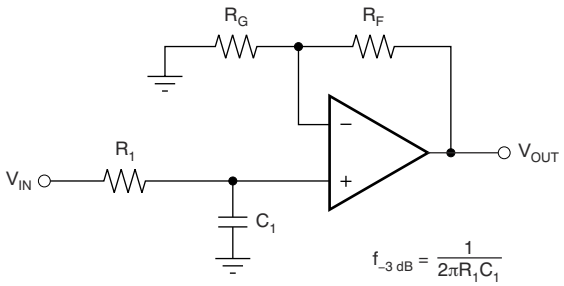
TLV905x-Q1 Automotive 5MHz, 15V/µs High Slew-Rate, RRIO, CMOS Op Amp

1 Features

- AEC-Q100 qualified for automotive applications:
  - Temperature: –40°C to 125°C, T_A
- High slew rate: 15V/µs
- Low quiescent current: 330µA
- Rail-to-rail input and output
- Low input offset voltage: ±0.33mV
- Unity-gain bandwidth: 5MHz
- Low broadband noise: 15nV/√Hz
- Low input bias current: 2pA
- Unity-gain stable
- Internal RFI and EMI filter
- Scalable family of CMOS op amps for low-cost applications
- Operational at supply voltages as low as 1.8V

2 Applications

- Optimized for AEC-Q100 grade 1 applications
- HEV/EV traction inverter and motor control
- HEV/EV DC/DC converter
- HEV/EV battery-management system (BMS)
- On-board (OBC) and wireless charger
- Automotive body motors
- Automotive heating and cooling



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

Single-Pole, Low-Pass Filter

3 Description

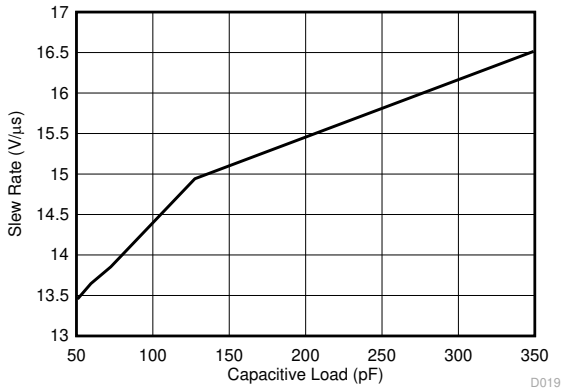
The TLV9051-Q1, TLV9052-Q1, and TLV9054-Q1 devices are single, dual, and quad operational amplifiers, respectively. The devices are designed for low voltage operation from 1.8V to 6.0V. The inputs and outputs can operate from rail to rail at a very high slew rate. These devices are an excellent choice for cost-constrained applications where low-voltage operation, high slew rate, and low quiescent current is needed. The capacitive-load drive of the TLV905x-Q1 family is 150pF, and the resistive open-loop output impedance makes stabilization easier with much higher capacitive loads.

The TLV905x-Q1 family is easy to use due to the devices being unity-gain stable, including a RFI and EMI filter, and being free from phase reversal in an overdrive condition.

Device Information

PART NUMBER(1)	CHANNEL COUNT	PACKAGE	PACKAGE SIZE(4)
TLV9051-Q1	Single	DBV (SOT-23, 5)	2.90mm × 2.80mm
		DCK (SC70, 5)(3)	2.00mm × 2.10mm
TLV9052-Q1	Dual	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)	Quad	D (SOIC, 14)(3)	8.65mm × 6.00mm
		PW (TSSOP, 14)(3)	5.00mm × 6.40mm

(1) For more information, see Section 10
(2) This device is for preview only.
(3) This package is for preview only.
(4) The package size (length x width) is a nominal value and includes pins, where applicable.



Slew Rate vs Load Capacitance

An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. UNLESS OTHERWISE NOTED, this document contains PRODUCTION DATA.

Table of Contents

1 Features....1
2 Applications....1
3 Description....1
4 Pin Configuration and Functions....3
5 Specifications....6
5.1 Absolute Maximum Ratings....6
5.2 ESD Ratings....6
5.3 Recommended Operating Conditions....6
5.4 Thermal Information for Single Channel....7
5.5 Thermal Information for Dual Channel....7
5.6 Thermal Information for Quad Channel....7
5.7 Electrical Characteristics: V_S (Total Supply Voltage) = (V+) – (V–) = 1.8V to 5.5V....8
5.8 Typical Characteristics....10
6 Detailed Description....17
6.1 Overview....17
6.2 Functional Block Diagram....17
6.3 Feature Description....18
6.4 Device Functional Modes....20
7 Application and Implementation....21
7.1 Application Information....21
7.2 Typical Low-Side Current Sense Application....21
7.3 Power Supply Recommendations....23
7.4 Layout....23
8 Device and Documentation Support....25
8.1 Device Support....25
8.2 Documentation Support....25
8.3 Receiving Notification of Documentation Updates....25
8.4 Support Resources....25
8.5 Trademarks....25
8.6 Electrostatic Discharge Caution....25
8.7 Glossary....25
9 Revision History....26
10 Mechanical, Packaging, and Orderable Information....26

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4 Pin Configuration and Functions

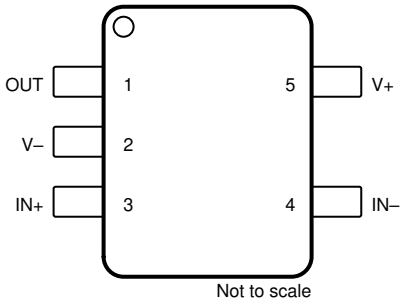


Figure 4-1. TLV9051-Q1 DBV Package, 5-Pin SOT-23 (Top View)

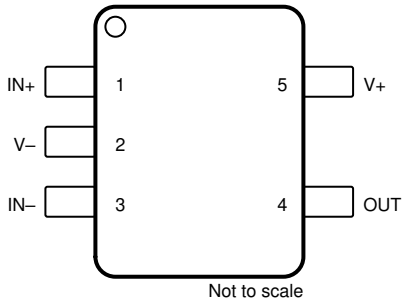


Figure 4-2. TLV9051-Q1 DCK Package, 5-Pin SC70 (Top View)

Table 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

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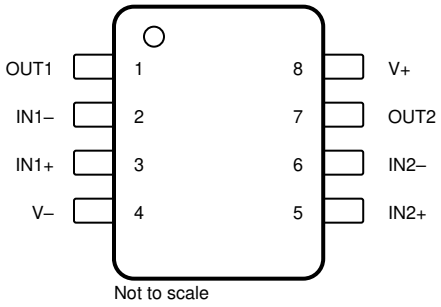


Figure 4-3. TLV9052-Q1 D, DGK, PW Packages, 8-Pin SOIC, VSSOP, TSSOP (Top View)

Table 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

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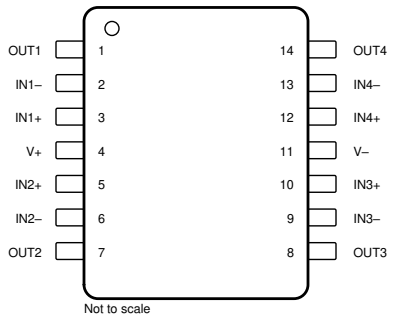


Figure 4-4. TLV9054-Q1 D, PW Packages, 14-Pin SOIC, TSSOP (Top View)

Table 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

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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

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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	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	TBD	TBD	85.2	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	TBD	TBD	120.7	°C/W
ψ_{JT}	Junction-to-top characterization parameter	TBD	TBD	15.7	°C/W
ψ_{JB}	Junction-to-board characterization parameter	TBD	TBD	118.1	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	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.

5.6 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.

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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						
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	

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

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
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.

