

### Description

The TLV313 family of single-, dual-, and quad-channel precision operational amplifiers combine low power consumption with good performance. This makes them suitable for a wide range of applications, such as wearables, utility metering, building automation, currency counters and more. The family features rail-to-rail input and output (RRIO) swings, low quiescent current (65  $\mu$ A, typical), wide bandwidth (1 MHz) and very low noise (26 nV/ $\sqrt{\text{Hz}}$  at 1 kHz), making it attractive for a variety of battery-powered applications that require a good balance between cost and performance. Further, low-input-bias current enables these devices to be used in applications with megaohm source impedances.

The robust design of the TLV313 devices provides ease-of-use to the circuit designer: unity-gain stability with capacitive loads of up to 150 pF, integrated RF/EMI rejection filter, no phase reversal in overdrive conditions, and high electrostatic discharge (ESD) protection (4-kV HBM).

The devices are optimized for operation at voltages as low as +1.8 V ( $\pm 0.9$  V) and up to +5.5 V ( $\pm 2.75$  V), and are specified over the extended temperature range of  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

The single-channel TLV313 device is available in both SC70-5 and SOT23-5 packages. The dual-channel TLV2313 device is offered in SOIC-8 and VSSOP-8 packages, and the quad-channel TLV4313 device is offered in a TSSOP-14 package.

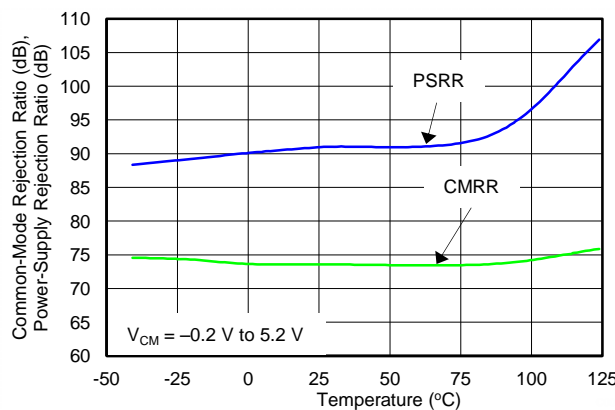
### Features

- Precision Amplifier for Cost-Sensitive Systems
- Low  $I_Q$ : 65  $\mu\text{A}/\text{ch}$
- Wide Supply Range: 1.8 V to 5.5 V
- Low Noise: 26 nV/ $\sqrt{\text{Hz}}$  at 1 kHz
- Gain Bandwidth: 1 MHz
- Rail-to-Rail Input/Output
- Low Input Bias Current: 1 pA
- Low Offset Voltage: 0.75 mV
- Unity-Gain Stable
- Internal RF/EMI Filter
- Extended Temperature Range:  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$

### Applications

- Medical and Healthcare
- Fitness and Wearable Electronics
- Utility Metering (Heat, Water, Energy)
- Building Automation Equipment
- Currency Counters

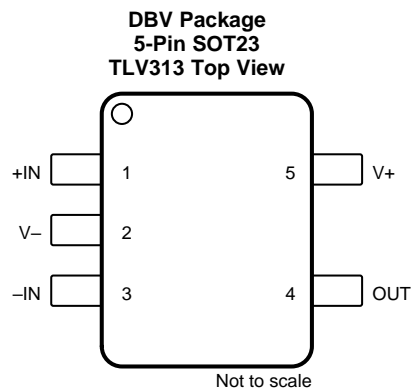
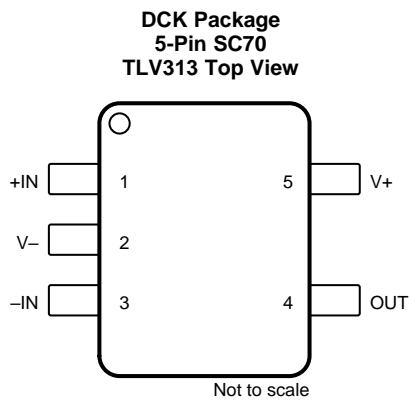
CMRR and PSRR vs Temperature



**Device Comparison Table**

DEVICE	NO. OF CHANNELS	PACKAGE LEADS			
		SC70	SOT23	SOP	TSSOP
TLV313	1	5	5	—	—
TLV2313	2	—	—	8	—
TLV4313	4	—	—	—	14

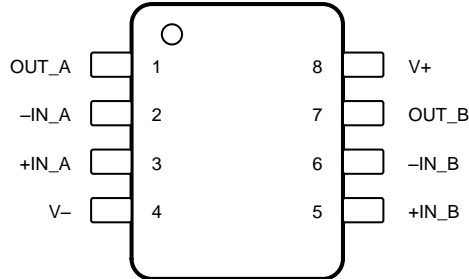
**Pin Configuration and Functions**



**Pin Functions: TLV313**

NAME	PIN		I/O	DESCRIPTION
	DCK (SC70)	DBV (SOT23)		
+IN	3	3	I	Inverting input
V-	2	2	—	Negative (lowest) power supply
-IN	4	4	I	Output
OUT	1	1	O	Noninverting input
V+	5	5	—	Positive (highest) power supply

