









TLV9151, TLV9152, TLV9154 SBOS986E - OCTOBER 2019 - REVISED JANUARY 2022

TLV915x 4.5-MHz, Rail-to-Rail Input/Output, Low Offset Voltage, Low Noise Op Amp

1 Features

Low offset voltage: ±125 μV

Low offset voltage drift: ±0.3 µV/°C

Low noise: 10.5 nV/√Hz at 1 kHz

High common-mode rejection: 120 dB

Low bias current: ±10 pA

Rail-to-rail input and output

Wide bandwidth: 4.5-MHz GBW

High slew rate: 20 V/us

Low quiescent current: 560 µA per amplifier

Wide supply: ±1.35 V to ±8 V, 2.7 V to 16 V

Robust EMIRR performance: EMI/RFI filters on input pins

Differential and common-mode input voltage range to supply rail

Industry standard packages:

Single in SOT-23-5, SOT-23-6, and SC70-5

- Dual in SOIC-8, SOT-23-8, TSSOP-8, VSSOP-8, WSON-8, and X2QFN-10

- Quad in SOIC-14, SOT-23-14, TSSOP-14, and X2QFN-14

2 Applications

- Professional microphones and wireless systems
- Multiplexed data-acquisition systems
- Test and measurement equipment
- · Factory automation and control
- High-side and low-side current sensing

3 Description

The TLV915x family (TLV9151, TLV9152, and TLV9154) is a family of 16-V, general purpose operational amplifiers. These devices exceptional DC precision and AC performance, including rail-to-rail output, low offset (±125 µV, typical), low offset drift (±0.3 µV/°C, typical), and 4.5-MHz bandwidth.

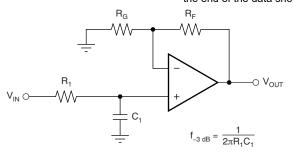
Convenient features such as wide differential inputvoltage range, high output current (±75 mA), high slew rate (20 V/ μ s), and low noise (10.5 nV/ $\sqrt{\text{Hz}}$) make the TLV915x a robust, low-noise operational amplifier for industrial applications.

The TLV915x family of op amps is available in standard packages and is specified from -40°C to 125°C.

Device Information

PART NUMBER (1)	PACKAGE	BODY SIZE (NOM)
	SOT-23 (5)	2.90 mm × 1.60 mm
TLV9151	SOT-23 (6)	2.90 mm × 1.60 mm
	SC70 (5)	2.00 mm × 1.25 mm
	SOIC (8)	4.90 mm × 3.90 mm
	SOT-23 (8)	2.90 mm × 1.60 mm
TLV9152	TSSOP (8)	3.00 mm × 4.40 mm
1609132	VSSOP (8)	3.00 mm × 3.00 mm
	WSON (8)	2.00 mm × 2.00 mm
	X2QFN (10)	1.50 mm × 1.50 mm
	SOIC (14)	8.65 mm × 3.90 mm
TLV9154	SOT-23 (14)	4.20 mm × 1.90 mm
1LV9104	TSSOP (14)	5.00 mm × 4.40 mm
	X2QFN (14)	2.00 mm × 2.00 mm

For all available packages, see the orderable addendum at the end of the data sheet.



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

TLV915x in a Single-Pole, Low-Pass Filter



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4 Revision History

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

C	hanges from Revision D (May 2021) to Revision E (January 2022)	Page
•	Updated industry standard packages in <i>Features</i> to match the packages available in <i>Device Information</i> section	
	Added SOT-23-14 (DYY) package to <i>Device Information</i>	
	Added SOT-23-14 (DYY) package and pin functions in <i>Pin Configurations and Functions</i> section	
	Removed WQFN-14 (RTE) package and pin functions in <i>Pin Configurations and Functions</i> section	
	Removed WQFN-16 (RTE) package and pin functions in <i>Pin Configurations and Functions</i> section	
	Corrected typo mislabeling the RUC package as having an "Exposed Thermal Pad" in <i>Pin Configuration</i>	
-	Functions section	4
•	Removed SOT-553 (DRL) package and pin functions from Pin Configurations and Functions section	4
•	Removed SOT-563 (DRL) package and pin functions from Pin Configurations and Functions section	4
•	Corrected typo in Recommended Operating Conditions which labeled VIH as amplifier enabled and VIL	as
	amplifier disabled to correctly label V _{IH} as amplifier disabled and V _{IL} as amplifier enabled	9
•	Added SOT-23-14 (DYY) package in Thermal Information for Quad Channel section	10
•	Corrected typo mislabeling the RUC package as a "WQFN" package instead of as a "X2QFN" package	
	Thermal Information for Quad Channel section	
•	Removed "TLV9154S" from header of Thermal Information for Quad Channel section	10
•	Maximum PSRR specification from $V_S = 4 \text{ V}$ to 16 V changed from $\pm 1 \mu\text{V/V}$ to $\pm 1.6 \mu\text{V/V}$	11
•	Maximum PSRR specification from $V_S = 2.7 \text{ V}$ to 16 V changed from ±5 μ V/V to ±8.64 μ V/V	
•	Minimum CMRR specification for V _S = 16 V changed from 109dB to 99dB	11
•	Corrected typo in I _{QSD} test conditions in <i>Electrical Characteristics</i> table from "SHDN = V-" to "SHDN = V	V- + 2
	V"	11
•	Removed the overbar from the SHDN pin name in the note on toff and ton in the Electrical Characteristic	
	section for consistency	11
•	Updated Figure EMIRR Testing and Table TLV9151 EMIRR IN+ for Frequencies of Interest in EMI Reje	
	to match the increased performance from Figure EMIRR (Electromagnetic Interference Rejection Ratio)	
	Frequency in Electrical Characteristics	23
•	Changed input resistor values in Equivalent Internal ESD Circuitry Relative to a Typical Circuit Application	
	Electrical Overstress section to more closely resemble device	
•	Removed WQFN (RTE) package from Packages With an Exposed Thermal Pad	<mark>29</mark>



Expanded the <i>Shutdown</i> section in the <i>Detailed Description</i> section to further clarify shutdown operation and corrected the current consumption in shutdown from 20µA to 30µA and the "typical enable time" in the section from 30µs to 8µs to align with the <i>Electrical Characteristics</i> section				
section from 30µs to 8µs to align with the <i>Electrical Characteristics</i> section	29			
Changes from Revision C (December 2020) to Revision D (May 2021)	Page			
• Changed VSSOP (8) package status on Device Information from Preview to Active	1			
· Removed preview notation on VSSOP-8 (DGK) package in Pin Configurations and Fun	nctions4			
Removed VSSOP-10 (DGS) package in Pin Configurations and Functions	4			
Changes from Revision B (May 2020) to Revision C (December 2020)	Page			
· Updated the numbering format for tables, figures and cross-references throughout the				
• Changed SOT-23 (5) package status on Device Information from Preview to Active	1			
• Changed SC70 (5) package status on Device Information from Preview to Active	1			
• Changed SOT-23 (6) package status on Device Information from Preview to Active	1			
• Changed SOT-23 (8) package status on Device Information from Preview to Active	1			
• Changed VSSOP (8) package status on Device Information from Preview to Active	1			
• Changed SOIC (14) package status on Device Information from Preview to Active				
• Changed TSSOP (14) package status on Device Information from Preview to Active	1			
• Changed X2QFN (14) package status on Device Information from Preview to Active	1			
 Removed preview notation on SOT-23-5 (DBV), SC70-5 (DCK) SOT-23-6 (DBV), and S 				
packages in Pin Configurations and Functions	4			
• Removed preview notation on SOIC-14 (D) package in Pin Configurations and Function	ns4			
• Removed preview notation on TSSOP-14 (PW) package in Pin Configurations and Fun				
 Removed preview notation on X2QFN-14 (RUC) package in Pin Configurations and Fu 				
Changes from Revision A (March 2020) to Revision B (May 2020)	Page			
Changed X2QFN (10) package status on <i>Device Information</i> from Preview to Active				
 Removed preview notation on X2QFN (RUG) package in Pin Configurations and Function 				
Added V _{IH} and V _{IL} in <i>Recommended Operating Conditions</i> section				
Added SHUTDOWN in <i>Electrical Characteristics</i> table				
Changes from Revision * (October 2019) to Revision A (March 2020)	Page			
Changed document status from Advance Information to Production Data	1			
• Changed SOIC (8) package status on <i>Device Information</i> from Preview to Active				
• Changed TSSOP (8) package status on Device Information from Preview to Active				
• Changed WSON (8) package status on Device Information from Preview to Active				
 Removed preview notation on SOIC-8 (D), TSSOP-8 (PW), and WSON-8 (DSG) packa 	_			
Configurations and Functions				
Added Typical Characteristics section in Specifications section	15			



5 Pin Configuration and Functions

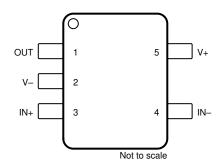


Figure 5-1. TLV9151 DBV Package 5-Pin SOT-23 (Top View)

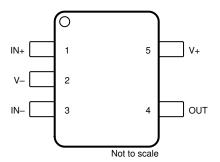


Figure 5-2. TLV9151 DCK 5-Pin SC70 (Top View)

Table 5-1. Pin Functions: TLV9151

	PIN		- I/O	DESCRIPTION	
NAME	DBV	DCK	1/0	DESCRIPTION	
+IN	3	1	I	Noninverting input	
-IN	4	3	ı	Inverting input	
OUT	1	4	0	Output	
V+	5	5	_	Positive (highest) power supply	
V-	2	2	_	Negative (lowest) power supply	



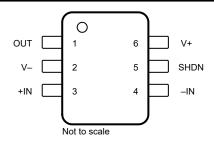


Figure 5-3. TLV9151S DBV Package 6-Pin SOT-23 (Top View)

Table 5-2. Pin Functions: TLV9151S

Р	IN			
NAME	NO. DESCRIPTION		DESCRIPTION	
+IN	3	I	Noninverting input	
-IN	4	I	I Inverting input	
OUT	1	0	Output	
SHDN	5	I	Shutdown: low = amplifier enabled, high = amplifier disabled. See Shutdown for more information.	
V+	6	_	Positive (highest) power supply	
V-	2	_	Negative (lowest) power supply	



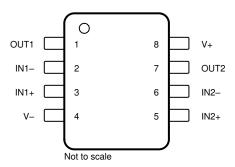
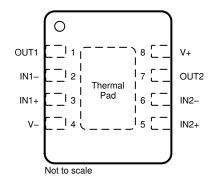


