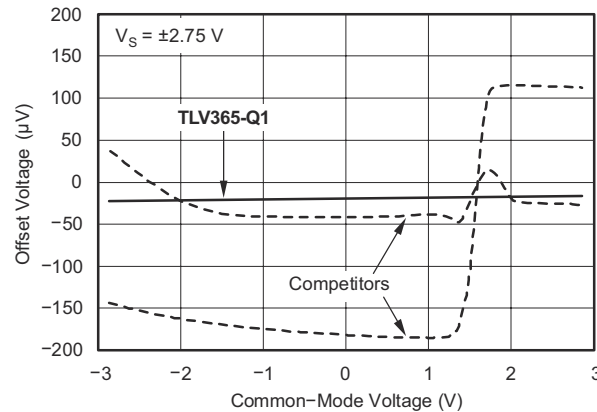
### 7.2 Functional Block Diagram



## 7.3 Feature Description

### 7.3.1 Rail-to-Rail Input

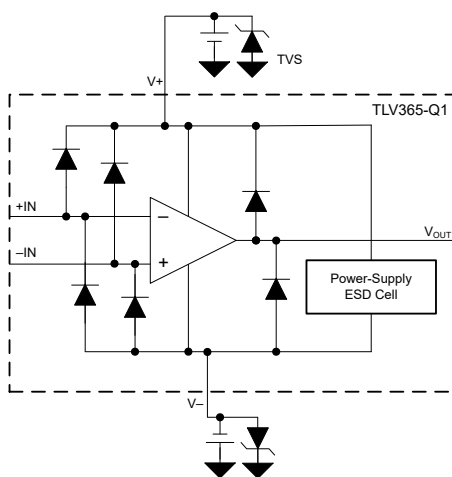
The TLVx365-Q1 product family features true rail-to-rail input operation, with supply voltages as low as  $\pm 1.1$  V (2.2 V). A unique zero-crossover input topology eliminates the input offset transition region typical of many rail-to-rail, complementary stage operational amplifiers. As shown in [Figure 7-1](#), this topology also allows the TLVx365-Q1 to provide excellent common-mode performance over the entire input range, which extends 100 mV beyond both power-supply rails. When driving ADCs, the highly linear  $V_{CM}$  range of the TLVx365-Q1 makes sure that the system linearity performance is not compromised. For a simplified schematic illustrating the rail-to-rail input circuitry, see [Section 7.2](#).



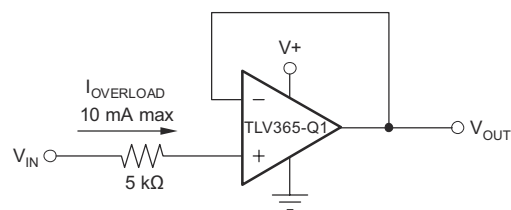
**Figure 7-1. TLVx365-Q1 Linear Offset Over the Entire Common-Mode Range**

### 7.3.2 Input and ESD Protection

[Figure 7-2](#) shows that the TLVx365-Q1 incorporates internal electrostatic discharge (ESD) protection circuits on all pins. In the case of input and output pins, this protection primarily consists of current-steering diodes connected between the input and power-supply pins. These ESD protection diodes also provide in-circuit, input overdrive protection if the current is limited to 10 mA; see also [Section 6.1](#). [Figure 7-3](#) shows how a series input resistor can be added to the driven input to limit the input current. The added resistor contributes thermal noise at the amplifier input; the resistor must be kept to the minimum value in noise-sensitive applications.



**Figure 7-2. ESD Protection Scheme**

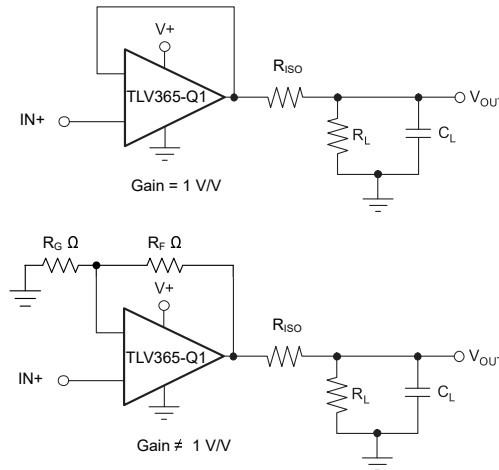


**Figure 7-3. Input Current Protection**

### 7.3.3 Driving Capacitive Loads

The TLVx365-Q1 can be used in applications where driving a capacitive load is required. An op amp in a unity-gain, buffer configuration and driving a capacitive load exhibits a greater tendency to be unstable than an amplifier operated at a higher gain. The capacitive load, in conjunction with the op-amp output impedance, creates a pole within the feedback loop that degrades the phase margin. The degradation of the phase margin increases as the capacitive loading increases. This degradation is observed in the increase in peaking with increased capacitive load in [Figure 6-16](#).

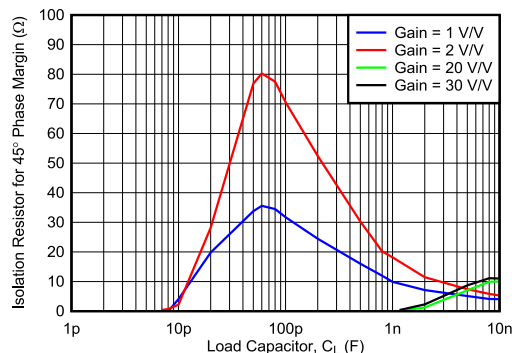
[Improving Capacitive Load Drive](#) shows one technique to increase the capacitive-load drive capability of the amplifier operating in unity gain is to insert a small resistor,  $R_{ISO}$ , in series with the output. This resistor significantly reduces the overshoot and ringing associated with capacitive loads.