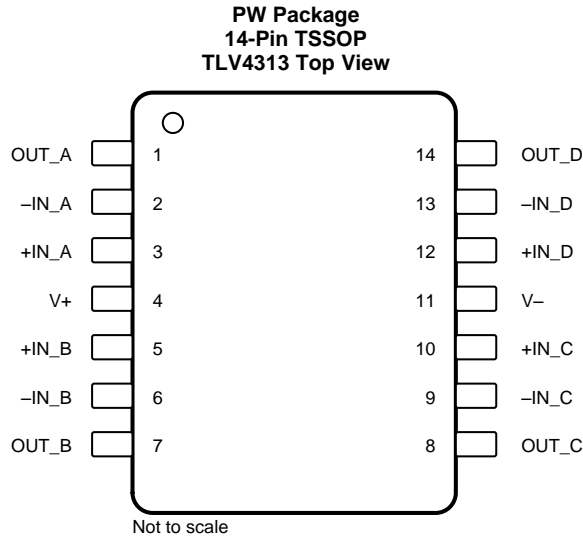
D, DGK Packages  
8-Pin SOP



Not to scale

Pin Functions: TLV2313

PIN		I/O	DESCRIPTION
NAME	D (SOIC)		
V-	4	—	Negative (lowest) power supply
V+	8	—	Positive (highest) power supply
OUT A	1	O	Output, channel A
OUT B	7	O	Output, channel B
-IN A	2	I	Inverting input, channel A
+IN A	3	I	Noninverting input, channel A
-IN B	6	I	Inverting input, channel B
+IN B	5	I	Noninverting input, channel B



**Pin Functions: TLV4313**

PIN		I/O	DESCRIPTION
NAME	PW (TSSOP)		
V-	11	—	Negative (lowest) power supply
V+	4	—	Positive (highest) power supply
OUT A	1	O	Output, channel A
OUT B	7	O	Output, channel B
OUT C	8	O	Output, channel C
OUT D	14	O	Output, channel D
-IN A	2	I	Inverting input, channel A
+IN A	3	I	Noninverting input, channel A
-IN B	6	I	Inverting input, channel B
+IN B	5	I	Noninverting input, channel B
-IN C	9	I	Inverting input, channel C
+IN C	10	I	Noninverting input, channel C
-IN D	13	I	Inverting input, channel D
+IN D	12	I	Noninverting input, channel D

### AbsoluteMaximumRatings

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

		MIN	MAX	UNIT
Voltage	Supply voltage		7	V
	Signal input terminals <sup>(2)</sup>	(V-) - (0.5)	(V+) + 0.5	V
Current	Signal input terminals <sup>(2)</sup>	-10	10	mA
	Output short circuit <sup>(3)</sup>	Continuous		
Temperature	Operating, T <sub>A</sub>	-40	150	°C
	Junction, T <sub>J</sub>		150	°C
	Storage, T <sub>stg</sub>	-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) 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.
- (3) Short-circuit to ground, one amplifier per package.

### ESDRatings

		VALUE	UNIT
V <sub>(ESD)</sub> Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	±4000	V
	Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup>	±1000	

- (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.

### RecommendedOperatingConditions

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

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

**Thermal Information: TLV313**

THERMAL METRIC <sup>(1)</sup>		TLV313		UNIT
		DBV (SOT23)	DCK (SC70)	
		5 PINS	5 PINS	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	228.5	281.4	°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	99.1	91.6	°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	54.6	59.6	°C/W
ψ <sub>JT</sub>	Junction-to-top characterization parameter	7.7	1.5	°C/W
ψ <sub>JB</sub>	Junction-to-board characterization parameter	53.8	58.8	°C/W
R <sub>θJC(bot)</sub>	Junction-to-case (bottom) thermal resistance	N/A	N/A	°C/W

**Thermal Information: TLV2313**

THERMAL METRIC <sup>(1)</sup>		TLV2313		UNIT
		D(SOP)		
		8 PINS		
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	138.4		°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	89.5		°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	78.6		°C/W
ψ <sub>JT</sub>	Junction-to-top characterization parameter	29.9		°C/W
ψ <sub>JB</sub>	Junction-to-board characterization parameter	78.1		°C/W
R <sub>θJC(bot)</sub>	Junction-to-case (bottom) thermal resistance	N/A		°C/W

**Thermal Information: TLV4313**

THERMAL METRIC <sup>(1)</sup>		TLV4313		UNIT
		PW (TSSOP)		
		14 PINS		
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	121.0		°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	49.4		°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	62.8		°C/W
ψ <sub>JT</sub>	Junction-to-top characterization parameter	5.9		°C/W
ψ <sub>JB</sub>	Junction-to-board characterization parameter	62.2		°C/W
R <sub>θJC(bot)</sub>	Junction-to-case (bottom) thermal resistance	N/A		°C/W