Figure 5-4. TLV9152 D, DDF, DGK, and PW Package 8-Pin SOIC, SOT-23, TSSOP, and VSSOP (Top View)



A. Connect thermal pad to V–. See Packages with and Exposed Thermal Pad for more information.

Figure 5-5. TLV9152 DSG Package^(A)
8-Pin WSON With Exposed Thermal Pad
(Top View)

Table 5-3. Pin Functions: TLV9152

14400 0 0 1 1111 0 1100 0 1 1 1 1 1 1 1					
IN	1/0	DESCRIPTION			
NO.	1/0	DESCRIPTION			
3	I	Noninverting input, channel A			
5	I	Noninverting input, channel B			
2	I	Inverting input, channel A			
6	I	nverting input, channel B			
1	0	Dutput, channel A			
7	0	Output, channel B			
8	_	Positive (highest) power supply			
4	_	Negative (lowest) power supply			
	NO. 3 5 2 6 1 7 8	NO. 3			

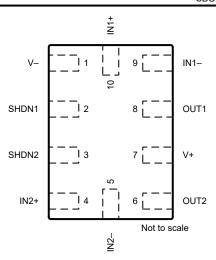


Figure 5-6. TLV9152S RUG Package 10-Pin X2QFN (Top View)

Table 5-4. Pin Functions: TLV9152S

	PIN			
NAME	NO.	I/O	DESCRIPTION	
+IN A	10	I	Noninverting input, channel A	
+IN B	4	I	Noninverting input, channel B	
–IN A	9	I	Inverting input, channel A	
–IN B	5	I	Inverting input, channel B	
OUT A	8	0	Output, channel A	
OUT B	6	0	Output, channel B	
SHDN1	2	I	Shutdown, channel 1: low = amplifier enabled, high = amplifier disabled. See Shutdown for more information.	
SHDN2	3	1	Shutdown, channel 2: low = amplifier enabled, high = amplifier disabled. See Shutdown for more information.	
V+	7	_	Positive (highest) power supply	
V-	1	_	Negative (lowest) power supply	



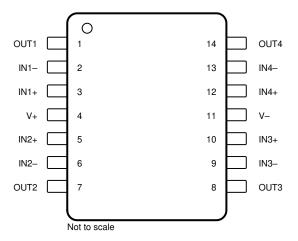


Figure 5-7. TLV9154 D, PW, and DYY Packages 14-Pin SOIC, TSSOP, and SOT-23 (Top View)

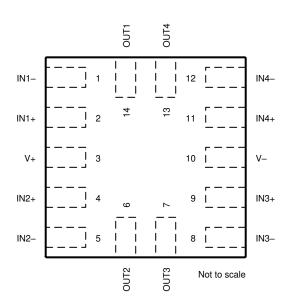


Figure 5-8. TLV9154 RUC Package 14-Pin X2QFN (Top View)

Table 5-5. Pin Functions: TLV9154

	PIN		I/O	DESCRIPTION	
NAME	SOIC, TSSOP, SOT-23	X2QFN	_	DESCRIPTION	
IN1+	3	2	I	Noninverting input, channel 1	
IN1-	2	1	I	Inverting input, channel 1	
IN2+	5	4	I	Noninverting input, channel 2	
IN2-	6	5	I	Inverting input, channel 2	
IN3+	10	9	I	Noninverting input, channel 3	
IN3-	9	8	I	Inverting input, channel 3	
IN4+	12	11	I	Noninverting input, channel 4	
IN4-	13	12	I	Inverting input, channel 4	
NC	_	_	_	Do not connect	
OUT1	1	14	0	Output, channel 1	
OUT2	7	6	0	Output, channel 2	
OUT3	8	7	0	Output, channel 3	
OUT4	14	13	0	Output, channel 4	
V+	4	3	_	Positive (highest) power supply	
V–	11	10	_	Negative (lowest) power supply	

6 Specifications

6.1 Absolute Maximum Ratings

over operating ambient temperature range (unless otherwise noted) (1)

		MIN	MAX	UNIT
Supply voltage, V _S = (V+)	- (V-)	0	20 V	
	Common-mode voltage (3)	(V-) - 0.5	(V+) + 0.5	V
Signal input pins	Differential voltage (3)		V _S + 0.2	V
	Current (3)	-10	10	mA
Output short-circuit (2)		Continue	Continuous	
Operating ambient temperature, T _A		-55	150	°C
Junction temperature, T _J			150	°C
Storage temperature, T _{stg}		-65	150	°C

- (1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) Short-circuit to ground, one amplifier per package.
- (3) Input pins are diode-clamped to the power-supply rails. Input signals that may swing more than 0.5 V beyond the supply rails must be current limited to 10 mA or less.

6.2 ESD Ratings

			VALUE	UNIT
V		Human body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾	±2000	V
V _(ESD)	Liectiostatic discharge	Charged device model (CDM), per JEDEC specification JESD22-C101 (2)	±1000	v

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

6.3 Recommended Operating Conditions

over operating ambient temperature range (unless otherwise noted)

		MIN	MAX	UNIT
Vs	Supply voltage, (V+) – (V–)	2.7	16	V
VI	Input voltage range	(V-) - 0.1	(V+) + 0.1	V
V _{IH}	High level input voltage at shutdown pin (amplifier disabled)	1.1	(V+)	V
V _{IL}	Low level input voltage at shutdown pin (amplifier enabled)	(V-)	0.2	V
T _A	Specified temperature	-40	125	°C

6.4 Thermal Information for Single Channel

			TLV9151, TLV9151S			
THERMAL METRIC (1)		_)BV)T-23)	DCK (SC70)	UNIT	
		5 PINS	6 PINS	5 PINS		
$R_{\theta JA}$	Junction-to-ambient thermal resistance	185.7	167.8	202.6	°C/W	
R _{θJC(top)}	Junction-to-case (top) thermal resistance	108.2	107.9	101.5	°C/W	
$R_{\theta JB}$	Junction-to-board thermal resistance	54.5	49.7	47.8	°C/W	
ΨЈТ	Junction-to-top characterization parameter	31.2	33.9	18.8	°C/W	
ΨЈВ	Junction-to-board characterization parameter	54.2	49.5	47.4	°C/W	
R _{0JC(bot)}	Junction-to-case (bottom) thermal resistance	N/A	N/A	N/A	°C/W	

For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application report, SPRA953.



6.5 Thermal Information for Dual Channel

		TLV9152, TLV9152S						
THERMAL METRIC (1)		D (SOIC)	DDF (SOT-23)	DGK (VSSOP)	DSG (WSON)	PW (TSSOP)	RUG (X2QFN)	UNIT
		8 PINS	8 PINS	8 PINS	8 PINS	8 PINS	10 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	138.7	143.5	176.5	77.6	185.1	142.3	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	78.7	79.9	68.1	93.7	74.0	53.5	°C/W
R _{θJB}	Junction-to-board thermal resistance	82.2	61.6	98.2	43.9	115.7	68.5	°C/W
Ψυτ	Junction-to-top characterization parameter	27.8	5.7	12.0	4.4	12.3	1.0	°C/W
ΨЈВ	Junction-to-board characterization parameter	81.4	61.3	96.7	43.9	114.0	68.4	°C/W
R _{θJC(bot)}	Junction-to-case (bottom) thermal resistance	N/A	N/A	N/A	19.0	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 report, SPRA953.

6.6 Thermal Information for Quad Channel

		TLV9154					
THERMAL METRIC (1)		D (SOIC)	DYY (SOT-23)	PW (TSSOP)	RUC (X2QFN)	UNIT	
		14 PINS	14 PINS	14 PINS	14 PINS		
R _{0JA}	Junction-to-ambient thermal resistance	101.4	110.6	131.4	125.9	°C/W	
R _{0JC(top)}	Junction-to-case (top) thermal resistance	57.6	53.7	51.8	39.8	°C/W	
R _{0JB}	Junction-to-board thermal resistance	57.3	35.3	75.8	68.0	°C/W	
ΨЈТ	Junction-to-top characterization parameter	18.5	2.2	7.9	0.8	°C/W	
ΨЈВ	Junction-to-board characterization parameter	56.9	35.0	74.8	67.8	°C/W	
R _{0JC(bot)}	Junction-to-case (bottom) thermal resistance	N/A	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 report, SPRA953.

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6.7 Electrical Characteristics

For V_S = (V+) – (V–) = 2.7 V to 16 V (±1.35 V to ±8 V) at T_A = 25°C, R_L = 10 k Ω connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2, unless otherwise noted.

	PARAMETER	TEST COND	ITIONS	MIN	TYP	MAX	UNIT
OFFSET V	/OLTAGE						
		TLV9151, TLV9152			±125	±750	
\/	Input offset voltage	V _{CM} = V-	$T_A = -40^{\circ}C \text{ to } 125^{\circ}C$			±780	μV
V _{OS}	Input onset voltage	TLV9154			±125	±830	
		V _{CM} = V-	$T_A = -40^{\circ}C \text{ to } 125^{\circ}C$			±880	
dV _{OS} /dT	Input offset voltage drift		$T_A = -40^{\circ}C \text{ to } 125^{\circ}C$		±0.3		μV/°C
PSRR	Input offset voltage	$V_{CM} = V_{-}, V_{S} = 4 V \text{ to } 16 V$	T _A = -40°C to 125°C		±0.3	±1.6	μV/V
TORK	versus power supply	$V_{CM} = V_{-}, V_{S} = 2.7 \text{ V to } 16 \text{ V}^{(2)}$	1A40 C to 125 C		±1	±8.64	μν/ν
	Channel separation	f = 0 Hz			5		μV/V
INPUT BIA	AS CURRENT						
I _B	Input bias current				±10		pA
I _{OS}	Input offset current				±10		pA
NOISE							
E _N	Input voltage noise	f = 0.1 Hz to 10 Hz			1.8		μV_{PP}
-N	input voltage noise				0.3		μV_{RMS}
e _N	Input voltage noise	f = 1 kHz			10.8		nV/√ Hz
ON .	density	f = 10 kHz			9.4		1107 1112
i _N	Input current noise	f = 1 kHz	f = 1 kHz				fA/√Hz
INPUT VO	LTAGE RANGE						
V_{CM}	Common-mode voltage range			(V-) - 0.1		(V+) + 0.1	V
		V _S = 16 V, (V–) – 0.1 V < V _{CM} < (V+) – 2 V (Main input pair)		99	130		
CMRR	Common-mode rejection	V _S = 4 V, (V–) – 0.1 V < V _{CM} < (V+) – 2 V (Main input pair)	T _A = -40°C to 125°C	84	100		dB
CIVIRR	ratio	$V_S = 2.7 \text{ V, (V-)} - 0.1 \text{ V} < V_{CM} < (V+) - 2 \text{ V (Main input pair)}^{(2)}$		75	95		uв
		$V_S = 2.7 \text{ V to } 16 \text{ V, (V+)} - 1 \text{ V < V}_{CM}$ < (V+) + 0.1 V (Aux input pair)			85		
INPUT CA	PACITANCE	•					
Z _{ID}	Differential				100 3		MΩ pF
Z _{ICM}	Common-mode				6 1		TΩ pF



6.7 Electrical Characteristics (continued)

For V_S = (V+) – (V–) = 2.7 V to 16 V (±1.35 V to ±8 V) at T_A = 25°C, R_L = 10 k Ω connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2, unless otherwise noted.