**Figure 7-4. Improving Capacitive Load Drive**

A possible drawback of this technique is the voltage divider created with the added series resistor ( $R_{ISO}$ ) and any resistor ( $R_L$ ) connected in parallel with the capacitive load. The voltage divider introduces a gain error at the output that also reduces the output swing. The error contributed by the voltage divider can be insignificant. For instance, with a load resistance of  $R_L = 10\text{ k}\Omega$  and  $R_{ISO} = 20\ \Omega$ , the gain error is only approximately 0.2%.

The following figure shows the recommended isolation resistor ( $R_{ISO}$ ) to be connected at the output of TLVx365-Q1 for different capacitive loads. The TLVx365-Q1 can drive higher capacitive loads without the need of isolation resistors at higher gains.




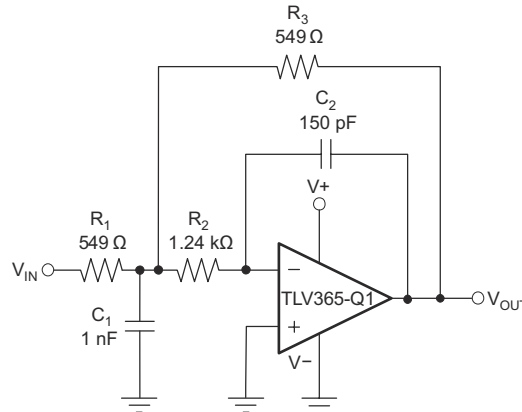
For gain > 1 V/V,  $R_F = 1\text{ k}\Omega$

For gain = 1 V/V,  $R_F = 0\ \Omega$

**Figure 7-5. Recommended Isolation Resistor vs Capacitive Load**

### 7.3.4 Active Filter

The TLVx365-Q1 is an excellent choice for active filter applications requiring a wide bandwidth, fast slew rate, low-noise, single-supply operational amplifier.  7-6 shows a 500-kHz, second-order, low-pass filter using a multiple-feedback (MFB) topology. The components have been selected to provide a maximally-flat Butterworth response. Beyond the cutoff frequency, rolloff is  $-40$  dB/dec. The Butterworth response is designed for applications requiring predictable gain characteristics, such as the antialiasing filter used ahead of an ADC.

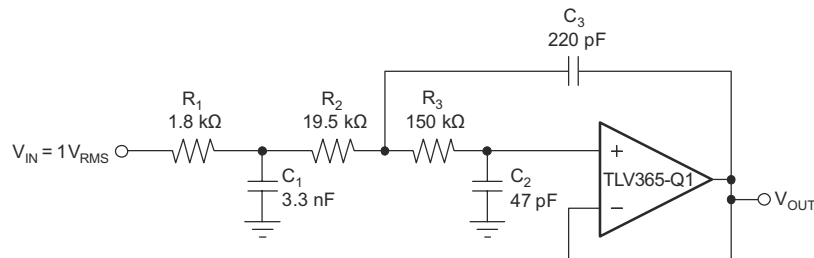


 7-6. Second-Order Butterworth, 500-kHz Low-Pass Filter

When considering the MFB filter, the output is inverted, relative to the input. If this inversion is not desired, then a noninverting output can be achieved through one of these options:

- add an inverting amplifier
- add an additional second-order MFB stage
- use a noninverting filter topology, such as the Sallen-Key

 7-7 shows the Sallen-Key topology.



 7-7. Configured as a Three-Pole, 20-kHz, Sallen-Key Filter

## 7.4 Device Functional Modes

The TLVx365-Q1 have a single-mode of operation. The devices can be configured with unipolar supplies, split and symmetrical bipolar supplies ( $\pm 2.5$  V, for example), or split and asymmetrical supplies (+4 V and  $-1$  V, for example). There are no power-down or low-power modes in the TLVx365-Q1.

## 8 Application and Implementation

注

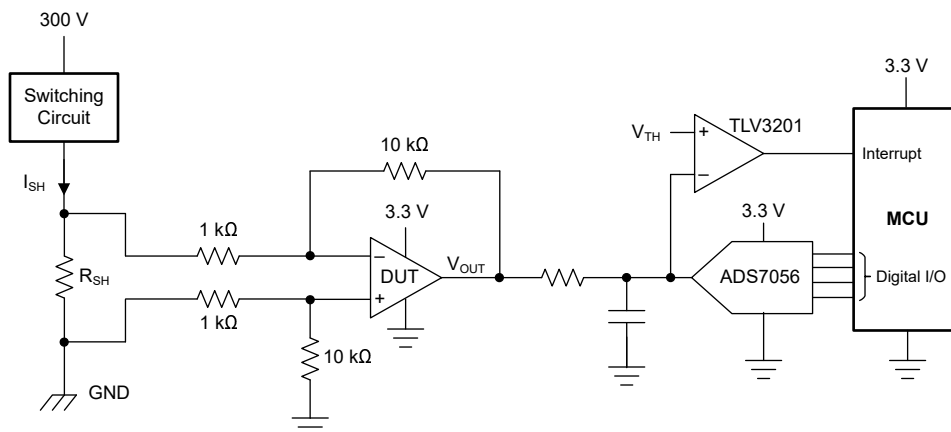
Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation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

### 8.1 Application Information

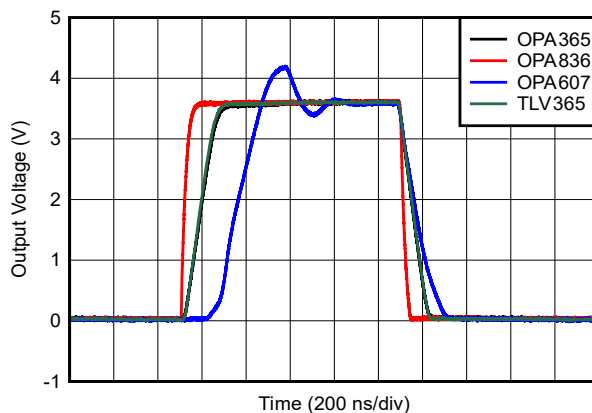
The TLVx365-Q1 offer outstanding dc and ac performance. These devices operate with up to a 5.5-V power supply, offer an ultra-low input bias current and a 50-MHz bandwidth with true rail-to-rail input capability.

