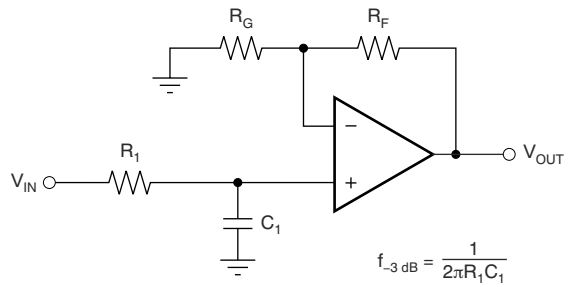
TLV905x-Q1 汽车类 5MHz 15V/µs 高压摆率 RRIO CMOS 运算放大器

1 特性

- 符合面向汽车应用的 AEC-Q100 标准：
  - 温度：–40°C 至 125°C，T_A
- 高压摆率：15V/µs
- 低静态电流：330µA
- 轨至轨输入和输出
- 低输入失调电压：±0.33mV
- 单位增益带宽：5MHz
- 低宽带噪声：15nV/ $\sqrt{Hz}$
- 低输入偏置电流：2pA
- 单位增益稳定
- 内置 RFI 和 EMI 滤波器
- 适用于低成本应用的可扩展 CMOS 运算放大器系列
- 可在电源电压低至 1.8V 的情况下运行

2 应用

- 针对 AEC-Q100 1 级应用进行了优化
- 混合动力汽车/电动汽车逆变器和电机控制
- 混合动力汽车/电动汽车直流/直流转换器
- 混合动力汽车/电动汽车电池管理系统 (BMS)
- 车载充电器 (OBC) 和无线充电器
- 汽车车身电机
- 汽车加热和冷却



$$\frac{V_{OUT}}{V_{IN}} = \left(1 + \frac{R_F}{R_G}\right)\left(\frac{1}{1 + sR_1C_1}\right)$$

单极低通滤波器

3 说明

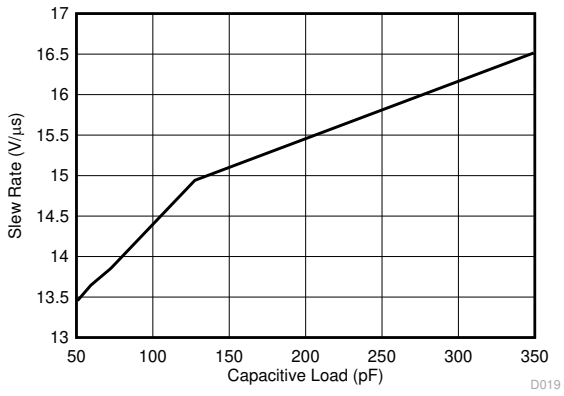
TLV9051-Q1、TLV9052-Q1 和 TLV9054-Q1 器件分别为单通道、双通道和四通道的运算放大器。这些器件可在 1.8V 至 6.0V 的低电压下运行。输入和输出可以在非常高的压摆率下轨到轨运行。这些器件非常适合需要低工作电压、高压摆率和低静态电流的成本受限应用。TLV905x-Q1 系列的容性负载驱动器具有 150pF 的电容，而电阻式开环输出阻抗使其能够在更高的容性负载下更轻松地实现稳定。

TLV905x-Q1 系列器件具有单位增益稳定特性，集成了 RFI 和 EMI 滤波器，并且不会在过驱动情况下出现相位反转，因此非常易于使用。

器件信息

器件型号(1)	通道数	封装	封装尺寸(4)
TLV9051-Q1	单通道	DBV（SOT-23，5）	2.90mm × 2.80mm
		DCK（SC70，5）(3)	2.00mm × 2.10mm
TLV9052-Q1	双通道	D（SOIC，8）(3)	4.90mm × 6.00mm
		PW（TSSOP，8）	3.00mm × 6.40mm
		DGK（VSSOP，8）(3)	3.00mm × 4.90mm
TLV9054-Q1(2)	四通道	D（SOIC，14）(3)	8.65mm × 6.00mm
		PW（TSSOP，14）(3)	5.00mm × 6.40mm

(1) 有关更多信息，请参阅节 10
(2) 该器件仅处于预发布状态。
(3) 该封装仅处于预发布状态。
(4) 封装尺寸（长 × 宽）为标称值，并包括引脚（如适用）。



压摆率与负载电容间的关系

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4 Pin Configuration and Functions

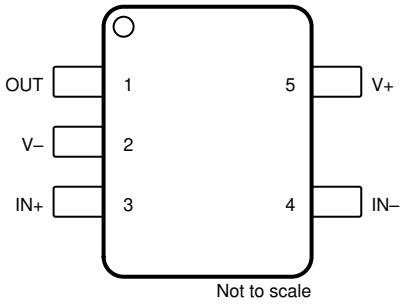


图 4-1. TLV9051-Q1 DBV Package, 5-Pin SOT-23 (Top View)

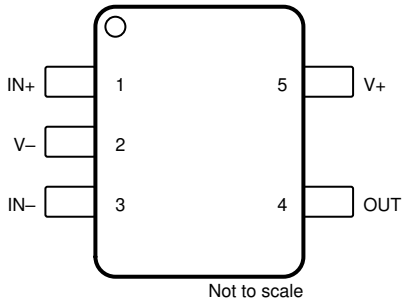


图 4-2. TLV9051-Q1 DCK Package, 5-Pin SC70 (Top View)

表 4-1. Pin Functions: TLV9051-Q1

PIN			TYPE[1]	DESCRIPTION
NAME	SOT-23	SC-70		
IN –	4	3	I	Inverting input
IN+	3	1	I	Noninverting input
OUT	1	4	O	Output
V –	2	2	—	Negative (low) supply or ground (for single-supply operation)
V+	5	5	—	Positive (high) supply

(1) I = input, O = output

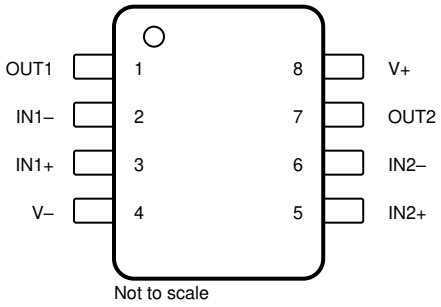


图 4-3. TLV9052-Q1 D, DGK, PW Packages, 8-Pin SOIC, VSSOP, TSSOP (Top View)

表 4-2. Pin Functions: TLV9052-Q1

PIN		TYPE(1)	DESCRIPTION
NAME	NO.		
IN1 –	2	I	Inverting input, channel 1
IN1+	3	I	Noninverting input, channel 1
IN2 –	6	I	Inverting input, channel 2
IN2+	5	I	Noninverting input, channel 2
OUT1	1	O	Output, channel 1
OUT2	7	O	Output, channel 2
V –	4	—	Negative (low) supply or ground (for single-supply operation)
V+	8	—	Positive (high) supply

(1) I = input, O = output

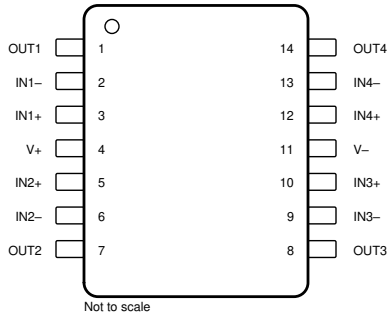


图 4-4. TLV9054-Q1 D, PW Packages, 14-Pin SOIC, TSSOP (Top View)

表 4-3. Pin Functions: TLV9054-Q1

PIN		TYPE(1)	DESCRIPTION
NAME	NO.		
IN1 –	2	I	Inverting input, channel 1
IN1+	3	I	Noninverting input, channel 1
IN2 –	6	I	Inverting input, channel 2
IN2+	5	I	Noninverting input, channel 2
IN3 –	9	I	Inverting input, channel 3
IN3+	10	I	Noninverting input, channel 3
IN4 –	13	I	Inverting input, channel 4
IN4+	12	I	Noninverting input, channel 4
OUT1	1	O	Output, channel 1
OUT2	7	O	Output, channel 2
OUT3	8	O	Output, channel 3
OUT4	14	O	Output, channel 4
V –	11	—	Negative (low) supply or ground (for single-supply operation)
V+	4	—	Positive (high) supply

(1) I = input, O = output

5 Specifications

5.1 Absolute Maximum Ratings

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

			MIN	MAX	UNIT
Supply voltage				7	V
Signal input pins	Voltage(2)	Common-mode	(V–) – 0.5	(V+) + 0.5	V
		Differential(4)		(V+) – (V–) + 0.2	
	Current(2)		–10	10	mA
Output short-circuit(3)			Continuous		mA
Temperature	Specified, T_A		–40	125	°C
	Junction, T_J			150	
	Storage, T_{stg}		–65	150	

(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. Current limit input signals that can swing more than 0.5V beyond the supply rails to 10mA or less.
(3) Short-circuit to ground, one amplifier per package.
(4) Differential input voltages greater than 0.5 V applied continuously can result in a shift to the input offset voltage and quiescent current above the maximum specifications of these parameters. The magnitude of this effect increases as the ambient operating temperature rises.

5.2 ESD Ratings

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

			VALUE	UNIT
$V_{(ESD)}$ - Other Packages	Electrostatic discharge	Human body model (HBM), per AEC-Q100-002(1)	±4000	V
		Charged device model (CDM), per AEC-Q100-001	±1500	

(1) AEC Q100-002 indicates HBM stressing is done in accordance with the ANSI/ESDA/JEDECE JS-001 specification.

