

## Features

- Supply Voltage: 2.1 V to 6.0 V
- Low Supply Current: 80  $\mu$ A per channel
- Rail to Rail Input and Output
- Bandwidth: 1 MHz
- Slew Rate: 0.7 V/ $\mu$ s
- Excellent EMI Suppress Performance
- Offset Voltage:  $\pm 3$  mV Maximum
- Offset Voltage Temperature Drift: 2  $\mu$ V/ $^{\circ}$ C
- Low Noise: 27 nV/ $\sqrt{\text{Hz}}$  at 1 kHz
- High Output Capability: 100 mA
- $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  Operation Temperature Range

## Applications

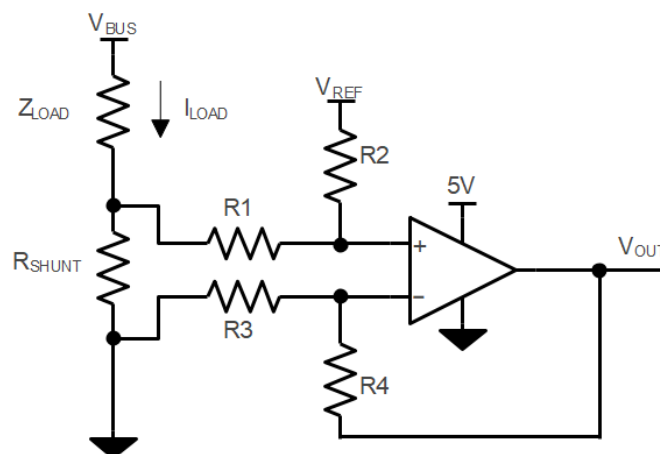
- Active Filters, ASIC Input or Output Amplifier
- Sensor Interface
- Smoke/Gas/Environment Sensors
- Portable Instruments and Mobile Device

## Description

The TP600X series are CMOS single, dual, quad op-amps with RRIO, low offset, low power and stable high-frequency response. They incorporate 3PEAK's proprietary and patented design techniques to achieve excellent AC performance with 1 MHz bandwidth, 0.7 V/ $\mu$ s slew rate, and low distortion while drawing only 80  $\mu$ A of quiescent current per amplifier. The common-mode input voltage range extends 100 mV beyond  $V^-$  and  $V^+$ , and the outputs swing rail-to-rail. The TP600X family can be used as plug-in replacements for many commercially available op-amps to reduce power and improve the input/output range and performance.

The combination of features makes the TP600X an ideal choice for motor control and portable audio amplification, sound ports, and other consumer Audio. The TP600X Op-amp is very stable, and it is capable of driving heavy capacitive loads such as those found in LCDs. 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



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

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

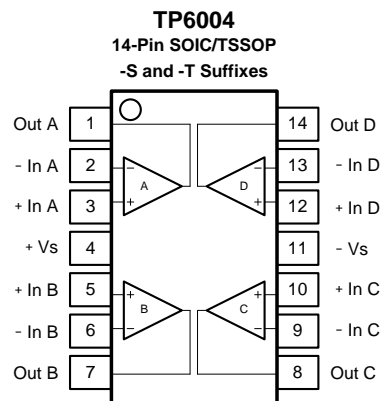
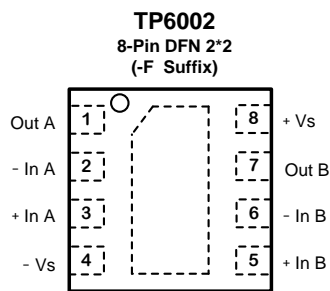
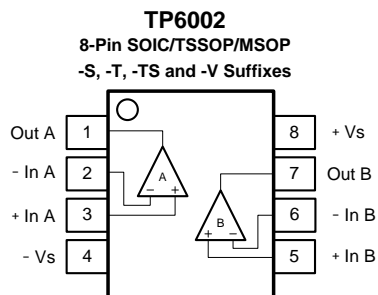
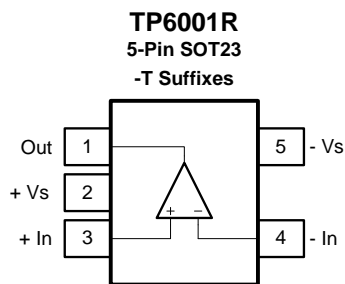
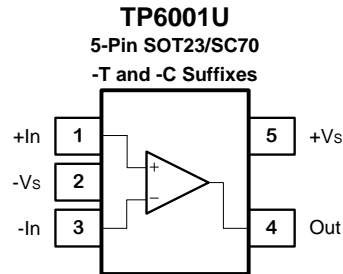
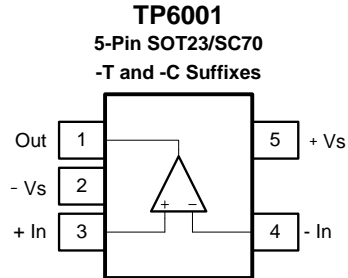
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## Revision History