#### 8.1.1 Overdrive Recovery Performance

The TLVx365-Q1 family exhibits excellent overdrive recovery when the output is driven well beyond the  $V+$  or  $V-$  supplies. When configured in a low-side current-sensing configuration (see [Figure 8-1](#)), the output of the op amp (TLVx365-Q1) is often driven to or less than ground as a result of ground bounce at the power ground or the  $\leq 0$ -A current being measured across shunt resistance  $R_{SH}$ . The TLVx365-Q1 has the ability to recover from an overdrive event in  $< 100$  ns. [Figure 8-2](#) shows the comparison of the overdrive recovery performance of TLVx365-Q1 and other popular op amps in the same category.



**Figure 8-1. Low-Side Current-Sensing Application Circuit**

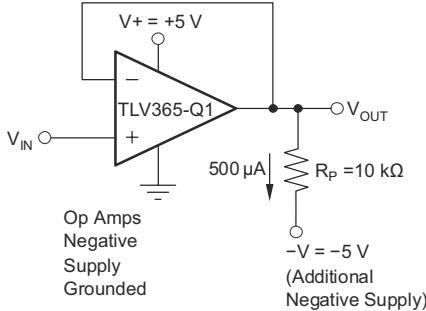


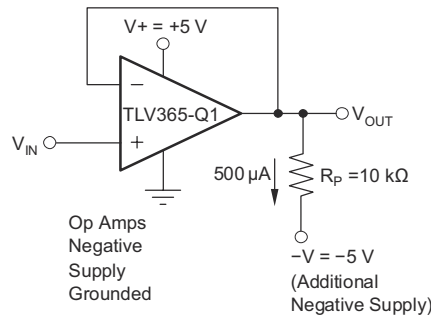
Gain = 10 V/V,  $V_{OUT}$  driven to  $(V-) - 1$  V

**Figure 8-2. TLVx365-Q1 Overdrive Recovery**

### 8.1.2 Achieving an Output Level of Zero Volts


Certain single-supply applications require the op-amp output to swing from 0 V to a positive full-scale voltage and have high accuracy. An example is an op amp employed to drive a single-supply ADC having an input range from 0 V to 3.3 V. Rail-to-rail output amplifiers with very light output loading can achieve an output level within few millivolts of 0 V (or V+ at the high end), but not true 0 V. Furthermore, the deviation from 0 V only becomes greater as the required load current increases. This increased deviation is a result of limitations of the CMOS output stage.

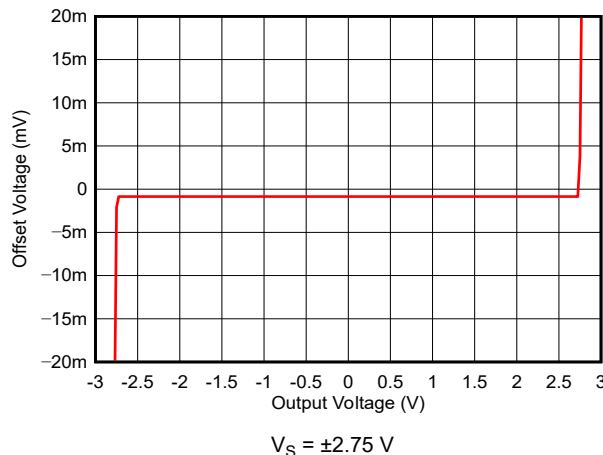
When a pulldown resistor is connected from the amplifier output to a negative voltage source, the TLVx365-Q1 can achieve an output level of 0 V, and even a few millivolts below 0 V.  8-3 shows a circuit using this technique.



 8-3. Swing-to-Ground

A pulldown current of approximately 500  $\mu\text{A}$  is required when TLVx365-Q1 is connected as a unity-gain buffer. Pulldown resistor  $R_L$  is calculated from  $R_L = [(V_O - V_{\text{NEG}}) / (500 \mu\text{A})]$ .

 8-4 shows the offset voltage vs output swing.

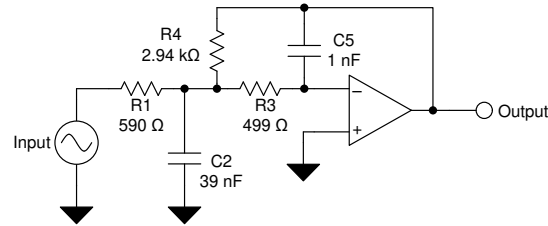


 8-4. Offset Voltage vs Output Swing

## 8.2 Typical Applications

### 8.2.1 Second-Order Low-Pass Filter

Low-pass filters are commonly employed in signal processing applications to reduce noise and prevent aliasing. The TLVx365-Q1 is designed to construct high-speed, high-precision active filters. [Figure 8-5](#) shows a second-order low-pass filter commonly encountered in signal processing applications.