5.3 Recommended Operating Conditions

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

		MIN	MAX	UNIT
V_S	Supply voltage	1.8	6	V
V_I	Common mode voltage range	(V–) – 0.1	(V+) + 0.1	V
T_A	Specified temperature	–40	125	°C

5.4 Thermal Information for Single Channel

THERMAL METRIC[1]		TLV9051-Q1		UNIT
		DBV (SOT-23)	DCK (SC70)	
		5 PINS	5 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	232.5	TBD	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	131.0	TBD	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	99.6	TBD	°C/W
ψ_{JT}	Junction-to-top characterization parameter	66.5	TBD	°C/W
ψ_{JB}	Junction-to-board characterization parameter	99.1	TBD	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	N/A	°C/W

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

5.5 Thermal Information for Dual Channel

THERMAL METRIC[1]		TLV9052-Q1			UNIT
		D (SOIC)	DGK (VSSOP)	PW (TSSOP)	
		8 PINS	8 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	TBD	TBD	180.5	℃/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	TBD	TBD	85.2	℃/W
$R_{\theta JB}$	Junction-to-board thermal resistance	TBD	TBD	120.7	℃/W
ψ_{JT}	Junction-to-top characterization parameter	TBD	TBD	15.7	℃/W
ψ_{JB}	Junction-to-board characterization parameter	TBD	TBD	118.1	℃/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	N/A	N/A	℃/W

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

5.6 Thermal Information for Quad Channel

THERMAL METRIC[1]		TLV9054-Q1		UNIT
		D (SOIC)	PW (TSSOP)	
		14 PINS	14 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	TBD	TBD	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	TBD	TBD	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	TBD	TBD	°C/W
ψ_{JT}	Junction-to-top characterization parameter	TBD	TBD	°C/W
ψ_{JB}	Junction-to-board characterization parameter	TBD	TBD	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	N/A	°C/W

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

5.7 Electrical Characteristics: V_S (Total Supply Voltage) = (V+) – (V–) = 1.8V to 5.5V

at T_A = 25°C, R_L = 10kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted);

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OFFSET VOLTAGE						
V_{OS}	Input offset voltage	V_S = 5V		±0.33	±1.85	mV
		V_S = 5V, T_A = –40°C to +125°C			±2.24	
dV_{OS}/dT	Drift	V_S = 5V, T_A = –40°C to +125°C		±0.5		µV/°C
PSRR	Power-supply rejection ratio	V_S = 1.8V – 5.5V, V_{CM} = (V–)		±13	±80	µV/V
	Channel separation, dc	At dc		115		dB
INPUT VOLTAGE RANGE						
V_{CM}	Common-mode voltage	V_S = 1.8V to 5.5V	(V–) – 0.1		(V+) + 0.1	V
CMRR	Common-mode rejection ratio	V_S = 5.5V, (V–) – 0.1V < V_{CM} < (V+) – 1.4V, T_A = –40°C to +125°C	80	96		dB
		V_S = 5.5V, V_{CM} = –0.1V to 5.6V, T_A = –40°C to +125°C	62	79		
		V_S = 1.8V, (V–) – 0.1V < V_{CM} < (V+) – 1.4V, T_A = –40°C to +125°C		88		
		V_S = 1.8V, V_{CM} = –0.1V to 1.9V, T_A = –40°C to +125°C		72		
INPUT BIAS CURRENT						
I_B	Input bias current			±2	±18[2]	pA
		T_A = –40°C to +125°C			±750[2]	pA
I_{OS}	Input offset current			±1	±15[2]	pA
		T_A = –40°C to +125°C			±440[2]	pA
NOISE						
E_n	Input voltage noise (peak-to-peak)	V_S = 5V, f = 0.1Hz to 10Hz		6		$µV_{PP}$
e_n	Input voltage noise density	V_S = 5V, f = 10kHz		15		nV/√Hz
		V_S = 5V, f = 1kHz		20		nV/√Hz
i_n	Input current noise density	f = 1kHz		18		fA/√Hz
INPUT CAPACITANCE						
C_{ID}	Differential			2		pF
C_{IC}	Common-mode			4		pF
OPEN-LOOP GAIN						
A_{OL}	Open-loop voltage gain	V_S = 1.8V, (V–) + 0.04V < V_O < (V+) – 0.04V, R_L = 10kΩ		106		dB
		V_S = 5.5V, (V–) + 0.05V < V_O < (V+) – 0.05V, R_L = 10kΩ	104	128		
		V_S = 1.8V, (V–) + 0.06V < V_O < (V+) – 0.06V, R_L = 2kΩ		108		
		V_S = 5.5V, (V–) + 0.15V < V_O < (V+) – 0.15V, R_L = 2kΩ		130		
FREQUENCY RESPONSE						
GBP	Gain bandwidth product	V_S = 5.5V, G = +1		5		MHz
Φ_m	Phase margin	V_S = 5.5V, G = +1		60		Degrees
SR	Slew rate	V_S = 5.5V, G = +1, C_L = 130pF		15		V/µs
t_S	Settling time	To 0.1%, V_S = 5.5V, 2V step , G = +1, C_L = 100pF		0.75		µs
		To 0.01%, V_S = 5.5V, 2V step , G = +1, C_L = 100pF		1		
t_{OR}	Overload recovery time	V_S = 5.5V, V_{IN} × gain > V_S		0.3		µs
THD + N	Total harmonic distortion + noise[1]	V_S = 5.5V, V_{CM} = 2.5V, V_O = $1V_{RMS}$, G = +1, f = 1kHz		0.0006%		
OUTPUT						

5.7 Electrical Characteristics: V_S (Total Supply Voltage) = (V+) – (V–) = 1.8V to 5.5V （续）

at T_A = 25°C, R_L = 10kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted);

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_O	Voltage output swing from supply rails	V_S = 5.5V, R_L = 10kΩ,			16	mV
		V_S = 5.5V, R_L = 2kΩ,			40	
I_{SC}	Short-circuit current	V_S = 5V		±50		mA
Z_O	Open-loop output impedance	V_S = 5V, f = 5MHz		250		Ω
POWER SUPPLY						
I_Q	Quiescent current per amplifier	V_S = 5.5V, I_O = 0mA,		330	450	μA
		V_S = 5.5V, I_O = 0mA, T_A = –40°C to +125°C			475	

(1) Third-order filter; bandwidth = 80kHz at –3dB.
(2) Specified by design and characterization; not production tested.

5.8 Typical Characteristics

at T_A = 25°C, V_S = 5.5V, R_L = 10kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)

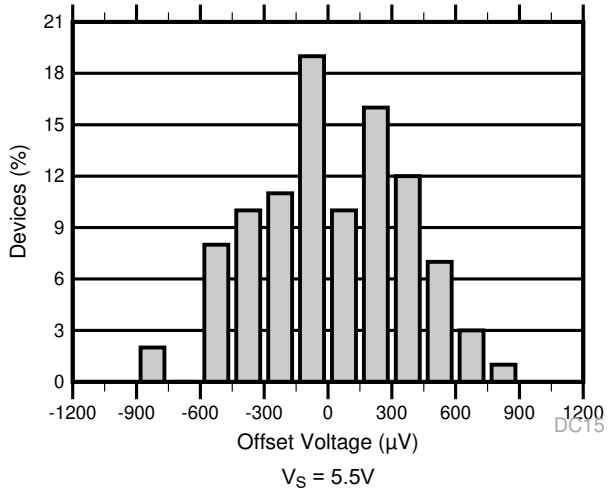


图 5-1. Offset Voltage Production Distribution

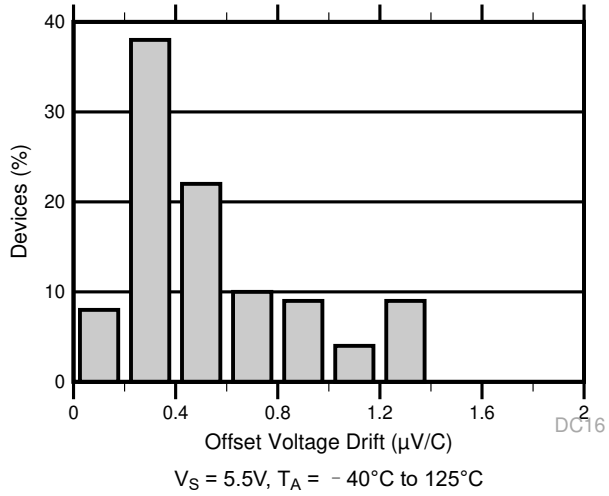


图 5-2. Offset Voltage Drift Distribution

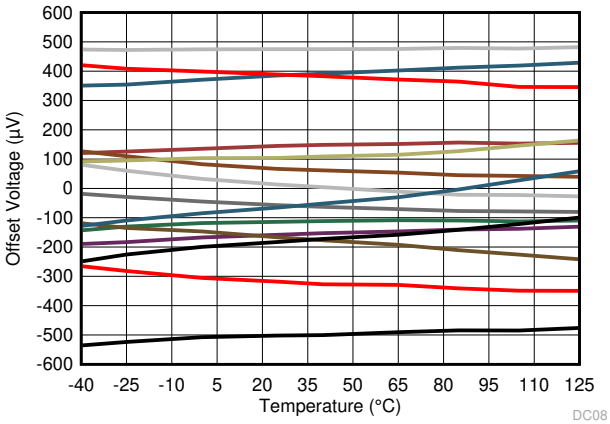


图 5-3. Offset Voltage vs Temperature

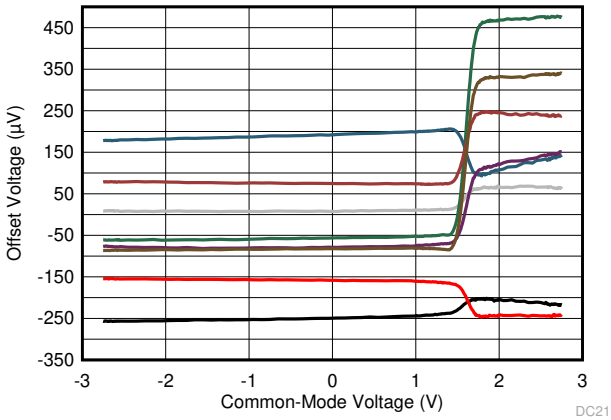


图 5-4. Offset Voltage vs Common-Mode Voltage

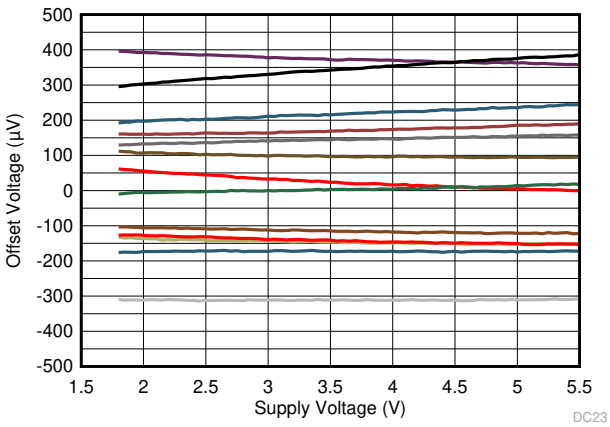


图 5-5. Offset Voltage vs Power Supply

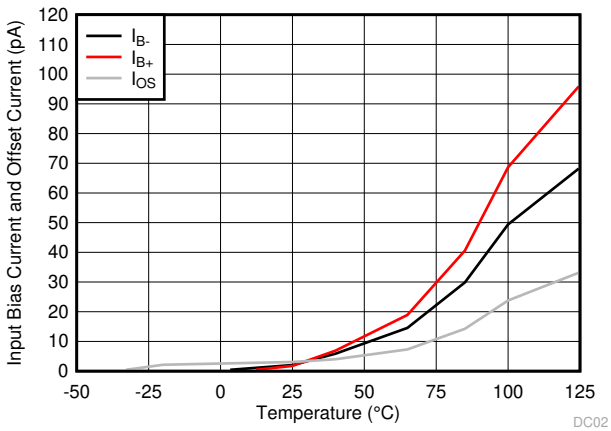


图 5-6. Input Bias Current vs Temperature

5.8 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5.5V, R_L = 10kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)