**Electrical Characteristics: 5.5 V<sup>(1)</sup>**

 At  $T_A = 25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S / 2$ , and  $V_{CM} = V_{OUT} = V_S / 2$ , unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>OFFSET VOLTAGE</b>						
$V_{OS}$	Input offset voltage			0.75	3	mV
$dV_{OS}/dT$	Input offset voltage vs temperature	$T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$		2		$\mu\text{V}/^\circ\text{C}$
PSRR	Power-supply rejection ratio		74	90		dB
<b>INPUT VOLTAGE RANGE</b>						
$V_{CM}$	Common-mode voltage range	No phase reversal, rail-to-rail input	$(V_-) - 0.2$		$(V_+) + 0.2$	V
CMRR	Common-mode rejection ratio	$(V_S^-) - 0.2\text{ V} < V_{CM} < (V_S^+) - 1.3\text{ V}$		85		dB
		$V_{CM} = -0.2\text{ V}$ to $5.7\text{ V}$	64	80		dB
<b>INPUT BIAS CURRENT</b>						
$I_B$	Input bias current			$\pm 1$		pA
$I_{OS}$	Input offset current			$\pm 1$		pA
<b>NOISE</b>						
	Input voltage noise (peak-to-peak)	$f = 0.1\text{ Hz}$ to $10\text{ Hz}$		6		$\mu\text{V}_{PP}$
$e_n$	Input voltage noise density	$f = 10\text{ kHz}$		22		$\text{nV}/\sqrt{\text{Hz}}$
		$f = 1\text{ kHz}$		26		$\text{nV}/\sqrt{\text{Hz}}$
$i_n$	Input current noise density	$f = 1\text{ kHz}$		5		$\text{fA}/\sqrt{\text{Hz}}$
<b>INPUT CAPACITANCE</b>						
$C_{IN}$	Differential			1		pF
	Common-mode			5		pF
<b>OPEN-LOOP GAIN</b>						
$A_{OL}$	Open-loop voltage gain	$0.05\text{ V} < V_O < (V_+) - 0.05\text{ V}$ , $R_L = 100\text{ k}\Omega$		104		dB
		$0.3\text{ V} < V_O < (V_+) - 0.3\text{ V}$ , $R_L = 2\text{ k}\Omega$	100	110		dB
	Phase margin	$V_S = 5.0\text{ V}$ , $G = +1$		65		$^\circ$

 (1) Parameters with minimum or maximum specification limits are 100% production tested at  $25^\circ\text{C}$ , unless otherwise noted. Over-temperature limits are based on characterization and statistical analysis.

**Electrical Characteristics: 5.5 V<sup>(1)</sup> (continued)**

 At  $T_A = 25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S / 2$ , and  $V_{CM} = V_{OUT} = V_S / 2$ , unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>FREQUENCY RESPONSE</b>						
GBW	Gain-bandwidth product	$V_S = 5.0\text{ V}$ , $C_L = 10\text{ pF}$		1		MHz
SR	Slew rate	$V_S = 5.0\text{ V}$ , $G = +1$		0.5		V/ $\mu$ s
$t_s$	Settling time	To 0.01%, $V_S = 5.0\text{ V}$ , 2-V step, $G = +1$		6		$\mu$ s
	Overload recovery time	$V_S = 5.0\text{ V}$ , $V_{IN} \times \text{Gain} > V_S$		3		$\mu$ s
<b>OUTPUT</b>						
$V_O$	Voltage output swing from supply rails	$R_L = 100\text{ k}\Omega^{(2)}$		5	20	mV
		$R_L = 2\text{ k}\Omega^{(2)}$		75	100	mV
$I_{SC}$	Short-circuit current			$\pm 15$		mA
$R_O$	Open-loop output impedance			2300		$\Omega$
<b>POWER SUPPLY</b>						
$V_S$	Specified voltage range		1.8 ( $\pm 0.9$ )	5.5 ( $\pm 2.75$ )		V
$I_Q$	Quiescent current per amplifier	$T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$ , $V_S = 5.0\text{ V}$ , $I_O = 0\text{ mA}$		65	90	$\mu$ A
	Power-on time	$V_S = 0\text{ V}$ to $5\text{ V}$ , to 90% $I_Q$ level		10		$\mu$ s
<b>TEMPERATURE</b>						
	Specified range		-40		125	$^\circ\text{C}$
	Operating range		-40		150	$^\circ\text{C}$
$T_{stg}$	Storage range		-65		150	$^\circ\text{C}$

(2) Specified by design and characterization; not production tested.

**Electrical Characteristics: 1.8 V<sup>(1)</sup>**

At  $T_A = 25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S / 2$ ,  $V_{CM} = V_{S+} - 1.3\text{ V}$ , and  $V_{OUT} = V_S / 2$ , unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>OFFSET VOLTAGE</b>						
$V_{OS}$	Input offset voltage			0.75	3	mV
$dV_{OS}/dT$	Input offset voltage vs temperature	$T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$		2		$\mu\text{V}/^\circ\text{C}$
PSRR	Power-supply rejection ratio		74	90		dB
<b>INPUT VOLTAGE RANGE</b>						
$V_{CM}$	Common-mode voltage range	No phase reversal, rail-to-rail input	$(V_-) - 0.2$		$(V_+) + 0.2$	V
CMRR	Common-mode rejection ratio	$(V_S-) - 0.2\text{ V} < V_{CM} < (V_S+) - 1.3\text{ V}$		85		dB
		$V_{CM} = -0.2\text{ V}$ to $+1.8\text{ V}$		73		dB
<b>INPUT BIAS CURRENT</b>						
$I_B$	Input bias current			$\pm 1$		pA
$I_{OS}$	Input offset current			$\pm 1$		pA
<b>NOISE</b>						
	Input voltage noise (peak-to-peak)	$f = 0.1\text{ Hz}$ to $10\text{ Hz}$		6		$\mu\text{V}_{PP}$
$e_n$	Input voltage noise density	$f = 10\text{ kHz}$		22		$\text{nV}/\sqrt{\text{Hz}}$
		$f = 1\text{ kHz}$		26		$\text{nV}/\sqrt{\text{Hz}}$
$i_n$	Input current noise density	$f = 1\text{ kHz}$		5		$\text{fA}/\sqrt{\text{Hz}}$
<b>INPUT CAPACITANCE</b>						
$C_{IN}$	Differential			1		pF
	Common-mode			5		pF
<b>OPEN-LOOP GAIN</b>						
$A_{OL}$	Open-loop voltage gain	$0.1\text{ V} < V_O < (V_+) - 0.1\text{ V}$ , $R_L = 10\text{ k}\Omega$		110		dB
		$0.05\text{ V} < V_O < (V_+) - 0.05\text{ V}$ , $R_L = 100\text{ k}\Omega$		110		dB

