

## Features

- Supply Voltage: 2.5 V to 6 V
- Low Supply Current: Typical 600- $\mu$ A per Channel
- Rail-to-Rail Input and Output
- Bandwidth: Typical 6 MHz
- Slew Rate: Typical 4.5 V/ $\mu$ s
- Excellent EMI Suppress Performance
- Offset Voltage: Maximum  $\pm 3$  mV
- Offset Voltage Temperature Drift: Typical 1  $\mu$ V/ $^{\circ}$ C
- Low Noise: Typical 19 nV/ $\sqrt{\text{Hz}}$  at 1 kHz
- High Output Capability: Typical 100 mA
- $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  Operation Temperature Range
- Qualified for Automotive Applications with AEC-Q100 Reliability Test

## Applications

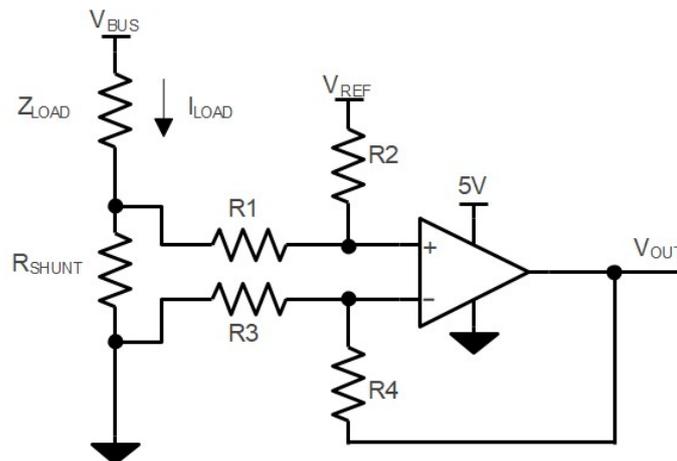
- Automotive Motor Control
- On-Board Charger

## Description

The TP156xAL1 series of products are CMOS dual and quad RRIO op-amps with low offset, low power and stable high-frequency response. They incorporate 3PEAK's proprietary and patented design techniques to achieve very good AC performance with 6-MHz bandwidth, 4.5-V/ $\mu$ s slew rate, and low distortion while drawing only 600  $\mu$ A of quiescent current per amplifier. The input common-mode voltage range extends 300 mV beyond  $V^-$  and  $V^+$ , and the outputs swing rail-to-rail. The TP156xAL1 family can be used as plug-in replacements for many commercially available op-amps to reduce power consumption and improve input/output range and performance.

The combination of features makes the TP156xAL1 ideal choice for motor control and automotive applications. The ability to swing rail-to-rail at the inputs and outputs enables designers to buffer CMOS DACs, ASICs, or other wide output swing devices in single-supply systems.

## Typical Application Circuit



$$V_{\text{OUT}} = (I_{\text{LOAD}} \times R_{\text{SHUNT}}) \times (R_2 / R_1) + V_{\text{REF}}$$

$$\text{When } R_3 = R_1, R_2 = R_4, R_{\text{SHUNT}} \ll R_1$$

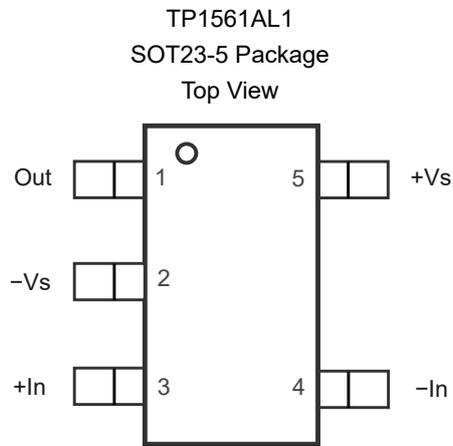
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## Revision History

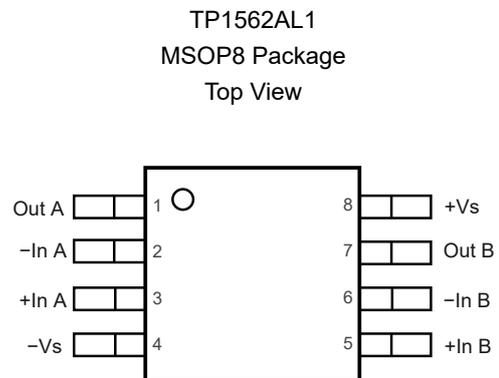
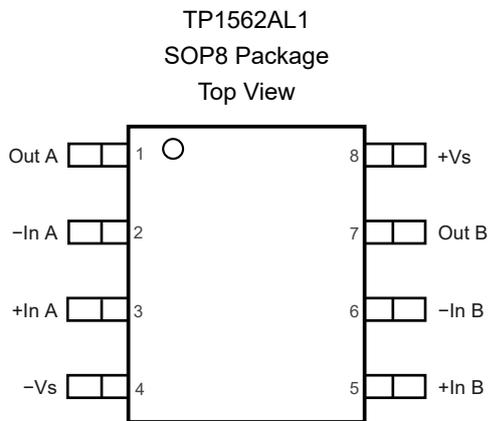
Date	Revision	Notes
2022-11-20	Rev.A.0	Initial version.
2023-02-01	Rev.A.1	Updated the status of AEC-Q100 test in Features.
2023-02-15	Rev.A.2	Corrected typo.
2023-09-15	Rev.A.3	Update the max value of supply voltage from 5.5V to 6V.
2024-07-25	Rev.A.4	Added part number: TPA1564AL1-TS2R-S. The following updates in Recommended Operating Conditions and Electrical Characteristics are all finished in Rev.A.3. Supply Voltage Range: from Min 2.7, Max 5.5 to Min 2.5, Max 6. Input Offset Voltage, VCM = 0 V to 3 V, TA = -40°C to 125°C: from Min -5, Max 5 to Min -4, Max 4. Input Offset Current: from Typ 10 to Typ 1. Maximum Output Voltage Swing, RLOAD = 10 k $\Omega$ , TA = -40°C to 125°C: from Max 30 to Max 20. Output Short-Circuit Current, TA = -40°C to 125°C: from Min 50 to Min 65. Slew Rate: Added Min 3 in TA = 25°C and Min 2 in TA = -40°C to 125°C.