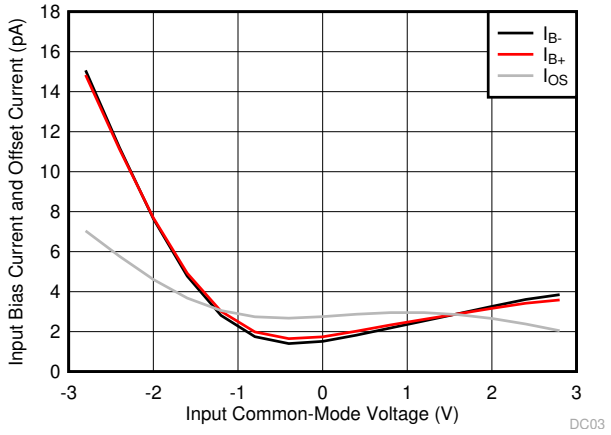


图 5-7. Input Bias Current and Offset Current vs Common-Mode Voltage

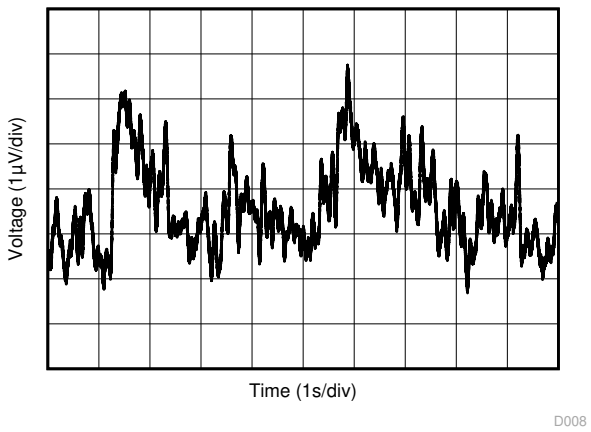


图 5-8. 0.1Hz to 10Hz Input Voltage Noise

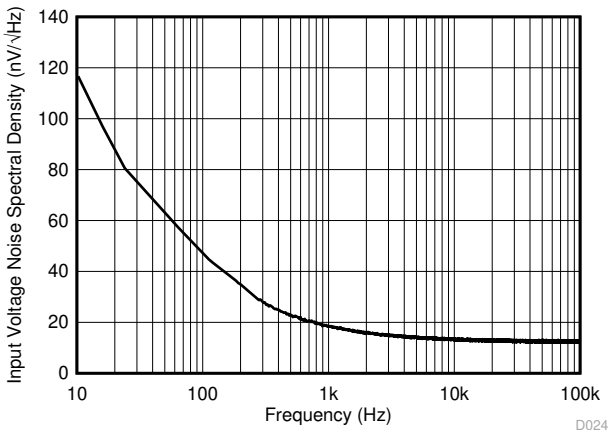


图 5-9. Input Voltage Noise Spectral Density vs Frequency

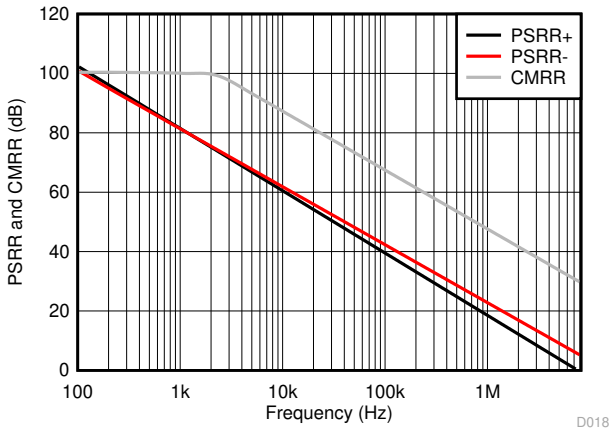


图 5-10. CMRR and PSRR vs Frequency (Referred to Input)

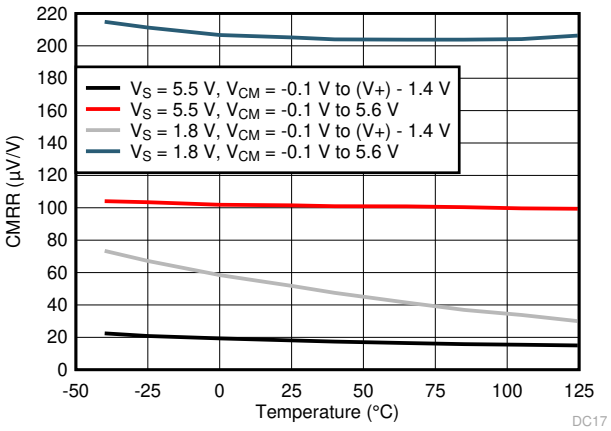
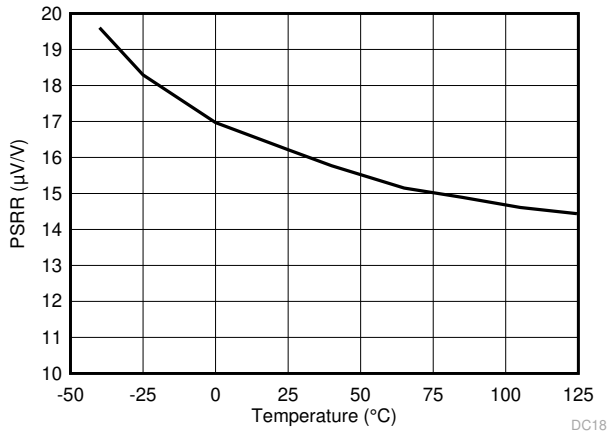


图 5-11. CMRR vs Temperature



VS = 1.8V to 5.5V

图 5-12. PSRR vs Temperature

5.8 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5.5V, R_L = 10kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)