Date	Revision	Notes
2017-08-11	Rev.0	Release Version, confirmed spec limit
2017-10-28	Rev.0.01	Corrected the max of Common-mode Input Voltage Range in Electrical Characteristics from (V+) - 0.1 to (V+) + 0.1. Corrected Operating Temperature Range in Maximum Ratings from -45 to 125°C to -40 to 125°C.
2017-12-07	Rev 0.02	Added Package: TP6001U-CR
2018-02-01	Rev 0.03	Corrected Pin configuration of TP6001R. Corrected the quiescent current per amplifier in "Description" from 500 $\mu$ A to 80 $\mu$ A
2018-05-10	Rev 0.04	Added new part number TP6002-FR. Updated package dimension with new data.
2021-03-21	Rev.A.0	Updated document format. Updated marking of TP6002-FR: 6002 $\rightarrow$ 602

## Pin Configuration and Functions



The thermal pad of DFN package is recommended to be left float or connected to -Vs

## Specifications

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

Parameter		Min	Max	Unit
Supply Voltage			7	V
Input Voltage		(V <sup>-</sup> ) - 0.3	(V <sup>+</sup> ) + 0.3	V
Input Current: +IN, -IN <sup>(2)</sup>			$\pm$ 10	mA
Differential Input Voltage		(V <sup>-</sup> ) - (V <sup>+</sup> )	(V <sup>+</sup> ) - (V <sup>-</sup> )	mV
Output Short-Circuit Duration <sup>(3)</sup>			Indefinite	
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 500 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	ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	8	kV
CDM	Charged Device Model ESD	ANSI/ESDA/JEDEC JS-002 <sup>(2)</sup>	2	kV

(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.

### Thermal Information

Package Type	$\theta_{JA}$	$\theta_{JC}$	Unit
SOT353 (SC70-5)	400	150	°C/W
SOT23-5	250	81	°C/W
SOP8	158	43	°C/W
MSOP8	210	45	°C/W
TSSOP8	191	44	°C/W
DFN2X2-8	100	60	°C/W
SOP14	120	36	°C/W
TSSOP14	180	35	°C/W

