

Features

- Supply Voltage: 3 V to 40 V or ± 1.5 V to ± 20 V
- Low Supply Current: 400 μ A per Channel
- Input Offset Voltage: ± 3 mV Maximum at 25°C
- Unity-gain Bandwidth: 1.5 MHz
- Slew Rate: 1.8 V/ μ s
- Can Work as Comparators
- Input Common-Mode Voltage Range Includes Ground
- Excellent EMI Suppression Performance: 75 dB at 1 GHz
- AEC-Q100 Qualified for Automotive Applications
– Grade 1: -40°C to 125°C T_A

Applications

- Automotive Lighting
- Body Electronics
- On-board (OBC) and Wireless Charger
- HEV/EV Inverter and Motor Control
- Passive Safety

Description

The LM2902Q, LM2904Q, and TS321Q devices are the new generation versions of the 40-V automotive operational amplifiers. These amplifiers are highly competitive for cost-sensitive applications. These amplifiers offer low input offset voltage (± 3 mV maximum at 25°C), low input offset voltage drift (2 $\mu\text{V}/^{\circ}\text{C}$ typical), and a typical quiescent current of 400 μ A per channel. This series incorporates 3PEAK's proprietary and patented design techniques to achieve excellent AC performance with 1.5-MHz bandwidth and 1.8-V/ μ s slew rate. Integrated EMI and RF filters strengthen the interference immunity and system robustness.

Device Table

Device	Package	Body Size
LM2904Q-SO1R-S	SOP8	4.9 mm $\times$ 3.9 mm
LM2904Q-VS1R-S	MSOP8	3.0 mm $\times$ 3.0 mm

Typical Application Circuit

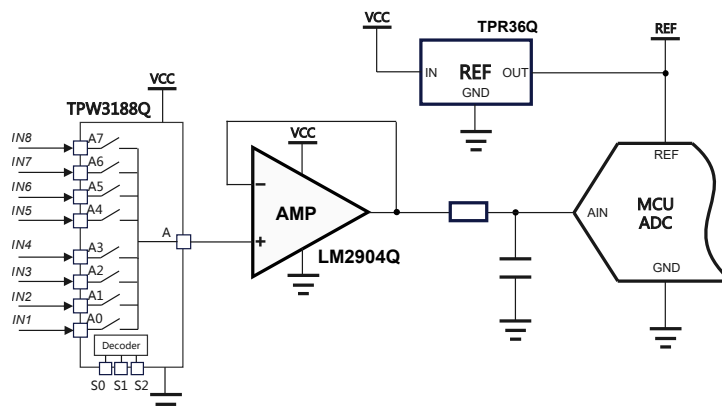


Table of Contents

Features	1
Applications	1
Description	1
Device Table	1
Typical Application Circuit	1
Revision History	3
Pin Configuration and Functions	4
Specifications	7
Absolute Maximum Ratings ⁽¹⁾	7
ESD, Electrostatic Discharge Protection.....	7
Recommended Operating Conditions.....	7
Thermal Information.....	7
Electrical Characteristics.....	9
Typical Performance Characteristics.....	12
Detailed Description	16
Overview.....	16
Functional Block Diagram.....	16
Feature Description.....	16
Application and Implementation	17
Application Information	17
Tape and Reel Information	18
Package Outline Dimensions	19
SOT23-5.....	19
SOP8.....	20
TSSOP8.....	21
MSOP8.....	22
SOP14.....	23
TSSOP14.....	24
Order Information	25
IMPORTANT NOTICE AND DISCLAIMER	26

Revision History

Date	Revision	Notes
2026-06-24	Rev.A.0	Initial Version.

Pin Configuration and Functions

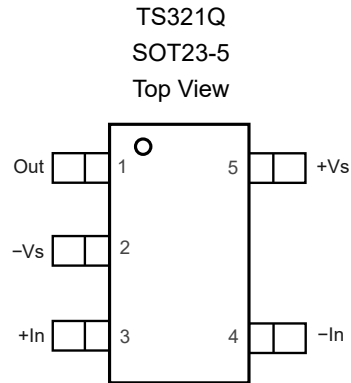
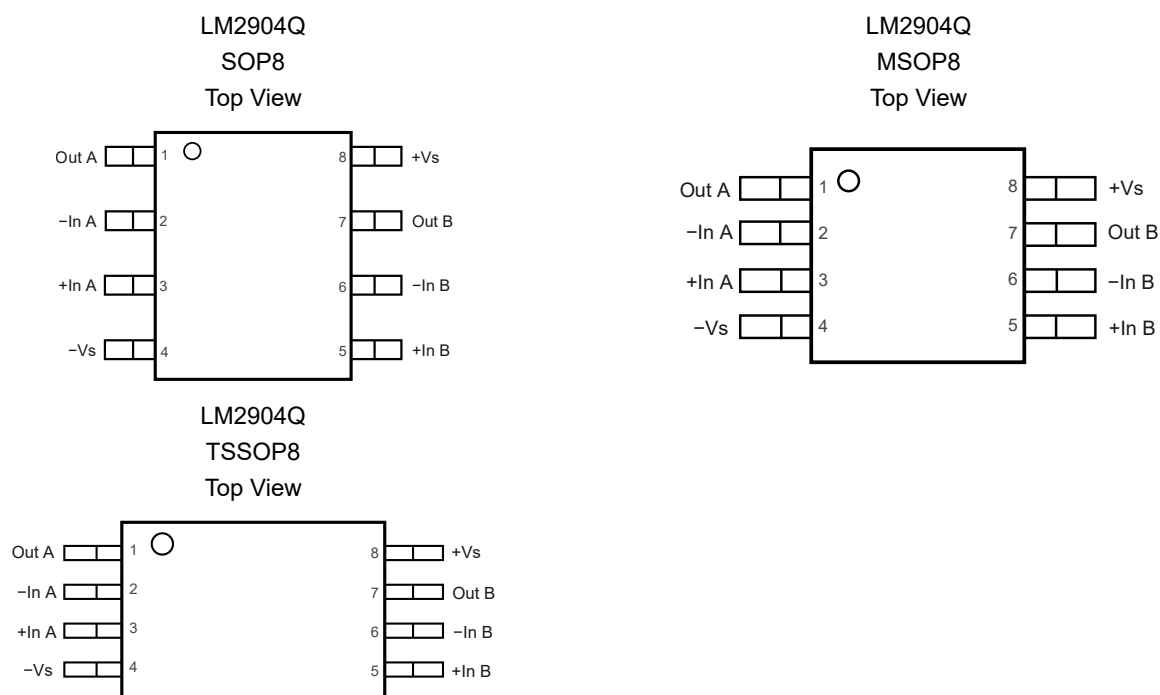
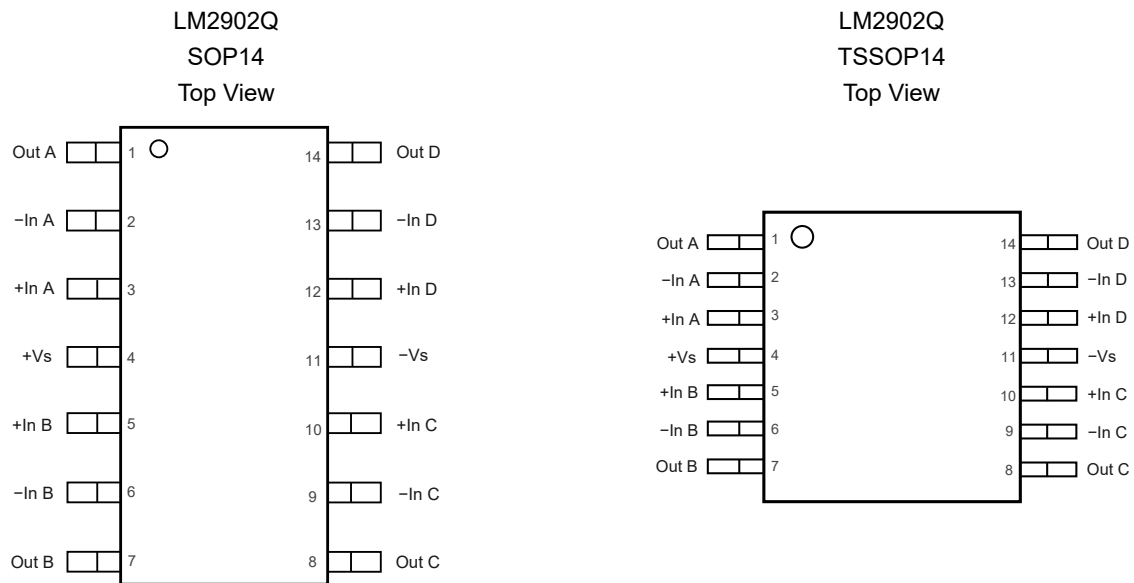