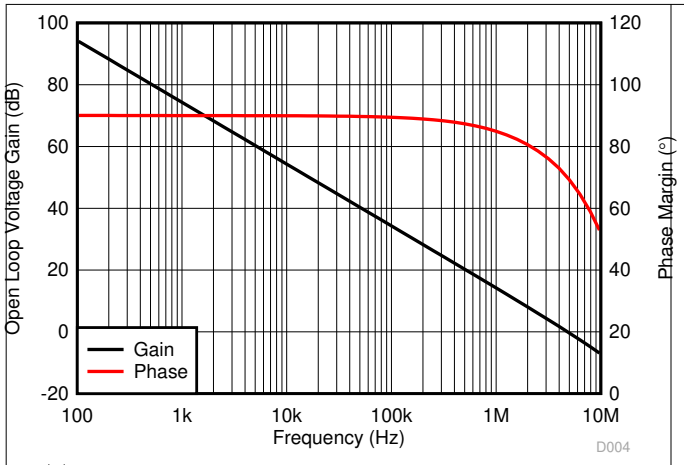


图 5-13. Open Loop Voltage Gain and Phase vs Frequency

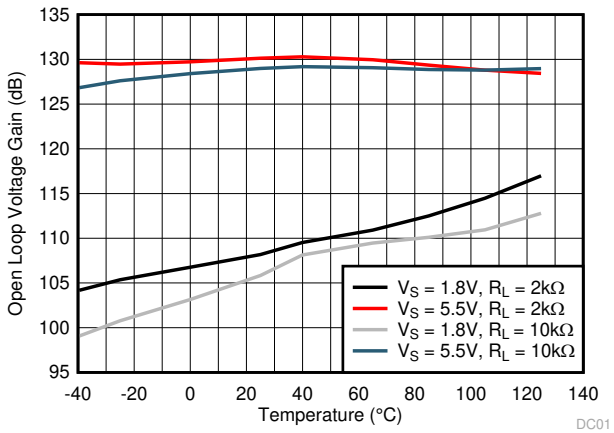


图 5-14. Open Loop Voltage Gain vs Temperature

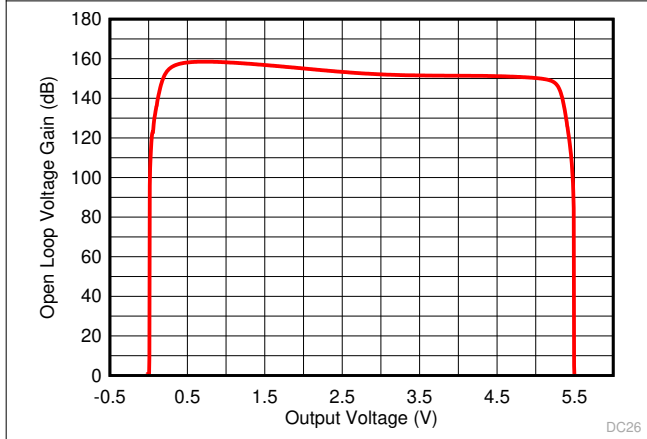


图 5-15. Open Loop Voltage Gain vs Output Voltage

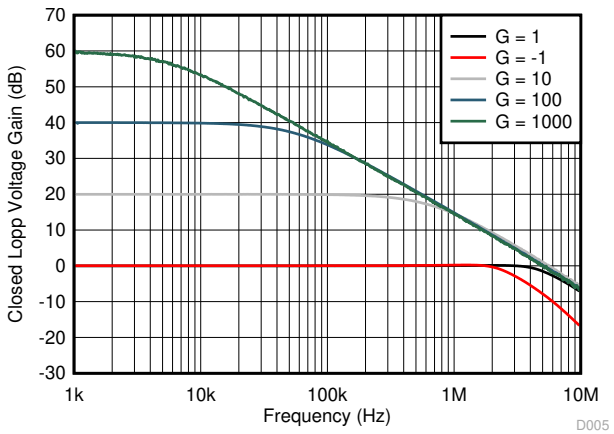


图 5-16. Closed Loop Voltage Gain vs Frequency

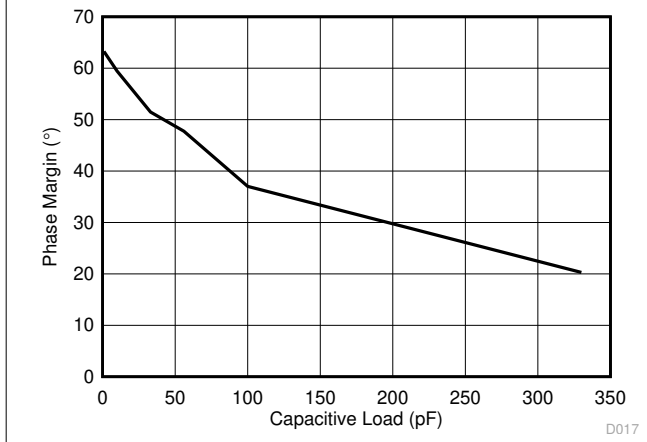


图 5-17. Phase Margin vs Capacitive Load

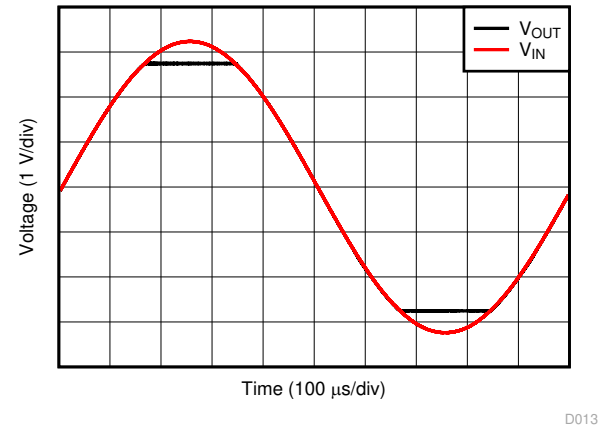
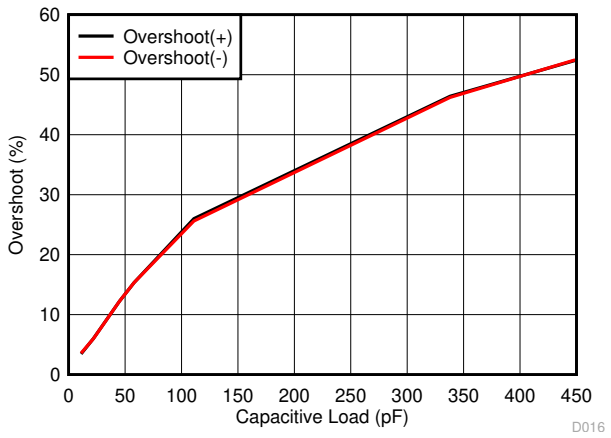


图 5-18. No Phase Reversal

5.8 Typical Characteristics (continued)

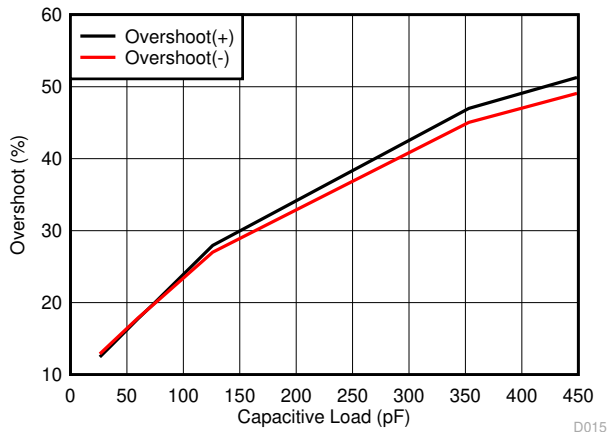
at T_A = 25°C, V_S = 5.5V, R_L = 10kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)



G = +1V/V

V_{OUT} step = 100mV_{p-p}

图 5-19. Small-Signal Overshoot vs Load Capacitance



G = –1V/V

V_{OUT} step = 100mV_{p-p}

图 5-20. Small-Signal Overshoot vs Load Capacitance

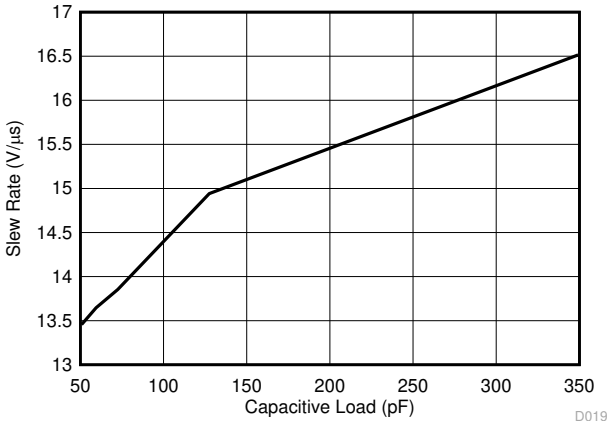
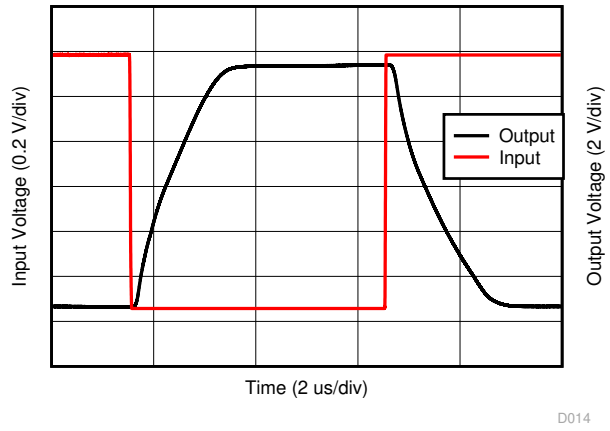
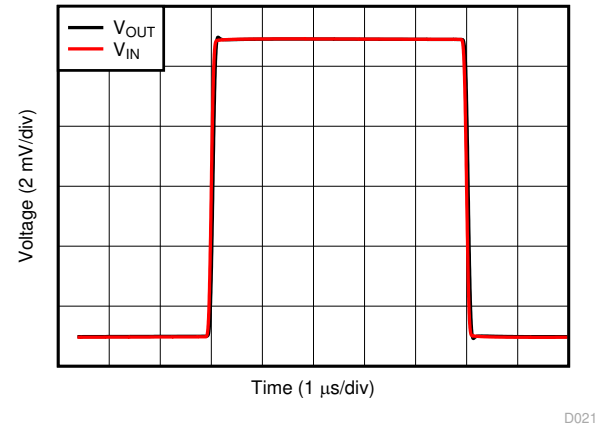


图 5-21. Slew Rate vs Capacitive Load



G = –10V/V

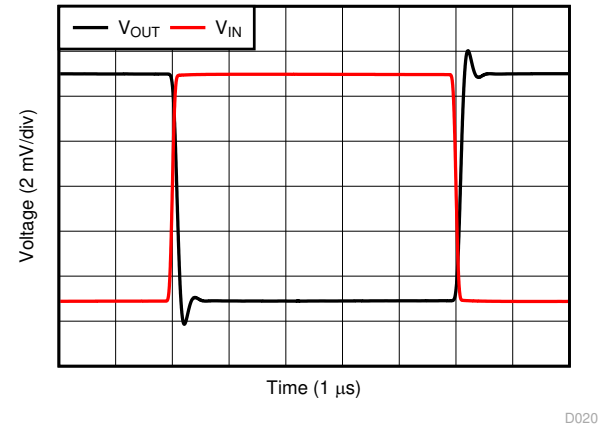
图 5-22. Overload Recovery



G = +1V/V

V_{OUT} step = 10mV_{p-p}

图 5-23. Small-Signal Step Response



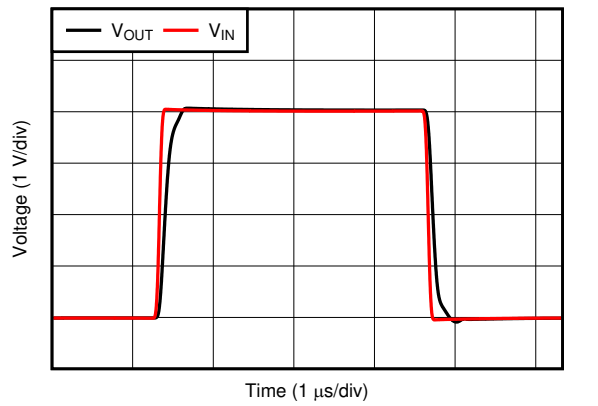
G = –1V/V

V_{OUT} step = 10mV_{p-p}

图 5-24. Small-Signal Step Response

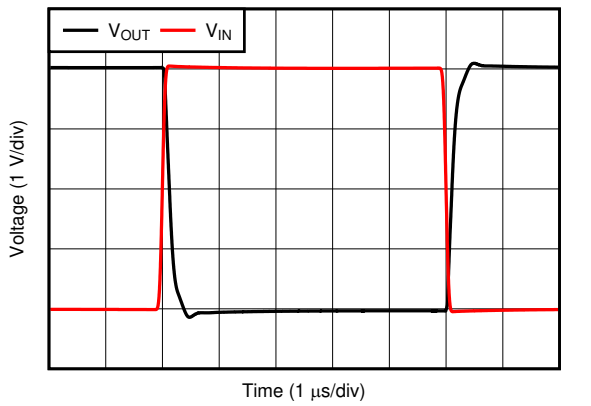
5.8 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5.5V, R_L = 10kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)