(1) Parameters with minimum or maximum specification limits are 100% production tested at  $25^\circ\text{C}$ , unless otherwise noted. Over-temperature limits are based on characterization and statistical analysis.

**Electrical Characteristics: 1.8 V<sup>(1)</sup> (continued)**

 At  $T_A = 25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S / 2$ ,  $V_{CM} = V_{S+} - 1.3\text{ V}$ , and  $V_{OUT} = V_S / 2$ , unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>FREQUENCY RESPONSE</b>						
GBW	Gain-bandwidth product	$C_L = 10\text{ pF}$		0.9		MHz
SR	Slew rate	$G = +1$		0.45		V/ $\mu$ s
$t_s$	Settling time	To 0.01%, $V_S = 5.0\text{ V}$ , 2-V step, $G = +1$		6		$\mu$ s
	Overload recovery time	$V_S = 5.0\text{ V}$ , $V_{IN} \times \text{Gain} > V_S$		3		$\mu$ s
<b>OUTPUT</b>						
$V_O$	Voltage output swing from supply rails	$R_L = 100\text{ k}\Omega^{(2)}$		5		mV
		$R_L = 2\text{ k}\Omega^{(2)}$		25		mV
$I_{SC}$	Short-circuit current			$\pm 6$		mA
$R_O$	Open-loop output impedance			2300		$\Omega$
<b>POWER SUPPLY</b>						
$V_S$	Specified voltage range		1.8 ( $\pm 0.9$ )	5.5 ( $\pm 2.75$ )		V
$I_Q$	Quiescent current per amplifier	$T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$ , $V_S = 5.0\text{ V}$ , $I_O = 0\text{ mA}$		65	90	$\mu$ A
	Power-on time	$V_S = 0\text{ V}$ to $5\text{ V}$ , to 90% $I_Q$ level		10		$\mu$ s
<b>TEMPERATURE</b>						
	Specified range		-40		125	$^\circ\text{C}$
	Operating range		-40		150	$^\circ\text{C}$
$T_{stg}$	Storage range		-65		150	$^\circ\text{C}$

(2) Specified by design and characterization; not production tested.

### Typical Characteristics

At  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S / 2$ , and  $V_{CM} = V_{OUT} = V_S / 2$ , unless otherwise noted.