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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)

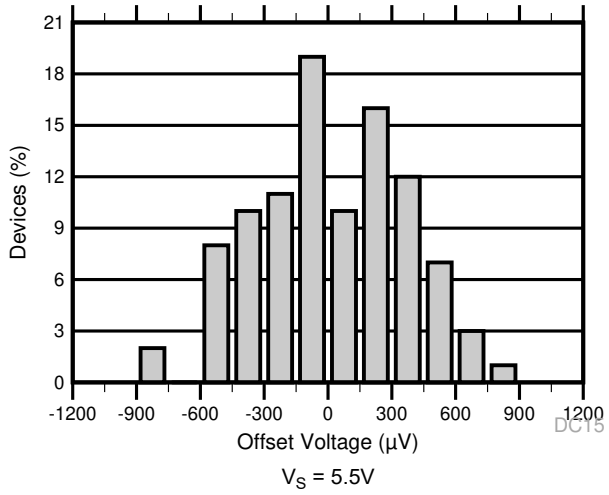


Figure 5-1. Offset Voltage Production Distribution

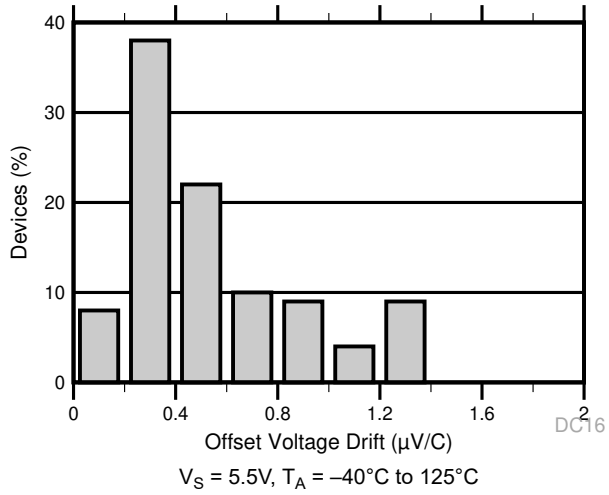


Figure 5-2. Offset Voltage Drift Distribution

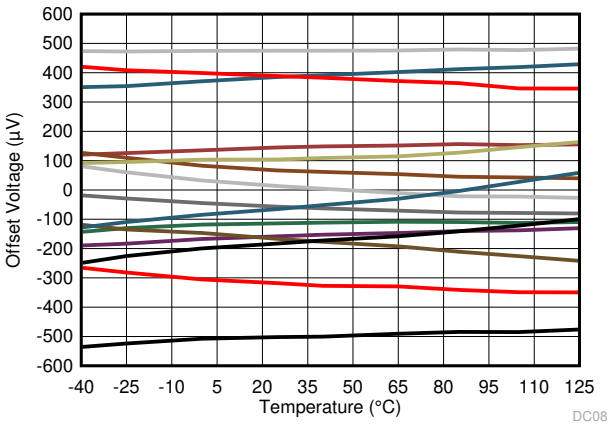


Figure 5-3. Offset Voltage vs Temperature

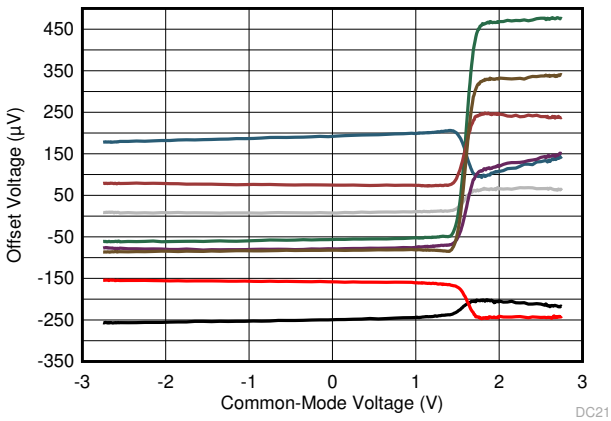


Figure 5-4. Offset Voltage vs Common-Mode Voltage

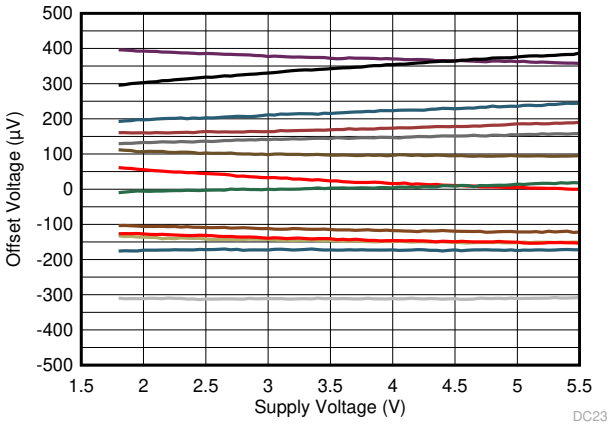


Figure 5-5. Offset Voltage vs Power Supply

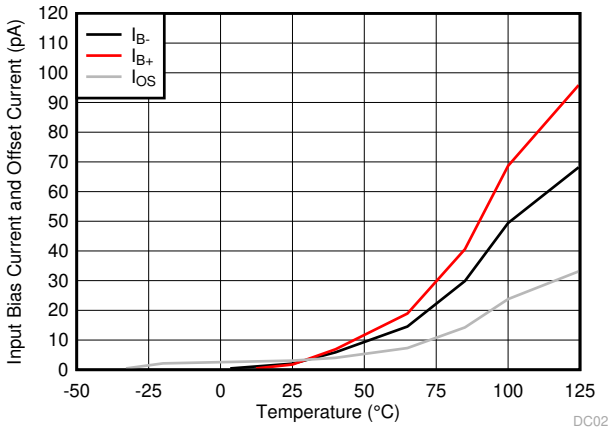


Figure 5-6. Input Bias Current vs Temperature

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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)