Table 1. Pin Functions: TS321Q

Pin No.	Name	I/O	Description
TS321Q			
3	+In	I	Non-inverting input
2	-Vs	-	Negative power supply
4	-In	I	Inverting input
1	Out	O	Output
5	+Vs	-	Positive power supply

Automotive 40-V General Purpose Operational Amplifiers

Table 2. Pin Functions: LM2904Q

Pin No.			Name	I/O	Description
SOP8	MSOP8	TSSOP8			
1	1	1	Out A	O	Output
2	2	2	-In A	I	Inverting input
3	3	3	+In A	I	Non-inverting input
4	4	4	-Vs		Negative power supply
5	5	5	+In B	I	Non-inverting input
6	6	6	-In B	I	Inverting input
7	7	7	Out B	O	Output
8	8	8	+Vs		Positive power supply

Automotive 40-V General Purpose Operational Amplifiers

Table 3. Pin Functions: LM2902Q

Pin No.		Name	I/O	Description
SOP14	TSSOP14			
1	1	Out A	O	Output
2	2	-In A	I	Inverting input
3	3	+In A	I	Non-inverting input
4	4	+Vs		Positive power supply
5	5	+In B	I	Non-inverting input
6	6	-In B	I	Inverting input
7	7	Out B	O	Output
8	8	Out C	O	Output
9	9	-In C	I	Inverting input
10	10	+In C	I	Non-inverting input
11	11	-Vs		Negative power supply
12	12	+In D	I	Non-inverting input
13	13	-In D	I	Inverting input
14	14	Out D	O	Output

Specifications

Absolute Maximum Ratings ⁽¹⁾

Parameter		Min	Max	Unit
	Supply Voltage, $(+V_S) - (-V_S)$		42	V
	Voltage on Input Pins and Output Pins	$(-V_S) - 0.3$	42	V
	Differential Input Voltage	$(-V_S) - (+V_S)$	$(+V_S) - (-V_S)$	V
	Input Current: $+I_{IN}$, $-I_{IN}$ ⁽²⁾	-10	10	mA
	Output Short-Circuit Duration ⁽³⁾		Infinite	
T_J	Maximum Junction Temperature		150	°C
T_A	Operating Temperature Range	-40	125	°C
T_{STG}	Storage Temperature Range	-65	150	°C
T_L	Lead Temperature (Soldering 10 sec)		260	°C

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

(2) The inputs are protected by ESD protection diodes to the negative power supply. If the input exceeds 300 mV beyond the power supply, the input current should be limited to less than 10 mA.

(3) A heat sink may be required to keep the junction temperature below the absolute maximum. This depends on the power supply voltage and how many amplifiers are shorted. Thermal resistance varies with the amount of PC board metal connected to the package. The specified values are for short traces connected to the leads.

ESD, Electrostatic Discharge Protection

Symbol	Parameter	Condition	Minimum Level	Unit
HBM	Human Body Model ESD	AEC-Q100-002 ⁽¹⁾	2	kV
CDM	Charged Device Model ESD	AEC-Q100-011	1.5	kV

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

Recommended Operating Conditions

Parameter		Min	Typ	Max	Unit
V_S	Supply Voltage, $(+V_S) - (-V_S)$	3		40	V
T_A	Operating Temperature Range	-40		125	°C

Thermal Information

Package Type	θ_{JA}	θ_{JC}	Unit
SOT23-5	250	81	°C/W
SOP8	158	43	°C/W

Automotive 40-V General Purpose Operational Amplifiers

Package Type	θ_{JA}	θ_{JC}	Unit
TSSOP8	191	44	°C/W
MSOP8	210	45	°C/W
SOP14	120	36	°C/W
TSSOP14	180	35	°C/W

Automotive 40-V General Purpose Operational Amplifiers
Electrical Characteristics

All test conditions: $V_S = 40\text{ V}$, $T_A = 25^\circ\text{C}$, $R_L = 10\text{ k}\Omega$, $C_L = 100\text{ pF}$, unless otherwise noted.

Symbol	Parameter	Conditions	T _A	Min	Typ	Max	Unit
Power Supply							
V _S	Supply Voltage Range			3		40	V
I _Q	Quiescent Current per Amplifier	V _S = 5 V, V _{CM} = V _S /2		300	400	550	μA
			−40°C to 125°C	250	400	650	μA
		V _S = 40 V, V _{CM} = V _S /2		300	450	700	μA
			−40°C to 125°C	250	500	750	μA
PSRR	Power Supply Rejection Ratio	V _S = 5 V to 40 V, V _{CM} = 0 V		96	120		dB
			−40°C to 125°C	90			dB
		V _S + = 40 V, V _S + AC = 100 mV _{PP} , 100 kHz, Sine Wave, V _{CM} = 18 V			60		dB
Input Characteristics							
V _{OS}	Input Offset Voltage	V _S = 5 V, V _{CM} = 2.5 V		−3	0.3	3	mV
			−40°C to 125°C	−4		4	mV
		V _S = 40 V, V _{CM} = 20 V		−3	0.3	3	mV
			−40°C to 125°C	−4		4	mV
V _{OS} TC	Input Offset Voltage Drift	V _S = 40 V, V _{CM} = 20 V	−40°C to 125°C		2		μV/°C
I _B	Input Bias Current ⁽¹⁾	V _S = 5 V, V _{CM} = 0 V to 3 V		−10		−100	nA
			−40°C to 125°C	−5		−150	nA
		V _S = 40 V, V _{CM} = 0 V to 38 V		−10		−150	nA
			−40°C to 125°C	−5		−200	nA
I _{OS}	Input Offset Current ⁽¹⁾	V _S = 5 V, V _{CM} = 0 V to 3 V		−25		25	nA
			−40°C to 125°C	−30		30	nA
		V _S = 40 V, V _{CM} = 0 V to 38 V		−60		60	nA
			−40°C to 125°C	−90		90	nA
R _{IN}	Input Impedance	Differential mode ⁽¹⁾			0.8		GΩ
		Common mode			2		GΩ
C _{IN} ⁽¹⁾	Input Capacitance	Differential mode			2		pF
		Common mode			5		pF
A _V	Open-Loop Voltage Gain	V _S = 15 V, V _O = 1V to 11 V		100	105		dB
			−40°C to 125°C	95			dB
V _{CMR}	Common-Mode Input Voltage Range	V _S = 5 V		0		3.5	V
			−40°C to 125°C	0		3	V
		V _S = 40 V		0		38.5	V