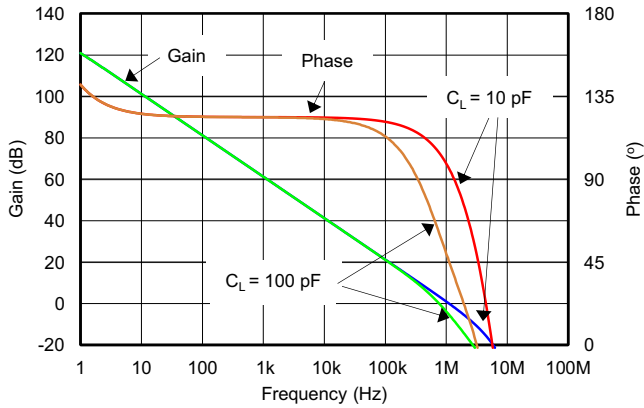


Figure 1. Open-Loop Gain and Phase vs Frequency

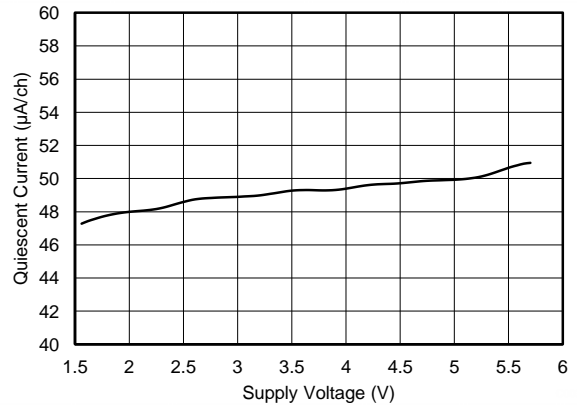


Figure 2. Quiescent Current vs Supply

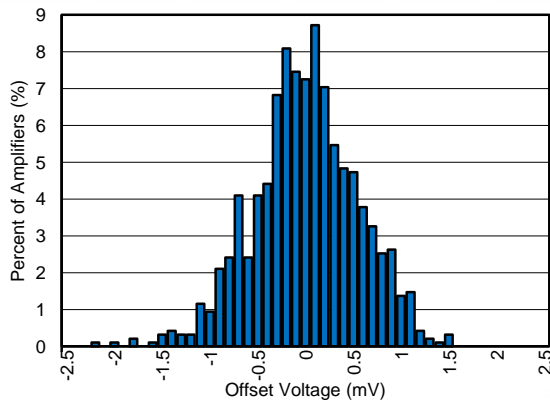


Figure 3. Offset Voltage Production Distribution

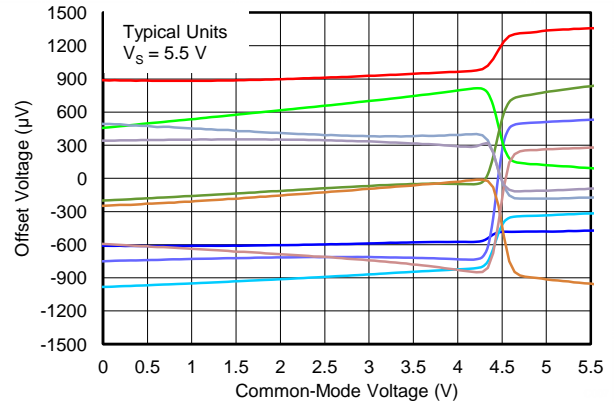


Figure 4. Offset Voltage vs Common-Mode Voltage

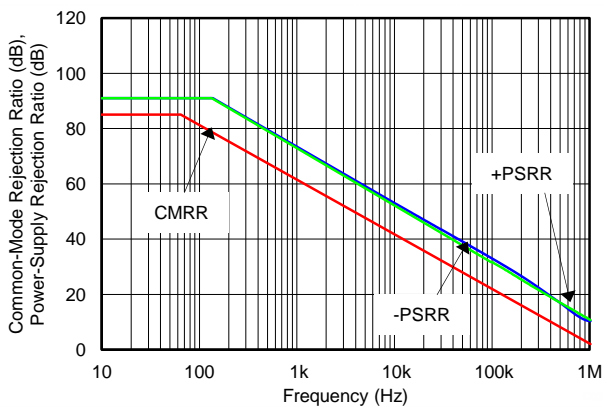


Figure 5. CMRR and PSRR vs Frequency (Referred-to-Input)

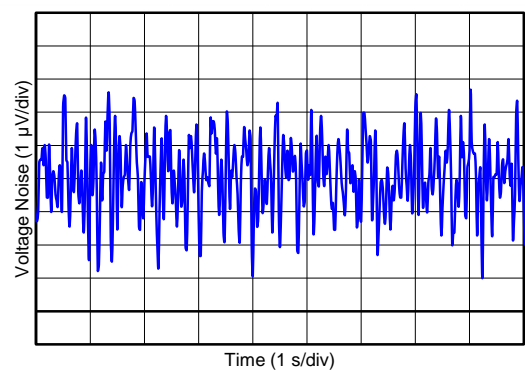


Figure 6. 0.1-Hz to 10-Hz Input Voltage Noise

**Typical Characteristics (continued)**

At  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S / 2$ , and  $V_{CM} = V_{OUT} = V_S / 2$ , unless otherwise noted.