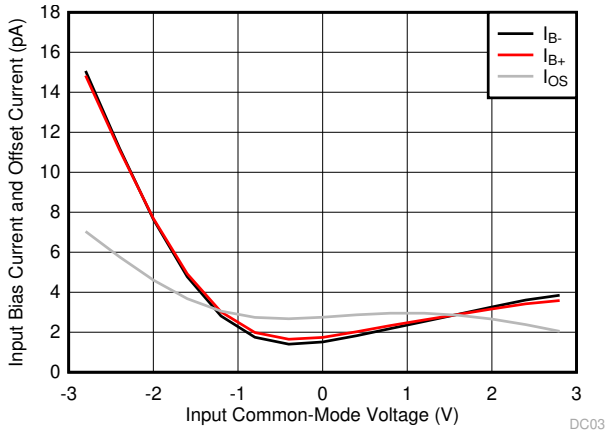


Figure 5-7. Input Bias Current and Offset Current vs Common-Mode Voltage

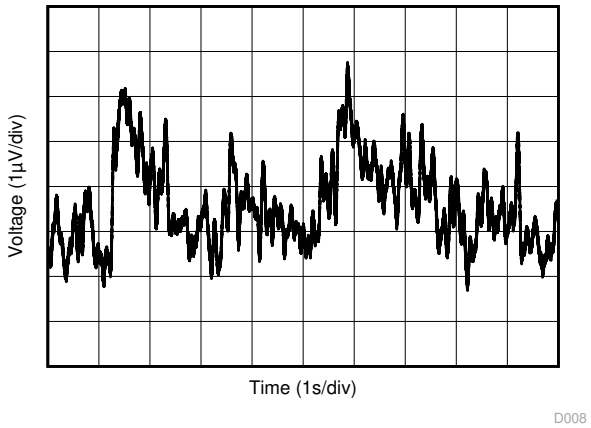


Figure 5-8. 0.1Hz to 10Hz Input Voltage Noise

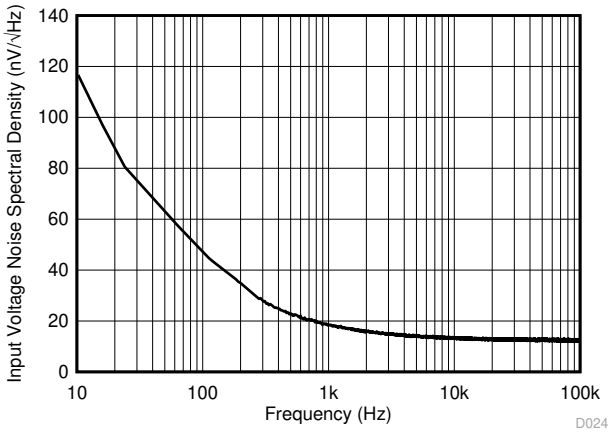


Figure 5-9. Input Voltage Noise Spectral Density vs Frequency

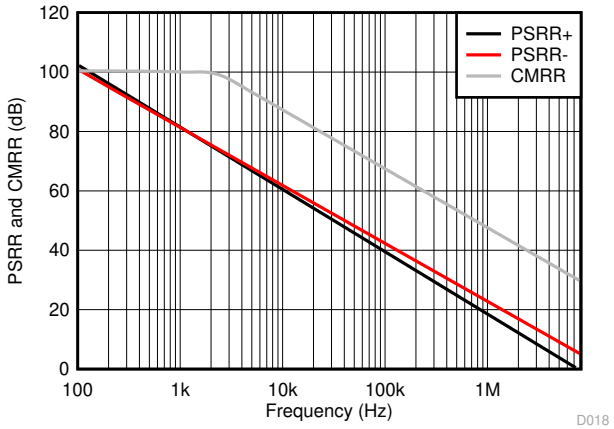


Figure 5-10. CMRR and PSRR vs Frequency (Referred to Input)

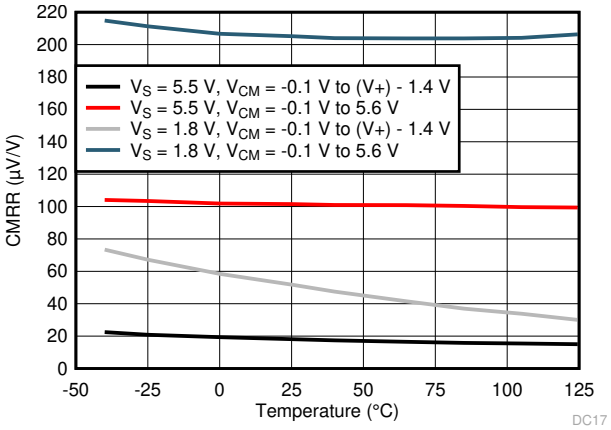
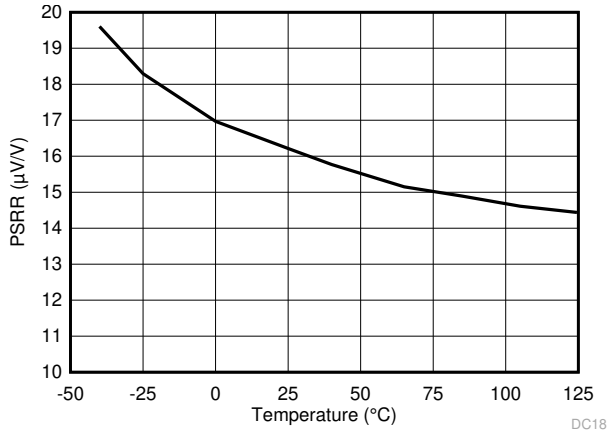


Figure 5-11. CMRR vs Temperature



VS = 1.8V to 5.5V

Figure 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)