Automotive 40-V General Purpose Operational Amplifiers

Symbol	Parameter	Conditions	T _A	Min	Typ	Max	Unit
			-40°C to 125°C	0		38	V
CMRR	Common-Mode Rejection Ratio	V _{CM} = 0 V to 38 V		95	110		dB
			-40°C to 125°C	90			dB
Output Characteristics							
V _O	Output Voltage Swing from Positive and Negative Rail	Positive power supply rail	I _{out} = 50 μA	0.5	1	1.4	V
			I _{out} = 1 mA	0.5	1.1	1.5	V
			I _{out} = 5 mA	0.5	1.5	1.7	V
		Negative power supply rail	I _{out} =50 μA	0	0.09	0.16	V
			I _{out} = 1 mA	0.5	0.8	1.3	V
			V _S = 5 V; R _{LOAD} = 10 kΩ to V(-)	-8		8	mV
I _{SC}	Output Short-Circuit Current	V _S = 5 V, I _{Sink}		30	40	60	mA
			-40°C to 125°C	10		80	mA
		V _S = 5 V, I _{Source}		20	30	40	mA
			-40°C to 125°C	10		65	mA
I _{PD}	Output Pull-Down Current	V _S = 5 V, V _{ID} = -1 V, V _O = -V _S + 200 mV		60	80		μA
R _O	Open-loop output resistance	f = 1 MHz			75		Ω
AC Specifications							
GBW	Gain-Bandwidth Product				1.5		MHz
SR	Slew Rate	G = 1, 2-V step			1.8		V/μs
T _{or}	Overload Recovery Time				1		μs
t _S	Settling Time, 0.1%	G = 1, 2-V step			4		μs
PM	Phase Margin	R _L = 10 kΩ, C _L = 100 pF			75		°
GM	Gain Margin	R _L = 10 kΩ, C _L = 100 pF			10		dB
X _{TALK}	Channel Separation	f = 0 Hz			120		dB
		f = 1 kHz			110		dB
EMIRR	Electromagnetic Interference Rejection Ratio	f = 1000 MHz			75		dB
Noise Performance							
E _N	Input Voltage Noise	f = 0.1 Hz to 10 Hz			3		μV _{PP}
e _N	Input Voltage Noise Density	f = 1 kHz			45		nV/√Hz
i _N ⁽¹⁾	Input Current Noise	f = 1 kHz			80		fA/√Hz

Automotive 40-V General Purpose Operational Amplifiers

Symbol	Parameter	Conditions	T _A	Min	Typ	Max	Unit
THD + N	Total harmonic distortion + Noise	G = +1, f = 1 kHz, V _O = 3.53 V _{RMS} , R _L = 100 kΩ, BW = 80 kHz			0.0005		%

(1) Provided by bench tests and design simulation.

Typical Performance Characteristics

All test conditions: $V_S = 36\text{ V}$ ($\pm 18\text{ V}$), $V_{CM} = V_S / 2$, $R_L = 10\text{ k}\Omega$, unless otherwise noted.