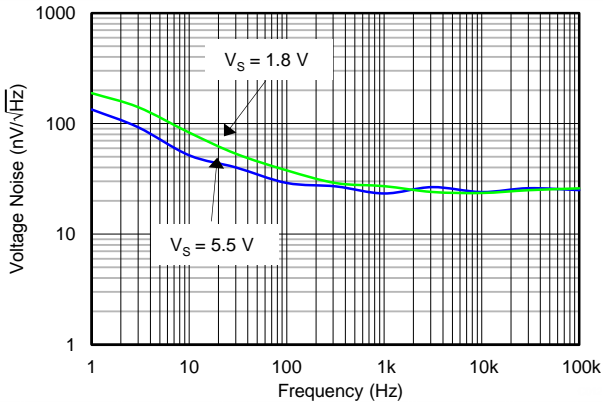


Figure 7. Input Voltage Noise Spectral Density vs Frequency

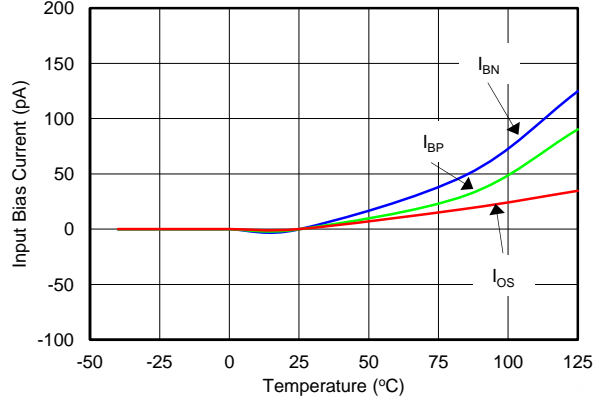


Figure 8. Input Bias and Offset Current vs Temperature

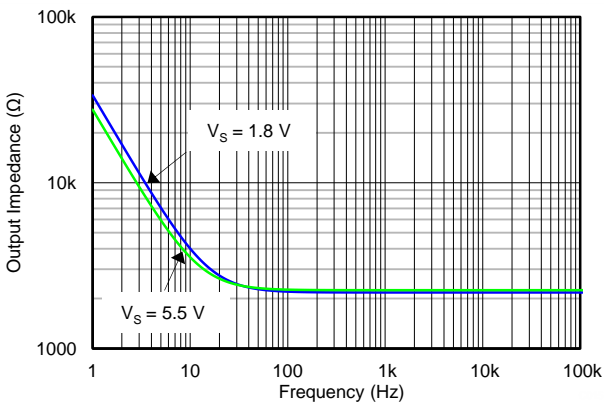


Figure 9. Open-Loop Output Impedance vs Frequency

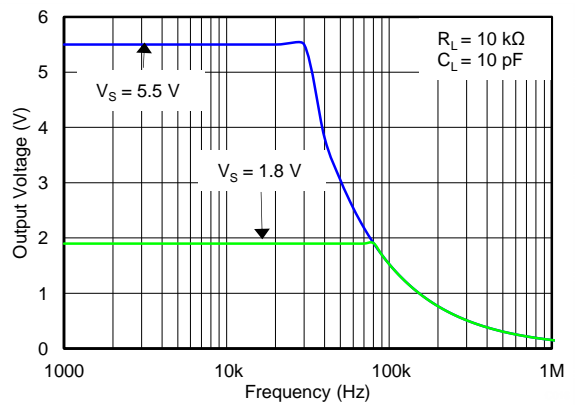


Figure 10. Maximum Output Voltage vs Frequency and Supply Voltage

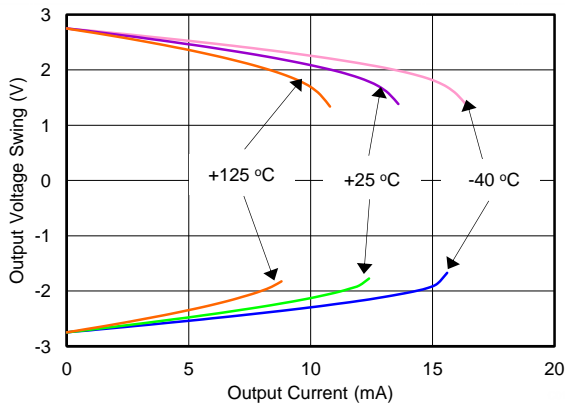


Figure 11. Output Voltage Swing vs Output Current (Over Temperature)

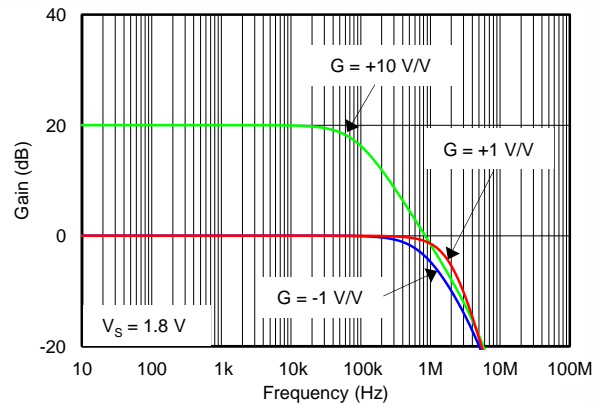
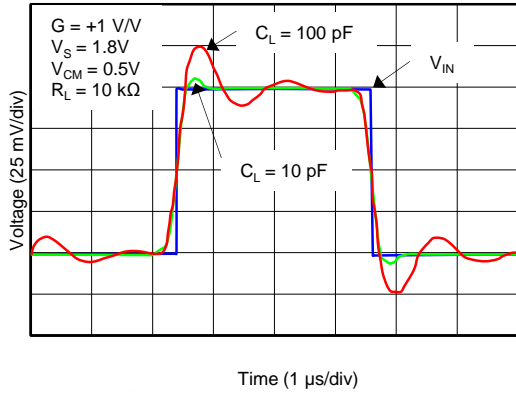


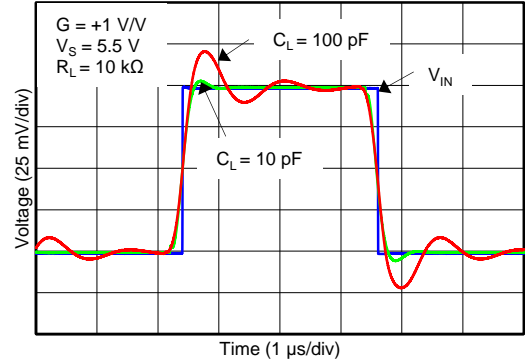
Figure 12. Closed-Loop Gain vs Frequency (Minimum Supply)

**Typical Characteristics (continued)**

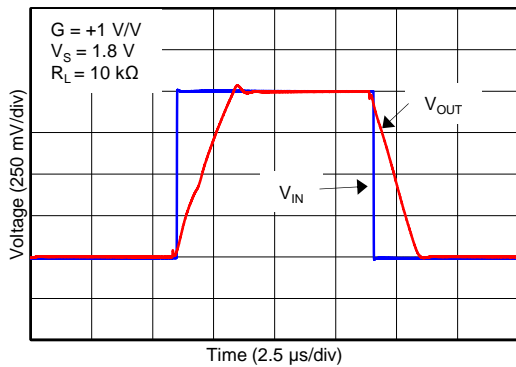
At  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S / 2$ , and  $V_{CM} = V_{OUT} = V_S / 2$ , unless otherwise noted.