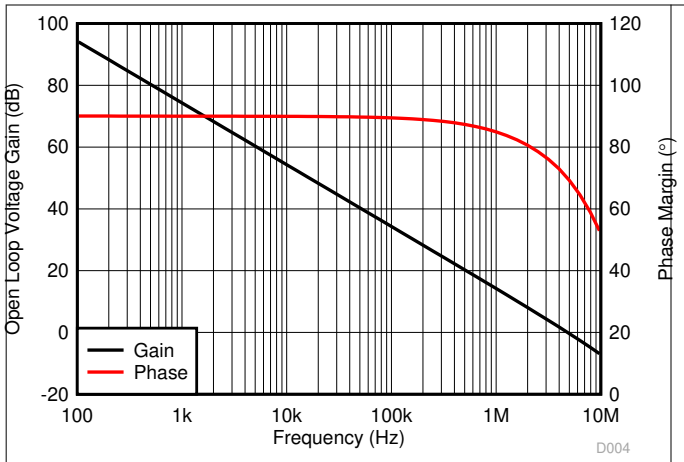


Figure 5-13. Open Loop Voltage Gain and Phase vs Frequency

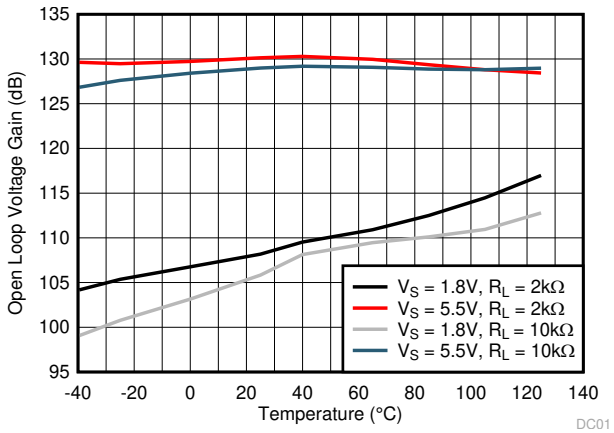


Figure 5-14. Open Loop Voltage Gain vs Temperature

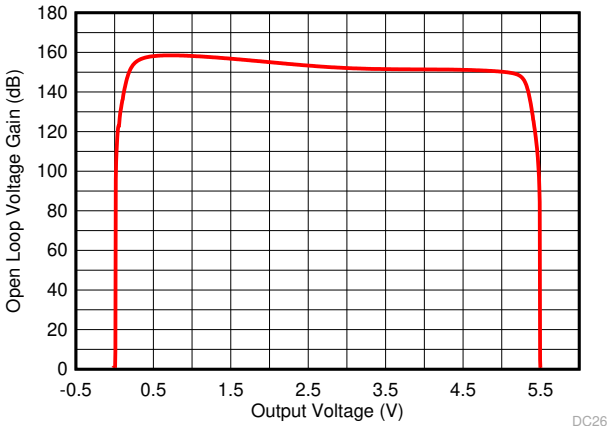


Figure 5-15. Open Loop Voltage Gain vs Output Voltage

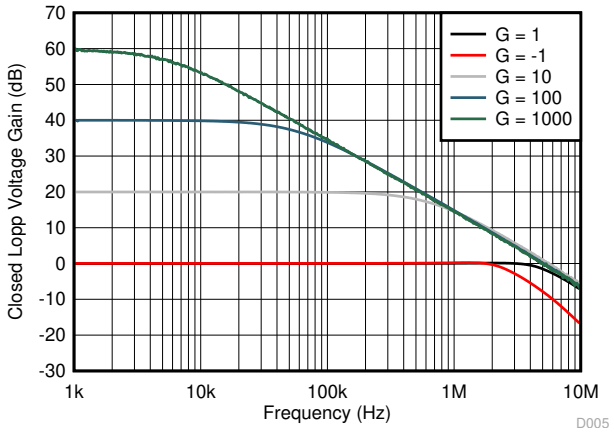


Figure 5-16. Closed Loop Voltage Gain vs Frequency

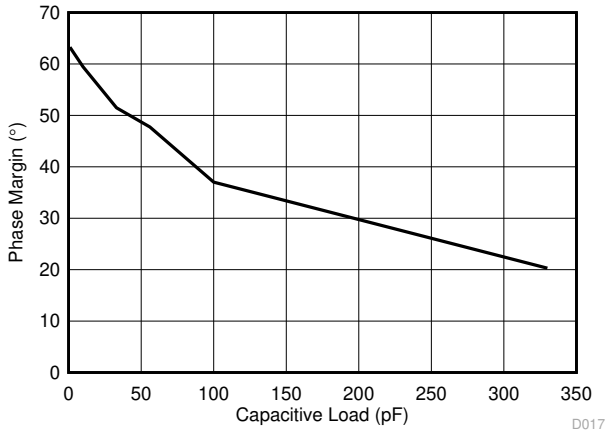


Figure 5-17. Phase Margin vs Capacitive Load

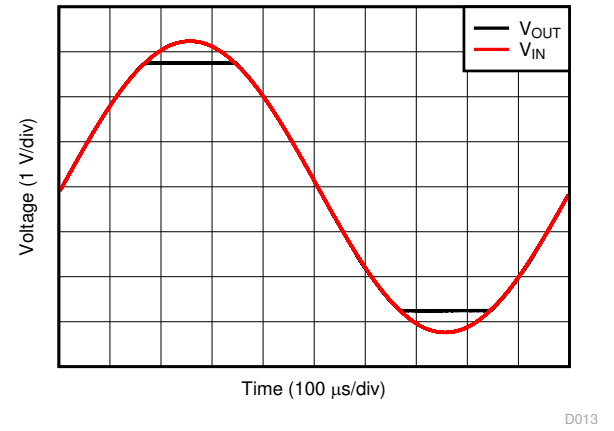
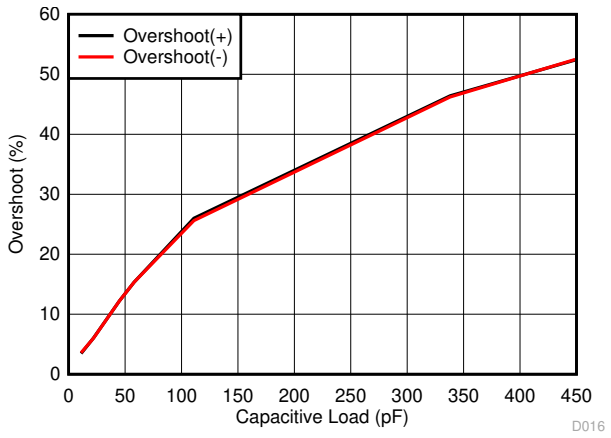


Figure 5-18. No Phase Reversal

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5.8 Typical Characteristics (continued)

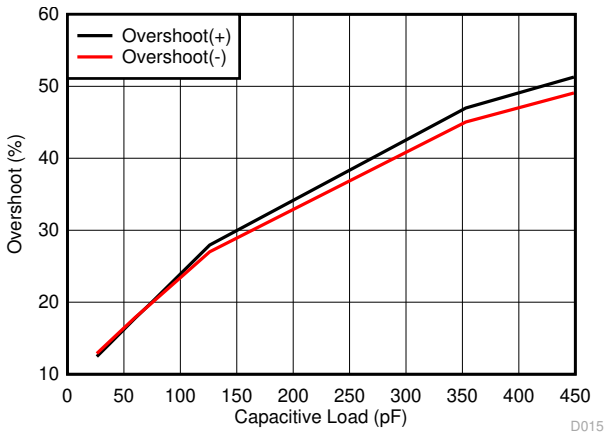
at T_A = 25°C, V_S = 5.5V, R_L = 10kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)



G = +1V/V

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

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



G = –1V/V

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

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

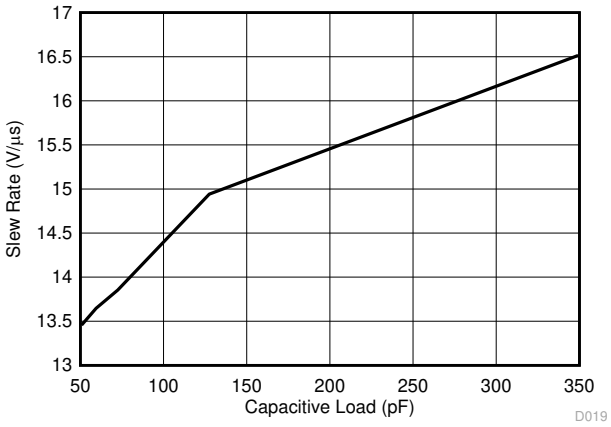
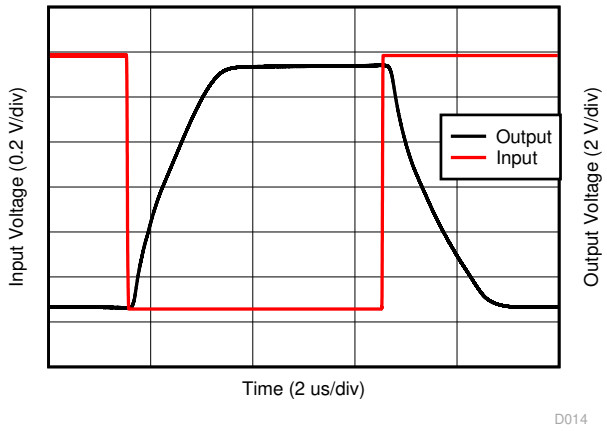
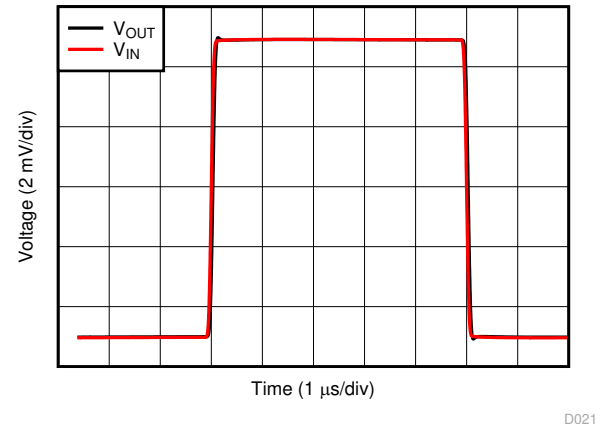