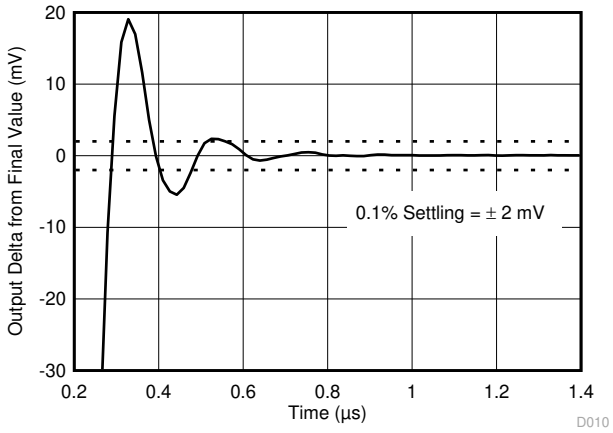
G = +1V/V
V_{OUT} step = $4V_{p-p}$

图 5-25. Large-Signal Step Response



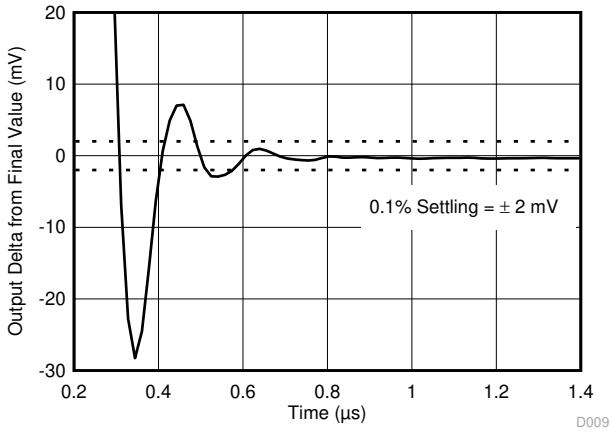
G = –1V/V
V_{OUT} step = $4V_{p-p}$

图 5-26. Large-Signal Step Response



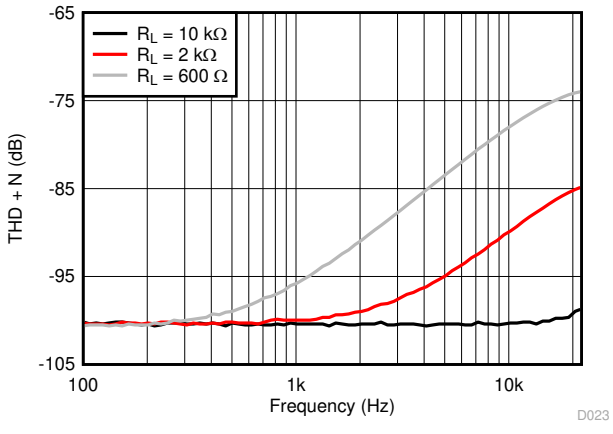
C_L = 100pF G = +1V/V

图 5-27. Positive Large-Signal Settling Time



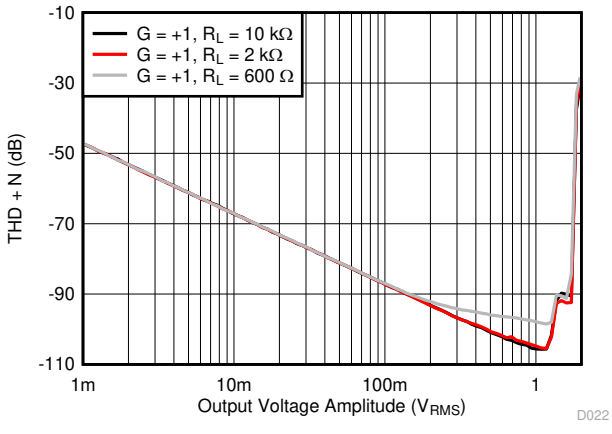
C_L = 100pF G = +1V/V

图 5-28. Negative Large-Signal Settling Time



V_{OUT} = 0.5V_{RMS} G = +1 V_{CM} = 2.5V
BW = 80kHz

图 5-29. THD + N vs Frequency



f = 1kHz G = +1 V_{CM} = 2.5V
BW = 80kHz

图 5-30. THD + N vs Amplitude

5.8 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5.5V, R_L = 10kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)

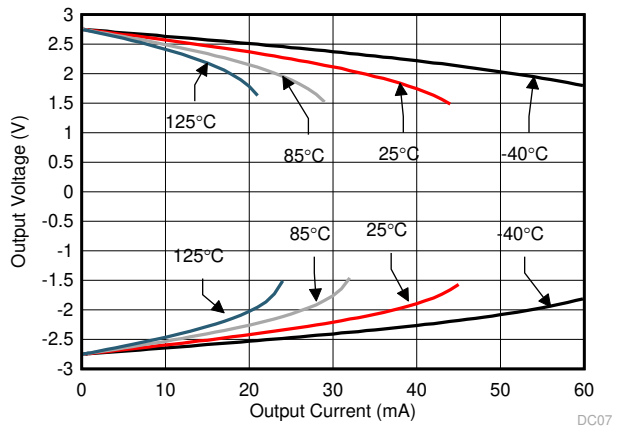


图 5-31. Output Voltage Swing vs Output Current

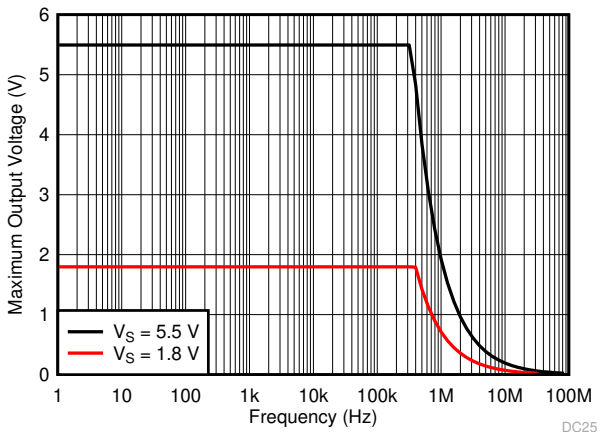


图 5-32. Maximum Output Voltage vs Frequency and Supply Voltage

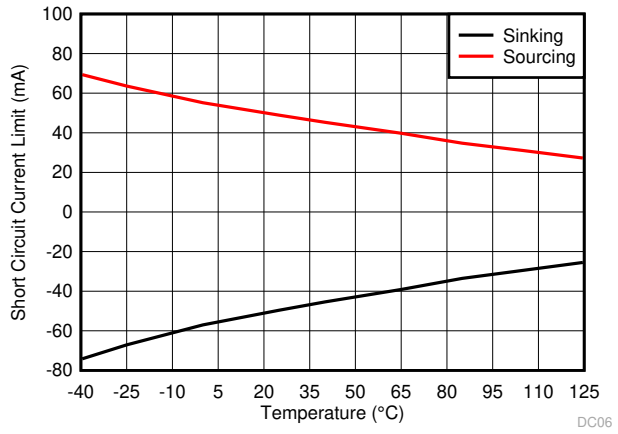


图 5-33. Short-Circuit Current vs Temperature

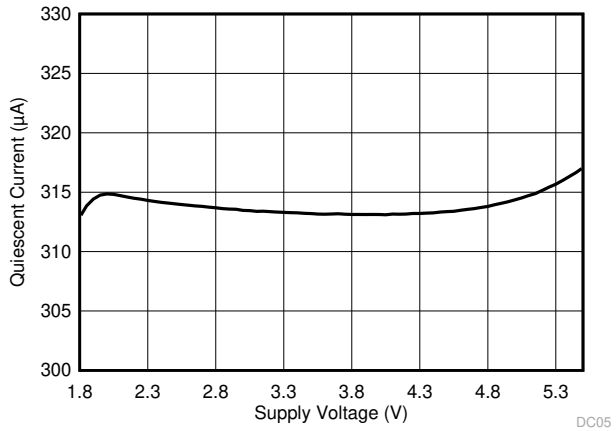


图 5-34. Quiescent Current vs Supply Voltage

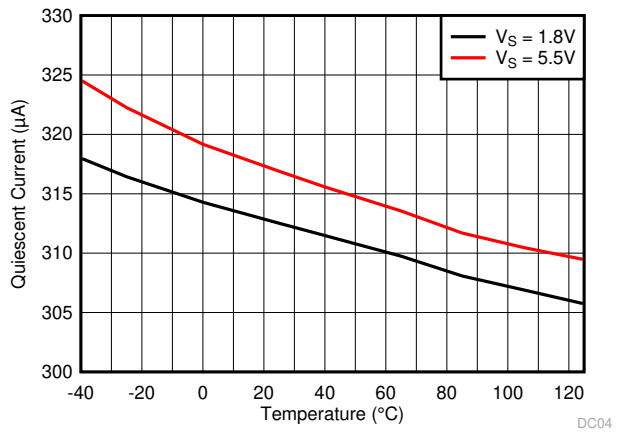


图 5-35. Quiescent Current vs Temperature

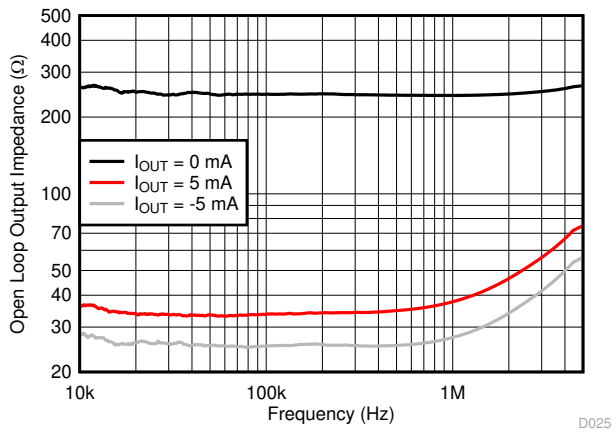
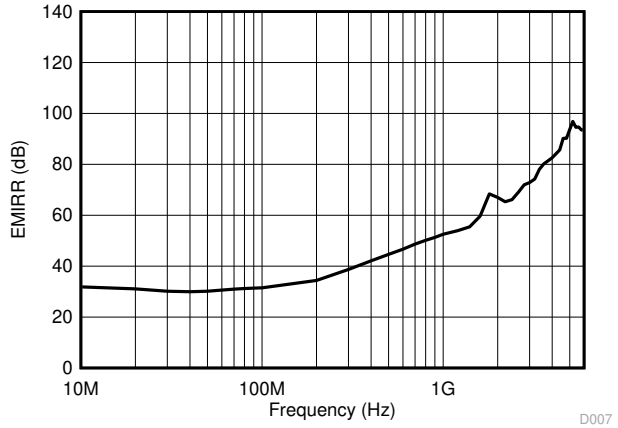