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**Figure 8-5. Second-Order Low-Pass Filter**

#### 8.2.1.1 Design Requirements

Use the following parameters for this design example:

- Gain = 5 V/V (inverting gain)
- Low-pass cutoff frequency = 25 kHz
- Second-order, Chebyshev filter response with 3-dB gain peaking in the pass band

#### 8.2.1.2 Detailed Design Procedure

[Figure 8-5](#) shows the infinite-gain, multiple-feedback circuit for a low-pass network function. Use [Equation 1](#) to calculate the voltage transfer function.

$$\frac{\text{Output}}{\text{Input}}(s) = \frac{-1/R_1 R_3 C_2 C_5}{s^2 + (s/C_2)(1/R_1 + 1/R_3 + 1/R_4) + 1/R_3 R_4 C_2 C_5} \quad (1)$$

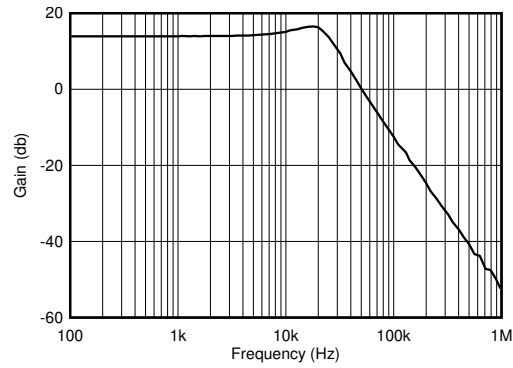
This circuit produces a signal inversion. For this circuit, use [Equation 2](#) to calculate the gain at dc and the low-pass cutoff frequency.

$$\text{Gain} = \frac{R_4}{R_1}$$

$$f_c = \frac{1}{2\pi} \sqrt{(1/R_3 R_4 C_2 C_5)} \quad (2)$$



### 8.2.1.3 Application Curve



8-6. TLVx365-Q1 Second-Order 25 kHz, Chebyshev, Low-Pass Filter

### 8.2.2 ADC Driver and Reference Buffer

Figure 8-7 shows the use of a TLVx365-Q1 op amp as a SAR ADC input and reference pin driver. Sensors, which are used for interfacing with the physical environment, exhibit high output impedance and cannot drive SAR ADC inputs directly. The TLVx365-Q1 devices exhibit a very low-input bias current of 20 pA (maximum), and therefore do not load these high-output impedance sensors. A wide-GBW amplifier connected to the output of these sensors is needed to charge the switching capacitors at the SAR ADC input and to settle fast, to the required accuracy, within the given acquisition time.

The ADC core draws transient current from the reference input during the conversion (digitization) phase, which must be driven with a wide-GBW amplifier to offer fast settling and maintain a stable reference voltage for excellent digitization performance. The TLVx365-Q1 reference buffer is used in a composite loop with the OPA378 precision amplifier because of limitations in precision performance of wide-GBW amplifiers. The precision amplifier maintains low-offset output, whereas the TLVx365-Q1 provide the output drive and fast-settling performance.

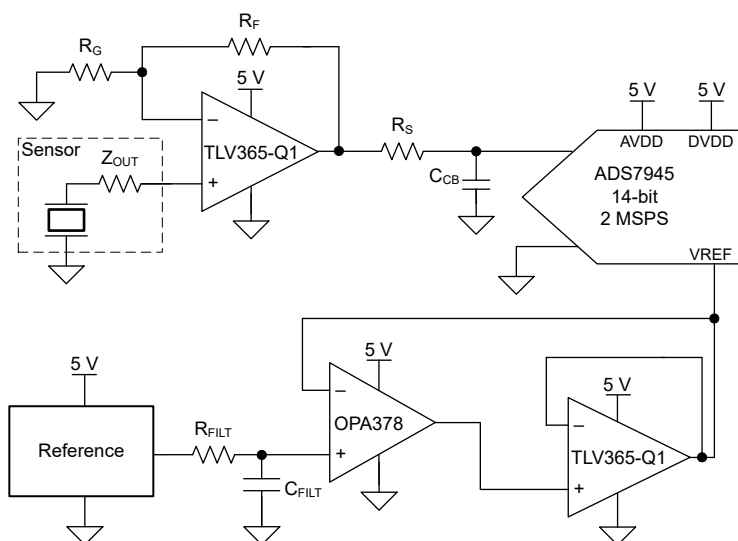


Figure 8-7. TLVx365-Q1 as a SAR ADC Driver

### 8.3 Power Supply Recommendations

The TLVx365-Q1 family can be configured with unipolar supplies, split and symmetrical bipolar supplies ( $\pm 2.5$  V, for example), or split and asymmetrical supplies (+4 V and  $-1$  V, for example). The maximum permissible voltage,  $V_S$ , is 6 V.

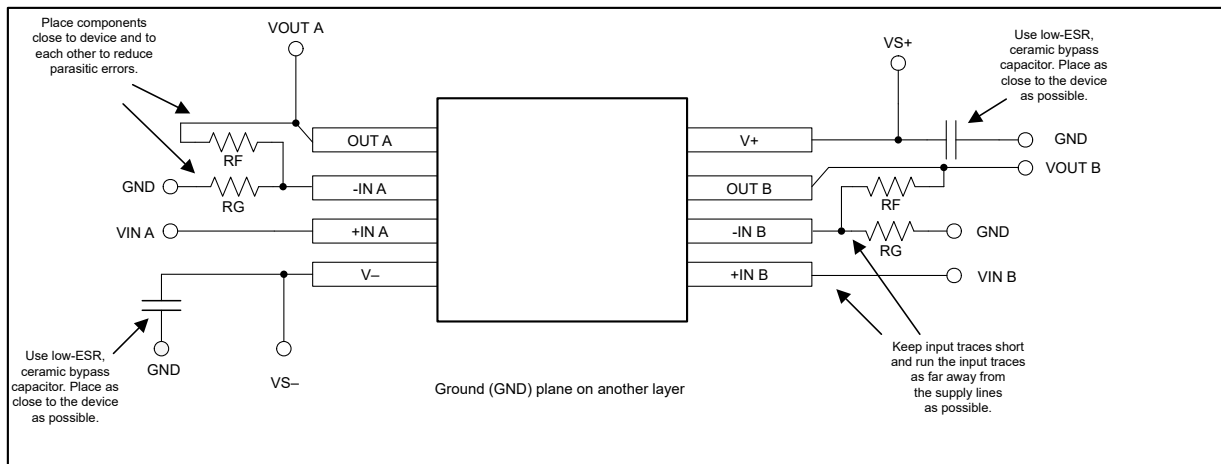
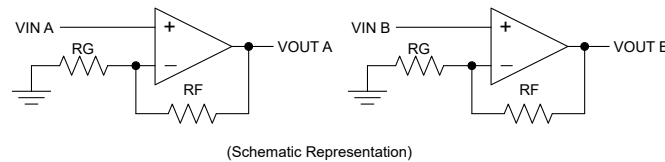
## 8.4 Layout