Figure 5-21. Slew Rate vs Capacitive Load



G = –10V/V

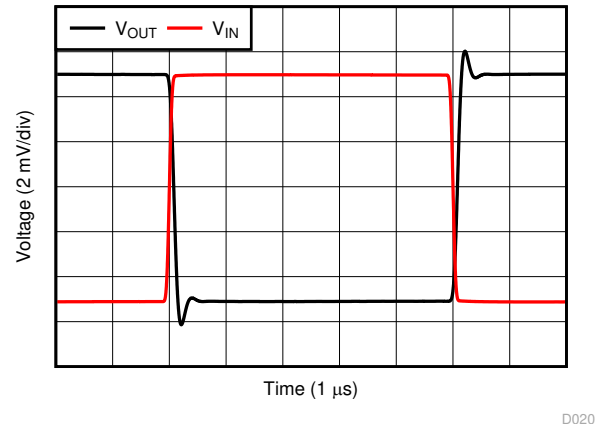
Figure 5-22. Overload Recovery



G = +1V/V

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

Figure 5-23. Small-Signal Step Response



G = –1V/V

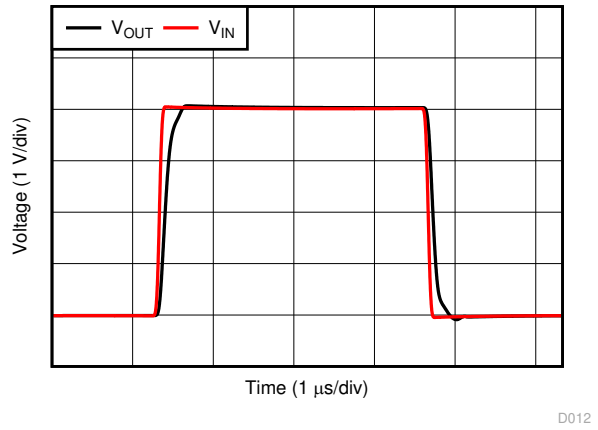
V_{OUT} step = 10mV_{p-p}

Figure 5-24. Small-Signal Step Response

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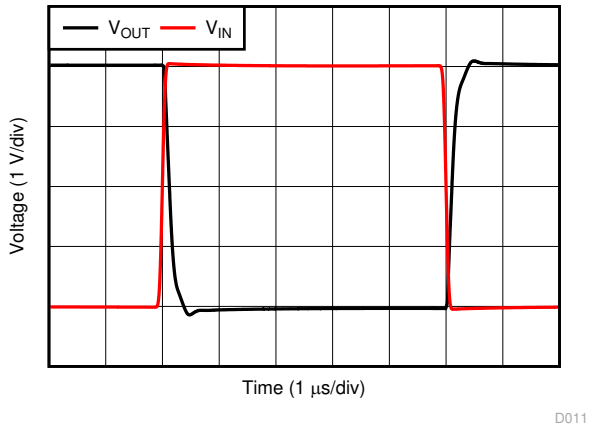
5.8 Typical Characteristics (continued)

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)



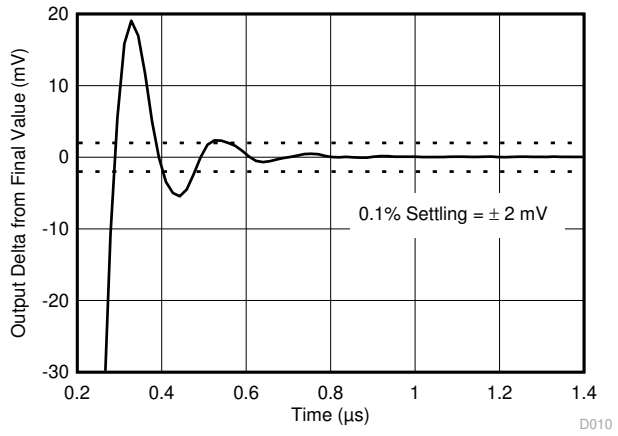
G = +1V/V
V_{OUT} step = $4V_{p-p}$

Figure 5-25. Large-Signal Step Response



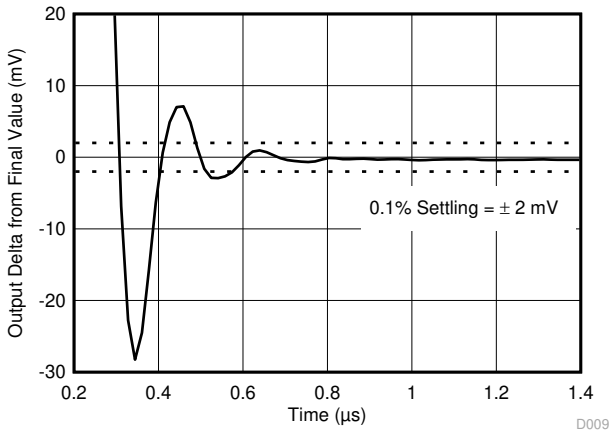
G = –1V/V
V_{OUT} step = $4V_{p-p}$

Figure 5-26. Large-Signal Step Response



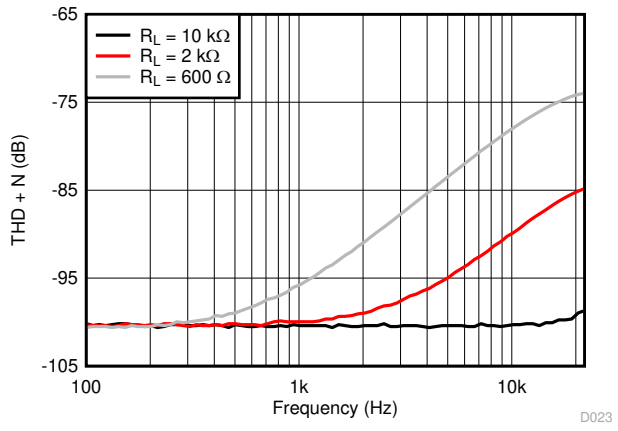
C_L = 100pF G = +1V/V

Figure 5-27. Positive Large-Signal Settling Time



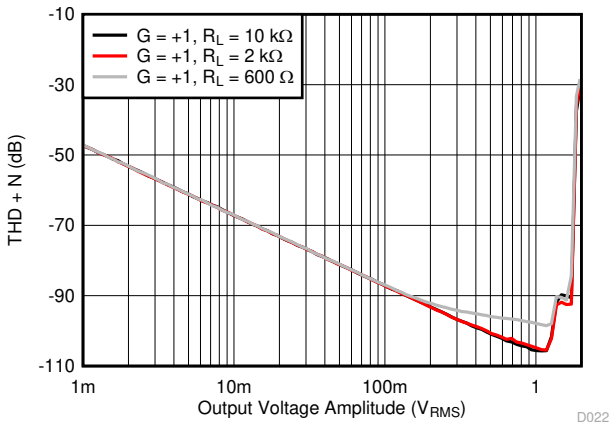
C_L = 100pF G = +1V/V

Figure 5-28. Negative Large-Signal Settling Time



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

Figure 5-29. THD + N vs Frequency



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

Figure 5-30. THD + N vs Amplitude

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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)