## Pin Configuration and Functions



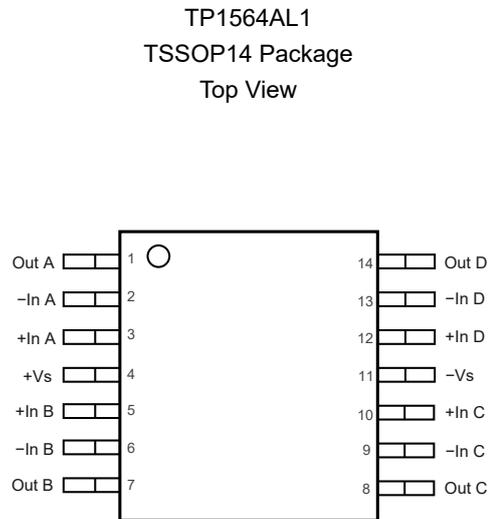
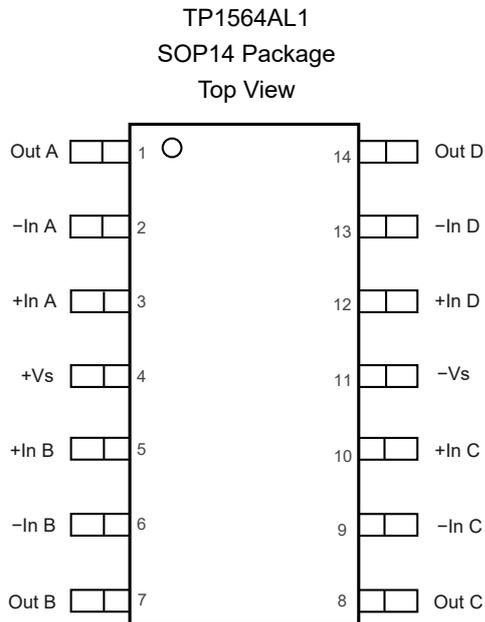
**Table 1. Pin Functions: TP1561AL1**

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



**Table 2. Pin Functions: TP1562AL1**

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



**Table 3. Pin Functions: TP1564AL1**

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

## Specifications

### Absolute Maximum Ratings <sup>(1)</sup>

Parameter		Min	Max	Unit
	Supply Voltage, (+V <sub>S</sub> ) – (–V <sub>S</sub> )		6.5	V
	Input Voltage	(–V <sub>S</sub> ) – 0.3	(+V <sub>S</sub> ) + 0.3	V
	Differential Input Voltage	(–V <sub>S</sub> ) – (+V <sub>S</sub> )	(+V <sub>S</sub> ) – (–V <sub>S</sub> )	V
	Input Current: +I <sub>N</sub> , –I <sub>N</sub> <sup>(2)</sup>	–10	+10	mA
	Output Short-Circuit Duration <sup>(3)</sup>		Infinite	
T <sub>J</sub>	Maximum Junction Temperature		150	°C
T <sub>A</sub>	Operating Temperature Range	–40	125	°C
T <sub>STG</sub>	Storage Temperature Range	–65	150	°C
T <sub>L</sub>	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 each power supply. If the input extends more than 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

Parameter		Condition	Minimum Level	Unit
HBM	Human Body Model ESD	AEC-Q100-002	4	kV
CDM	Charged Device Model ESD	AEC-Q100-011	1.5	kV

### Recommended Operating Conditions

Parameter		Min	Typ	Max	Unit
V <sub>S</sub>	Supply Voltage, (+V <sub>S</sub> ) – (–V <sub>S</sub> )	2.5		6	V
T <sub>A</sub>	Operating Temperature Range	–40		125	°C

### Thermal Information

Package Type	$\theta_{JA}$	$\theta_{JC}$	Unit
SOT23-5	250	81	°C/W
SOP8	158	43	°C/W
MSOP8	210	45	°C/W
SOP14	120	36	°C/W

## Electrical Characteristics

All test condition is at  $V_S = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $R_L = 2\text{ k}\Omega$ ,  $C_L = 100\text{ pF}$ , unless otherwise noted.

Parameter		Conditions	Min	Typ	Max	Unit
<b>Power Supply</b>						
$V_S$	Supply Voltage Range		2.5		6	V
$I_Q$	Quiescent Current per Amplifier			600	900	$\mu\text{A}$
		$T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$			1200	$\mu\text{A}$
PSRR	Power Supply Rejection Ratio	$V_S = 2.7\text{ V}$ to $5.5\text{ V}$ , $V_{CM} = 0.1\text{ V}$	75	90		dB
		$V_S = 2.7\text{ V}$ to $5.5\text{ V}$ , $V_{CM} = 0.1\text{ V}$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	65			dB
<b>Input Characteristics</b>						
$V_{OS}$	Input Offset Voltage	$V_{CM} = 0\text{ V}$ to $3\text{ V}$	-3		3	mV
$V_{OS}$	Input Offset Voltage	$V_{CM} = 0\text{ V}$ to $3\text{ V}$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	-4		4	mV
$V_{OS\ TC}$	Input Offset Voltage Drift	$T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$		1		$\mu\text{V}/^\circ\text{C}$
$I_B$	Input Bias Current	$T_A = 25^\circ\text{C}$	-200	1	200	pA
		$T_A = 125^\circ\text{C}$	-500	25	500	pA
$I_{OS}$	Input Offset Current			1		pA
$C_{IN}$	Input Capacitance	Differential Mode		8		pF
		Common Mode		7		pF
$A_v$	Open-loop Voltage Gain	$V_{OUT} = 0.1\text{ V}$ to $4.9\text{ V}$ , $R_{LOAD} = 100\text{ k}\Omega$	80	100		dB
		$V_{OUT} = 0.1\text{ V}$ to $4.9\text{ V}$ , $R_{LOAD} = 100\text{ k}\Omega$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	70			dB
$V_{CMR}$	Common-mode Input Voltage Range		$(-V_S) - 0.1$		$(+V_S) + 0.1$	V
CMRR	Common Mode Rejection Ratio	$V_{CM} = 0\text{ V}$ to $2.5\text{ V}$	70	100		dB
		$V_{CM} = 0\text{ V}$ to $2.5\text{ V}$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	60			dB
Xtalk	Channel Separation	$f = 1\text{ kHz}$ , $R_L = 2\text{ k}\Omega$		110		dB
<b>Output Characteristics</b>						
	Maximum Output Voltage Swing	$R_{LOAD} = 10\text{ k}\Omega$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$		3	20	mV
$I_{SC}$	Output Short-Circuit Current	$T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	65	100		mA
<b>AC Specifications</b>						
GBW	Gain-Bandwidth Product			6		MHz
SR	Slew Rate	$A_v = 1$ , $V_{OUT} = 1.5\text{ V}$ to $3.5\text{ V}$ , $C_{LOAD} = 60\text{ pF}$ , $R_{LOAD} = 1\text{ k}\Omega$		4.5		$\text{V}/\mu\text{s}$