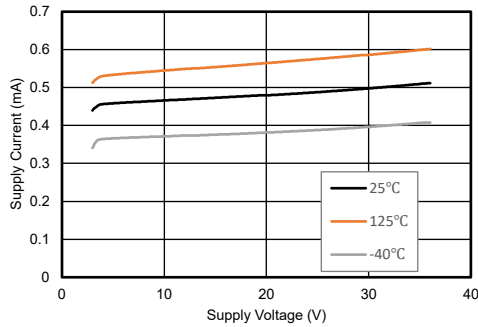


Figure 1. Quiescent Current vs. Supply Voltage

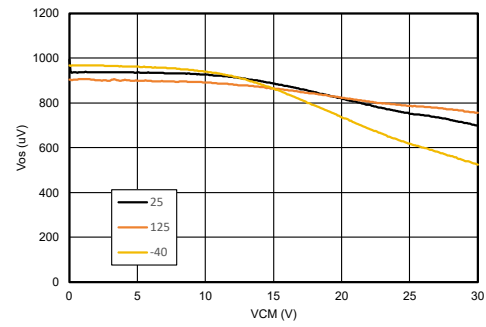


Figure 2. Offset Voltage vs. Common-Mode Voltage

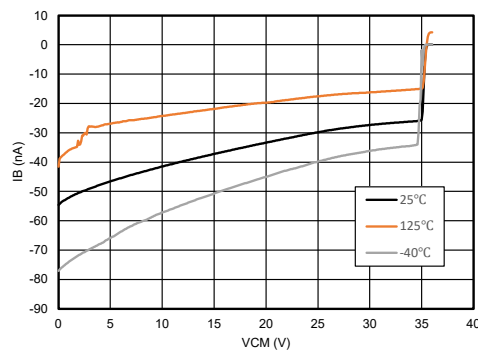


Figure 3. Input Bias Current vs. Common-Mode Voltage

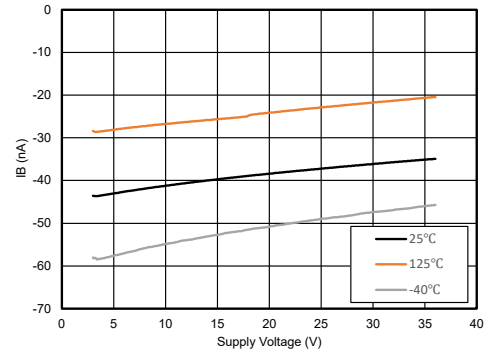


Figure 4. Input Bias Current vs. Supply Voltage

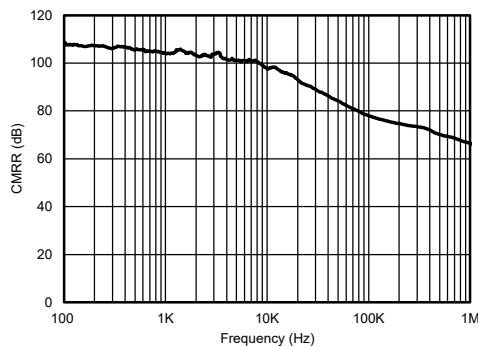


Figure 5. CMRR vs. Frequency

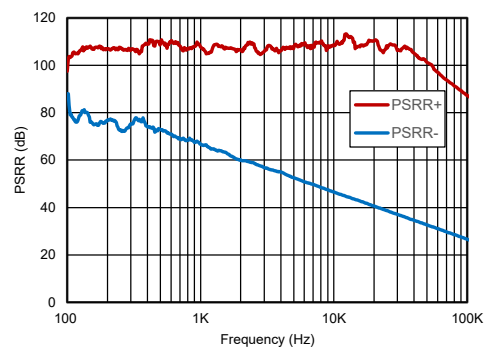
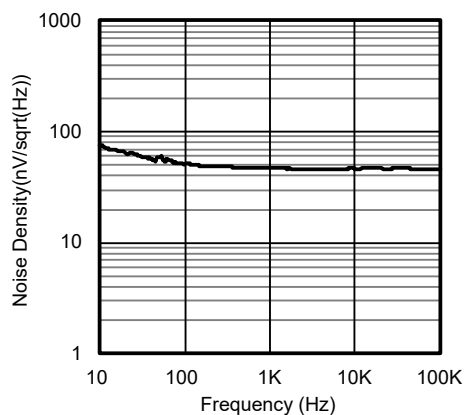
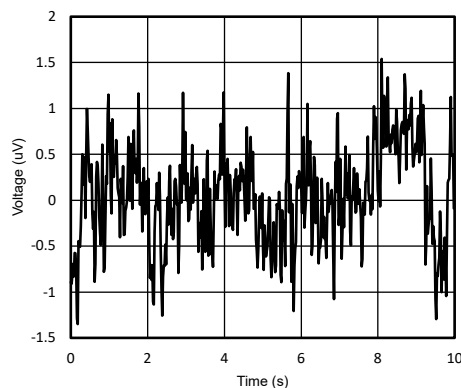
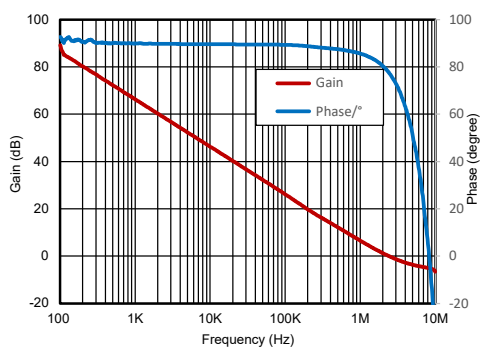
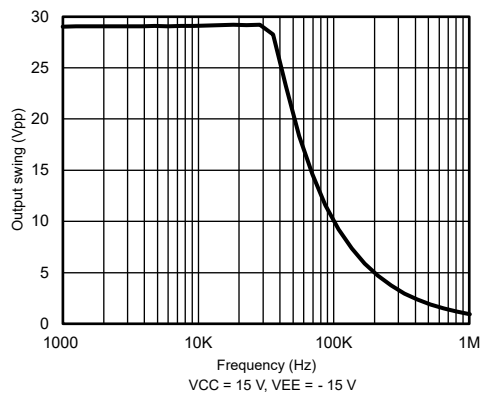
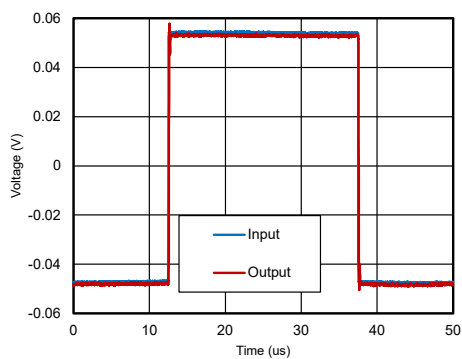
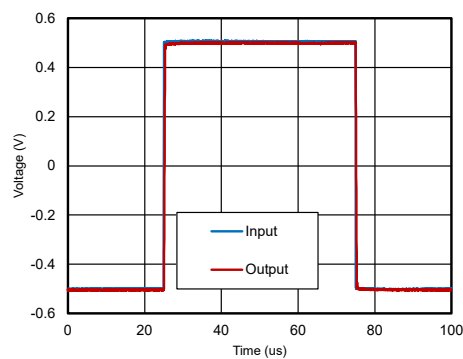
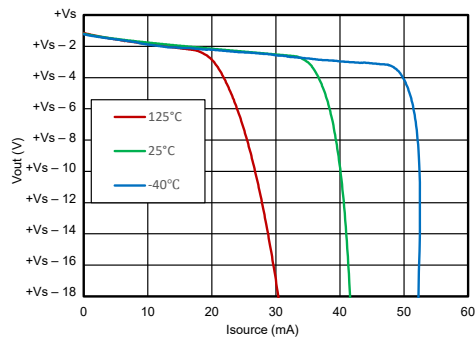
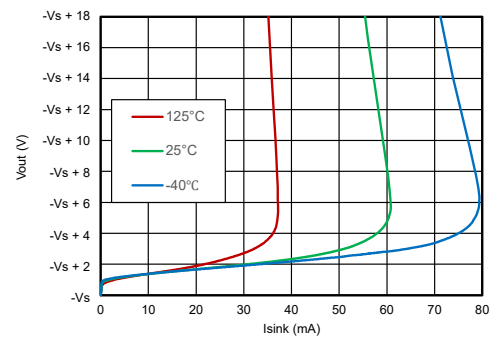
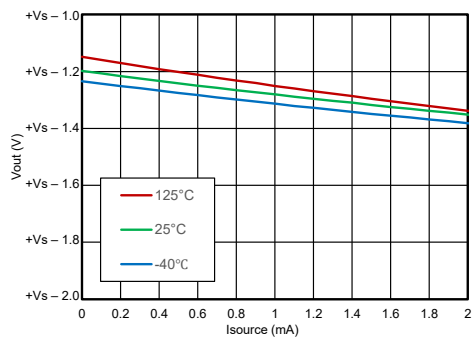
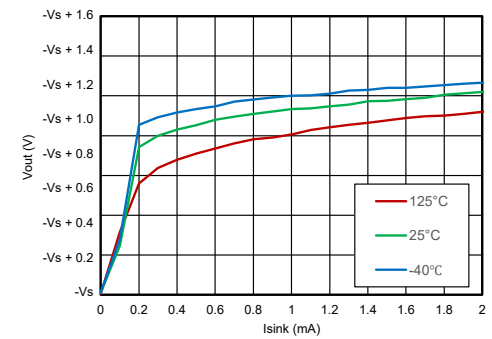
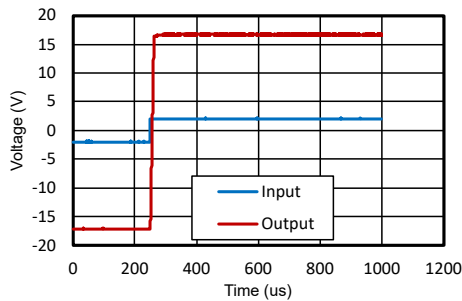
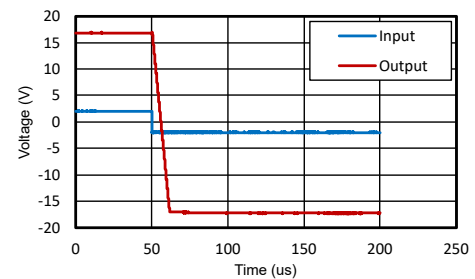
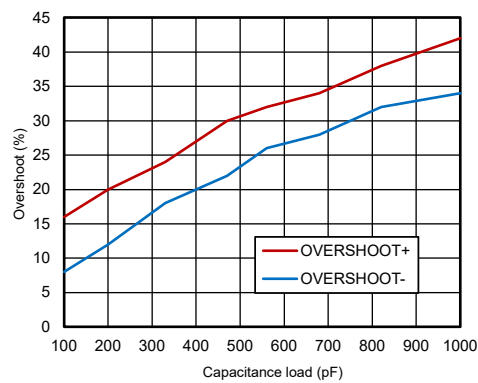
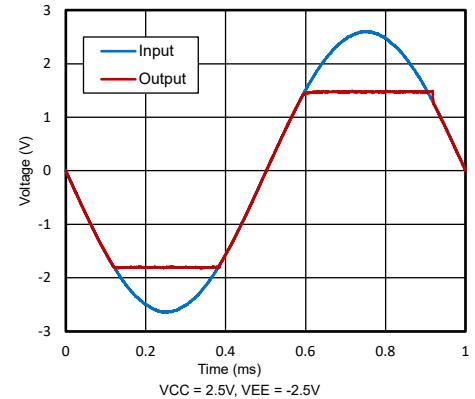
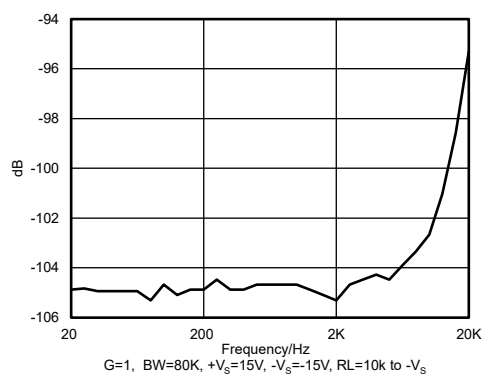
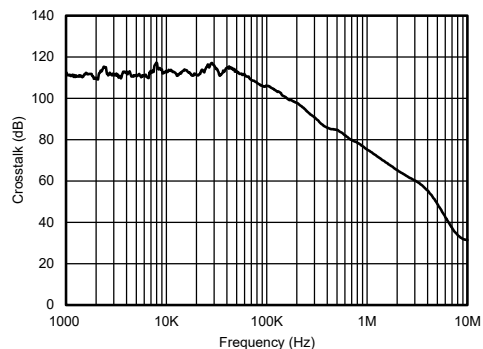
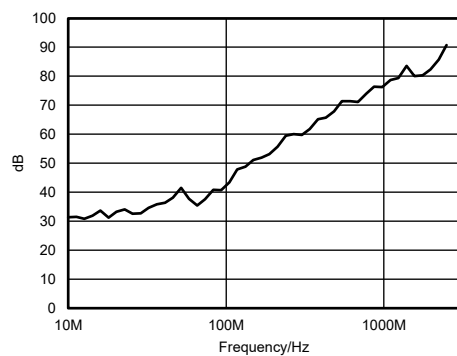