### 8.4.1 Layout Guidelines

For best operational performance of the device, use good printed circuit board (PCB) layout practices, including the following guidelines:

- Noise can propagate into analog circuitry through the power pins of the circuit as a whole or through the operational amplifier. Bypass capacitors are used to reduce the coupled noise by providing low-impedance power sources local to the analog circuitry.
  - Connect low-ESR, 0.1- $\mu\text{F}$  ceramic bypass capacitors between each supply pin and ground, placed as close to the device as possible. A single bypass capacitor from V+ to ground is applicable for single-supply applications.
  - The TLVx365-Q1 is capable of peak output current (in excess of 50 mA). Applications with low impedance loads or capacitive loads with fast transient signals demand large currents from the power supplies. Larger bypass capacitors, such as 1- $\mu\text{F}$  solid tantalum capacitors, can improve dynamic performance in these applications.
- Separate grounding for analog and digital portions of circuitry is one of the simplest and most-effective methods of noise suppression. One or more layers on multilayer PCBs are usually devoted to ground planes. A ground plane helps distribute heat and reduces EMI noise pickup. Make sure to physically separate digital and analog grounds paying attention to the flow of the ground current.
- To reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If these traces cannot be kept separate, crossing the sensitive trace perpendicular is much better as opposed to in parallel with the noisy trace.
- Place the external components as close to the device as possible. [Figure 8-8](#) shows that keeping  $R_F$  and  $R_G$  close to the inverting input minimizes parasitic capacitance.
- Keep the length of input traces as short as possible. Always remember that the input traces are the most sensitive part of the circuit.
- Consider a driven, low-impedance guard ring around the critical traces. A guard ring can significantly reduce leakage currents from nearby traces that are at different potentials.

### 8.4.2 Layout Example



**Figure 8-8. Layout Recommendation for TLV2365-Q1 SOIC Package**

## 9 Device and Documentation Support

### 9.1 Device Support

#### 9.1.1 Development Support

##### 9.1.1.1 PSpice® for TI

PSpice® for TI は、アナログ回路の性能評価に役立つ設計およびシミュレーション環境です。レイアウトと製造に移る前に、サブシステムの設計とプロトタイプ・ソリューションを作成することで、開発コストを削減し、市場投入までの期間を短縮できます。

##### 9.1.1.2 TINA-TI™シミュレーション ソフトウェア (無償ダウンロード)

TINA-TI™ シミュレーション ソフトウェアは、SPICE エンジンに基づいた単純かつ強力な、使いやすい回路シミュレーション プログラムです。TINA-TI シミュレーション ソフトウェアは、TINA™ ソフトウェアのすべての機能を持つ無償バージョンで、パッシブ モデルとアクティブ モデルに加えて、マクロモデルのライブラリがプリロードされています。TINA-TI シミュレーション ソフトウェアには、SPICE の標準的な DC 解析、過渡解析、周波数ドメイン解析などの全機能に加え、追加の設計機能が搭載されています。

TINA-TI シミュレーション ソフトウェアは設計およびシミュレーション ツール Web ページから無料でダウンロードでき、ユーザーが結果をさまざまな形式で処理できる、広範な後処理機能を備えています。仮想計測器により、入力波形を選択し、回路ノード、電圧、および波形をプローブして、動的なクイック スタート ツールを作成できます。

#### 注

これらのファイルを使用するには、TINA ソフトウェアまたは TINA-TI ソフトウェアがインストールされている必要があります。TINA-TI™ ソフトウェア フォルダから、無償の TINA-TI シミュレーション ソフトウェアをダウンロードしてください。

##### 9.1.1.3 DIP アダプタ評価基板

DIP アダプタ評価基板は、オペアンプの迅速なプロトタイプ製作とテストを可能にする評価基板です。小型の表面実装デバイスとのインターフェイスを迅速、容易、低コストで実現します。付属の Samtec 端子ストリップか、直接配線により既存の回路へサポートされているオペアンプを接続します。DIP アダプタ評価基板キットは、以下の業界標準パッケージをサポートしています。D または U (SOIC-8)、PW (TSSOP-8)、DGK (VSSOP-8)、DBV (SOT-23-6、SOT-23-5、および SOT-23-3)、DCK (SC70-6 および SC70-5)、および DRL (SOT563-6)。

##### 9.1.1.4 DIYAMP-EVM

DIYAMP-EVM は、実際のアンプ回路を提供する独自の評価基板 (EVM) であり、設計コンセプトの迅速な評価とシミュレーションの検証を実現します。この評価基板は、3 つの業界標準パッケージ (SC70、SOT23、SOIC) で供給されており、シングル / デュアル電源向けに、アンプ、フィルタ、安定性補償、コンパレータの各構成など、12 の一般的なアンプ構成が可能です。

##### 9.1.1.5 TI のリファレンス・デザイン

TI のリファレンス・デザインは、TI の高精度アナログ・アプリケーション専門家により作成されたアナログ・ソリューションです。TI のリファレンス・デザインは、動作原理、部品の選択、シミュレーション、完全な PCB 回路図およびレイアウト、部品表、測定済みの性能を提供します。TI のリファレンス・デザインは、<http://www.ti.com/ww/en/analog/precision-designs/> からオンラインで入手できます。

##### 9.1.1.6 Analog Filter Designer

Analog Filter Designer は、設計およびシミュレーション ツール Web ページから Web ベースのツールとして利用でき、包括的な複数段アクティブ フィルタ ソリューションの設計、最適化、シミュレーションをわずか数分で行います。

## 9.2 Documentation Support

### 9.2.1 Related Documentation

The following documents are relevant to using the TLVx365-Q1, and recommended for reference. All are available for download at [www.ti.com](http://www.ti.com) unless otherwise noted.