Parameter		Conditions	Min	Typ	Max	Unit
		Open loop	3	4.5		V/ $\mu$ s
		Open loop, $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	2			V/ $\mu$ s
$t_s$	Settling Time, 0.1%	$A_V = 1$ , 2 V Step, $C_{LOAD} = 60$ pF,		0.8		$\mu$ s
	Settling Time, 0.01%	$R_{LOAD} = 1$ k $\Omega$		1		$\mu$ s
PM	Phase Margin	$R_{LOAD} = 1$ k $\Omega$ , $C_{LOAD} = 60$ pF		60		$^\circ$
GM	Gain Margin	$R_{LOAD} = 1$ k $\Omega$ , $C_{LOAD} = 60$ pF		15		dB
<b>Noise Performance</b>						
$E_N$	Input Voltage Noise	$f = 0.1$ Hz to 10 Hz		8		$\mu$ V <sub>PP</sub>
$e_N$	Input Voltage Noise Density	$f = 1$ kHz		19		nV/ $\sqrt{\text{Hz}}$
$i_N$	Input Current Noise	$f = 1$ kHz		2		fA/ $\sqrt{\text{Hz}}$

### Typical Performance Characteristics

All test condition:  $V_S = 5\text{ V}$ ,  $V_{CM} = 2.5\text{ V}$ ,  $R_L = \text{Open}$ , unless otherwise noted.