Figure 6. PSRR vs. Frequency


Figure 7. Voltage Noise Spectral Density vs. Frequency

Figure 8. 0.1 Hz to 10 Hz Noise

Figure 9. Open-Loop Gain and Phase vs. Frequency

Figure 10. Output Swing vs. Frequency

Figure 11. 100-mV Signal Step Response

Figure 12. 10-V Signal Step Response


Figure 13. Source Current vs. Vout

Figure 14. Sinking Current vs. Vout

Figure 15. Source Current vs. Vout

Figure 16. Sinking Current vs. Vout

Figure 17. Positive Overload Recovery

Figure 18. Negative Overload Recovery

Figure 19. Small-Signal Overshoot vs. Capacitive Load

Figure 20. No Phase Reversal


Figure 21. THD_N vs. Frequency

Figure 22. Channel Separation

Figure 23. EMIRR vs. Frequency

Detailed Description

Overview

The LM2904 series is the next-generation version of general-purpose operational amplifiers. The series provide outstanding value for cost-sensitive applications, with features including a wide supply voltage range (3 V to 40 V), low offset voltage (± 3 mV Maximum at 25°C), and input common-mode voltage range to ground. With a bipolar input stage, the LM2904 series has no input to the +Vs diode and no differential input diode, which can work as comparators.

Functional Block Diagram

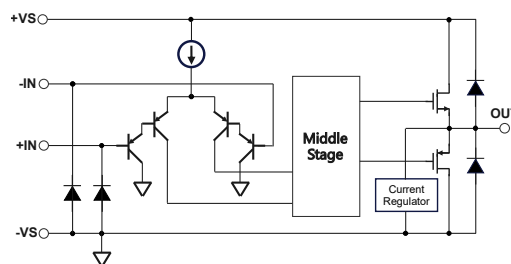


Figure 24. Functional Block Diagram

Feature Description

Operating Voltage Range

The LM2904 series is designed for single-supply operation from 3 V to 40 V or dual-supply operation from ± 1.5 V to ± 20 V. The recommended operating voltage conditions are as follows:

Power supply voltage ($+V_S$) – ($-V_S$): 3 V to 40 V. The power supply voltage can support the following three scenarios:

- Single supply;
- Dual supplies with equal voltage values;
- Various voltage configurations, as long as the voltage range of ($+V_S$) – ($-V_S$) is within 3 V to 40 V.

Bipolar Input Stage

With a bipolar input stage, there is no input to the $+V_S$ diode, which is critical for battery-powered applications to block input to the power path. Besides, there is no differential diodes across +IN and -IN pins. This benefits the comparator applications by avoiding additional leakage current.

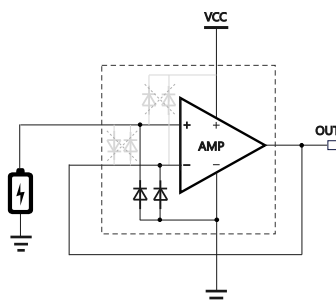


Figure 25. No Input Route to +Vs

Application and Implementation

Note

Information in the following application sections is not part of the 3PEAK's component specification and 3PEAK does not warrant its accuracy or completeness. 3PEAK's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

Application Information

Low-Side Current Sensing

Figure 26 shows the device configured as a difference amplifier in a current sensing application. V_{BIAS} can be used to add bias voltage for bidirectional current sensing. R_1 and R_F set the gain and the R_F and C_F set the cut-off frequency.

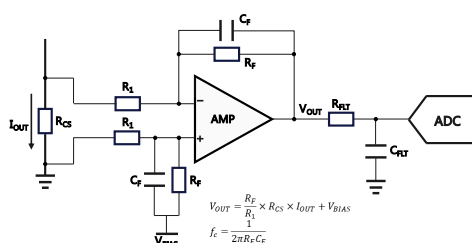


Figure 26. Low-Side Current Sensing

Driving Capacitive Load

The LM2904 series can drive a capacitor up to 1 nF directly. To drive a larger load capacitor in unity-gain configurations, an additional isolated resistor R_{ISO} (5 Ω to 100 Ω) should be added. R_{ISO} modifies the open-loop gain of the system to increase the phase margin for better stability.