	PARAMETER	TEST COND	TIONS	MIN	TYP	MAX	UNIT
OPEN-LO	OP GAIN						
		V _S = 16 V, V _{CM} = V-		120	145		
		$(V-) + 0.1 V < V_0 < (V+) - 0.1 V$	T _A = -40°C to 125°C		142		
	Onen leen veltege gein	V _S = 4 V, V _{CM} = V-		104	130		dB
A _{OL}	Open-loop voltage gain	$(V-) + 0.1 V < V_O < (V+) - 0.1 V$	T _A = -40°C to 125°C		125		αв
		V _S = 2.7 V, V _{CM} = V-		101	120		
		$(V-) + 0.1 V < V_0 < (V+) - 0.1 V^{(2)}$	T _A = -40°C to 125°C		118		
FREQUEN	NCY RESPONSE						
GBW	Gain-bandwidth product				4.5		MHz
SR	Slew rate	V _S = 16 V, G = +1, C _L = 20 pF			21		V/µs
		To 0.01%, V _S = 16 V, V _{STEP} = 10 V ,	G = +1, CL = 20 pF		2.5		
+	Sottling time	To 0.01%, V _S = 16 V, V _{STEP} = 2 V , G = +1, CL = 20 pF			1.5		
t _S	Settling time	To 0.1%, V _S = 16 V, V _{STEP} = 10 V , G	i = +1, CL = 20 pF		2		μs
		To 0.1%, V _S = 16 V, V _{STEP} = 2 V , G = +1, CL = 20 pF			1		
	Phase margin	G = +1, R _L = 10 kΩ			60		۰
	Overload recovery time	/ _{IN} × gain > V _S			400		ns
THD+N	Total harmonic distortion + noise	V _S = 16 V, V _O = 3 V _{RMS} , G = 1, f = 1	kHz	0	.00021%		
OUTPUT	•	1	1				
			V _S = 16 V, R _L = no load ⁽²⁾		5	10	
			V _S = 16 V, R _L = 10 kΩ		50	55	
	Voltage output swing from	Positive and negative rail headroom	$V_S = 16 \text{ V}, R_L = 2 \text{ k}\Omega$		200	250	mV
	rail	Positive and negative fall neadroom	V _S = 2.7 V, R _L = no load ⁽²⁾		1	6	IIIV
			$V_S = 2.7 \text{ V}, R_L = 10 \text{ k}\Omega$		5	12	
			$V_S = 2.7 \text{ V}, R_L = 2 \text{ k}\Omega$		25	40	
I _{SC}	Short-circuit current				±75		mA
C _{LOAD}	Capacitive load drive				1000		pF
Z _O	Open-loop output impedance	f = 1 MHz, I _O = 0 A		525		Ω	
POWER S	SUPPLY	•		,			
	Quiescent current per	I _O = 0 A			560	685	
IQ	amplifier	I _O = 0 A	$T_A = -40^{\circ}\text{C to } 125^{\circ}\text{C}$ 750	750	μA		

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6.7 Electrical Characteristics (continued)

For V_S = (V+) – (V–) = 2.7 V to 16 V (±1.35 V to ±8 V) at T_A = 25°C, R_L = 10 k Ω 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
SHUTDO	WN					
I _{QSD}	Quiescent current per amplifier	V _S = 2.7 V to 16 V, all amplifiers disabled, SHDN = V- + 2 V		30	45	μА
Z _{SHDN}	Output impedance during shutdown	V _S = 2.7 V to 16 V, amplifier disabled		10 2		GΩ pF
V _{IH}	Logic high threshold voltage (amplifier disabled)	For valid input high, the SHDN pin voltage should be greater than the maximum threshold but less than or equal to V+		(V-) + 0.8	(V–) + 1.1	V
V _{IL}	Logic low threshold voltage (amplifier enabled)	For valid input low, the SHDN pin voltage should be less than the minimum threshold but greater than or equal to V–	(V-) + 0.2	(V-) + 0.8		V
t _{ON}	Amplifier enable time (1)	$G = +1, V_{CM} = V_{-}, V_{O} = 0.1 \times V_{S}/2$		8		μs
t _{OFF}	Amplifier disable time (1)	$V_{CM} = V_{-}, V_{O} = V_{S}/2$		3		μs
	SHDN pin input bias	$V_S = 2.7 \text{ V to } 16 \text{ V}, (V+) \ge \text{SHDN} \ge (V-) + 0.9 \text{ V}$		500		nΛ
	current (per pin)	V _S = 2.7 V to 16 V, (V−) ≤ SHDN ≤ (V−) + 0.7 V		150		nA

Disable time (t_{OFF}) and enable time (t_{ON}) are defined as the time interval between the 50% point of the signal applied to the SHDN pin and the point at which the output voltage reaches the 10% (disable) or 90% (enable) level.

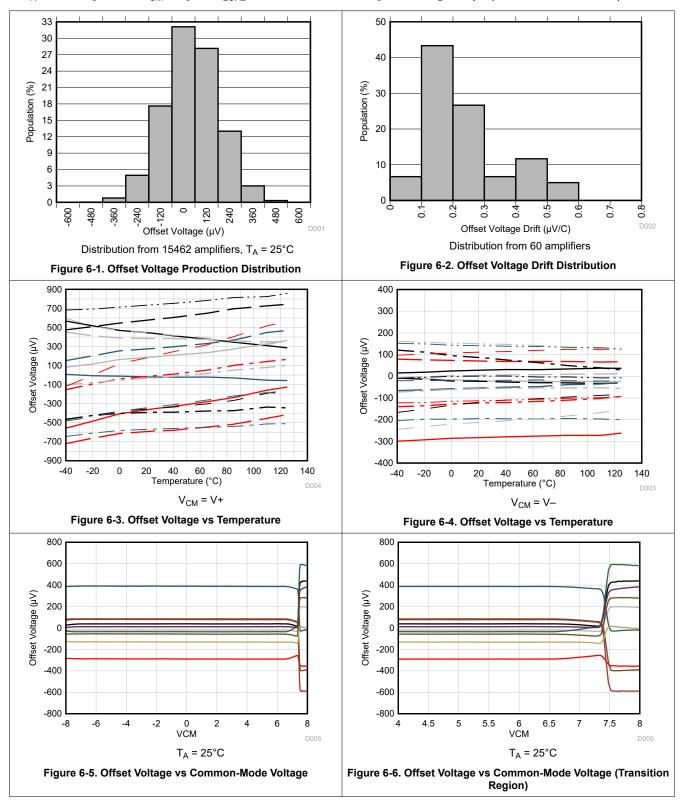
⁽²⁾ Specified by characterization only.



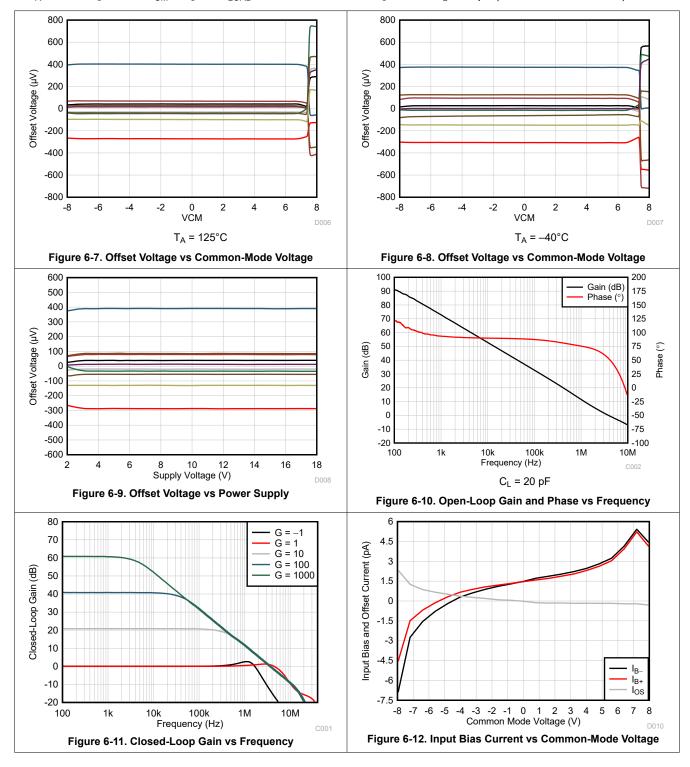
Table 6-1. Table of Graphs

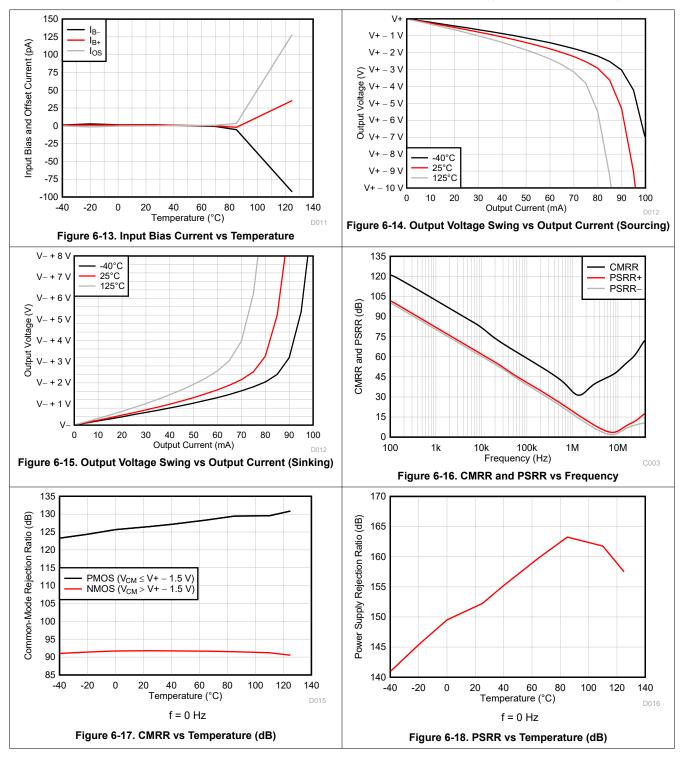
DESCRIPTION	FIGURE
Offset Voltage Production Distribution	Figure 6-1
Offset Voltage Drift Distribution	Figure 6-2
Offset Voltage vs Temperature	Figure 6-3, Figure 6-4
Offset Voltage vs Common-Mode Voltage	Figure 6-5, Figure 6-6, Figure 6-7, Figure 6-8
Offset Voltage vs Power Supply	Figure 6-9
Open-Loop Gain and Phase vs Frequency	Figure 6-10
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Input Bias Current vs Common-Mode Voltage	Figure 6-12
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Maximum Output Voltage vs Frequency	Figure 6-39
Channel Separation vs Frequency	Figure 6-40
EMIRR vs Frequency	Figure 6-41