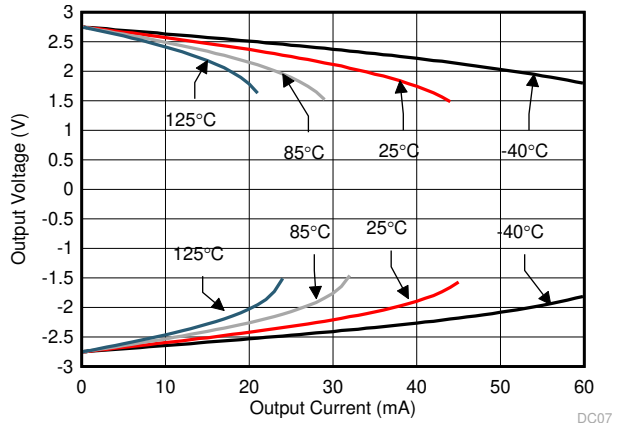


Figure 5-31. Output Voltage Swing vs Output Current

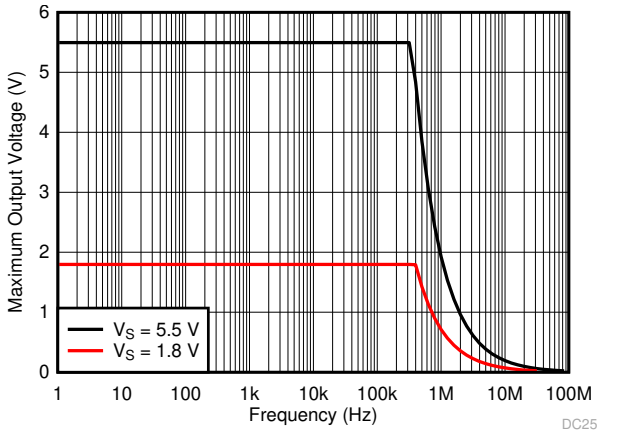


Figure 5-32. Maximum Output Voltage vs Frequency and Supply Voltage

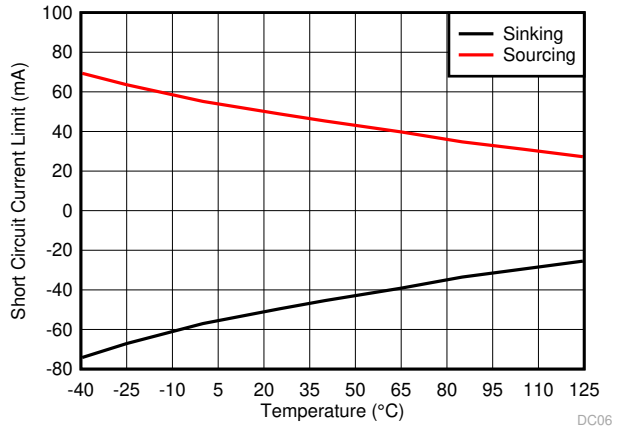


Figure 5-33. Short-Circuit Current vs Temperature

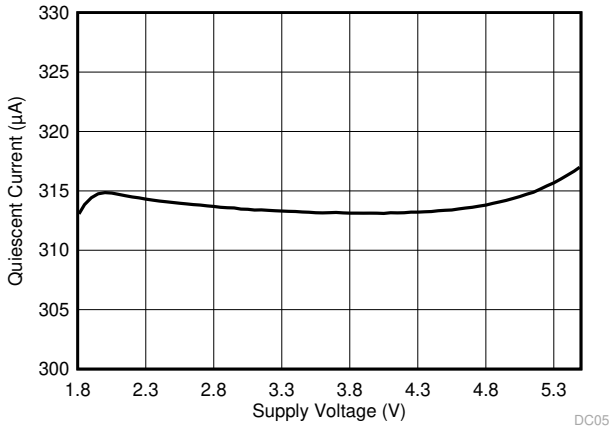


Figure 5-34. Quiescent Current vs Supply Voltage

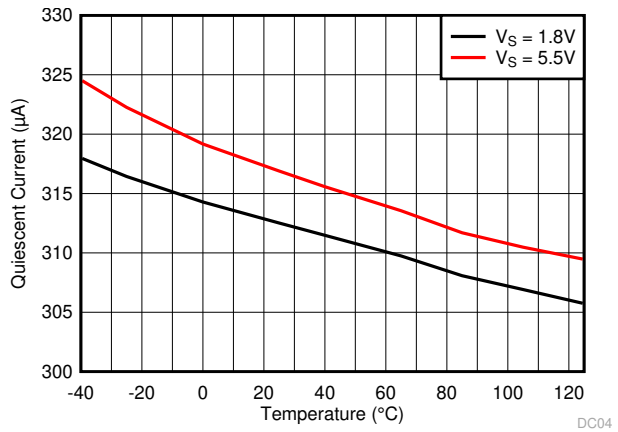


Figure 5-35. Quiescent Current vs Temperature

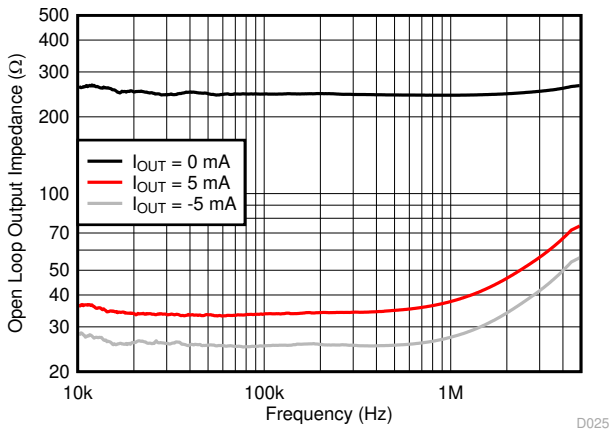
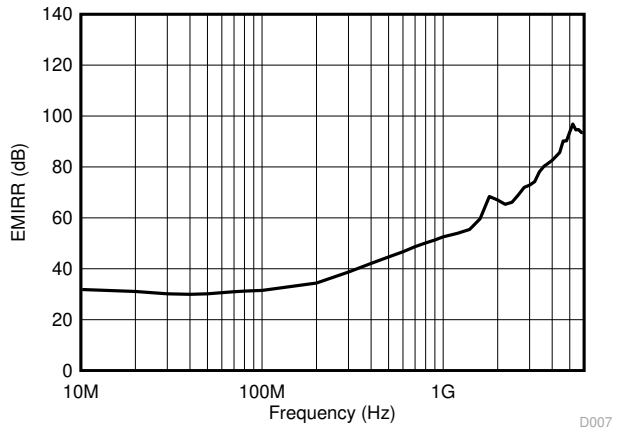


Figure 5-36. Open-Loop Output Impedance vs Frequency

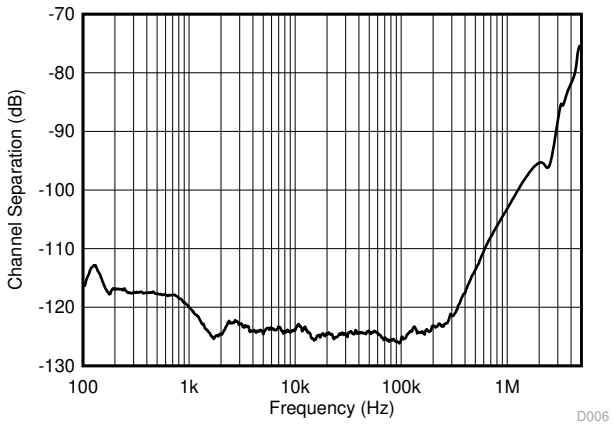
5.8 Typical Characteristics (continued)

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

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



P_{RF} = –10dBm

Figure 5-38. Channel Separation vs Frequency

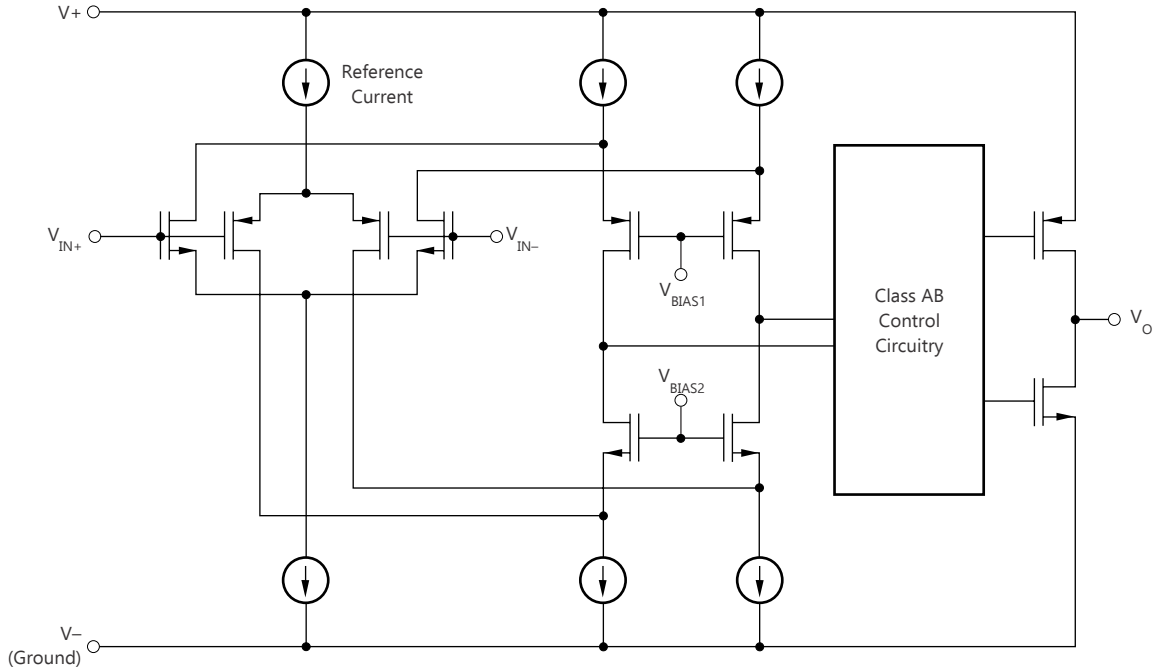
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6 Detailed Description

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. Figure 6-1 shows the results of this testing on the TLV905x-Q1. Table 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.