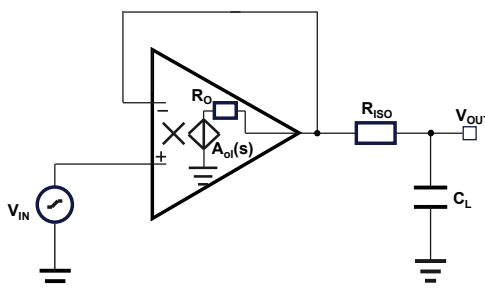
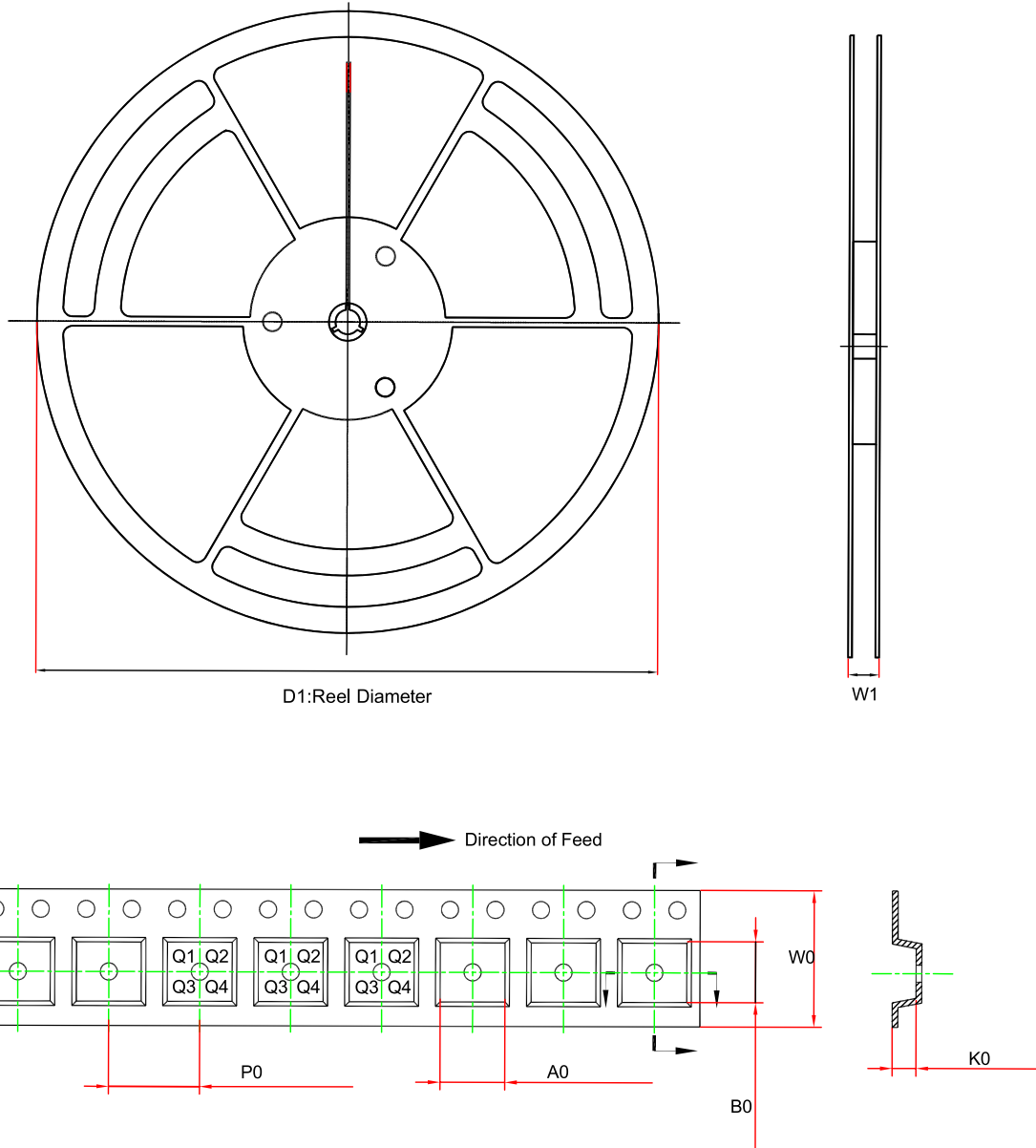


Figure 27. Isolated Resistor for Driving Capacitive Load

Power Supply Recommendations

Place 0.1- μ F bypass capacitors close to the power supply pins to reduce coupling errors from the noisy or high-impedance power supplies.