6.8 Typical Characteristics

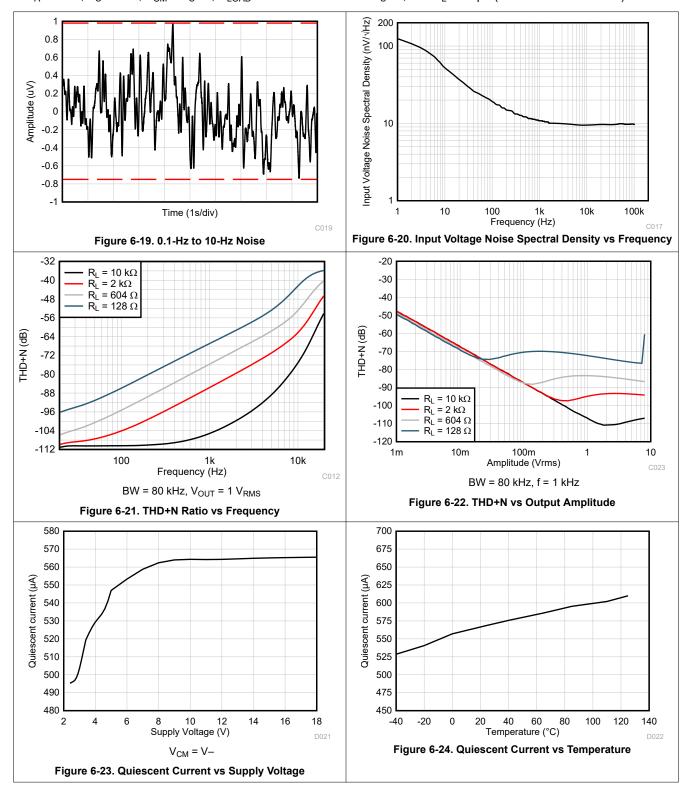


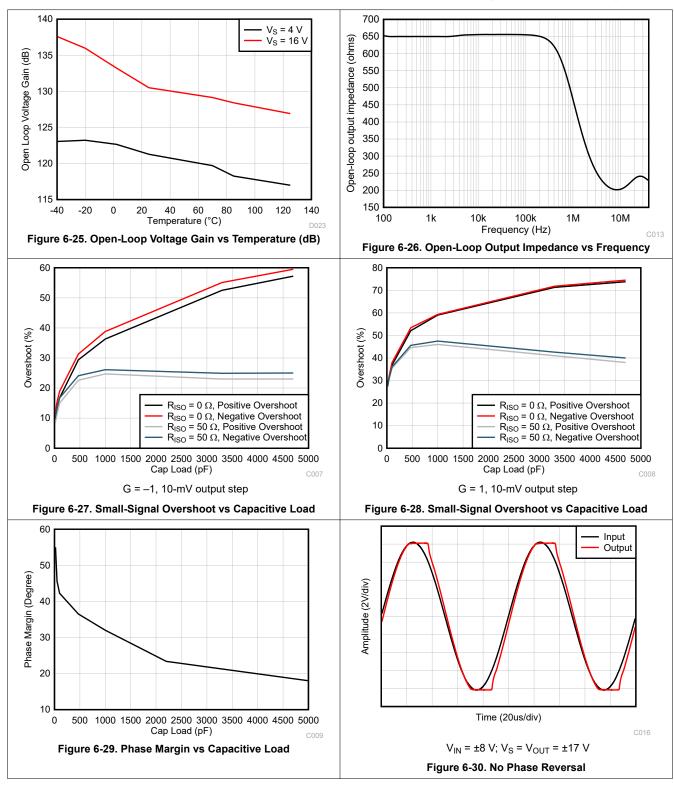




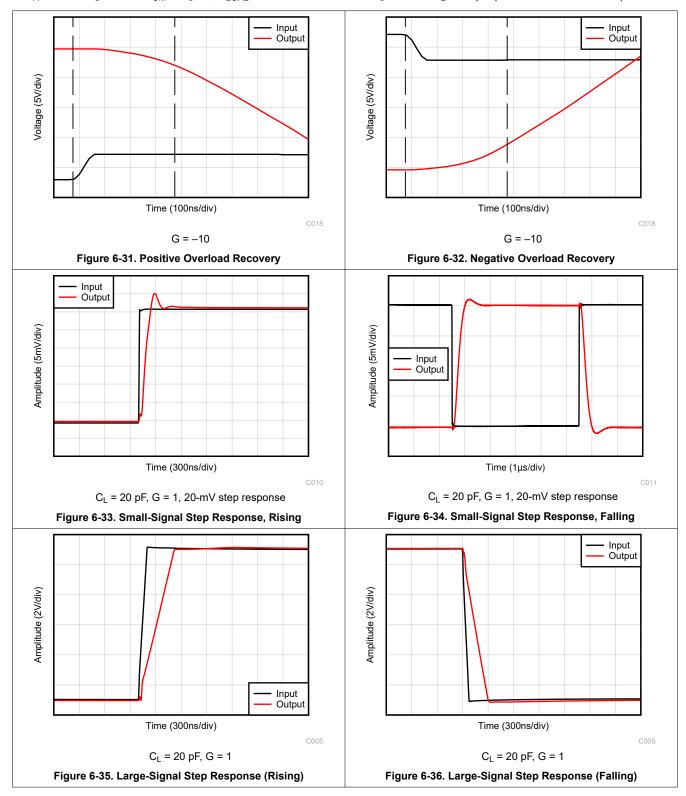




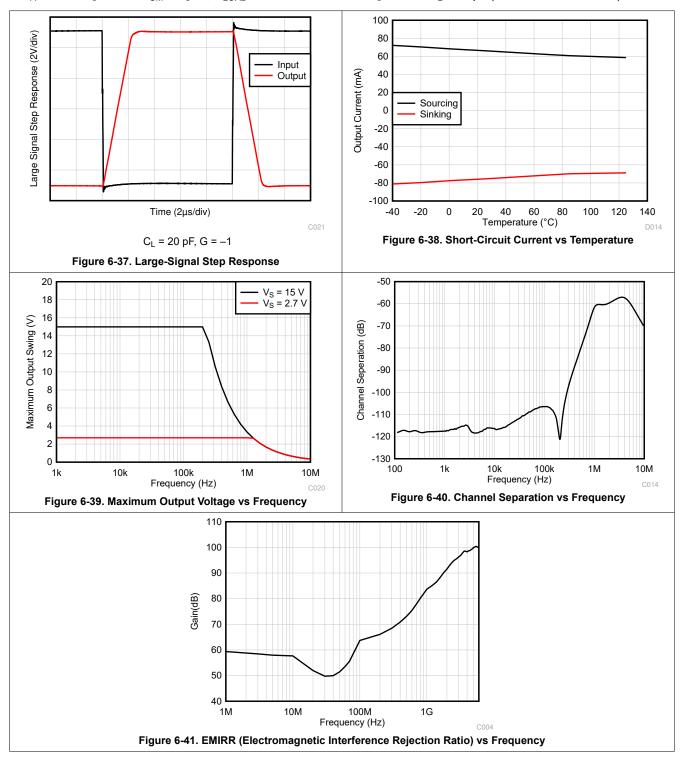












7 Detailed Description

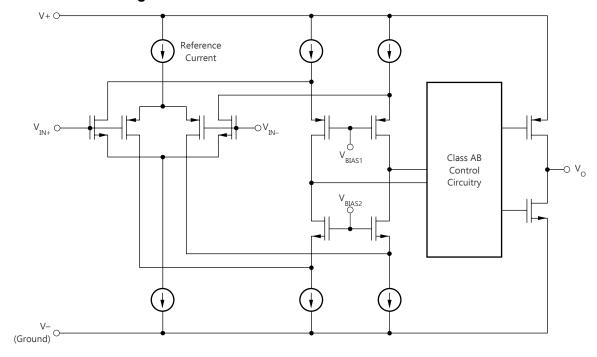
7.1 Overview

The TLV915x family (TLV9151, TLV9152, and TLV9154) is a family of 16-V general purpose operational amplifiers.

These devices offer excellent DC precision and AC performance, including rail-to-rail input/output, low offset $(\pm 125 \,\mu\text{V}, \,\text{typ})$, low offset drift $(\pm 0.3 \,\mu\text{V}/^{\circ}\text{C}, \,\text{typ})$, and 4.5-MHz bandwidth.

Wide differential and common-mode input-voltage range, high output current (± 80 mA), high slew rate (21 V/ μ s), low power operation (560 μ A, typ) and shutdown functionality make the TLV915x a robust, high-speed, high-performance operational amplifier for industrial applications.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 EMI Rejection

The TLV915x 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 TLV915x 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 10 MHz to 6 GHz. Figure 7-1 shows the results of this testing on the TLV915x. Table 7-1 shows the EMIRR IN+ values for the TLV915x at particular frequencies commonly encountered in real-world applications. The *EMI Rejection Ratio of Operational Amplifiers* application report contains detailed information on the topic of EMIRR performance as it relates to op amps and is available for download from www.ti.com.