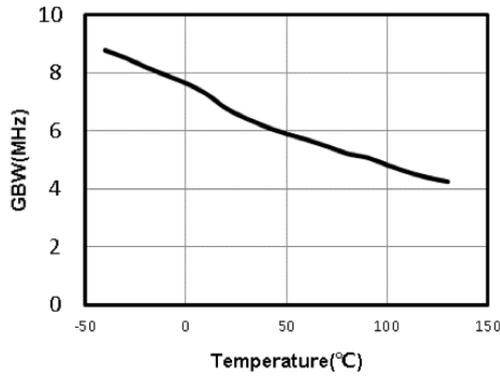


Figure 1. Unity Gain Bandwidth vs. Temperature

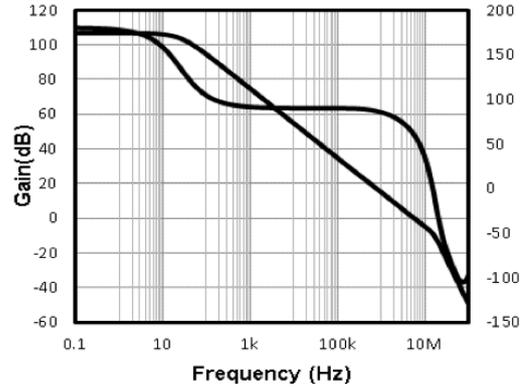


Figure 2. Open-Loop Gain and Phase

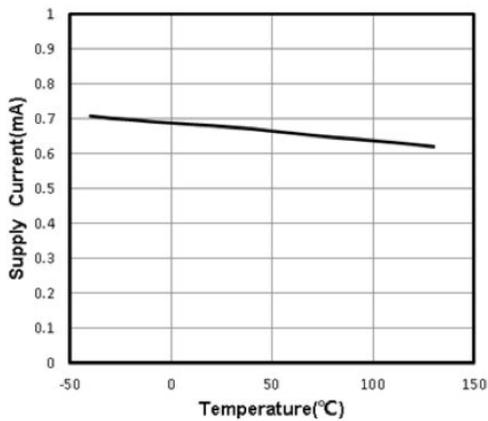


Figure 3. Supply Current vs. Temperature

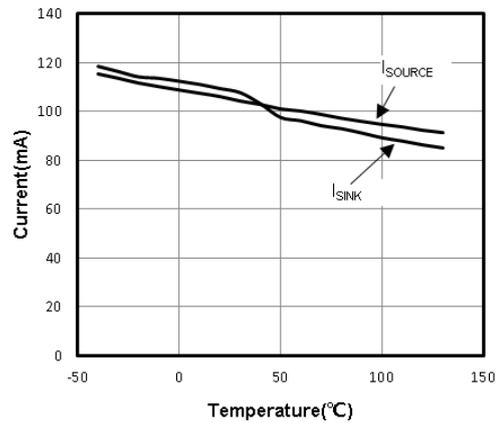


Figure 4. Short Circuit Current vs. Temperature

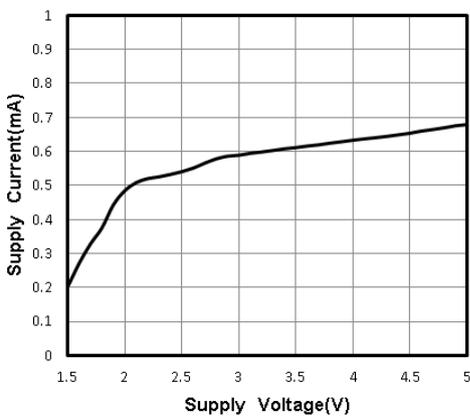


Figure 5. Quiescent Current vs. Supply Voltage

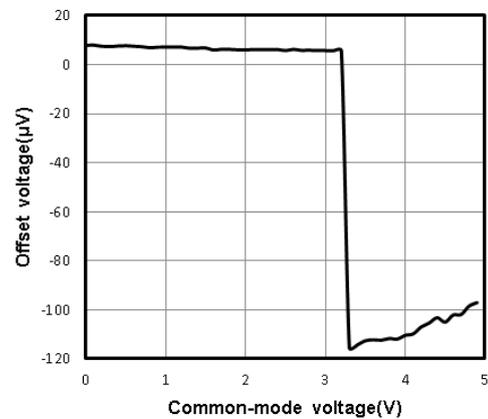


Figure 6. Offset Voltage vs. Common-Mode Voltage

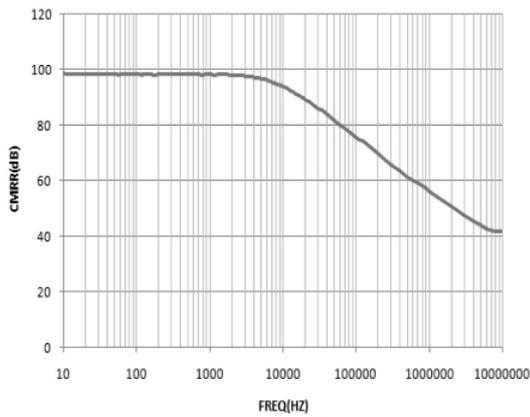


Figure 7. CMRR vs. Frequency

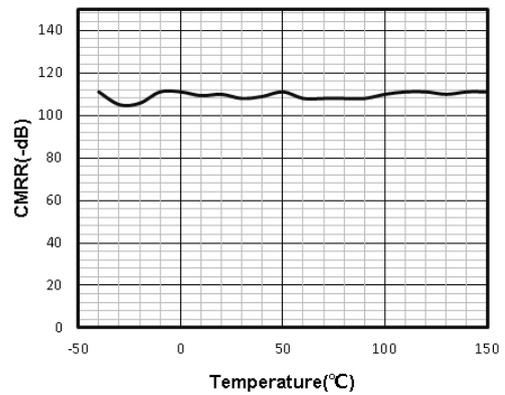


Figure 8. CMRR vs. Temperature

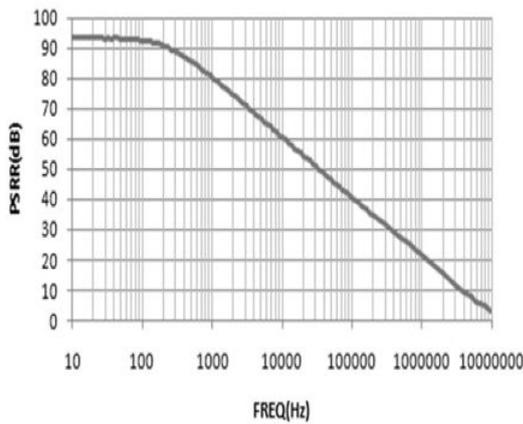


Figure 9. PSRR vs. Frequency

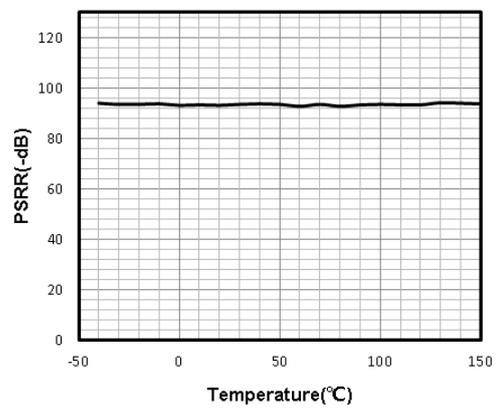


Figure 10. PSRR vs. Temperature

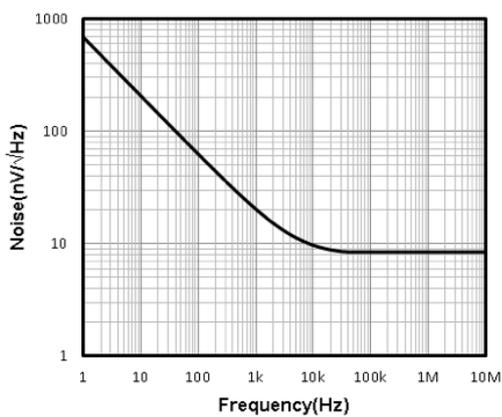


Figure 11. Input Voltage Noise Spectral Density

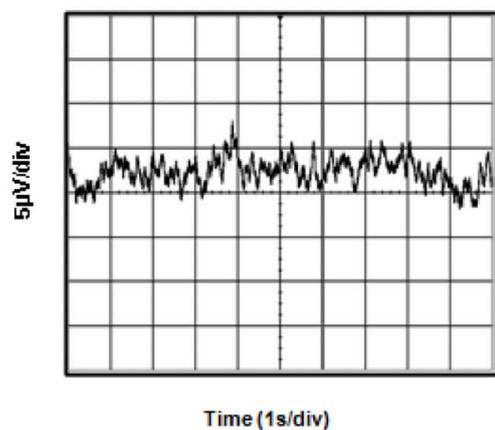


Figure 12. 0.1-Hz to 10-Hz Input Voltage Noise

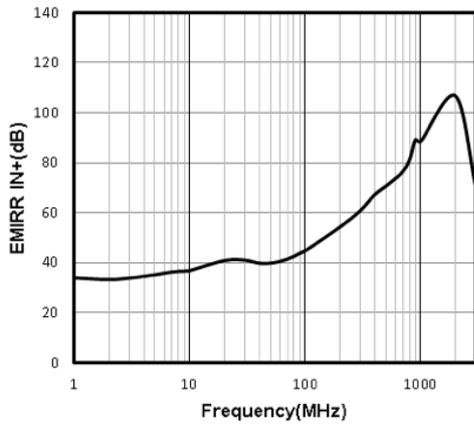


Figure 13. EMIRR IN+ vs. Frequency

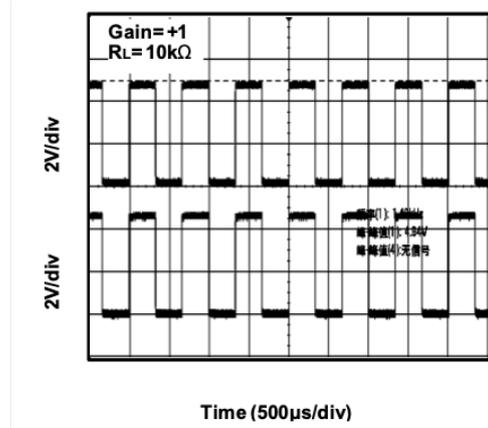


Figure 14. Large-Scale Step Response

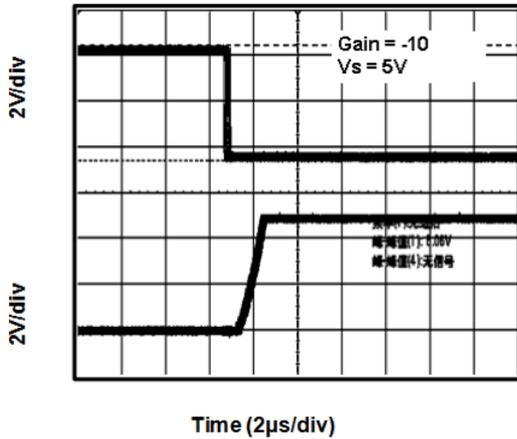