图 5-36. Open-Loop Output Impedance vs Frequency

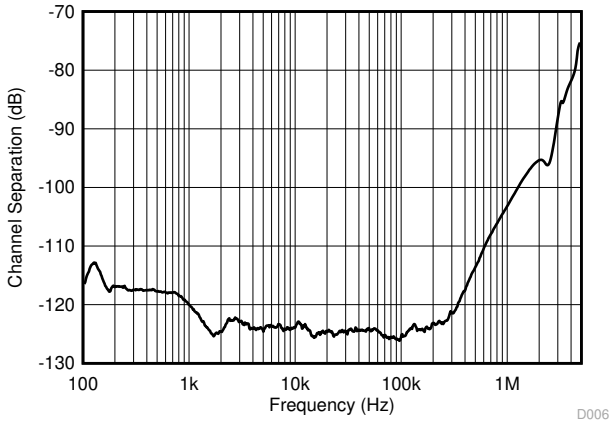
5.8 Typical Characteristics (continued)

at T_A = 25°C, V_S = 5.5V, R_L = 10kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)



P_{RF} = –10dBm

图 5-37. Electromagnetic Interference Rejection Ratio Referred to Noninverting Input (EMIRR+) vs Frequency



P_{RF} = –10dBm

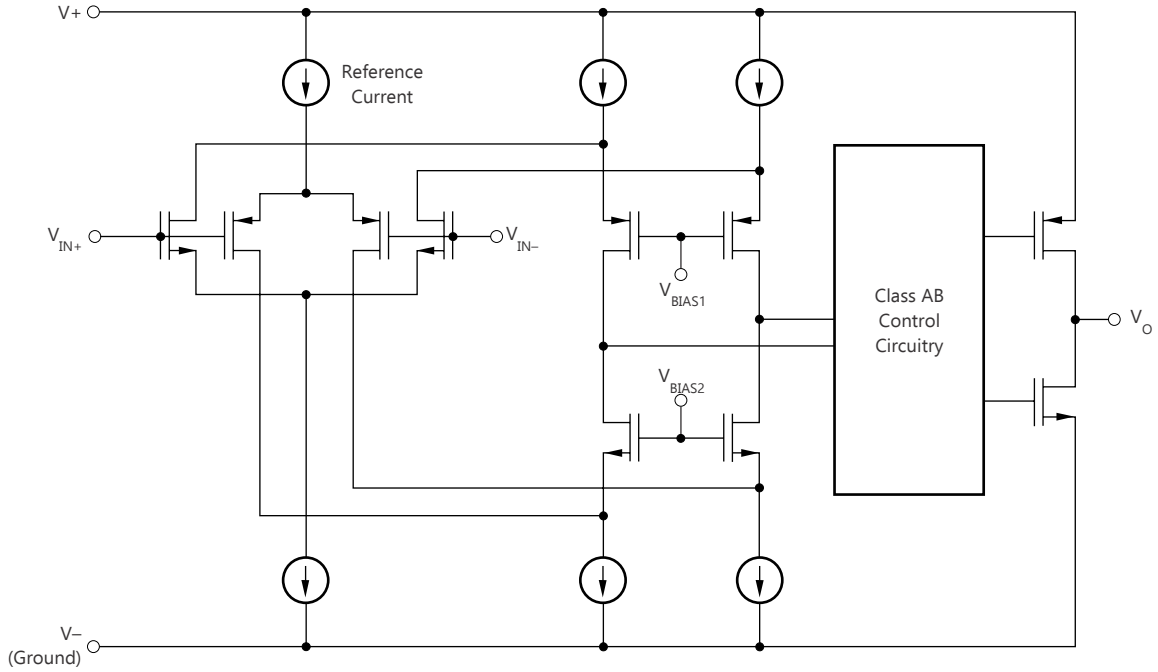
图 5-38. Channel Separation vs Frequency

6 Detailed Description

6.1 Overview

The TLV905x-Q1 devices are a 5MHz family of low-power, rail-to-rail input and output op amps. These devices operate from 1.8V to 6V, are unity-gain stable, and are designed for a wide range of general-purpose applications. The input common-mode voltage range includes both rails and allows the TLV905x-Q1 family to be used in virtually any single-supply application. The unique combination of a high slew rate and low quiescent current makes this family a potential choice for battery-powered motor-drive applications. Rail-to-rail input and output swing significantly increases dynamic range, especially in low-supply applications.

6.2 Functional Block Diagram



6.3 Feature Description

6.3.1 Operating Voltage

The TLV905x-Q1 family of op amps is specified for operation from 1.8V to 6.0V. In addition, many specifications apply from –40°C to 125°C. Parameters that vary significantly with operating voltages or temperature are illustrated in the *Typical Characteristics*.

6.3.2 Rail-to-Rail Input

The input common-mode voltage range of the TLV905x-Q1 family extends 100mV beyond the supply rails for the full supply voltage range of 1.8V to 6.0V. This performance is achieved with a complementary input stage: an N-channel input differential pair in parallel with a P-channel differential pair, as shown in the *Functional Block Diagram*. The N-channel pair is active for input voltages close to the positive rail, typically (V+) – 1.4V to 200mV above the positive supply, whereas the P-channel pair is active for inputs from 200mV below the negative supply to approximately (V+) – 1.4V. There is a small transition region, typically (V+) – 1.2V to (V+) – 1V, in which both pairs are on. This 200mV transition region can vary up to 200mV with process variation. Thus, the transition region (with both stages on) can range from (V+) – 1.4V to (V+) – 1.2V on the low end, and up to (V+) – 1V to (V+) – 0.8V on the high end. Within this transition region, PSRR, CMRR, offset voltage, offset drift, and THD can degrade compared to device operation outside this region.

6.3.3 Rail-to-Rail Output

Designed as low-power, low-voltage operational amplifiers, the TLV905x-Q1 family delivers a robust output drive capability. A class AB output stage with common-source transistors achieves full rail-to-rail output swing capability. For resistive loads of 10kΩ, the output swings to within 16mV of either supply rail, regardless of the applied power-supply voltage. Different load conditions change the ability of the amplifier to swing close to the rails.

6.3.4 EMI Rejection

The TLV905x-Q1 uses integrated electromagnetic interference (EMI) filtering to reduce the effects of EMI from sources such as wireless communications and densely-populated boards with a mix of analog signal chain and digital components. EMI immunity can be improved with circuit design techniques; the TLV905x-Q1 benefits from these design improvements. Texas Instruments has developed the ability to accurately measure and quantify the immunity of an operational amplifier over a broad frequency spectrum extending from 10MHz to 6GHz. 图 6-1 shows the results of this testing on the TLV905x-Q1. 表 6-1 lists the EMIRR IN+ values for the TLV905x-Q1 at particular frequencies commonly encountered in real-world applications. The *EMI Rejection Ratio of Operational Amplifiers* application note contains detailed information on the topic of EMIRR performance as it relates to operational amplifiers.

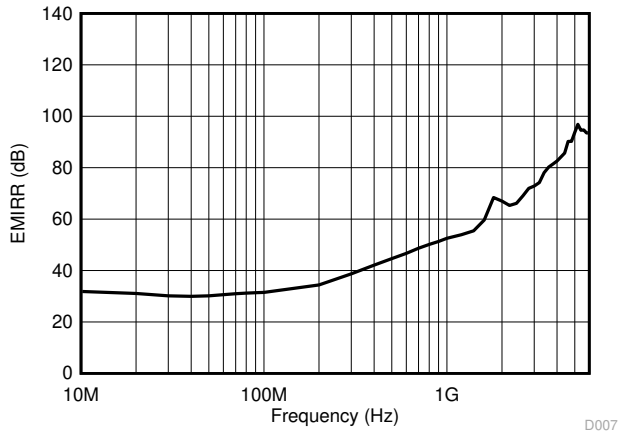


图 6-1. EMIRR Testing

表 6-1. TLV905x-Q1 EMIRR IN+ for Frequencies of Interest

FREQUENCY	APPLICATION OR ALLOCATION	EMIRR IN+
400MHz	Mobile radio, mobile satellite, space operation, weather, radar, ultra-high frequency (UHF) applications	41.8dB
900MHz	Global system for mobile communications (GSM) applications, radio communication, navigation, GPS (to 1.6GHz), GSM, aeronautical mobile, UHF applications	53.1dB
1.8GHz	GSM applications, mobile personal communications, broadband, satellite, L-band (1GHz to 2GHz)	71.8dB
2.4GHz	802.11b, 802.11g, 802.11n, Bluetooth®, mobile personal communications, industrial, scientific and medical (ISM) radio band, amateur radio and satellite, S-band (2GHz to 4GHz)	70.0dB
3.6GHz	Radiolocation, aero communication and navigation, satellite, mobile, S-band	81.2dB
5GHz	802.11a, 802.11n, aero communication and navigation, mobile communication, space and satellite operation, C-band (4GHz to 8GHz)	92.5dB

6.3.5 Overload Recovery

Overload recovery is defined as the time required for the operational amplifier output to recover from a saturated state to a linear state. The output devices of the operational amplifier enter a saturation region when the output voltage exceeds the rated operating voltage, because of the high input voltage or high gain. After the device enters the saturation region, the output devices require time to return to the linear operating state. After the output devices return to a linear operating state, the device begins to slew at the specified slew rate. Therefore, the propagation delay (in case of an overload condition) is the sum of the overload recovery time and the slew time. The overload recovery time for the TLV905x-Q1 family is approximately 300ns.

6.3.6 Electrical Overstress

Designers often ask questions about the capability of an operational amplifier to withstand electrical overstress. These questions tend to focus on the device inputs, but can involve the supply voltage pins or even the output pin. Each of these different pin functions have electrical stress limits determined by the voltage breakdown characteristics of the particular semiconductor fabrication process and specific circuits connected to the pin. Additionally, internal electrostatic discharge (ESD) protection is built into these circuits to protect them from accidental ESD events both before and during product assembly.