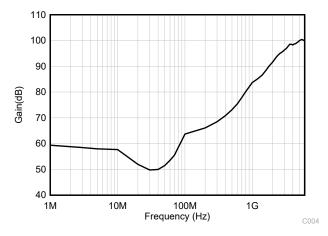


Figure 7-1. EMIRR Testing

Table 7-1. TLV9151 EMIRR IN+ for Frequencies of Interest

FREQUENCY	APPLICATION OR ALLOCATION	EMIRR IN+
400 MHz	Mobile radio, mobile satellite, space operation, weather, radar, ultra-high frequency (UHF) applications	73.2 dB
900 MHz	Global system for mobile communications (GSM) applications, radio communication, navigation, GPS (to 1.6 GHz), GSM, aeronautical mobile, UHF applications	82.5 dB
1.8 GHz	GSM applications, mobile personal communications, broadband, satellite, L-band (1 GHz to 2 GHz)	89.7 dB
2.4 GHz	802.11b, 802.11g, 802.11n, Bluetooth®, mobile personal communications, industrial, scientific and medical (ISM) radio band, amateur radio and satellite, S-band (2 GHz to 4 GHz)	93.9 dB
3.6 GHz	Radiolocation, aero communication and navigation, satellite, mobile, S-band	95.7 dB
5 GHz	802.11a, 802.11n, aero communication and navigation, mobile communication, space and satellite operation, C-band (4 GHz to 8 GHz)	98.0 dB

7.3.2 Thermal Protection

The internal power dissipation of any amplifier causes its internal (junction) temperature to rise. This phenomenon is called *self heating*. The absolute maximum junction temperature of the TLV915x is 150°C. Exceeding this temperature causes damage to the device. The TLV915x has a thermal protection feature that reduces damage from self heating. The protection works by monitoring the temperature of the device and turning off the op amp output drive for temperatures above 170°C. Figure 7-2 shows an application example for the TLV9151 that has significant self heating because of its power dissipation (0.81 W). Thermal calculations indicate that for an ambient temperature of 65°C, the device junction temperature must reach 177°C. The actual device, however, turns off the output drive to recover towards a safe junction temperature. Figure 7-2 shows how the circuit behaves during thermal protection. During normal operation, the device acts as a buffer so the output is 3 V. When self heating causes the device junction temperature to increase above the internal limit, the thermal protection forces the output to a high-impedance state and the output is pulled to ground through resistor R_L. If the condition that caused excessive power dissipation is not removed, the amplifier will oscillate between a shutdown and enabled state until the output fault is corrected.

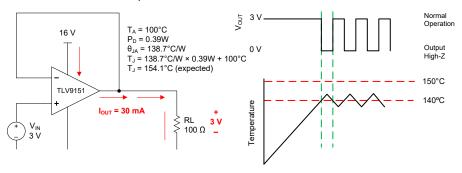
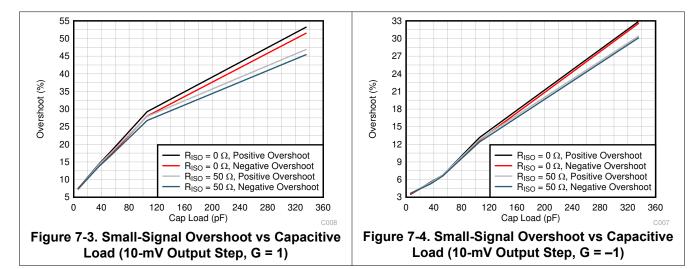


Figure 7-2. Thermal Protection

7.3.3 Capacitive Load and Stability

The TLV915x features a resistive output stage capable of driving moderate capacitive loads, and by leveraging an isolation resistor, the device can easily be configured to drive large capacitive loads. Increasing the gain enhances the ability of the amplifier to drive greater capacitive loads; see Figure 7-3 and Figure 7-4. The particular op amp circuit configuration, layout, gain, and output loading are some of the factors to consider when establishing whether an amplifier will be stable in operation.



For additional drive capability in unity-gain configurations, improve capacitive load drive by inserting a small resistor, $R_{\rm ISO}$, in series with the output, as shown in Figure 7-5. This resistor significantly reduces ringing and maintains DC performance for purely capacitive loads. However, if a resistive load is in parallel with the

capacitive load, then a voltage divider is created, thus introducing a gain error at the output and slightly reducing the output swing. The error introduced is proportional to the ratio R_{ISO} / R_{L} , and is generally negligible at low output levels. A high capacitive load drive makes the TLV915x well suited for applications such as reference buffers, MOSFET gate drives, and cable-shield drives. The circuit shown in Figure 7-5 uses an isolation resistor, R_{ISO}, to stabilize the output of an op amp. R_{ISO} modifies the open-loop gain of the system for increased phase margin.

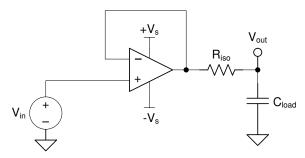


Figure 7-5. Extending Capacitive Load Drive With the TLV9151

7.3.4 Common-Mode Voltage Range

The TLV915x is a 16-V, rail-to-rail input operational amplifier with an input common-mode range that extends 200 mV beyond either supply rail. This wide range is achieved with paralleled complementary N-channel and P-channel differential input pairs, as shown in Figure 7-6. The N-channel pair is active for input voltages close to the positive rail, typically (V+) - 1 V to 100 mV above the positive supply. The P-channel pair is active for inputs from 100 mV below the negative supply to approximately (V+) - 2 V. There is a small transition region, typically (V+) - 2 V to (V+) - 1 V in which both input pairs are on. This transition region can vary modestly with process variation, and within this region PSRR, CMRR, offset voltage, offset drift, noise, and THD performance may be degraded compared to operation outside this region.

Figure 6-5 shows this transition region for a typical device in terms of input voltage offset in more detail.

For more information on common-mode voltage range and PMOS/NMOS pair interaction, see *Op Amps With Complementary-Pair Input Stages* application note.

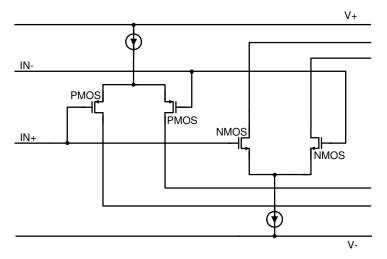


Figure 7-6. Rail-to-Rail Input Stage

7.3.5 Phase Reversal Protection

The TLV915x family has internal phase-reversal protection. Many op amps exhibit a phase reversal when the input is driven beyond its linear common-mode range. This condition is most often encountered in non-inverting circuits when the input is driven beyond the specified common-mode voltage range, causing the output to reverse into the opposite rail. The TLV915x is a rail-to-rail input op amp; therefore, the common-mode range can extend up to the rails. Input signals beyond the rails do not cause phase reversal; instead, the output limits into the appropriate rail. This performance is shown in Figure 7-7. For more information on phase reversal, see *Op Amps With Complementary-Pair Input Stages* application note.

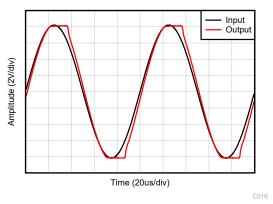


Figure 7-7. No Phase Reversal

7.3.6 Electrical Overstress

Designers often ask questions about the capability of an operational amplifier to withstand electrical overstress (EOS). These questions tend to focus on the device inputs, but may 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 its relevance to an electrical overstress event is helpful. Figure 7-8 shows an illustration of the ESD circuits contained in the TLV915x (indicated by the dashed line area). 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 diodes meet at an absorption device or the power-supply ESD cell, internal to the operational amplifier. This protection circuitry is intended to remain inactive during normal circuit operation.

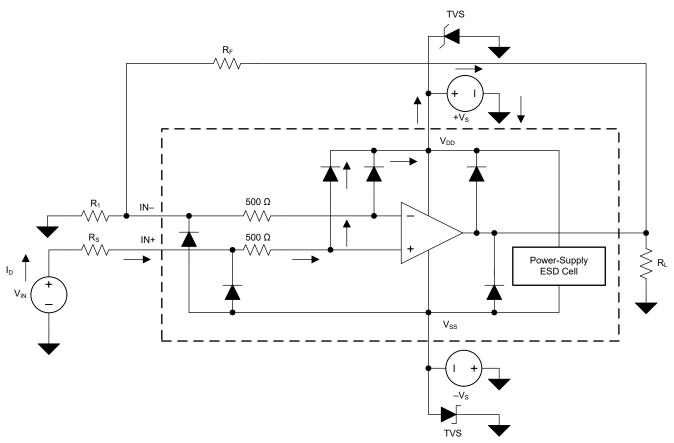


Figure 7-8. Equivalent Internal ESD Circuitry Relative to a Typical Circuit Application

An ESD event is very short in duration and very high voltage (for example; 1 kV, 100 ns), whereas an EOS event is long duration and lower voltage (for example; 50 V, 100 ms). The ESD diodes are designed for out-of-circuit ESD protection (that is, during assembly, test, and storage of the device before being soldered to the PCB). During an ESD event, the ESD signal is passed through the ESD steering diodes to an absorption circuit (labeled ESD power-supply circuit). The ESD absorption circuit clamps the supplies to a safe level.

Although this behavior is necessary for out-of-circuit protection, excessive current and damage is caused if activated in-circuit. A transient voltage suppressors (TVS) can be used to prevent against damage caused by turning on the ESD absorption circuit during an in-circuit ESD event. Using the appropriate current limiting resistors and TVS diodes allows for the use of device ESD diodes to protect against EOS events.

7.3.7 Overload Recovery

Overload recovery is defined as the time required for the op amp output to recover from a saturated state to a linear state. The output devices of the op amp enter a saturation region when the output voltage exceeds the rated operating voltage, either due to the high input voltage or the high gain. After the device enters the saturation region, the charge carriers in the output devices require time to return back to the linear state. After the charge carriers return back to the linear state, the device begins to slew at the specified slew rate. Thus, 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 TLV915x is approximately 500 ns.

7.3.8 Typical Specifications and Distributions

Designers often have questions about a typical specification of an amplifier in order to design a more robust circuit. Due to natural variation in process technology and manufacturing procedures, every specification of an amplifier will exhibit some amount of deviation from the ideal value, like an amplifier's input offset voltage. These deviations often follow *Gaussian* ("bell curve"), or *normal* distributions, and circuit designers can leverage this information to guardband their system, even when there is not a minimum or maximum specification in the *Electrical Characteristics* table.