- Texas Instruments, [FilterPro™ software user's guide](#)
- Texas Instruments, [Low Power Input and Reference Driver Circuit for ADS8318 and ADS8319 application report](#)
- Texas Instruments, [Op Amp Performance Analysis application bulletin](#)
- Texas Instruments, [Single-Supply Operation of Operational Amplifiers application bulletin](#)
- Texas Instruments, [The Best of Baker's Best – Amplifiers eBook reference book](#)

## 9.3 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、[www.tij.co.jp](http://www.tij.co.jp) のデバイス製品フォルダを開いてください。[通知] 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ることができます。変更の詳細については、改訂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。

## 9.4 サポート・リソース

[テキサス・インスツルメンツ 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、各寄稿者により「現状のまま」提供されるものです。これらはテキサス・インスツルメンツの仕様を構成するものではなく、必ずしもテキサス・インスツルメンツの見解を反映したものではありません。テキサス・インスツルメンツの[使用条件](#)を参照してください。

## 9.5 Trademarks

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TINA™ is a trademark of DesignSoft, Inc.

PSpice® is a registered trademark of Cadence Design Systems, Inc.

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## 9.6 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。

## 9.7 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。

## 10 Revision History

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

Changes from Revision A (December 2023) to Revision B (September 2024)	Page
• TLV2365-Q1 デバイスのステータスをプレビューから事前情報 (サンプルありのプレビュー) に変更.....	1
• TLV2365-Q1 の事前情報の DGK パッケージを追加.....	1
• Added <i>Thermal Information</i> for DGK package.....	4

Changes from Revision * (June 2023) to Revision A (December 2023)	Page
• データシートのステータスを事前混合から量産混合に変更.....	1
• DBV パッケージの TLV365-Q1 の情報を事前情報 (プレビュー) から量産データ (アクティブ) に変更.....	1

## 11 Mechanical, Packaging, and Orderable Information

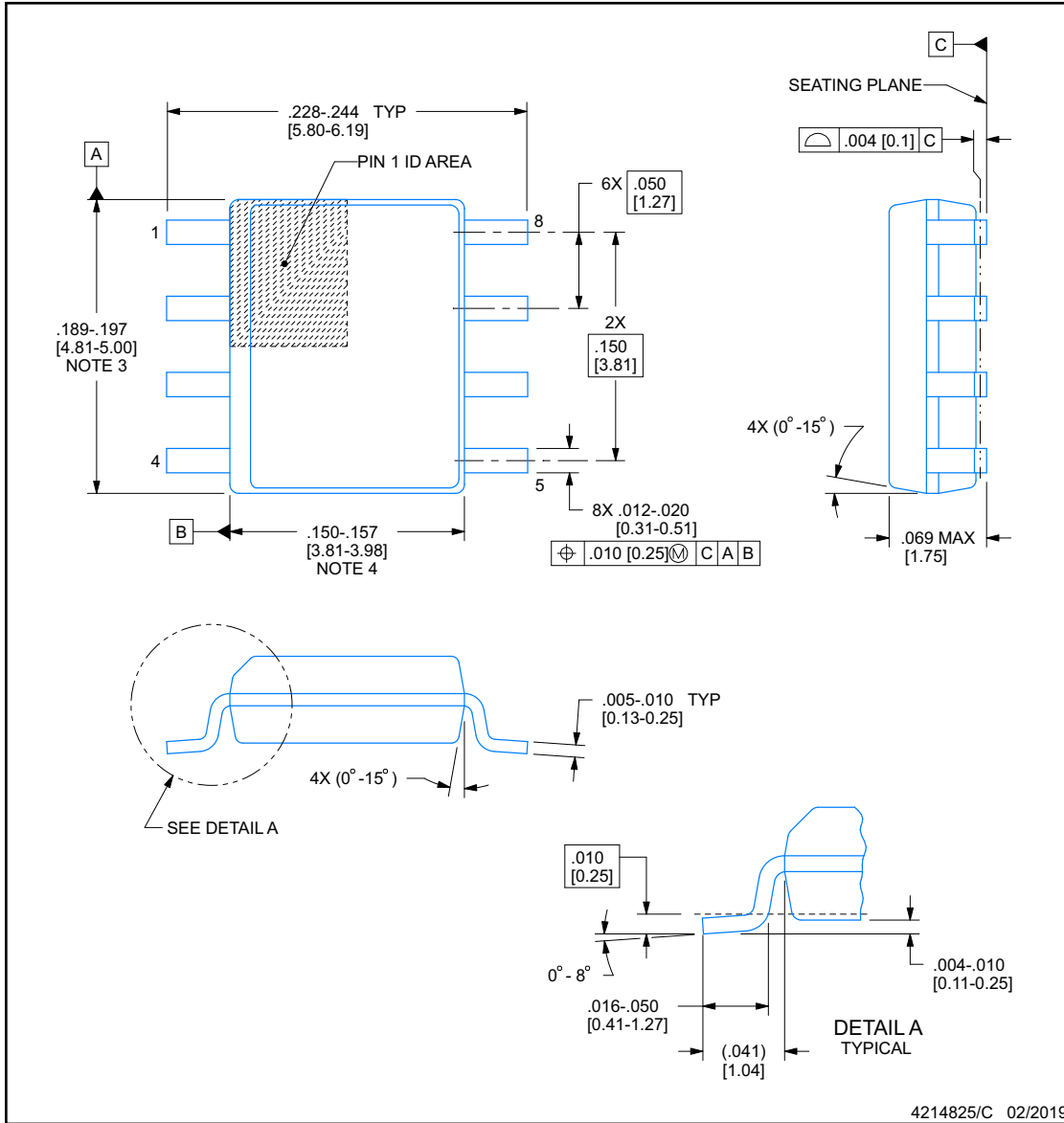
The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand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