Having a good understanding of this basic ESD circuitry and the relevance ESD circuitry has to an electrical overstress event is helpful. 图 6-2 shows the ESD circuits contained in the TLV905x-Q1 devices. The ESD protection circuitry involves several current-steering diodes connected from the input and output pins and routed back to the internal power supply lines, where the diode routes meet at an absorption device internal to the operational amplifier. This protection circuitry is intended to remain inactive during normal circuit operation.

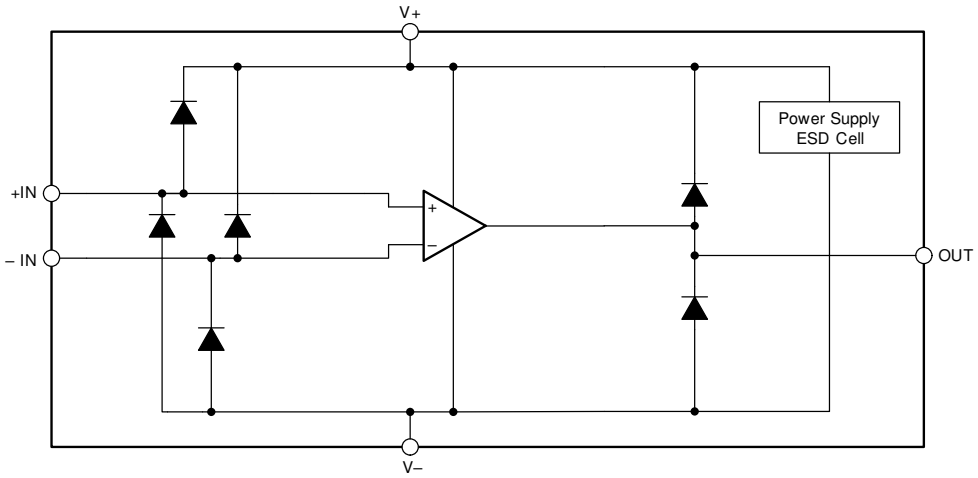


图 6-2. Equivalent Internal ESD Circuitry

6.3.7 Input Protection

The TLV905x-Q1 family incorporates internal ESD protection circuits on all pins. For input and output pins, this protection primarily consists of current-steering diodes connected between the input and power-supply pins. These ESD protection diodes provide in-circuit, input overdrive protection, as long as the current is limited to 10mA (for more information, see *Absolute Maximum Ratings*). 图 6-3 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 and the value must be kept to a minimum in noise-sensitive applications.

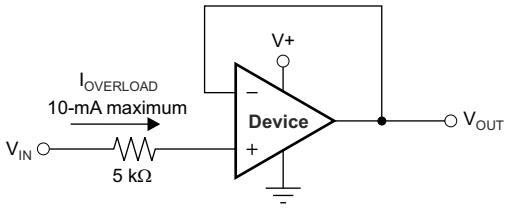


图 6-3. Input Current Protection

6.4 Device Functional Modes

The TLV905x-Q1 family is operational when the power-supply voltage is between 1.8V (±0.9V) and 6.0V (±3.0V).

7 Application and Implementation

备注

以下应用部分中的信息不属于 TI 元件规格，TI 不担保其准确性和完整性。TI 的客户负责确定元件是否适合其用途，以及验证和测试其设计实现以确认系统功能。

7.1 Application Information

The TLV905x-Q1 family features 5MHz bandwidth and very high slew rate of 15V/µs with only 330µA of supply current per channel, providing excellent AC performance at very low-power consumption. DC applications are well served with a very low input noise voltage of 15nV/ √ Hz at 10kHz, low input bias current, and a typical input offset voltage of 0.33mV.

7.2 Typical Low-Side Current Sense Application

图 7-1 shows the TLV905x-Q1 configured in a low-side current sensing application.

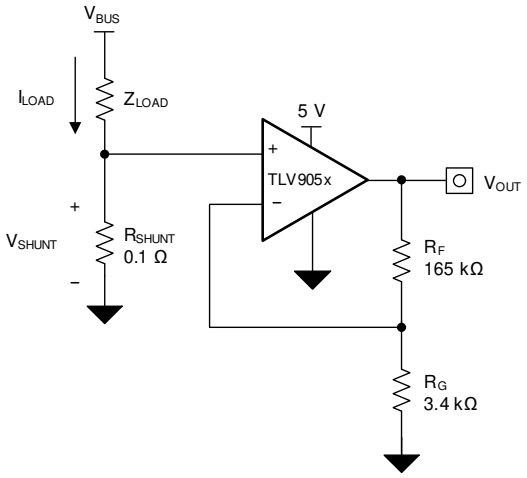


图 7-1. TLV905x-Q1 in a Low-Side, Current-Sensing Application

7.2.1 Design Requirements

The design requirements for this design are:

- Load current: 0A to 1A
- Output voltage: 4.95V
- Maximum shunt voltage: 100mV

7.2.2 Detailed Design Procedure

The transfer function of the circuit in 图 7-1 is given in 方程式 1.

$$V_{OUT} = I_{LOAD} \times R_{SHUNT} \times Gain \quad (1)$$

The load current (I_{LOAD}) produces a voltage drop across the shunt resistor (R_{SHUNT}). The load current is set from 0A to 1A. To keep the shunt voltage below 100mV at maximum load current, the largest shunt resistor is defined using 方程式 2.

$$R_{SHUNT} = \frac{V_{SHUNT\_MAX}}{I_{LOAD\_MAX}} = \frac{100\ mV}{1\ A} = 100\ m\Omega \quad (2)$$

Using 方程式 2, R_{SHUNT} equals 100m Ω. The voltage drop produced by I_{LOAD} and R_{SHUNT} is amplified by the TLV905x-Q1 device to produce an output voltage of approximately 0V to 4.95V. 方程式 3 calculates the gain required for the TLV905x-Q1 device to produce the required output voltage.

$$Gain = \frac{(V_{OUT\_MAX} - V_{OUT_{MIN}})}{(V_{IN\_MAX} - V_{IN\_MIN})} \quad (3)$$

Using 方程式 3, the required gain equals 49.5V/V, which is set with the R_F and R_G resistors. 方程式 4 sizes the R_F and R_G, resistors to set the gain of the TLV905x-Q1 device to 49.5V/V.

$$Gain = 1 + \frac{(R_F)}{(R_G)} \quad (4)$$

Selecting R_F to equal 165k Ω and R_G to equal 3.4k Ω provides a combination that equals approximately 49.5V/V. 图 7-2 shows the measured transfer function of the circuit shown in 图 7-1.

7.2.3 Application Curve

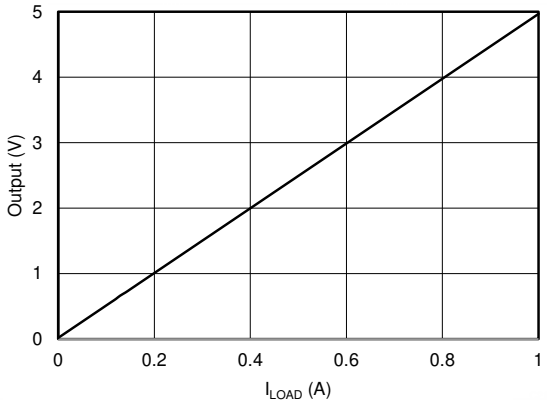


图 7-2. Low-Side, Current-Sense Transfer Function

7.3 Power Supply Recommendations

The TLV905x-Q1 family is specified for operation from 1.8V to 6.0V (±0.9V to ±3.0V); many specifications apply from –40°C to 125°C. The *Typical Characteristics* section presents parameters that can exhibit significant variance with regard to operating voltage or temperature.

> 小心
>
> Supply voltages larger than 7V can permanently damage the device; for more information, see the *Absolute Maximum Ratings* table.

Place 0.1µF bypass capacitors close to the power-supply pins to reduce errors coupling in from noisy or high-impedance power supplies. For more-detailed information on bypass capacitor placement, see 图 7-3.

7.4 Layout

7.4.1 Layout Guidelines

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

- Noise can propagate into analog circuitry through the power pins of the circuit as a whole, as well as through the op amp. Bypass capacitors are used to reduce the coupled noise by providing low-impedance power sources local to the analog circuitry.
  - Connect low-ESR, 0.1µF 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.
- 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 electromagnetic interference (EMI) noise pickup. Take care to physically separate digital and analog grounds, paying attention to the flow of the ground current. For more detailed information, see *Circuit Board Layout Techniques*.
- 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. As illustrated in 图 7-3, keeping R_F and R_G close to the inverting input minimizes parasitic capacitance on the inverting input.
- 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.
- Cleaning the PCB following board assembly is recommended for best performance.
- Any precision integrated circuit can experience performance shifts resulting from moisture ingress into the plastic package. Following any aqueous PCB cleaning process, baking the PCB assembly is recommended to remove moisture introduced into the device packaging during the cleaning process. A low-temperature, post-cleaning bake at 85°C for 30 minutes is sufficient for most circumstances.