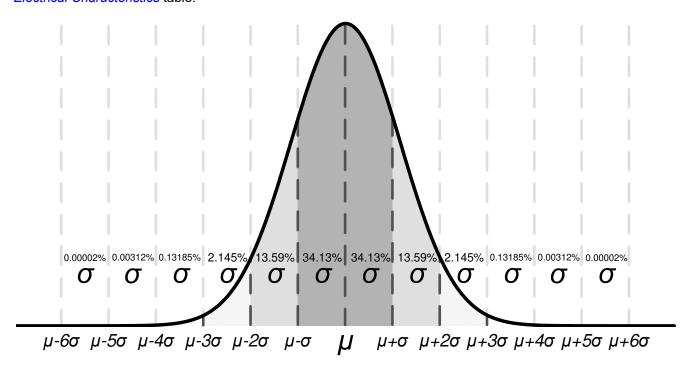


Figure 7-9. Ideal Gaussian Distribution

Figure 7-9 shows an example distribution, where μ , or mu, is the mean of the distribution, and where σ , or sigma, is the standard deviation of a system. For a specification that exhibits this kind of distribution, approximately two-thirds (68.26%) of all units can be expected to have a value within one standard deviation, or one sigma, of the mean (from $\mu - \sigma$ to $\mu + \sigma$).

Depending on the specification, values listed in the *typical* column of the *Electrical Characteristics* table are represented in different ways. As a general rule of thumb, if a specification naturally has a nonzero mean (for example, like gain bandwidth), then the typical value is equal to the mean (μ). However, if a specification naturally has a mean near zero (like input offset voltage), then the typical value is equal to the mean plus one standard deviation (μ + σ) in order to most accurately represent the typical value.

You can use this chart to calculate approximate probability of a specification in a unit; for example, for TLV915x, the typical input voltage offset is 125 μ V, so 68.2% of all TLV915x devices are expected to have an offset from

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 $-125 \mu V$ to 125 μV . At 4 σ ($\pm 500 \mu V$), 99.9937% of the distribution has an offset voltage less than $\pm 500 \mu V$, which means 0.0063% of the population is outside of these limits, which corresponds to about 1 in 15.873 units.

Specifications with a value in the minimum or maximum column are assured by TI, and units outside these limits will be removed from production material. For example, the TLV915x family has a maximum offset voltage of 675 µV at 25°C, and even though this corresponds to about 5 σ (≈1 in 1.7 million units), which is extremely unlikely, TI assures that any unit with larger offset than 675 µV will be removed from production material.

For specifications with no value in the minimum or maximum column, consider selecting a sigma value of sufficient guardband for your application, and design worst-case conditions using this value. For example, the 6-σ value corresponds to about 1 in 500 million units, which is an extremely unlikely chance, and could be an option as a wide guardband to design a system around. In this case, the TLV915x family does not have a maximum or minimum for offset voltage drift, but based on Figure 6-2 and the typical value of 0.3 μV/°C in the Electrical Characteristics table, it can be calculated that the 6 σ value for offset voltage drift is about 1.8 μV/°C. When designing for worst-case system conditions, this value can be used to estimate the worst possible offset across temperature without having an actual minimum or maximum value.

However, process variation and adjustments over time can shift typical means and standard deviations, and unless there is a value in the minimum or maximum specification column, TI cannot assure the performance of a device. This information should be used only to estimate the performance of a device.

7.3.9 Packages With an Exposed Thermal Pad

The TLV915x family is available in the WSON-8 (DSG) package which features an exposed thermal pad. Inside the package, the die is attached to this thermal pad using an electrically conductive compound. For this reason, when using a package with an exposed thermal pad, the thermal pad must either be connected to V- or left floating. Attaching the thermal pad to a potential other than V- is not allowed, and performance of the device is not assured when doing so.

7.3.10 Shutdown

The TLV915xS devices feature one or more shutdown pins (SHDN) that disable the op amp, placing it into a low-power standby mode. In this mode, the op amp typically consumes about 30 uA. The SHDN pins are active high, meaning that shutdown mode is enabled when the input to the SHDN pin is a valid logic high. The amplifier is enabled when the input to the SHDN pin is a valid logic low.

The SHDN pins are referenced to the negative supply rail of the op amp. The threshold of the shutdown feature lies around 800 mV (typical) and does not change with respect to the supply voltage. Hysteresis has been included in the switching threshold to ensure smooth switching characteristics. To ensure optimal shutdown behavior, the SHDN pins should be driven with valid logic signals. A valid logic low is defined as a voltage between V- and V- + 0.2 V. A valid logic high is defined as a voltage between V- + 1.1 V and V+. The shutdown pin circuitry includes a pull-down resistor, which will inherently pull the voltage of the pin to the negative supply rail if not driven. Thus, to enable the amplifier, the SHDN pins should either be left floating or driven to a valid logic low. To disable the amplifier, the SHDN pins must be driven to a valid logic high. The maximum voltage allowed at the SHDN pins is V+.

The SHDN pins are high-impedance CMOS inputs. Channels of single and dual op amp packages are independently controlled, and channels of quad op amp packages are controlled in pairs. For battery-operated applications, this feature may be used to greatly reduce the average current and extend battery life. The typical enable time out of shutdown is 8 µs; disable time is 3 µs. When disabled, the output assumes a high-impedance state. This architecture allows the TLV915xS family to operate as a gated amplifier, multiplexer, or programmable-gain amplifier. Shutdown time (t_{OFF}) depends on loading conditions and increases as load resistance increases. To ensure shutdown (disable) within a specific shutdown time, the specified 10-k Ω load to midsupply (V_S / 2) is required. If using the TLV915xS without a load, the resulting turnoff time significantly increases.



7.4 Device Functional Modes

The TLV915x has a single functional mode and is operational when the power-supply voltage is greater than 2.7 V (±1.35 V). The maximum power supply voltage for the TLV915x is 16 V (±8 V).

The TLV915xS devices feature a shutdown pin, which can be used to place the op amp into a low-power mode. See Shutdown section for more information.

8 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.

8.1 Application Information

The TLV915x family offers excellent DC precision and DC performance. These devices operate up to 16-V supply rails and offer true rail-to-rail input/output, low offset voltage and offset voltage drift, as well as 4.5-MHz bandwidth and high output drive. These features make the TLV915x a robust, high-performance operational amplifier for high-voltage industrial applications.

8.2 Typical Applications

8.2.1 Low-Side Current Measurement

Figure 8-1 shows the TLV9151 configured in a low-side current sensing application. For a full analysis of the circuit shown in Figure 8-1 including theory, calculations, simulations, and measured data, see TI Precision Design TIPD129, *0-A to 1-A Single-Supply Low-Side Current-Sensing Solution*.

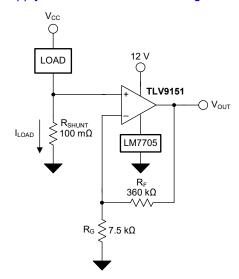


Figure 8-1. TLV9151 in a Low-Side, Current-Sensing Application

8.2.1.1 Design Requirements

The design requirements for this design are:

Load current: 0 A to 1 AOutput voltage: 4.9 V

Maximum shunt voltage: 100 mV

8.2.1.2 Detailed Design Procedure

The transfer function of the circuit in Figure 8-1 is given in Equation 1.

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

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

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

Using Equation 2, R_{SHUNT} is calculated to be 100 m Ω . The voltage drop produced by I_{LOAD} and R_{SHUNT} is amplified by the TLV9151 to produce an output voltage of 0 V to 4.9 V. The gain needed by the TLV9151 to produce the necessary output voltage is calculated using Equation 3.

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

Using Equation 3, the required gain is calculated to be 49 V/V, which is set with resistors R_F and R_G . Equation 4 is used to size the resistors, R_F and R_G , to set the gain of the TLV9151 to 49 V/V.

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

Choosing R_F as 360 k Ω , R_G is calculated to be 7.5 k Ω . R_F and R_G were chosen as 360 k Ω and 7.5 k Ω because they are standard value resistors that create a 49:1 ratio. Other resistors that create a 49:1 ratio can also be used. Figure 8-2 shows the measured transfer function of the circuit shown in Figure 8-1.

8.2.1.3 Application Curves

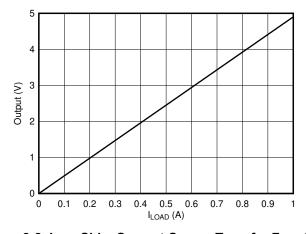


Figure 8-2. Low-Side, Current-Sense, Transfer Function

9 Power Supply Recommendations

The TLV915x is specified for operation from 2.7 V to 16 V (±1.35 V to ±8 V); many specifications apply from –40°C to 125°C. Parameters that can exhibit significant variance with regard to operating voltage or temperature are presented in the *Typical Characteristics*.

CAUTION

Supply voltages larger than 16 V can permanently damage the device; see the *Absolute Maximum Ratings*.

Place 0.1-µF 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, refer to the *Layout* section.

10 Layout

10.1 Layout Guidelines

For best operational performance of the device, use good PCB layout practices, including:

- Noise can propagate into analog circuitry through the power pins of the circuit as a whole and op amp itself.
 Bypass capacitors are used to reduce the coupled noise by providing low-impedance power sources local to the analog circuitry.
 - Connect low-ESR, 0.1-µF 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 singlesupply applications.
- Separate grounding for analog and digital portions of circuitry is one of the simplest and most-effective methods of noise suppression. One or more layers on multilayer PCBs are usually devoted to ground planes. A ground plane helps distribute heat and reduces EMI noise pickup. Make sure to physically separate digital and analog grounds paying attention to the flow of the ground current.
- In order 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 10-2, keeping RF and RG close to the inverting input minimizes parasitic capacitance.
- Keep the length of input traces as short as possible. Always remember that the input traces are the most sensitive part of the circuit.
- Consider a driven, low-impedance guard ring around the critical traces. A guard ring can significantly reduce leakage currents from nearby traces that are at different potentials.
- Cleaning the PCB following board assembly is recommended for best performance.
- Any precision integrated circuit may experience performance shifts due to 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.