Tape and Reel Information

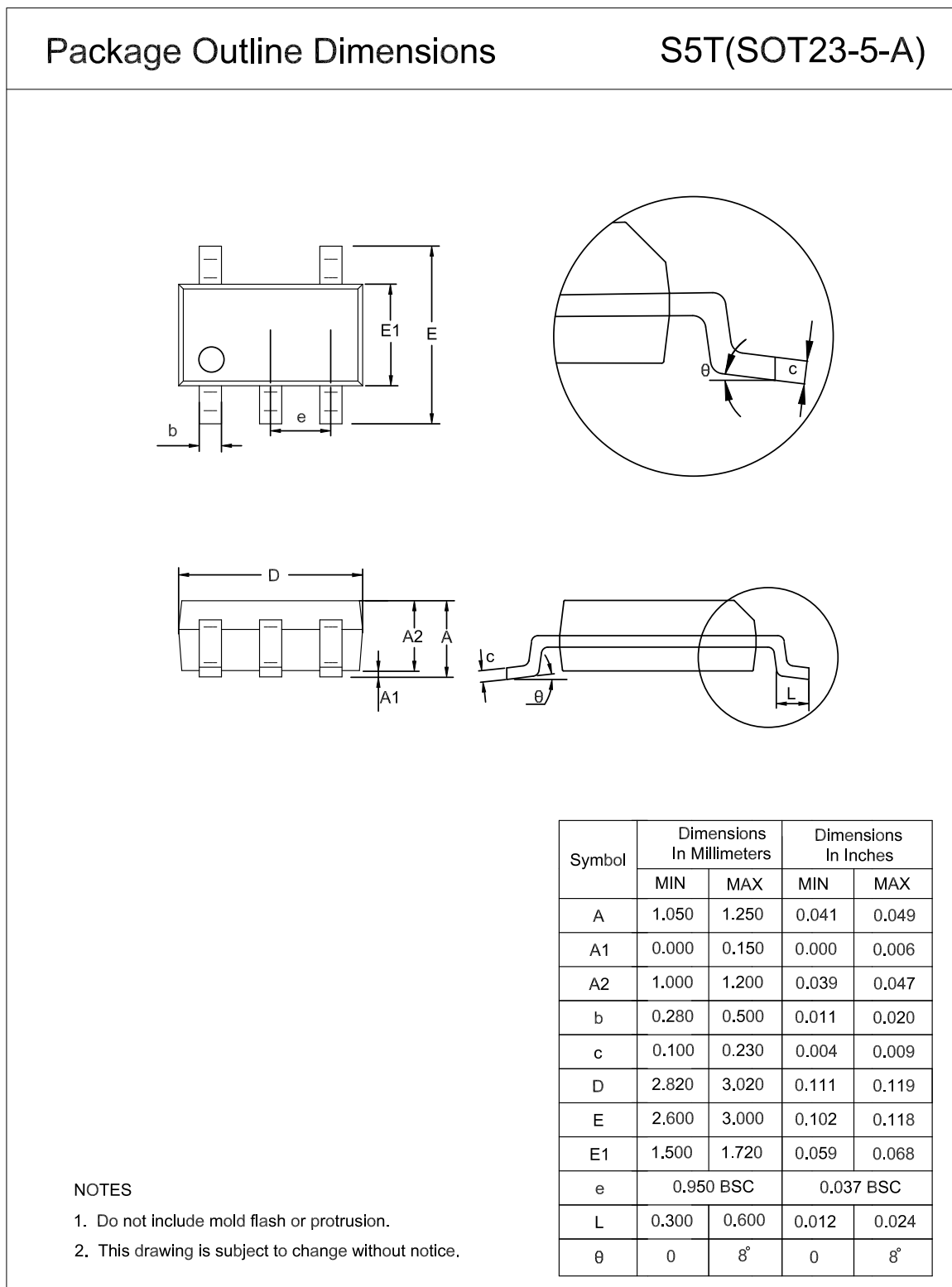


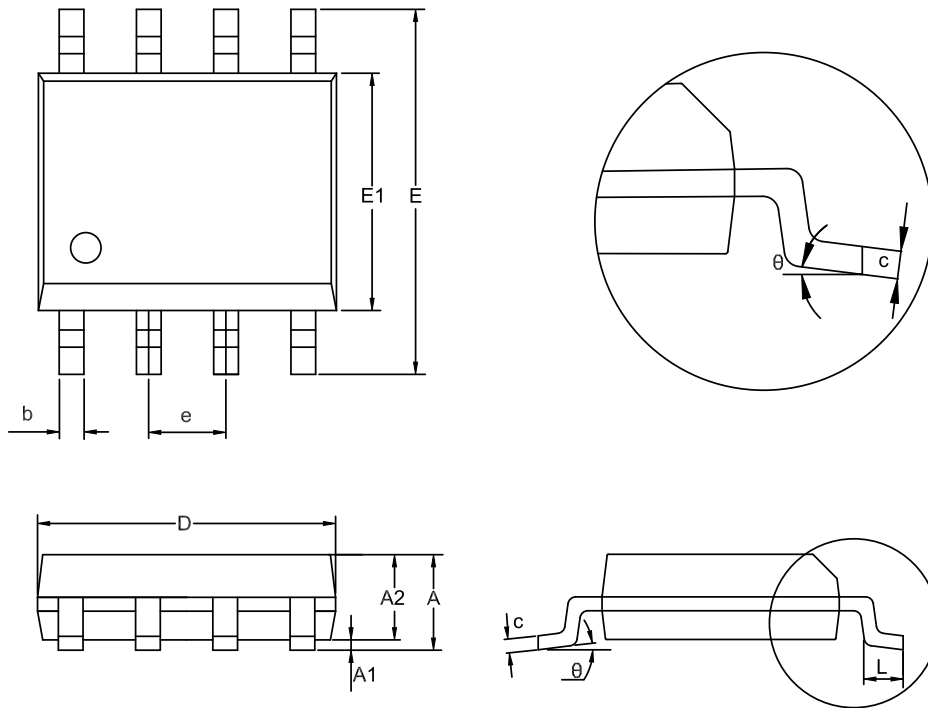
Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm) ⁽¹⁾	B0 (mm) ⁽¹⁾	K0 (mm) ⁽¹⁾	P0 (mm)	W0 (mm)	Pin1 Quadrant
TS321Q-S5TR-S	SOT23-5	180.0	12.0	3.3	3.25	1.4	4.0	8.0	Q3
LM2904Q-SO1R-S	SOP8	330.0	17.6	6.5	5.4	2.0	8.0	12.0	Q1
LM2904Q-VS1R-S	MSOP8	330.0	17.6	5.3	3.4	1.3	8.0	12.0	Q1
LM2904Q-TS1R-S	TSSOP8	330.0	17.6	6.8	3.4	1.2	8.0	12.0	Q1
LM2902Q-SO2R-S	SOP14	330.0	21.6	6.5	9.15	1.8	8.0	16.0	Q1
LM2902Q-TS2R-S	TSSOP14	330.0	17.6	6.8	5.5	1.3	8.0	12.0	Q1

(1) The value is for reference only. Contact the 3PEAK factory for more information.

Package Outline Dimensions

SOT23-5

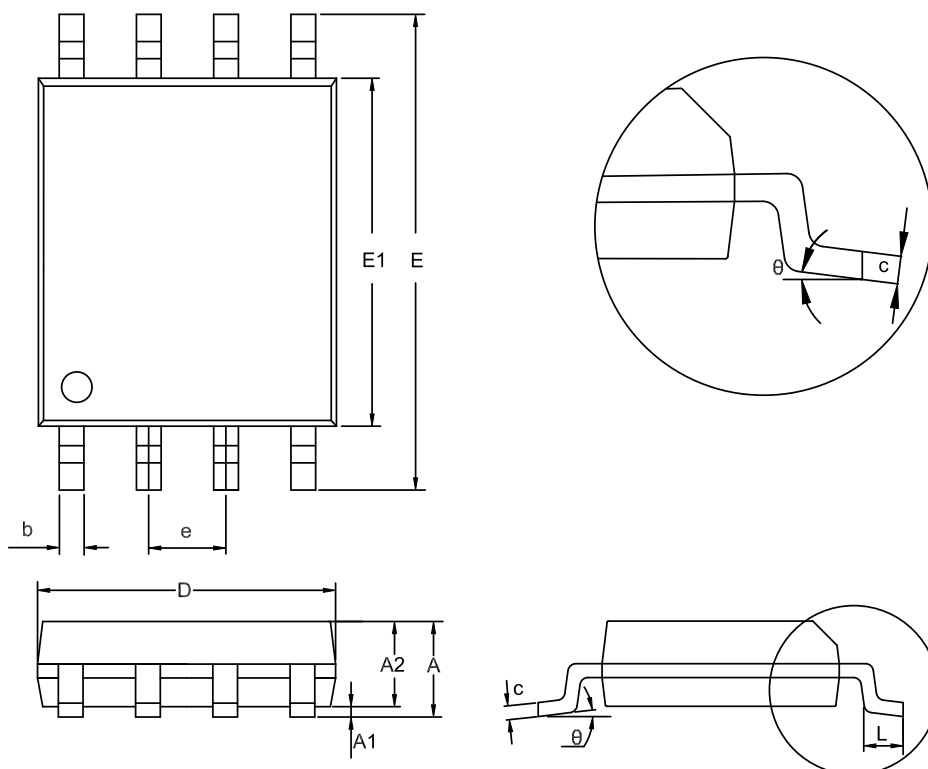


SOP8
Package Outline Dimensions
SO1(SOP-8-A)


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.550	0.049	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050 BSC	
L	0.400	1.000	0.016	0.039
θ	0	8°	0	8°

NOTES

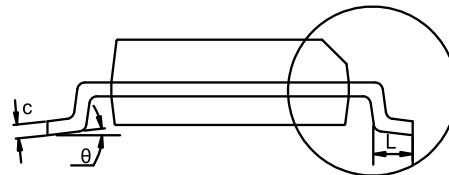
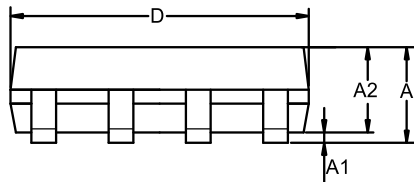
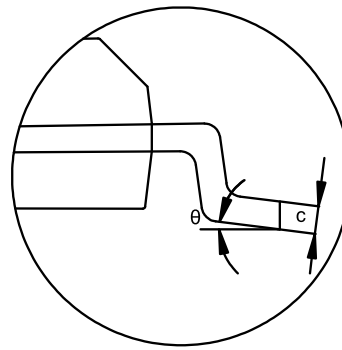
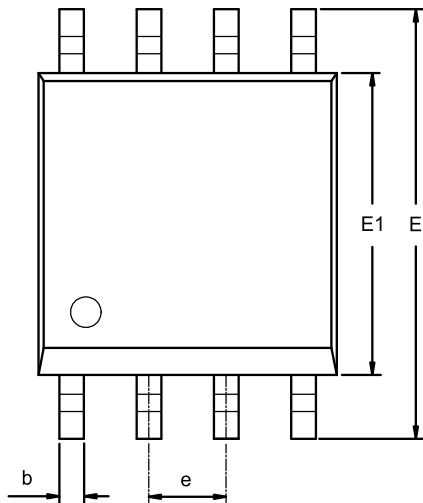
1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