Figure 15. Negative Over-Voltage Recovery

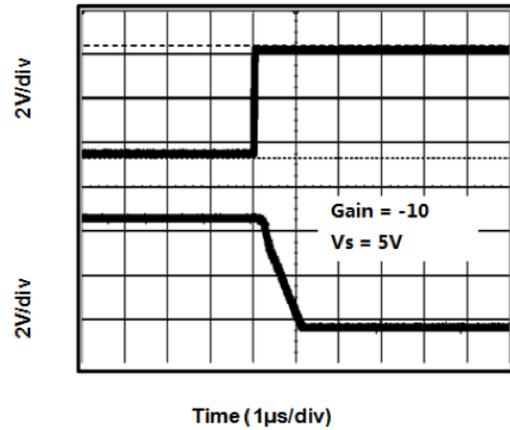


Figure 16. Positive Over-Voltage Recovery

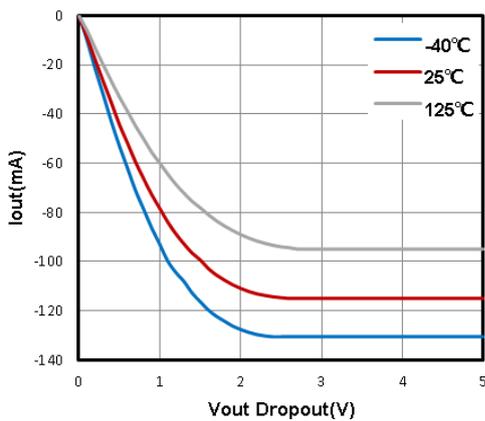


Figure 17. Negative Output Swing vs. Load Current

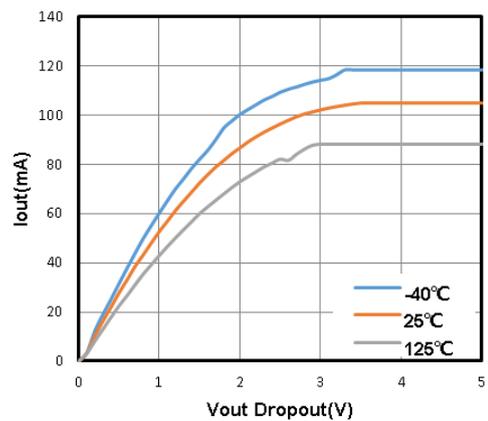


Figure 18. Positive Output Swing vs. Load Current

## Detailed Description

### Functional Block Diagram

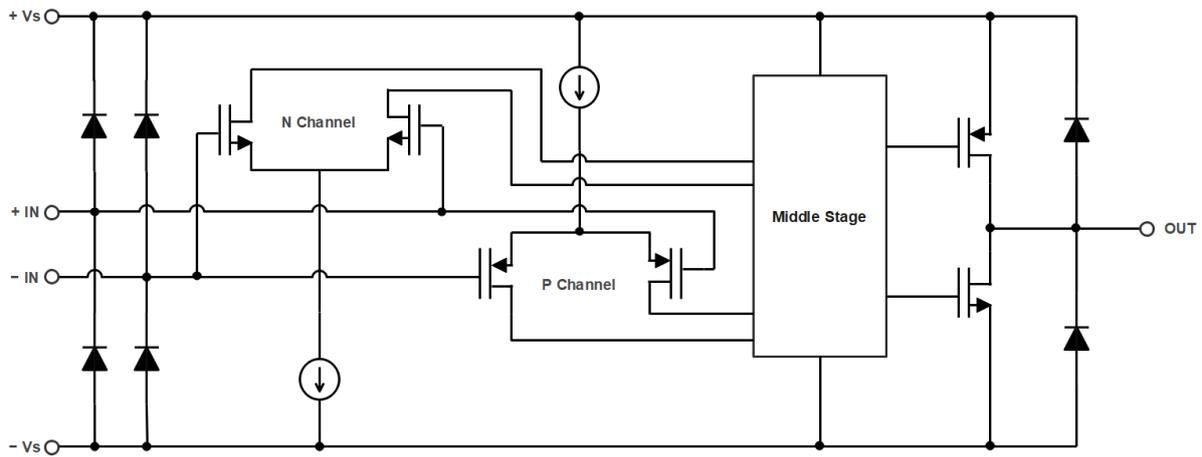


Figure 19. Functional Block Diagram

## 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 Supply Voltage and Low Power Consumption

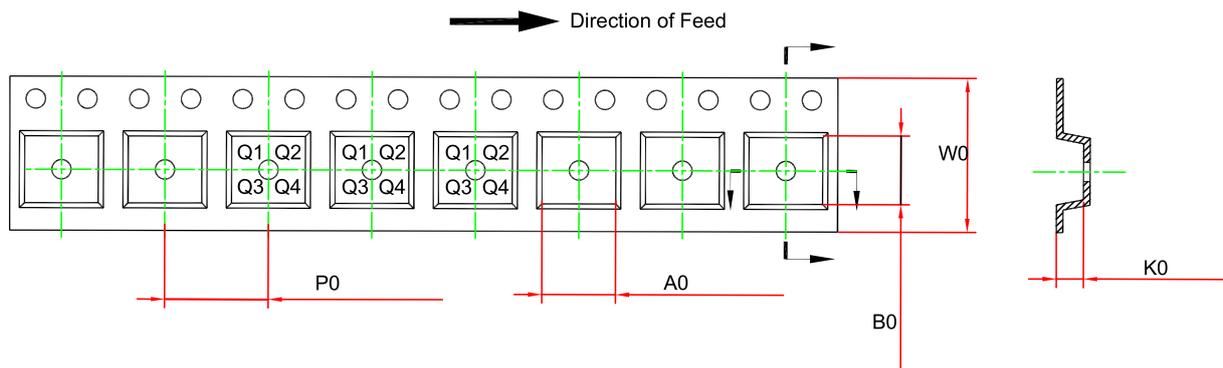
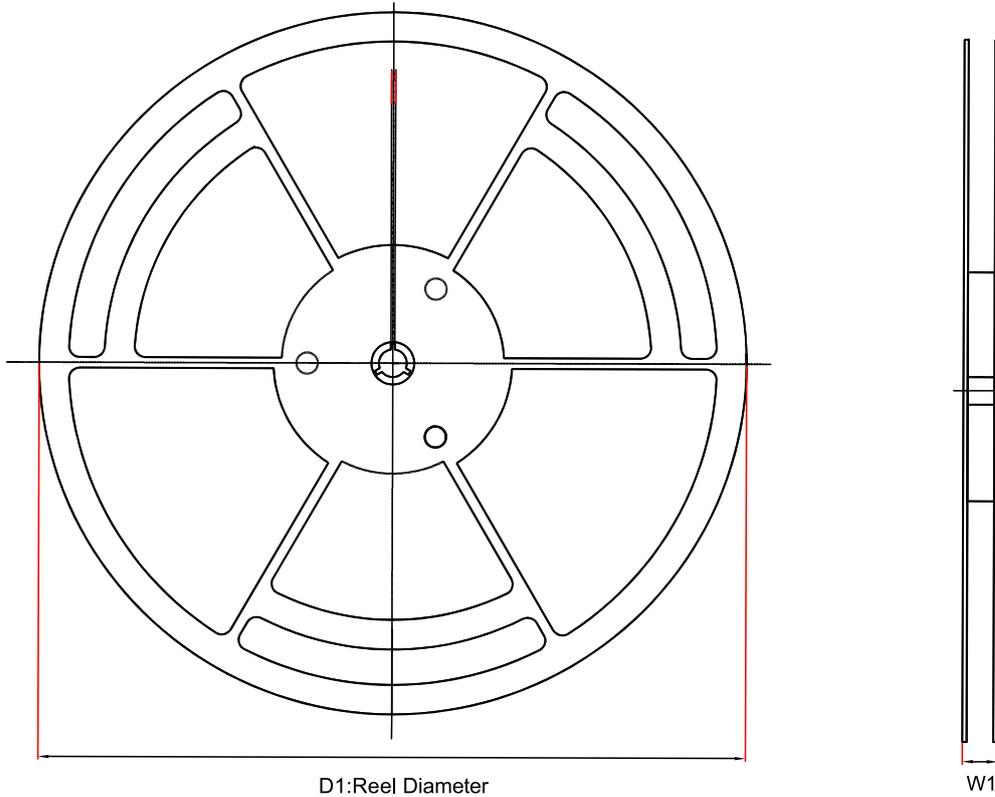
The TP156xAL1 family of operational amplifiers can operate with power supply voltages ranging from 2.5 V to 6 V. Each amplifier draws only 600- $\mu$ A quiescent current. The low-supply voltage capability and low-supply current are ideal for portable applications demanding high capacitive load driving capability and stable wide bandwidth. The TP156xAL1 family is optimized for wide bandwidth and low-power applications. They have an industry leading high GBWP to power ratio and are unity gain stable for any capacitive load. When the load capacitance increases, the increased capacitance at the output pushed the non-dominant pole to lower frequency in the open loop frequency response, lowering the phase and gain margin. Higher gain configurations tend to have better capacitive drive capability than lower gain configurations due to lower closed loop bandwidth and hence higher phase margin.

### Ground Sensing and Rail-to-Rail Output

The TP156xAL1 family has excellent output drive capability, delivering over 100 mA of output drive current. The output stage is a rail-to-rail topology that is capable of swinging to within 10 mV of either rail. Since the inputs can go 300 mV beyond either rail, the op-amp can easily perform 'true ground' sensing.

The maximum output current is a function of total supply voltage. As the supply voltage to the amplifier increases, the output current capability also increases. Attention must be paid to keep the junction temperature of the IC below 150°C when the output is in continuous short-circuit. The output of the amplifier has reverse-biased ESD diodes connected to each supply. The output should not be forced more than 0.5 V beyond either supply, otherwise the current will flow through these diodes.