10.2 Layout Example

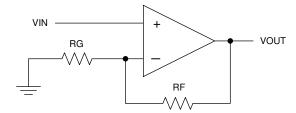


Figure 10-1. Schematic Representation

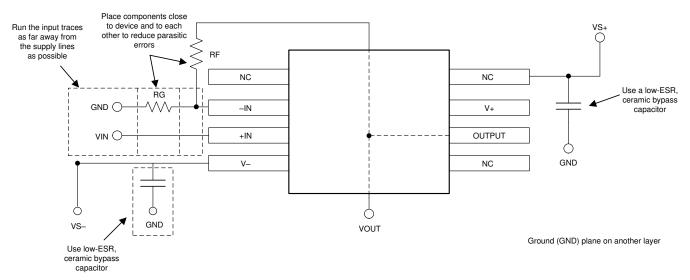


Figure 10-2. Operational Amplifier Board Layout for Noninverting Configuration



11 Device and Documentation Support

11.1 Device Support

11.1.1 Development Support

11.1.1.1 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.

11.1.1.2 TI Precision Designs

The TLV915x is featured in several TI Precision Designs, available online at http://www.ti.com/ww/en/analog/precision-designs/. TI Precision Designs are analog solutions created by TI's precision analog applications experts and offer the theory of operation, component selection, simulation, complete PCB schematic and layout, bill of materials, and measured performance of many useful circuits.

11.2 Documentation Support

11.2.1 Related Documentation

Texas Instruments, Analog Engineer's Circuit Cookbook: Amplifiers.

Texas Instruments, AN31 amplifier circuit collection.

11.3 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Subscribe to updates* 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.

11.4 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.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

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11.5 Trademarks

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TI E2E[™] is a trademark of Texas Instruments.

Bluetooth® is a registered trademark of Bluetooth SIG, Inc.

All trademarks are the property of their respective owners.

11.6 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.

11.7 Glossary

TI Glossary

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



12 Mechanical, Packaging, and Orderable Information

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

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PACKAGING INFORMATION

Orderable part number	Status (1)	Material type	Package Pins	Package qty Carrier	RoHS (3)	Lead finish/ Ball material	MSL rating/ Peak reflow	Op temp (°C)	Part marking (6)
TLV9151IDBVR	Active	Production	SOT-23 (DBV) 5	3000 LARGE T&R	Yes	NIPDAU SN	Level-1-260C-UNLIM	-40 to 125	T51V
TLV9151IDBVR.A	Active	Production	SOT-23 (DBV) 5	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T51V
TLV9151IDCKR	Active	Production	SC70 (DCK) 5	3000 LARGE T&R	Yes	SN	Level-2-260C-1 YEAR	-40 to 125	1HD
TLV9151IDCKR.A	Active	Production	SC70 (DCK) 5	3000 LARGE T&R	Yes	SN	Level-2-260C-1 YEAR	-40 to 125	1HD
TLV9151SIDBVR	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAU SN	Level-1-260C-UNLIM	-40 to 125	T91S
TLV9151SIDBVR.A	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T91S
TLV9151SIDBVRG4	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T91S
TLV9151SIDBVRG4.A	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T91S
TLV9152IDDFR	Active	Production	SOT-23-THIN (DDF) 8	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T52F
TLV9152IDDFR.A	Active	Production	SOT-23-THIN (DDF) 8	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T52F
TLV9152IDDFRG4	Active	Production	SOT-23-THIN (DDF) 8	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T52F
TLV9152IDDFRG4.A	Active	Production	SOT-23-THIN (DDF) 8	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T52F
TLV9152IDGKR	Active	Production	VSSOP (DGK) 8	2500 LARGE T&R	Yes	NIPDAU SN	Level-1-260C-UNLIM	-40 to 125	27TT
TLV9152IDGKR.A	Active	Production	VSSOP (DGK) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	27TT
TLV9152IDR	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T9152D
TLV9152IDR.A	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T9152D
TLV9152IDSGR	Active	Production	WSON (DSG) 8	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T52G
TLV9152IDSGR.A	Active	Production	WSON (DSG) 8	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T52G
TLV9152IDSGRG4	Active	Production	WSON (DSG) 8	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T52G
TLV9152IDSGRG4.A	Active	Production	WSON (DSG) 8	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T52G
TLV9152IPWR	Active	Production	TSSOP (PW) 8	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T9152P
TLV9152IPWR.A	Active	Production	TSSOP (PW) 8	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T9152P
TLV9152SIRUGR	Active	Production	X2QFN (RUG) 10	3000 LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	GSF
TLV9152SIRUGR.A	Active	Production	X2QFN (RUG) 10	3000 LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	GSF
TLV9154IDR	Active	Production	SOIC (D) 14	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TLV9154D
TLV9154IDR.A	Active	Production	SOIC (D) 14	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TLV9154D
TLV9154IDYYR	Active	Production	SOT-23-THIN (DYY) 14	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TLV9154I
TLV9154IDYYR.A	Active	Production	SOT-23-THIN (DYY) 14	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TLV9154I



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Orderable part number	Status	Material type	Package Pins	Package qty Carrier	RoHS	Lead finish/ Ball material	MSL rating/ Peak reflow	Op temp (°C)	Part marking (6)
	. ,	.,				(4)	(5)		. ,
TLV9154IPWR	Active	Production	TSSOP (PW) 14	2000 LARGE T&R	Yes	NIPDAU SN	Level-2-260C-1 YEAR	-40 to 125	(TL9154, TL9154PW)
TLV9154IPWR.A	Active	Production	TSSOP (PW) 14	2000 LARGE T&R	Yes	SN	Level-2-260C-1 YEAR	-40 to 125	(TL9154, TL9154PW)
TLV9154IPWRG4	Active	Production	TSSOP (PW) 14	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TL9154
TLV9154IPWRG4.A	Active	Production	TSSOP (PW) 14	2000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TL9154
TLV9154IRUCR	Active	Production	QFN (RUC) 14	3000 LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	I5F
TLV9154IRUCR.A	Active	Production	QFN (RUC) 14	3000 LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	I5F

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

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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⁽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.

PACKAGE OPTION ADDENDUM

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OTHER QUALIFIED VERSIONS OF TLV9151, TLV9152, TLV9154:

• Automotive : TLV9151-Q1, TLV9152-Q1, TLV9154-Q1

NOTE: Qualified Version Definitions:

• Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects



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TAPE AND REEL INFORMATION





A0	Dimension designed to accommodate the component width
В0	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
TLV9151IDBVR	SOT-23	DBV	5	3000	178.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TLV9151IDCKR	SC70	DCK	5	3000	178.0	9.0	2.4	2.5	1.2	4.0	8.0	Q3
TLV9151SIDBVR	SOT-23	DBV	6	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TLV9151SIDBVRG4	SOT-23	DBV	6	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TLV9152IDDFR	SOT-23- THIN	DDF	8	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TLV9152IDDFRG4	SOT-23- THIN	DDF	8	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TLV9152IDGKR	VSSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
TLV9152IDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TLV9152IDSGR	WSON	DSG	8	3000	180.0	8.4	2.3	2.3	1.15	4.0	8.0	Q2
TLV9152IDSGRG4	WSON	DSG	8	3000	180.0	8.4	2.3	2.3	1.15	4.0	8.0	Q2
TLV9152IPWR	TSSOP	PW	8	2000	330.0	12.4	7.0	3.6	1.6	8.0	12.0	Q1
TLV9152SIRUGR	X2QFN	RUG	10	3000	178.0	8.4	1.75	2.25	0.56	4.0	8.0	Q1
TLV9154IDR	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
TLV9154IDYYR	SOT-23- THIN	DYY	14	3000	330.0	12.4	4.8	3.6	1.6	8.0	12.0	Q3



PACKAGE MATERIALS INFORMATION

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	Device	Package Type	Package Drawing		SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
	TLV9154IPWR	TSSOP	PW	14	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
ĺ	TLV9154IPWRG4	TSSOP	PW	14	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
ĺ	TLV9154IRUCR	QFN	RUC	14	3000	180.0	9.5	2.16	2.16	0.5	4.0	8.0	Q2



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*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLV9151IDBVR	SOT-23	DBV	5	3000	208.0	191.0	35.0
TLV9151IDCKR	SC70	DCK	5	3000	190.0	190.0	30.0
TLV9151SIDBVR	SOT-23	DBV	6	3000	210.0	185.0	35.0
TLV9151SIDBVRG4	SOT-23	DBV	6	3000	210.0	185.0	35.0
TLV9152IDDFR	SOT-23-THIN	DDF	8	3000	210.0	185.0	35.0
TLV9152IDDFRG4	SOT-23-THIN	DDF	8	3000	210.0	185.0	35.0
TLV9152IDGKR	VSSOP	DGK	8	2500	353.0	353.0	32.0
TLV9152IDR	SOIC	D	8	2500	353.0	353.0	32.0
TLV9152IDSGR	WSON	DSG	8	3000	210.0	185.0	35.0
TLV9152IDSGRG4	WSON	DSG	8	3000	210.0	185.0	35.0
TLV9152IPWR	TSSOP	PW	8	2000	353.0	353.0	32.0
TLV9152SIRUGR	X2QFN	RUG	10	3000	205.0	200.0	33.0
TLV9154IDR	SOIC	D	14	2500	353.0	353.0	32.0
TLV9154IDYYR	SOT-23-THIN	DYY	14	3000	336.6	336.6	31.8
TLV9154IPWR	TSSOP	PW	14	2000	353.0	353.0	32.0
TLV9154IPWRG4	TSSOP	PW	14	2000	353.0	353.0	32.0
TLV9154IRUCR	QFN	RUC	14	3000	205.0	200.0	30.0





- 1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
 2. This drawing is subject to change without notice.
 3. Reference JEDEC MO-178.

- 4. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25 mm per side.
- 5. Support pin may differ or may not be present.





NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

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





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





SMALL OUTLINE PACKAGE



PowerPAD is a trademark of Texas Instruments.

- 1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.

 2. This drawing is subject to change without notice.

 3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not
- exceed 0.15 mm per side.
- 4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
- 5. Reference JEDEC registration MO-187.



SMALL OUTLINE PACKAGE



- 6. Publication IPC-7351 may have alternate designs.
- 7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
- 8. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.
- 9. Size of metal pad may vary due to creepage requirement.



SMALL OUTLINE PACKAGE



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





- All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
- 2. This drawing is subject to change without notice.
- 3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per side
- 4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
- 5. Reference JEDEC Registration MO-345, Variation AB





- 6. Publication IPC-7351 may have alternate designs.
- 7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.





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







- 1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.