TSSOP8
Package Outline Dimensions
TS1(TSSOP-8-A)


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.900	1.200	0.035	0.047
A1	0.050	0.150	0.002	0.006
A2	0.800	1.050	0.031	0.041
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
D	2.900	3.100	0.114	0.122
E	6.200	6.600	0.244	0.260
E1	4.300	4.500	0.169	0.177
e	0.650 BSC		0.026 BSC	
L	0.450	0.750	0.018	0.030
θ	0	8°	0	8°

NOTES

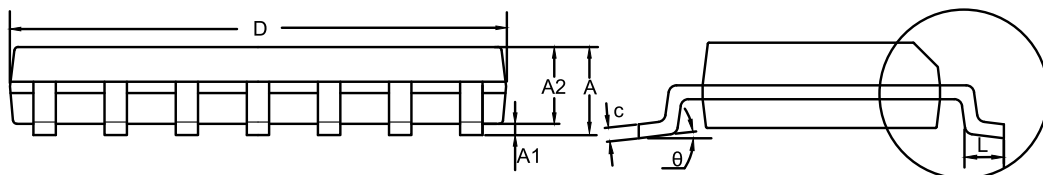
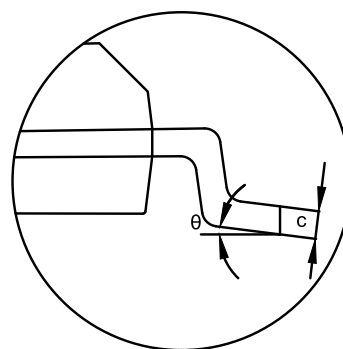
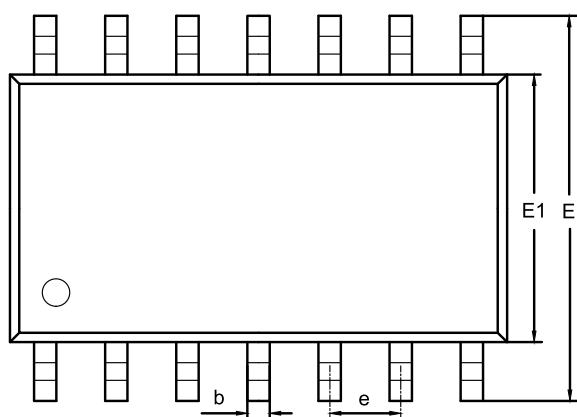
1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

MSOP8
Package Outline Dimensions
VS1(MSOP-8-A)


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.800	1.100	0.031	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	4.700	5.100	0.185	0.201
E1	2.900	3.100	0.114	0.122
e	0.650 BSC		0.026 BSC	
L	0.400	0.800	0.016	0.031
θ	0	8°	0	8°

NOTES

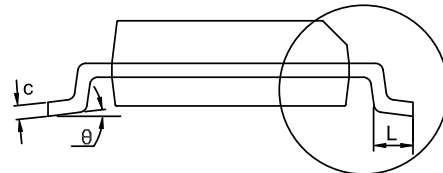
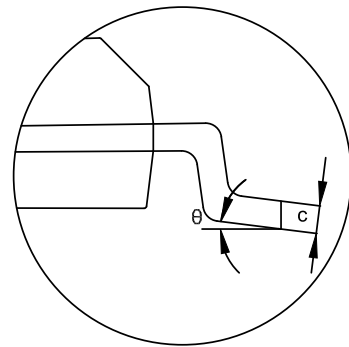
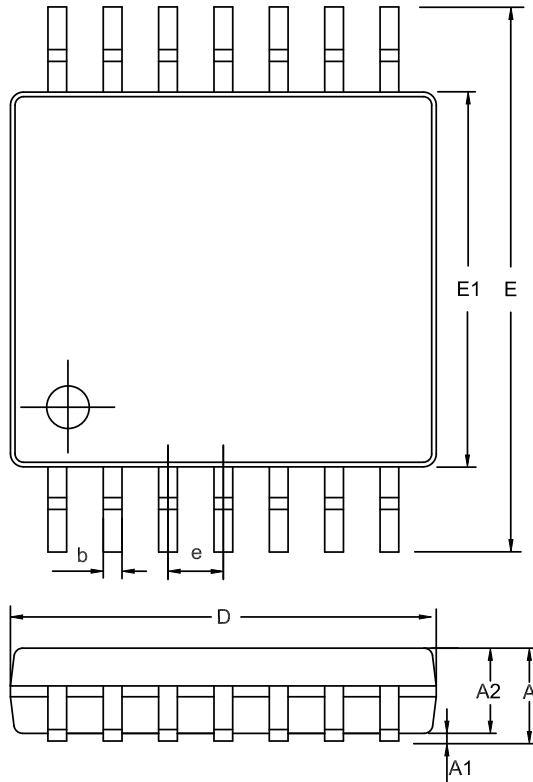
1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

SOP14
Package Outline Dimensions
SO2(SOP-14-A)


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.650	0.049	0.065
b	0.310	0.510	0.012	0.020
c	0.100	0.250	0.004	0.010
D	8.450	8.850	0.333	0.348
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050 BSC	
L	0.400	1.270	0.016	0.050
θ	0	8°	0	8°

NOTES

1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

TSSOP14
Package Outline Dimensions
TS2(TSSOP-14-A)


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.900	1.200	0.035	0.047
A1	0.050	0.150	0.002	0.006
A2	0.800	1.050	0.031	0.041
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
D	4.900	5.100	0.193	0.201
E	6.200	6.600	0.244	0.260
E1	4.300	4.500	0.169	0.177
e	0.650 BSC		0.026 BSC	
L	0.450	0.750	0.018	0.030
θ	0	8°	0	8°

NOTES

1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

Order Information

Order Number	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TS321Q-S5TR-S ⁽¹⁾	-40 to 125°C	SOT23-5	A9H	1	Tape and Reel, 3000	Green
LM2904Q-SO1R-S	-40 to 125°C	SOP8	L904Q	1	Tape and Reel, 4000	Green
LM2904Q-TS1R-S ⁽¹⁾	-40 to 125°C	TSSOP8	L904Q	1	Tape and Reel, 3000	Green
LM2904Q-VS1R-S	-40 to 125°C	MSOP8	L904Q	1	Tape and Reel, 3000	Green
LM2902Q-SO2R-S ⁽¹⁾	-40 to 125°C	SOP14	L902Q	1	Tape and Reel, 2500	Green
LM2902Q-TS2R-S ⁽¹⁾	-40 to 125°C	TSSOP14	L902Q	1	Tape and Reel, 3000	Green

(1) For future products, contact the 3PEAK factory for more information and samples.

Green: 3PEAK defines "Green" to mean RoHS compatible and free of halogen substances.

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