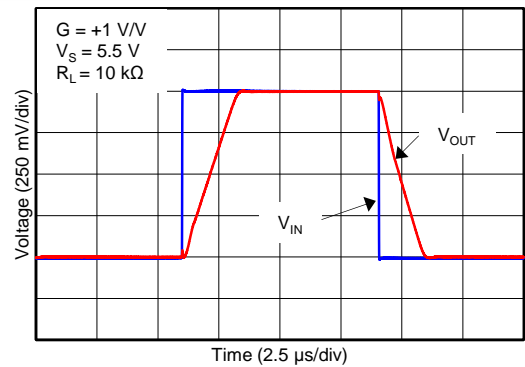
**Figure 13. Small-Signal Pulse Response (Minimum Supply)**



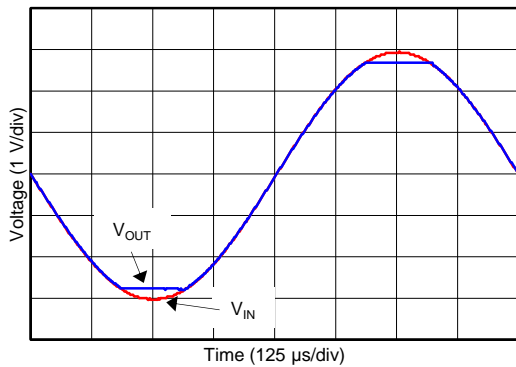
**Figure 14. Small-Signal Pulse Response (Maximum Supply)**



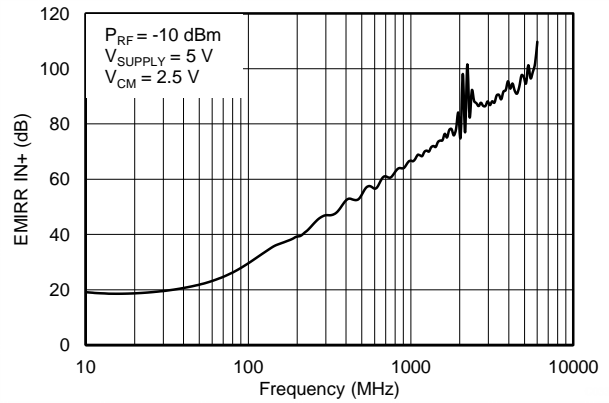
**Figure 15. Large-Signal Pulse Response (Minimum Supply)**



**Figure 16. Large-Signal Pulse Response (Maximum Supply)**



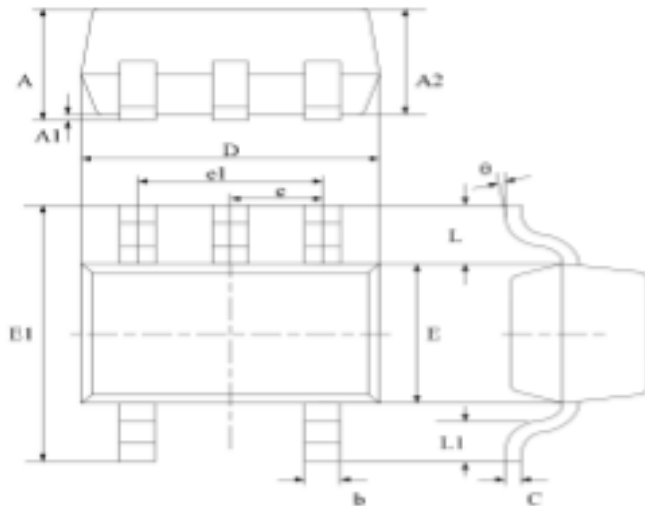
**Figure 17. No Phase Reversal**



**Figure 18. EMIRR IN+ vs Frequency**

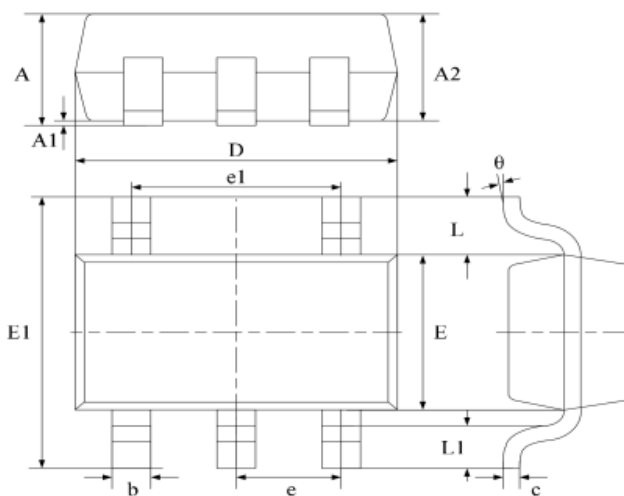
Package Dimension

SC70-5 (SOT353)