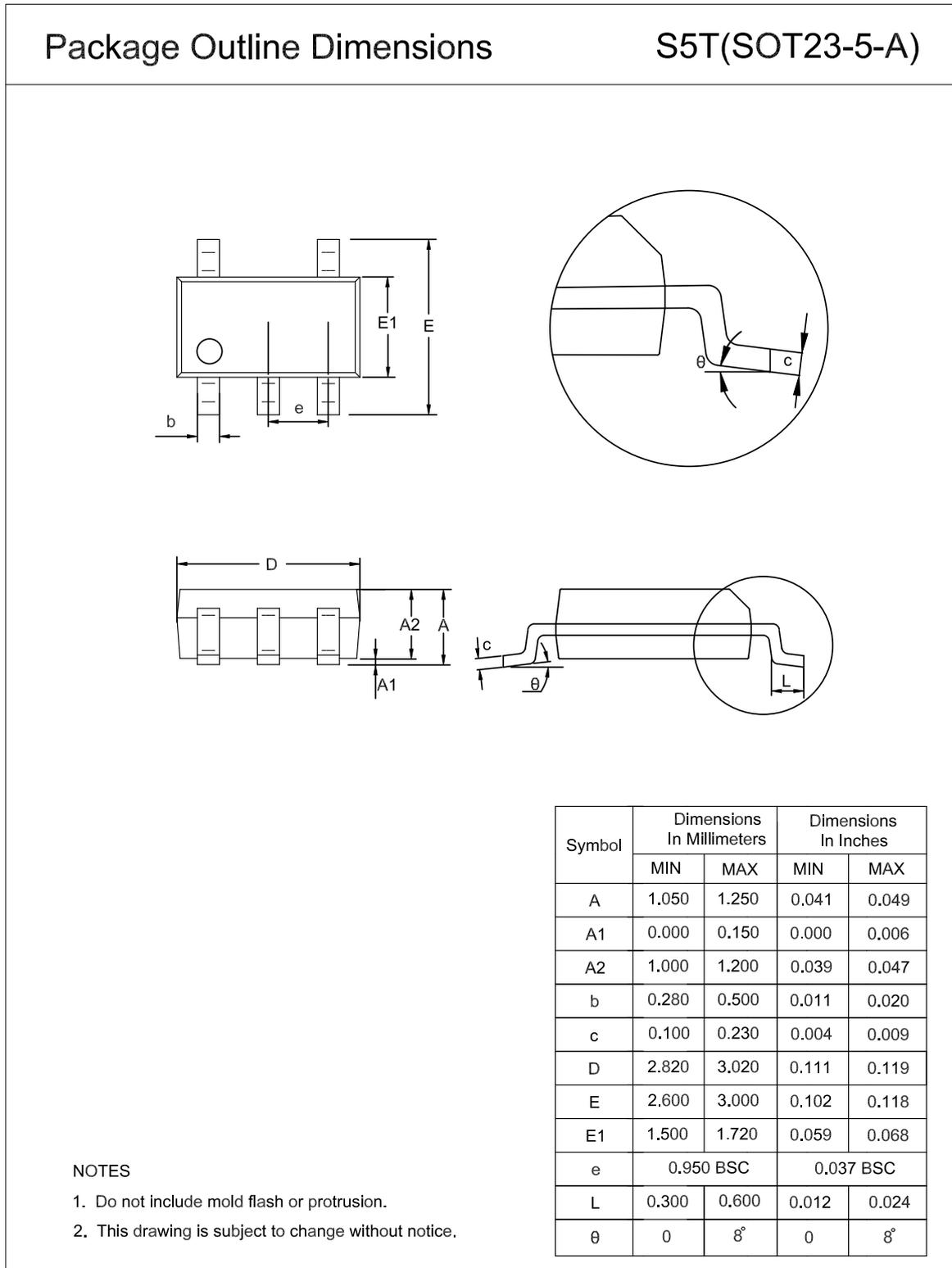
### Tape and Reel Information



Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TP1561AL1-S5TR-S	SOT23-5	180.0	13.1	3.2	3.2	1.4	4.0	8.0	Q3
TP1562AL1-SO1R-S	SOP8	330.0	17.6	6.4	5.4	2.1	8.0	12.0	Q1
TP1562AL1-VS1R-S	MSOP8	330.0	17.6	5.2	3.3	1.5	8.0	12.0	Q1
TP1564AL1-SO2R-S	SOP14	330.0	21.6	6.5	9.0	2.1	8.0	16.0	Q1
TP1564AL1-TS2R-S	TSSOP14	330.0	17.6	6.8	5.5	1.3	8.0	12.0	Q1

Package Outline Dimensions

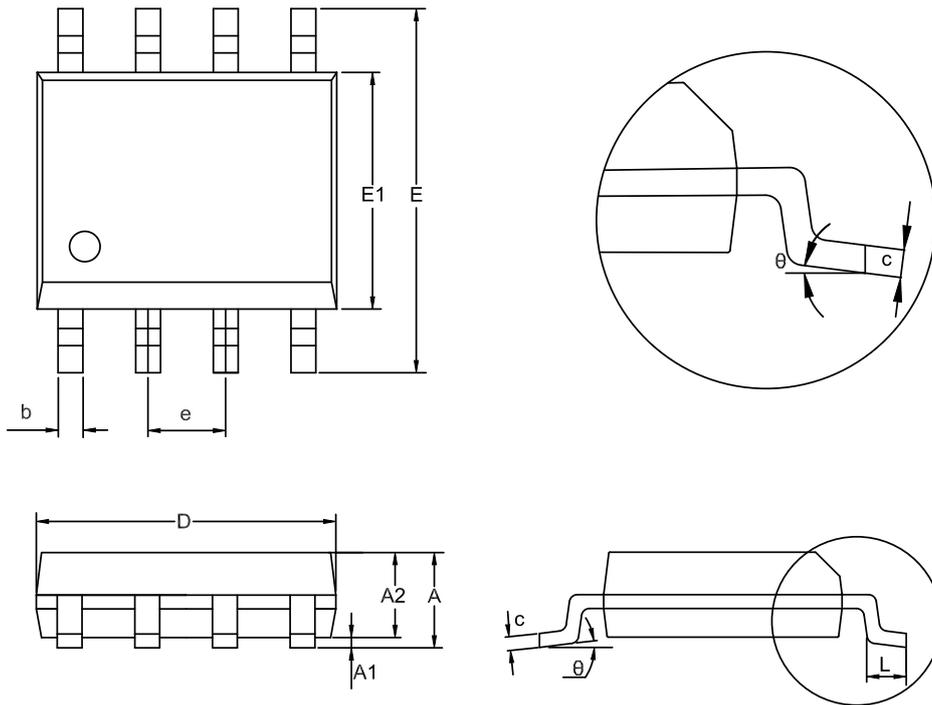
SOT23-5



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
theta	0	8°	0	8°

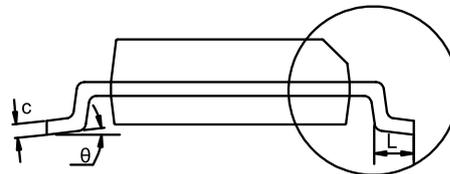
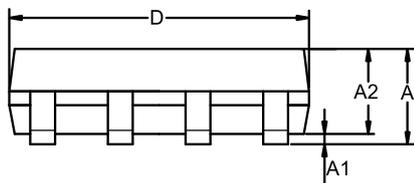
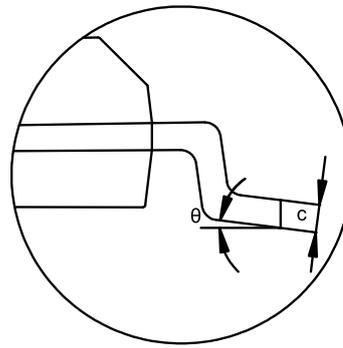
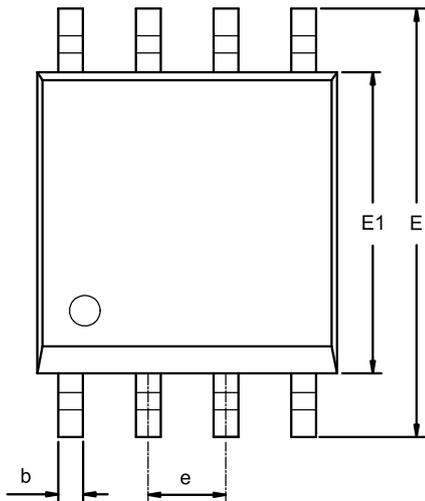
NOTES