**D0008A**

**PACKAGE OUTLINE**  
**SOIC - 1.75 mm max height**

SMALL OUTLINE INTEGRATED CIRCUIT



NOTES:

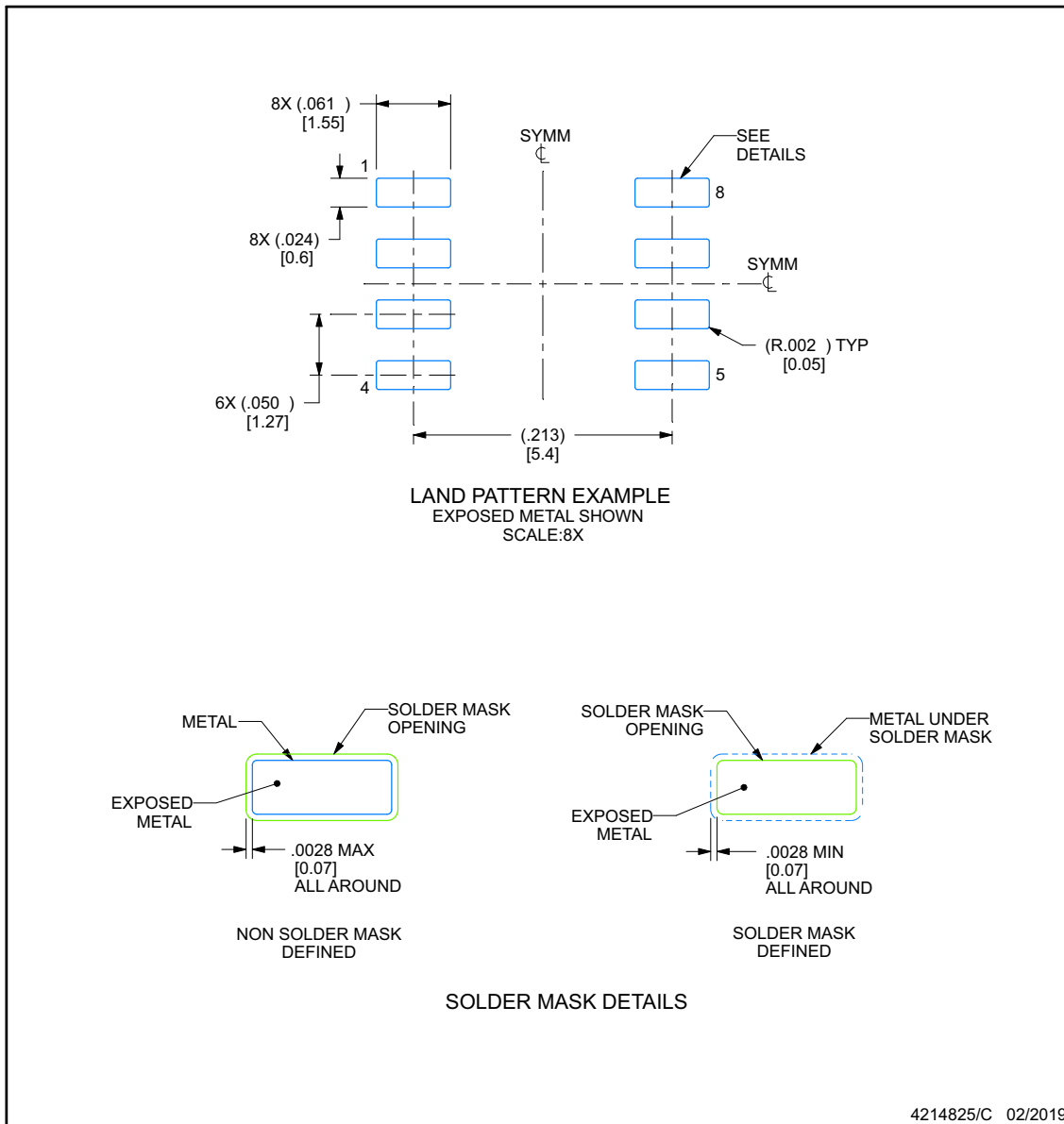
1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.

## EXAMPLE BOARD LAYOUT

**D0008A**

**SOIC - 1.75 mm max height**

SMALL OUTLINE INTEGRATED CIRCUIT



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.