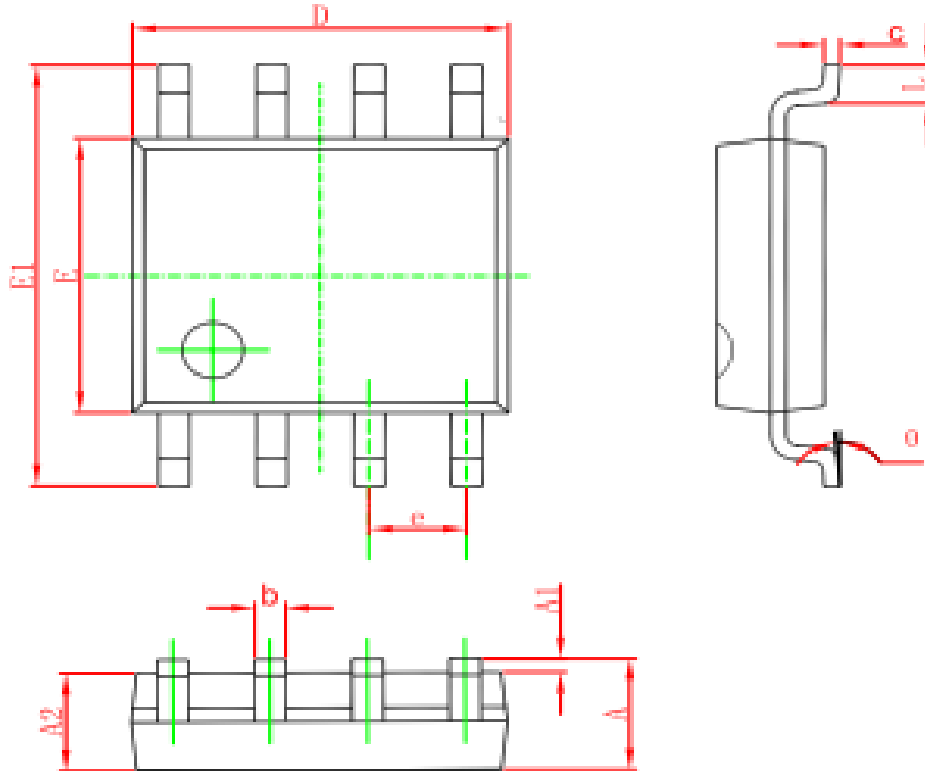
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.800	1.100	0.035	0.043
A1	0.000	0.100	0.000	0.004
A2	0.800	0.900	0.035	0.039
b	0.150	0.350	0.006	0.014
C	0.080	0.150	0.003	0.006
D	1.8500	2.150	0.079	0.087
E	1.100	1.400	0.045	0.053
E1	1.950	2.200	0.085	0.096
e	0.850 typ.		0.026 typ.	
e1	1.200	1.400	0.047	0.055
L	0.42 ref.		0.021 ref.	
L1	0.260	0.460	0.010	0.018
$\theta$	0°	8°	0°	8°

SOT23-5



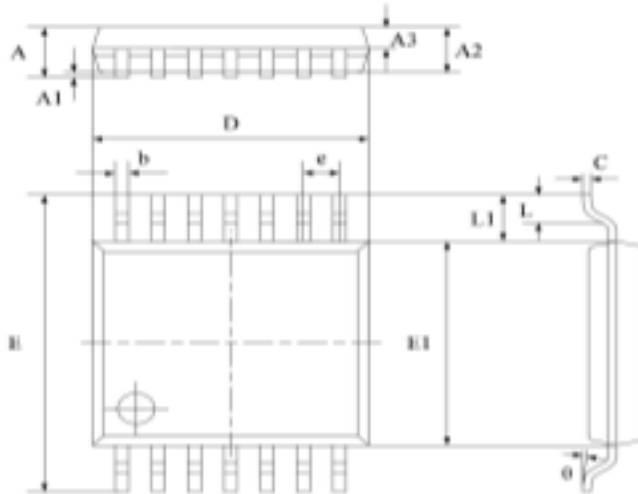
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.040	1.350	0.042	0.055
A1	0.040	0.150	0.002	0.006
A2	1.000	1.200	0.041	0.049
b	0.380	0.480	0.015	0.020
c	0.110	0.210	0.004	0.009
D	2.720	3.120	0.111	0.127
E	1.400	1.800	0.057	0.073
E1	2.600	3.000	0.106	0.122
e	0.950 typ.		0.037 typ.	
e1	1.900 typ.		0.078 typ.	
L	0.700 ref.		0.028 ref.	
L1	0.300	0.600	0.012	0.024
$\theta$	0°	8°	0°	8°

SOP-8



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.270(BSC)		0.050(BSC)	
L	0.400	1.270	0.016	0.050
$\theta$	0°	8°	0°	8°

TSSOP-14



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	-	1.200	-	0.0472
A1	0.050	0.150	0.002	0.006
A2	0.900	1.050	0.037	0.043
A3	0.390	0.490	0.016	0.020
b	0.200	0.290	0.008	0.012
C	0.130	0.180	0.005	0.007
D	4.860	5.060	0.198	0.207
E	6.200	6.600	0.253	0.269
E1	4.300	4.500	0.176	0.184
e	0.650 typ.		0.0256 typ.	
L1	1.000 ref.		0.0393 ref.	
L	0.450	0.750	0.018	0.031
$\theta$	0°	8°	0°	8°

Ordering information

Order code	Package	Baseqty	Deliverymode	Marking
UMW TLV313IDCKR	SC70-5	3000	Tape and reel	14E U
UMW TLV313IDBVR	SOT23-5	3000	Tape and reel	15F2 U
UMW TLV2313IDR	SOP-8	2500	Tape and reel	V2313
UMW TLV4313IPWR	TSSOP-14	4000	Tape and reel	TLV4313