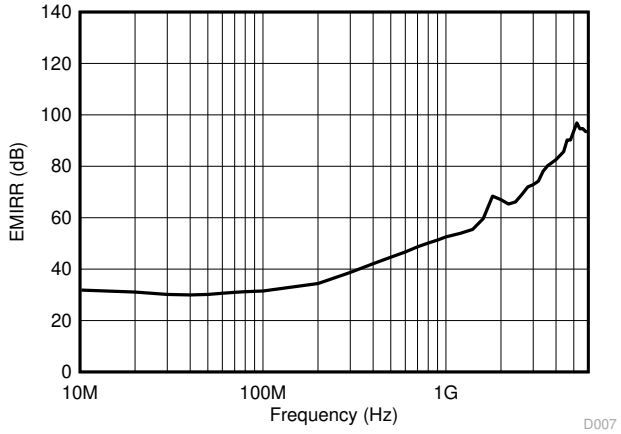


Figure 6-1. EMIRR Testing

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Table 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. Figure 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.

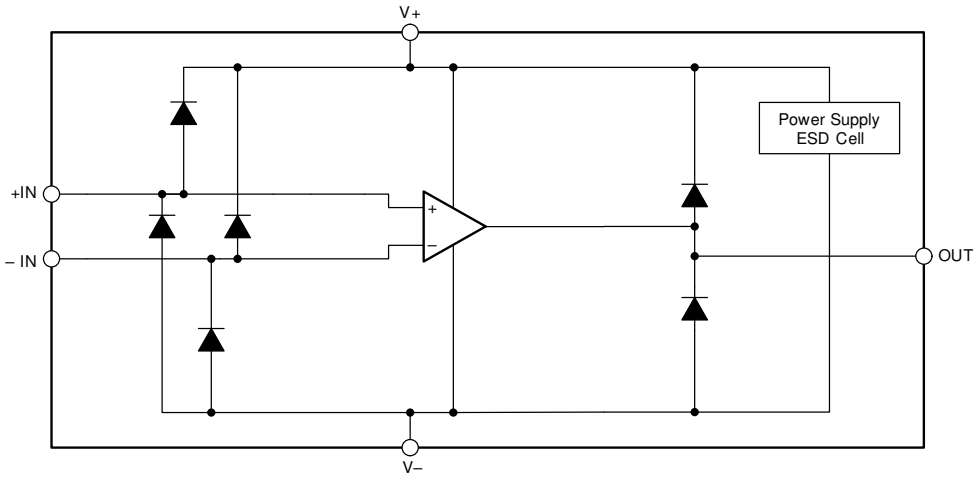


Figure 6-2. Equivalent Internal ESD Circuitry

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*). Figure 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.

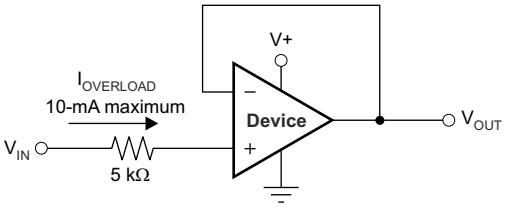


Figure 6-3. Input Current Protection

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).

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7 Application and Implementation

Note

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

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

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

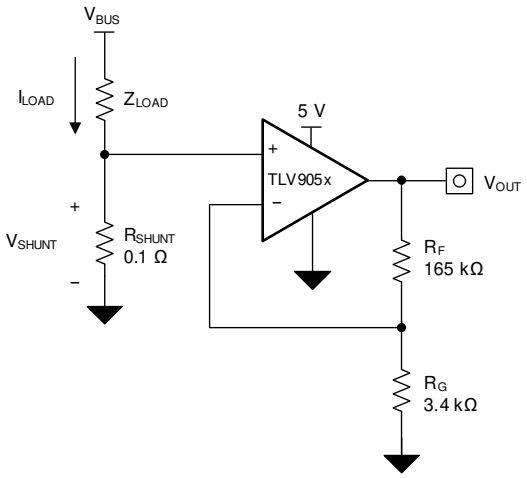


Figure 7-1. TLV905x-Q1 in a Low-Side, Current-Sensing Application

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

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7.2.2 Detailed Design Procedure

The transfer function of the circuit in Figure 7-1 is given in Equation 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 Equation 2.

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

Using Equation 2, R_{SHUNT} equals 100mΩ. 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. Equation 3 calculates the gain required for the TLV905x-Q1 device to produce the required output voltage.

$$Gain = \frac{\left(V_{OUT_MAX} - V_{OUT_{MIN}}\right)}{\left(V_{IN_MAX} - V_{IN_MIN}\right)} \quad (3)$$

Using Equation 3, the required gain equals 49.5V/V, which is set with the R_F and R_G resistors. Equation 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 165kΩ and R_G to equal 3.4kΩ provides a combination that equals approximately 49.5V/V. Figure 7-2 shows the measured transfer function of the circuit shown in Figure 7-1.

7.2.3 Application Curve

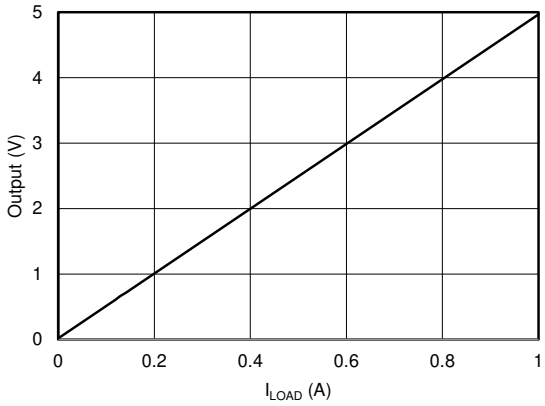


Figure 7-2. Low-Side, Current-Sense Transfer Function

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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.

CAUTION

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 *Figure 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 Figure 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.