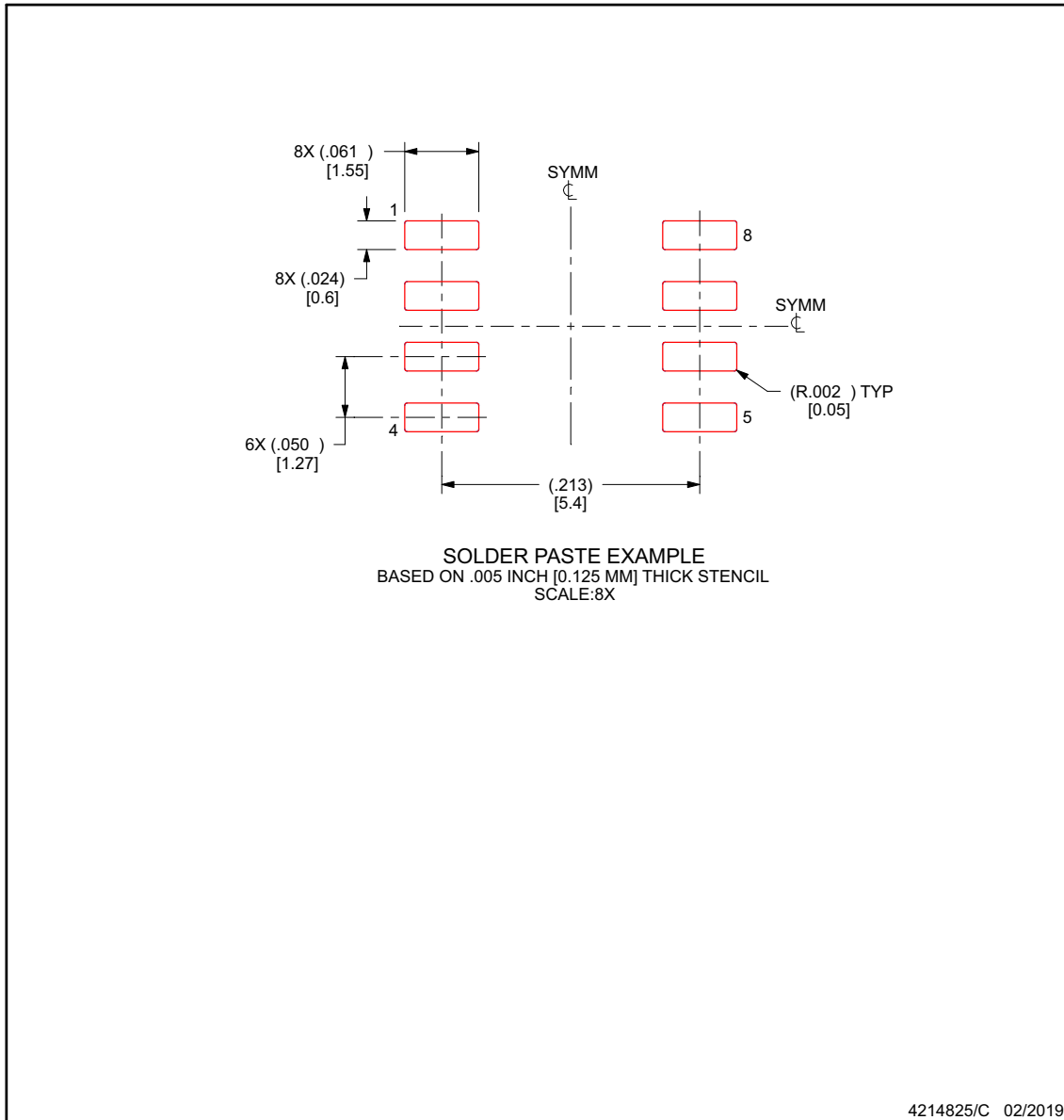


## EXAMPLE STENCIL DESIGN

**D0008A**

**SOIC - 1.75 mm max height**

SMALL OUTLINE INTEGRATED CIRCUIT



NOTES: (continued)

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

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**PACKAGING INFORMATION**

Orderable 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
PTLV2365QDRQ1	ACTIVE	SOIC	D	8	3000	TBD	Call TI	Call TI	-40 to 125		Samples
TLV365QDBVRQ1	ACTIVE	SOT-23	DBV	5	3000	RoHS & Green	SN	Level-1-260C-UNLIM	-40 to 125	Q365	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.

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**OTHER QUALIFIED VERSIONS OF TLV2365-Q1, TLV365-Q1 :**

- Catalog : [TLV2365](#), [TLV365](#)

## 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
TLV365QDBVRQ1	SOT-23	DBV	5	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLV365QDBVRQ1	SOT-23	DBV	5	3000	210.0	185.0	35.0



D0008A

# PACKAGE OUTLINE

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



## NOTES:

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. 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 .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.

# EXAMPLE BOARD LAYOUT

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:8X



SOLDER MASK DETAILS

4214825/C 02/2019

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

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE  
BASED ON .005 INCH [0.125 MM] THICK STENCIL  
SCALE:8X

4214825/C 02/2019

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.



# EXAMPLE BOARD LAYOUT

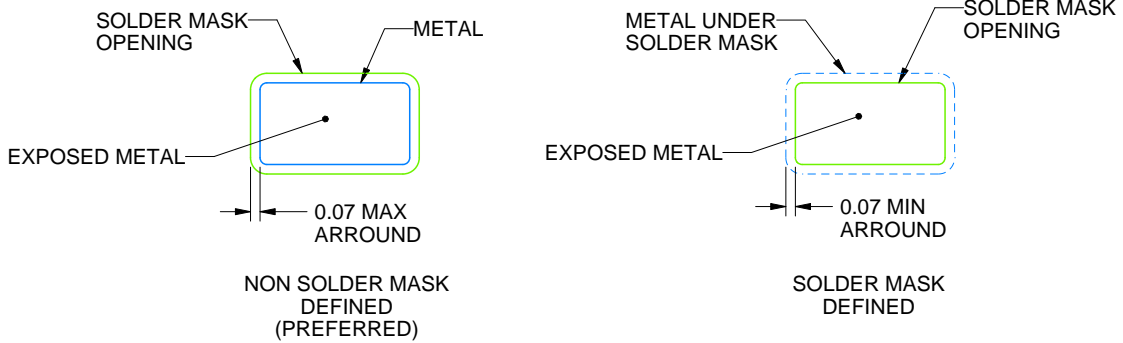
DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:15X



SOLDER MASK DETAILS

4214839/K 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

DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



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

4214839/K 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.

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