7.4.2 Layout Example

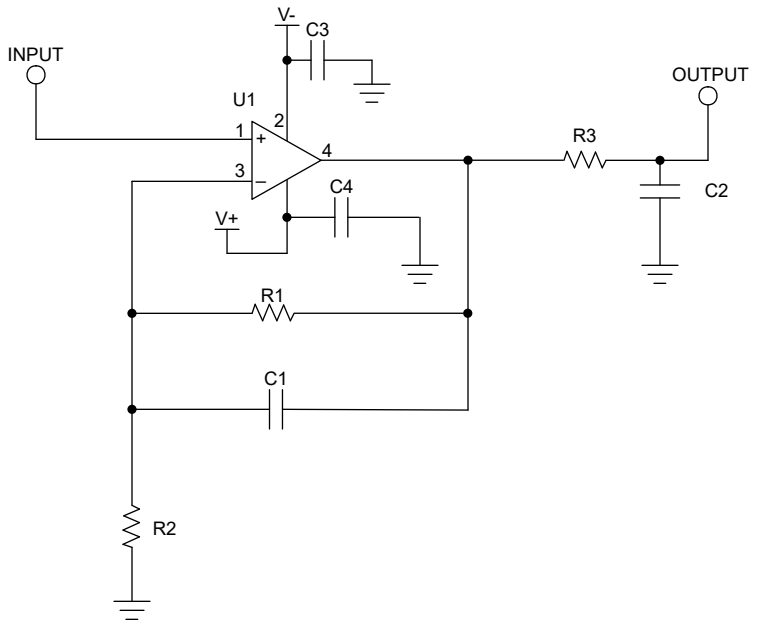


图 7-3. Schematic for Noninverting Configuration Layout Example

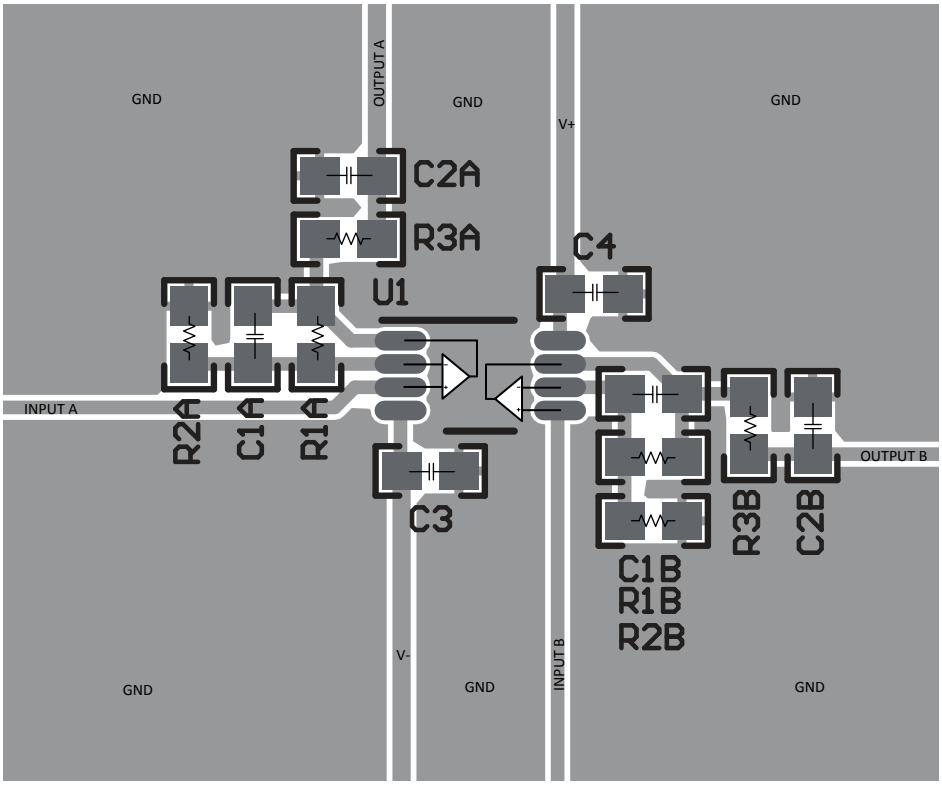


图 7-4. Example Layout for VSSOP-8 (DGK) Package

8 Device and Documentation Support

8.1 器件支持

8.1.1 开发支持

8.1.1.1 TINA-TI™（免费软件下载）

TINA™ 是一款基于 SPICE 引擎的 简单、功能强大且易于使用的电路仿真程序。TINA-TI 是 TINA 软件的一款免费全功能版本，除了一系列无源和有源模型外，此版本软件还预先载入了一个宏模型库。TINA-TI 提供所有传统的 SPICE 直流、瞬态和频域分析，以及其他设计功能。

TINA-TI 可通过模拟电子实验室设计中心免费下载，该软件提供了丰富的后处理能力，允许用户以各种方式格式化结果。虚拟仪器提供选择输入波形和探测电路节点、电压以及波形的能力，从而构建一个动态的快速启动工具。

备注

这些文件要求安装 TINA 软件（从 DesignSoft™）或者 TINA-TI 软件。请从 TINA-TI 文件夹中下载免费的 TINA-TI 软件。

8.2 Documentation Support

8.2.1 Related Documentation

For related documentation, see the following:

- Texas Instruments, *EMI Rejection Ratio of Operational Amplifiers* application note
- Texas Instruments, *Low Voltage, High Slew Rate Op-amps for Motor Drive Circuits* application note
- Texas Instruments, *TI Analog Circuit Cookbook* Analog Engineer's Circuit
- Texas Instruments, *TI Precision Labs - Amplifiers* training video

8.3 接收文档更新通知

要接收文档更新通知，请导航至 ti.com 上的器件产品文件夹。点击*通知* 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。

8.4 支持资源

TI E2E™ 中文支持论坛是工程师的重要参考资料，可直接从专家处获得快速、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，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。

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8.6 静电放电警告

静电放电 (ESD) 会损坏这个集成电路。德州仪器 (TI) 建议通过适当的预防措施处理所有集成电路。如果不遵守正确的处理和安装程序，可能会损坏集成电路。

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。

8.7 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。

9 Revision History

注：以前版本的页码可能与当前版本的页码不同

Changes from Revision A (May 2024) to Revision B (May 2024)	Page
• Added footnote about extended high differential input voltage usage	6
• Changed the maximum input offset voltage across temperature from 2mV to 2.24mV	8

Changes from Revision * (February 2024) to Revision A (May 2024)	Page
• 向*特性* 部分添加了 AEC-Q100 认证	1
• 将 SOT-23 (5) 和 TSSOP (8) 封装状态从*预发布* 更改为*正在供货*	1

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 without revision of this document. For browser-based versions of this data sheet, see the left-hand navigation pane.

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
TLV9051QDBVRQ1	ACTIVE	SOT-23	DBV	5	3000	RoHS & Green	Call TI	Level-1-260C-UNLIM	-40 to 125	TL51Q	Samples
TLV9052QPWRQ1	ACTIVE	TSSOP	PW	8	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	QTL905	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.

OTHER QUALIFIED VERSIONS OF TLV9051-Q1, TLV9052-Q1 :

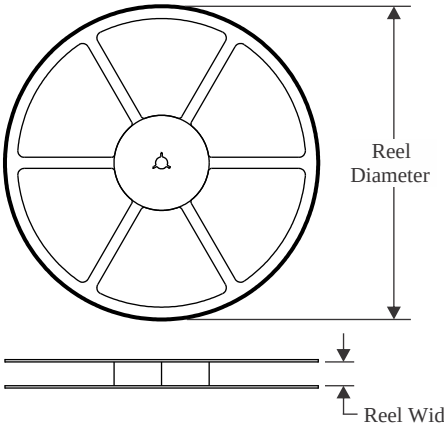
- Catalog : TLV9051, TLV9052

NOTE: Qualified Version Definitions:

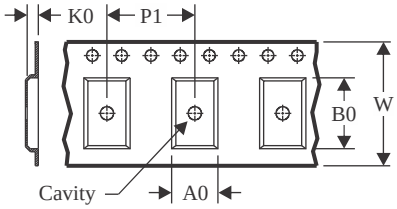
- Catalog - TI's standard catalog product

TAPE AND REEL INFORMATION

REEL DIMENSIONS

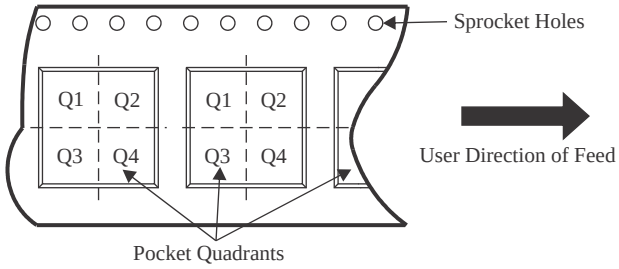


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

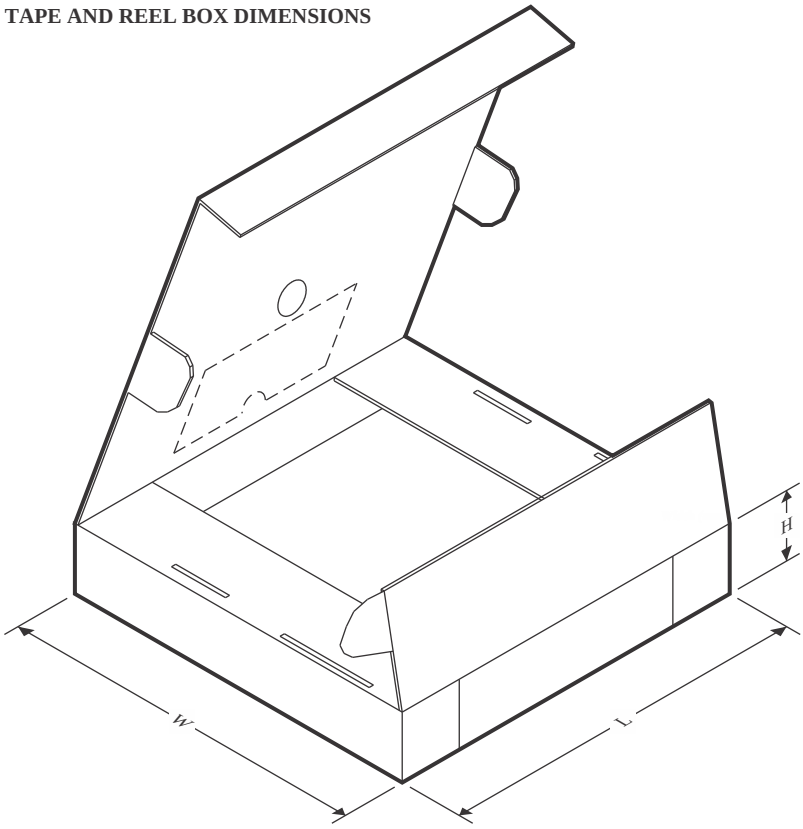
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TLV9051QDBVRQ1	SOT-23	DBV	5	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TLV9052QPWRQ1	TSSOP	PW	8	3000	330.0	12.4	7.0	3.6	1.6	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)
TLV9051QDBVRQ1	SOT-23	DBV	5	3000	210.0	185.0	35.0
TLV9052QPWRQ1	TSSOP	PW	8	3000	356.0	356.0	35.0

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