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7.4.2 Layout Example

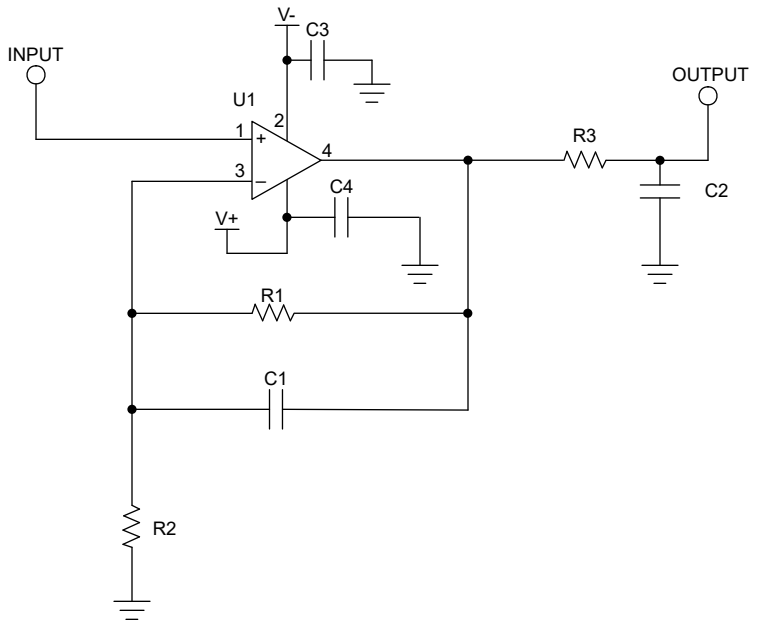


Figure 7-3. Schematic for Noninverting Configuration Layout Example

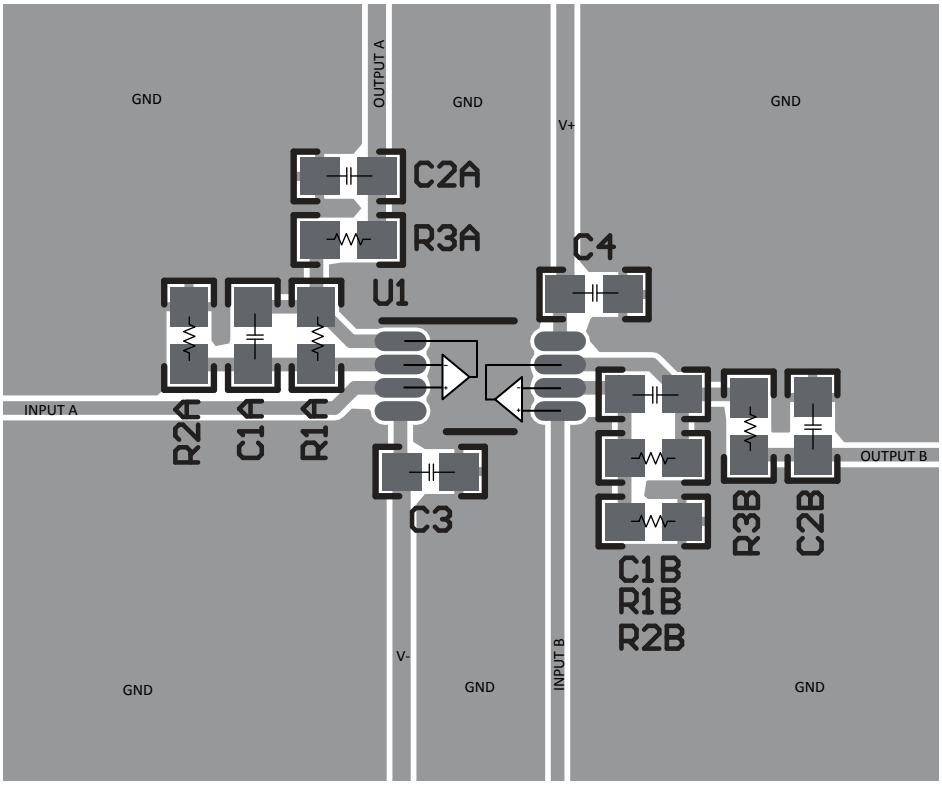


Figure 7-4. Example Layout for VSSOP-8 (DGK) Package

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8 Device and Documentation Support

8.1 Device Support

8.1.1 Development Support

8.1.1.1 TINA-TI™ (Free Software Download)

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

Available as a free download from the Analog eLab Design Center, TINA-TI offers extensive post-processing capability that allows users to format results in a variety of ways. Virtual instruments offer the ability to select input waveforms and probe circuit nodes, voltages, and waveforms, creating a dynamic quick-start tool.

Note

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

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 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

8.4 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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8.6 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

8.7 Glossary

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

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9 Revision History

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

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
• Added AEC-Q100 qualifications to the *Features* section	1
• Changed the status of the SOT-23 (5) and TSSOP (8) packages from: *preview* to *active*	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.

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PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
TLV9051QDBVRQ1	Active	Production	SOT-23 (DBV) | 5	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	TL51Q
TLV9051QDBVRQ1.A	Active	Production	SOT-23 (DBV) | 5	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	TL51Q
TLV9052QPWRQ1	Active	Production	TSSOP (PW) | 8	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	QTL905
TLV9052QPWRQ1.A	Active	Production	TSSOP (PW) | 8	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	QTL905

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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

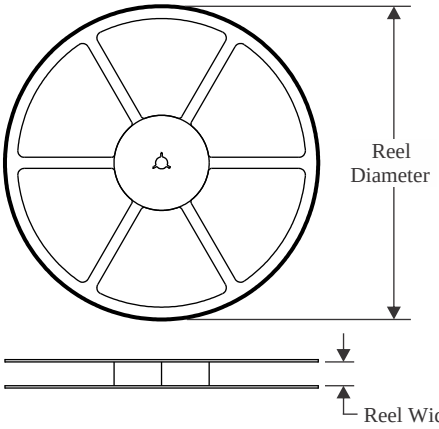
- Catalog : TLV9051, TLV9052

NOTE: Qualified Version Definitions:

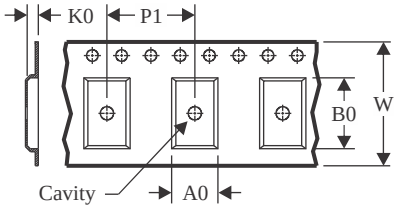
- Catalog - TI's standard catalog product

TAPE AND REEL INFORMATION

REEL DIMENSIONS

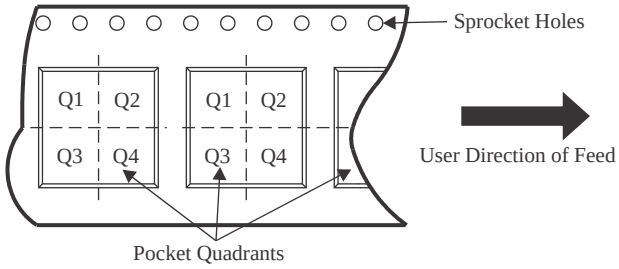


TAPE DIMENSIONS



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

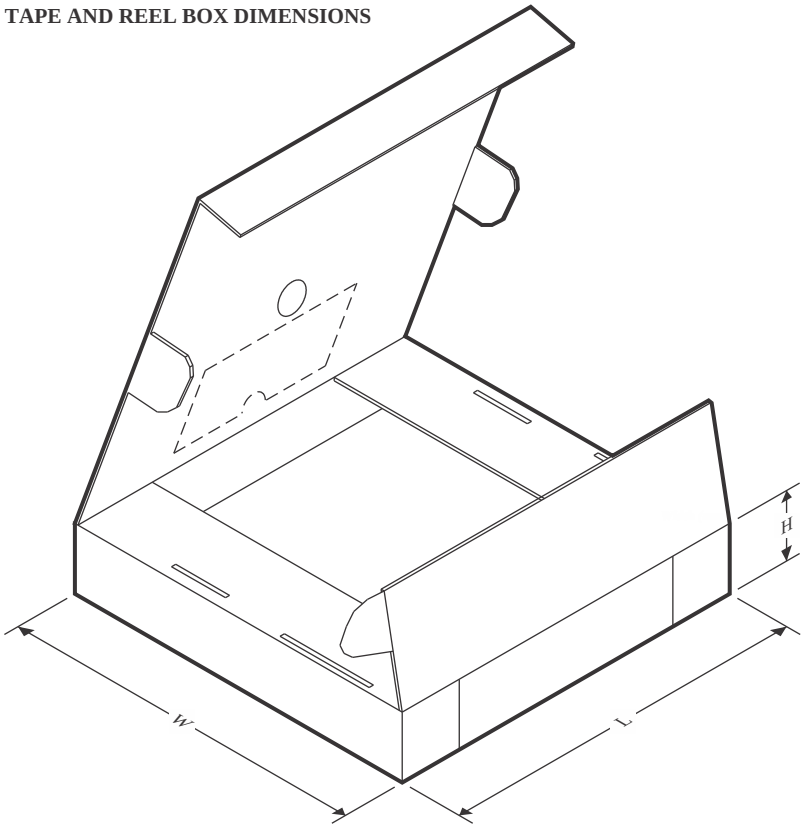
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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	353.0	353.0	32.0

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