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
theta	0	8°	0	8°

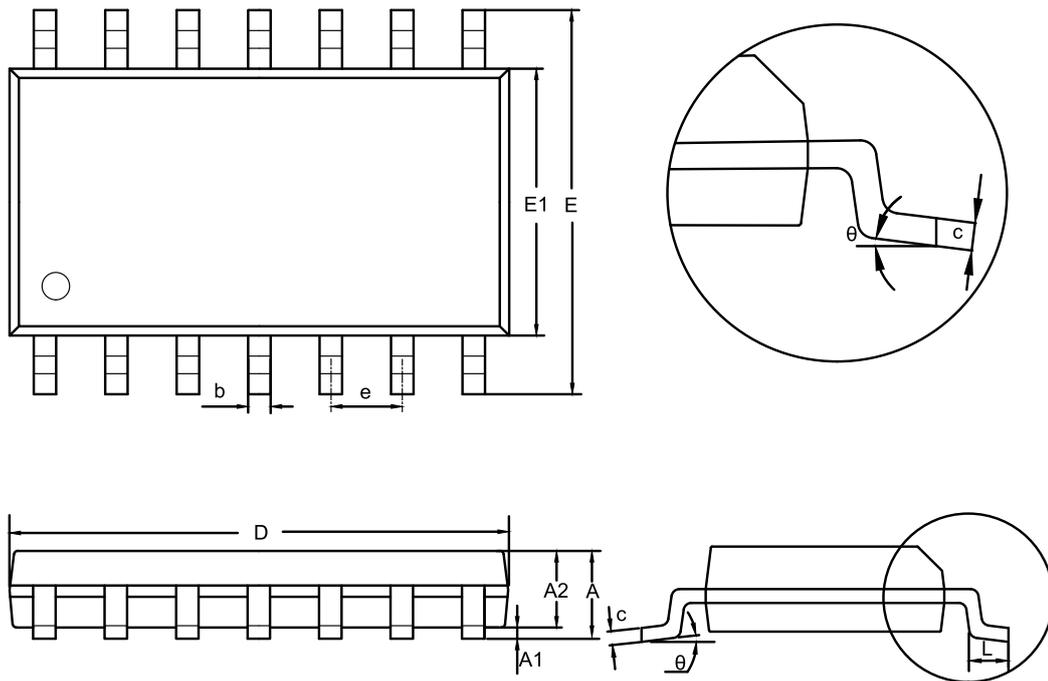
NOTES

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)

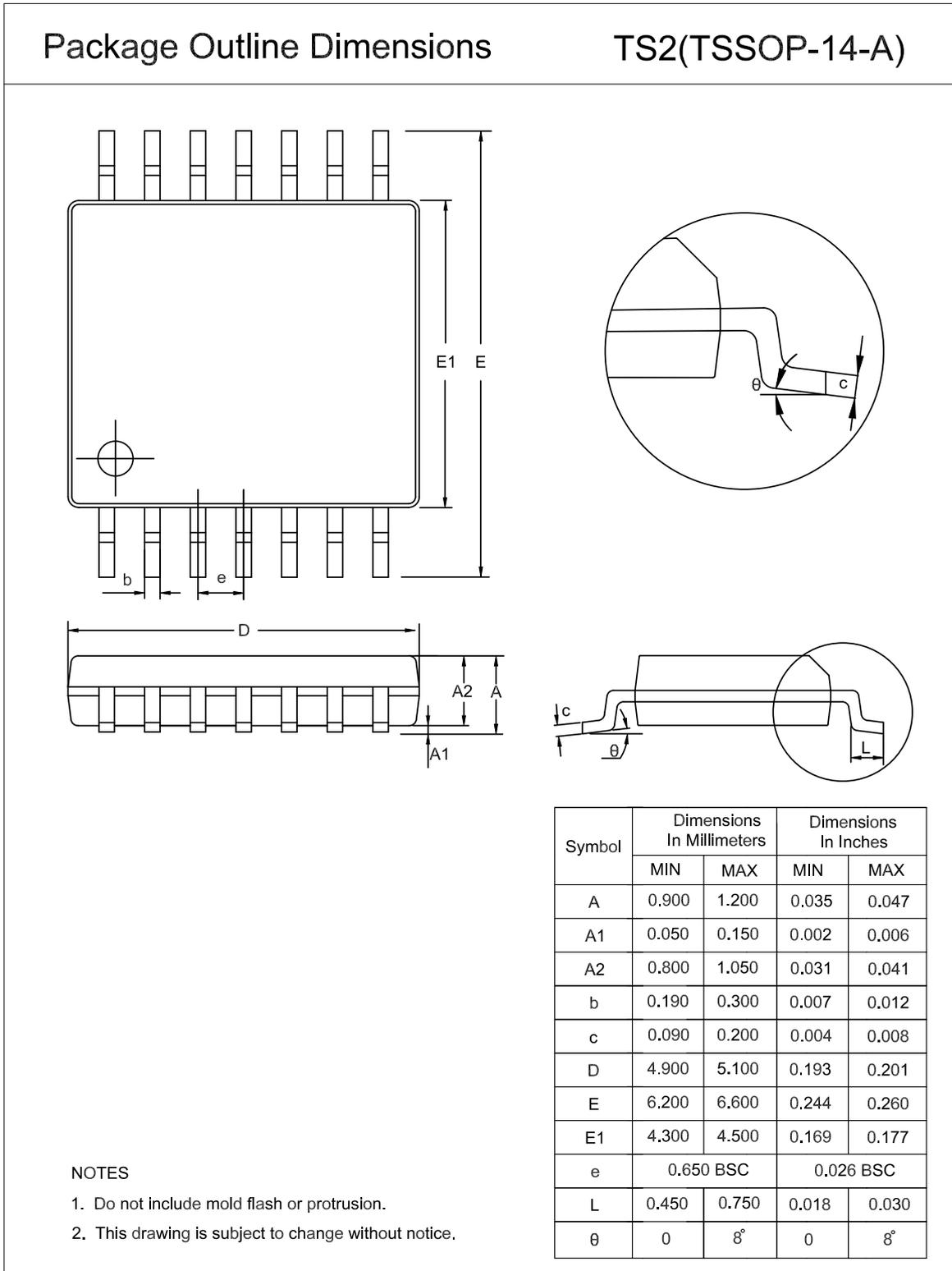


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.650	0.049	0.065
b	0.310	0.510	0.012	0.020
c	0.100	0.250	0.004	0.010
D	8.450	8.850	0.333	0.348
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050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

NOTES

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

TSSOP14



**Order Information**

Order Number	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TP1561AL1-S5TR-S	-40 to 125°C	SOT23-5	61S	MSL 3	Tape and Reel, 3000	Green
TP1562AL1-SO1R-S	-40 to 125°C	SOP8	1562S	MSL 1	Tape and Reel, 4000	Green
TP1562AL1-VS1R-S	-40 to 125°C	MSOP8	1562S	MSL 1	Tape and Reel, 3000	Green
TP1564AL1-SO2R-S	-40 to 125°C	SOP14	1564S	MSL 1	Tape and Reel, 2500	Green
TP1564AL1-TS2R-S	-40 to 125°C	TSSOP14	1564S	MSL 3	Tape and Reel, 3000	Green

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

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