 2. This drawing is subject to change without notice.

 3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not
- exceed 0.15 mm, per side.
- 4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.43 mm, per side.
- 5. Reference JEDEC registration MS-012, variation AB.





NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

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





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



1.5 x 2, 0.5 mm pitch

PLASTIC QUAD FLATPACK - NO LEAD

This image is a representation of the package family, actual package may vary. Refer to the product data sheet for package details.





NOTES: All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.

- B. This drawing is subject to change without notice.
 C. QFN (Quad Flatpack No-Lead) package configuration.
 D. This package complies to JEDEC MO-288 variation X2EFD.



RUG (R-PQFP-N10)



- NOTES: A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Publication IPC-7351 is recommended for alternate designs.
 - D. Customers should contact their board fabrication site for minimum solder mask web tolerances between signal pads.
 - E. Maximum stencil thickness 0,127 mm (5 mils). All linear dimensions are in millimeters.
 - F. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
 - G. Side aperture dimensions over-print land for acceptable area ratio > 0.66. Customer may reduce side aperture dimensions if stencil manufacturing process allows for sufficient release at smaller opening.







- 1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
 2. This drawing is subject to change without notice.
 3. Reference JEDEC MO-203.

- 4. Support pin may differ or may not be present.5. Lead width does not comply with JEDEC.
- 6. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25mm per side





NOTES: (continued)

7. Publication IPC-7351 may have alternate designs.8. Solder mask tolerances between and around signal pads can vary based on board fabrication site.





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







- 1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.

 2. This drawing is subject to change without notice.

 3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not
- exceed 0.15 mm per side.





- 4. Publication IPC-7351 may have alternate designs.
- 5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.





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







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





NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

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





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







- 1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.

 2. This drawing is subject to change without notice.

 3. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.25 per side.

- 4. Leads 1,2,3 may be wider than leads 4,5,6 for package orientation.
- 5. Refernce JEDEC MO-178.





NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

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





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



2 x 2, 0.5 mm pitch

PLASTIC SMALL OUTLINE - NO LEAD

This image is a representation of the package family, actual package may vary. Refer to the product data sheet for package details.





PLASTIC SMALL OUTLINE - NO LEAD



- All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
- 2. This drawing is subject to change without notice.
- 3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.



PLASTIC SMALL OUTLINE - NO LEAD



NOTES: (continued)

- 4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
- Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.



PLASTIC SMALL OUTLINE - NO LEAD



NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.







NOTES:

- 1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.

 2. This drawing is subject to change without notice.

 3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not
- exceed 0.15 mm per side.
- 4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
- 5. Reference JEDEC registration MO-153.





NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

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





NOTES: (continued)

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







NOTES:

- 1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.

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- exceed 0.15 mm per side.
- 4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
- 5. Reference JEDEC registration MO-153, variation AA.



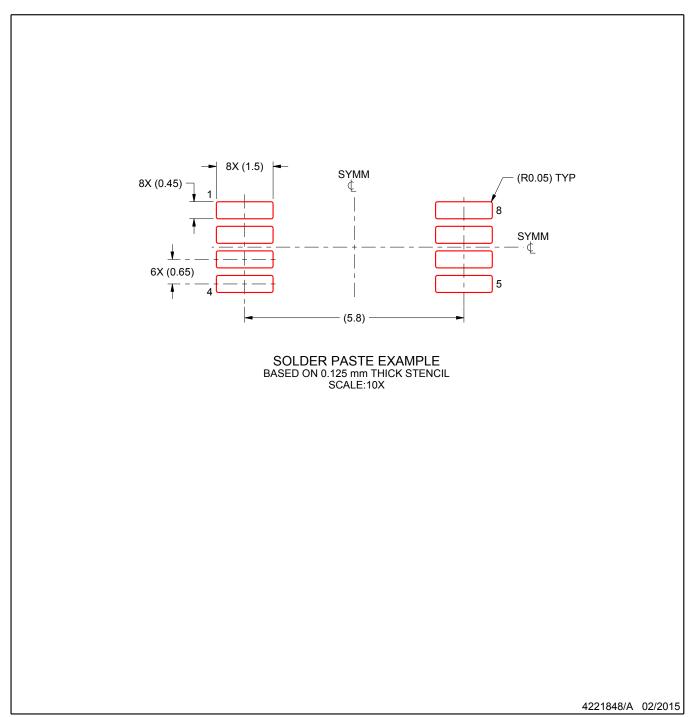


NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

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





NOTES: (continued)

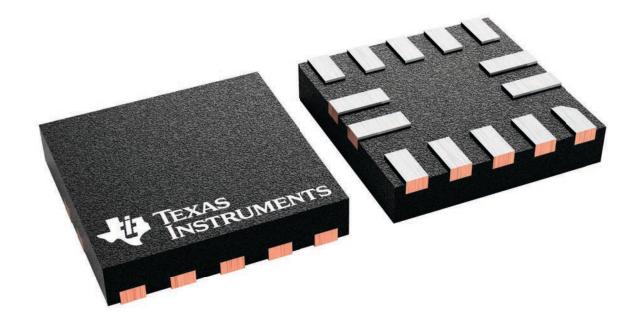
- 8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
- 9. Board assembly site may have different recommendations for stencil design.



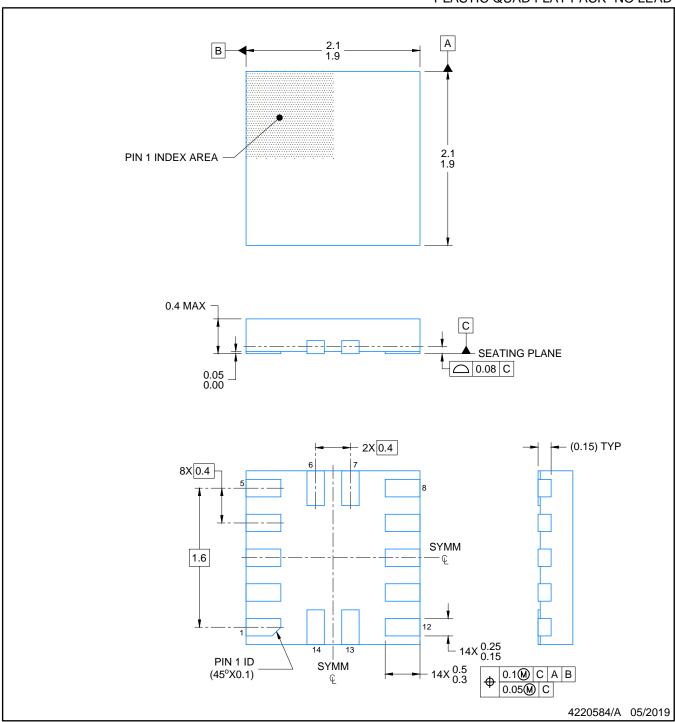
2 x 2, 0.4 mm pitch

PLASTIC QUAD FLATPACK - NO LEAD

This image is a representation of the package family, actual package may vary. Refer to the product data sheet for package details.



PLASTIC QUAD FLAT PACK- NO LEAD

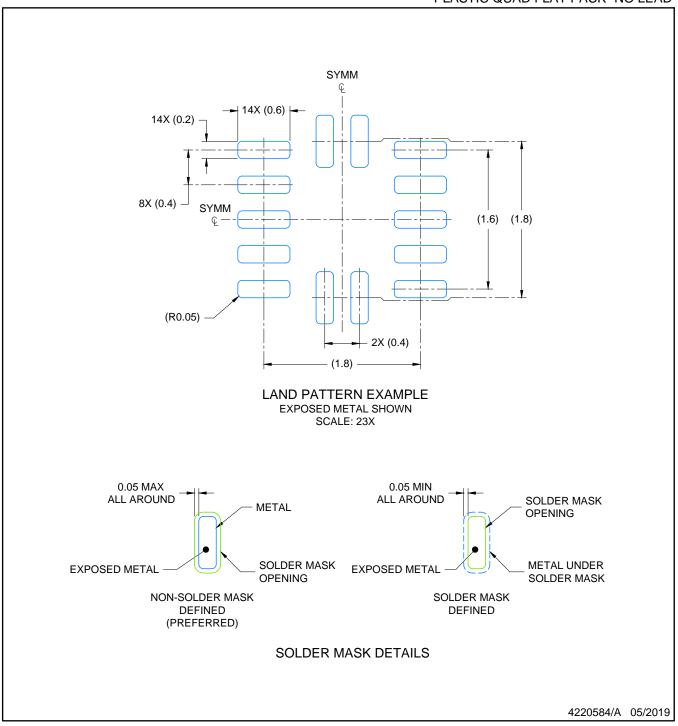


NOTES:

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- 2. This drawing is subject to change without notice.



PLASTIC QUAD FLAT PACK- NO LEAD

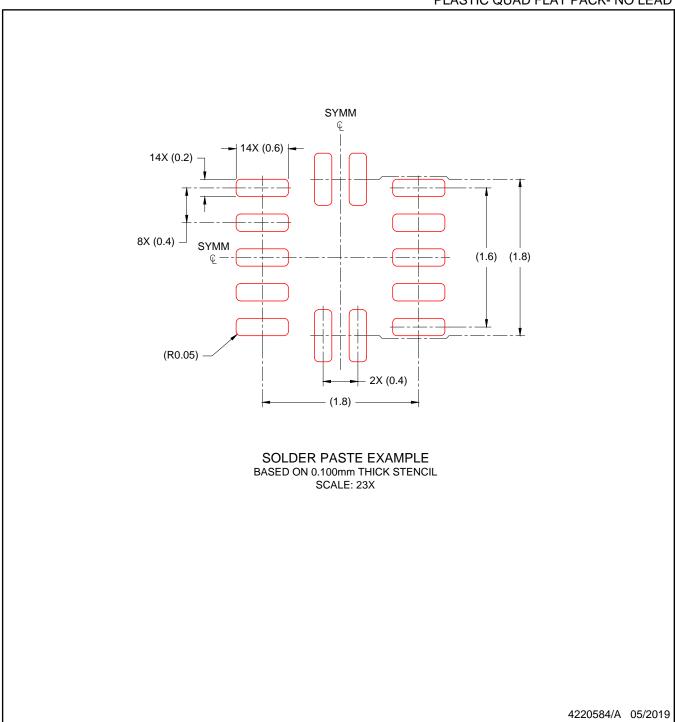


NOTES: (continued)

3. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).



PLASTIC QUAD FLAT PACK- NO LEAD



NOTES: (continued)

4. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.



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