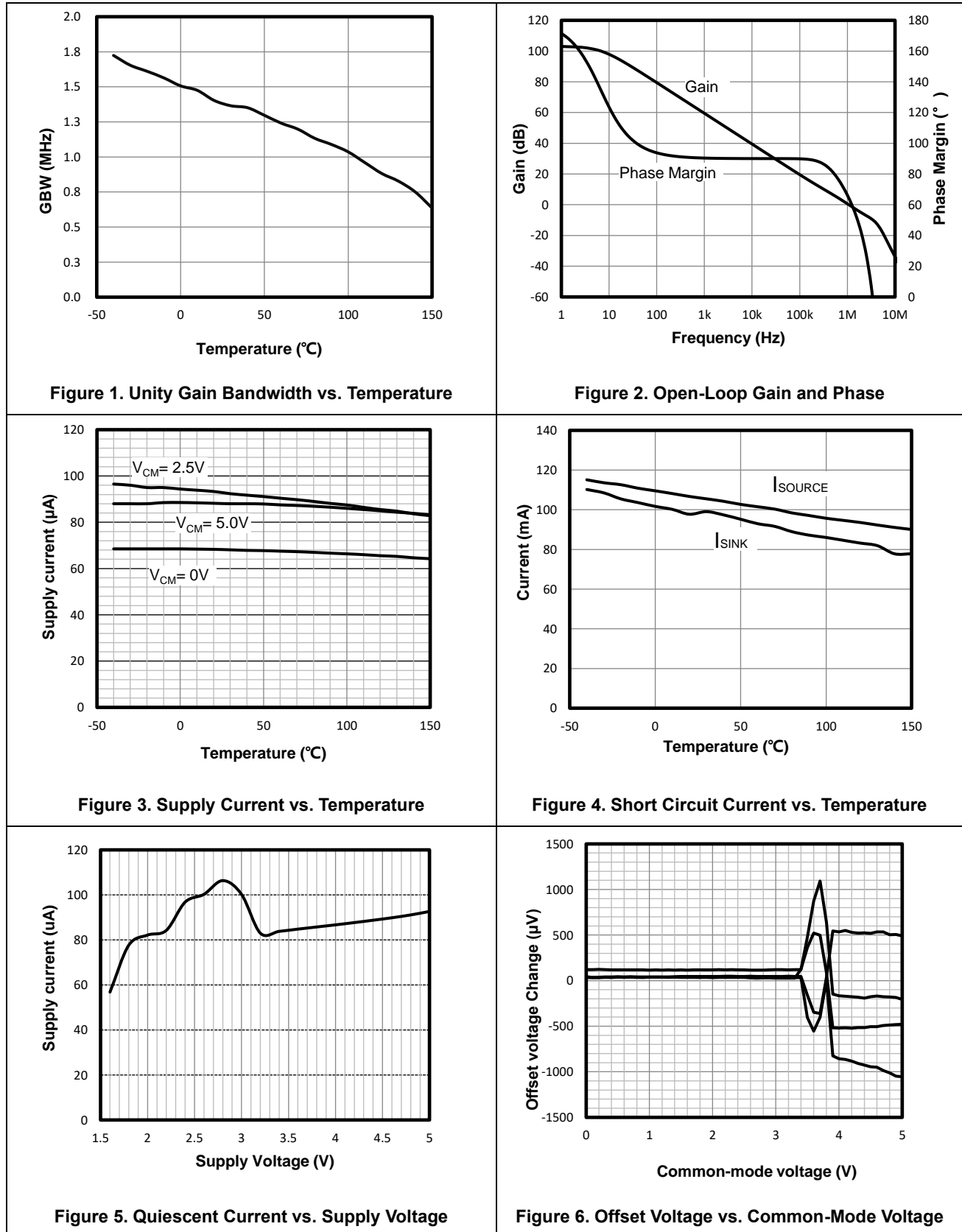
## Electrical Characteristics

All test conditions:  $V_S = 5$  V,  $R_L = 10$  K,  $V_{CM} = V_{DD}/2$ ,  $T_A = +27^\circ\text{C}$ , unless otherwise noted.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>Power Supply</b>						
$V_S$	Supply Voltage Range		2.1		6	V
$I_Q$	Quiescent Current per Amplifier			80	130	$\mu$ A
PSRR	Power Supply Rejection Ratio		80	100		dB
<b>Input Characteristics</b>						
$V_{OS}$	Input Offset Voltage	$V_{CM} = 0$ V to 3 V	-3	0.5	3	mV
$V_{OS\ TC}$	Input Offset Voltage Drift	$T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$		2		$\mu\text{V}/^\circ\text{C}$
$I_B$	Input Bias Current	$T_A = 25^\circ\text{C}$		1		pA
		$T_A = 85^\circ\text{C}$		25		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	$R_{LOAD} = 10$ k $\Omega$	85	110		dB
$V_{CMR}$	Common-mode Input Voltage Range		(V-) - 0.1		(V+) + 0.1	V
CMRR	Common Mode Rejection Ratio	$V_{CM} = 0$ V to 3 V	70	100		dB
Xtalk	Channel Separation	$f = 1$ kHz, $R_L = 2$ k $\Omega$		110		dB
<b>Output Characteristics</b>						
$V_{OH}, V_{OL}$	Maximum Output Voltage Swing	$R_{LOAD} = 10$ k $\Omega$		3	15	mV
$I_{SC}$	Output Short-Circuit Current			100		mA
<b>AC Specifications</b>						
GBW	Gain-Bandwidth Product			1		MHz
SR	Slew Rate	$A_V = 1$ , $V_{OUT} = 1.5$ V to 3.5 V, $C_{LOAD} = 60$ pF, $R_{LOAD} = 1$ k $\Omega$		0.7		V/ $\mu$ s
$t_s$	Settling Time, 0.1%	$A_V = 1$ , 2 V Step, $C_{LOAD} = 60$ pF, $R_{LOAD} = 1$ k $\Omega$		3.5		$\mu$ s
	Settling Time, 0.01%			4.8		$\mu$ 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		$\mu\text{V}_{PP}$
$e_N$	Input Voltage Noise Density	$f = 1$ kHz		27		nV/ $\sqrt{\text{Hz}}$
$i_N$	Input Current Noise	$f = 1$ kHz		2		fA/ $\sqrt{\text{Hz}}$
THD+N	Total Harmonic Distortion and Noise	$f = 1$ kHz, $A_V = 1$ , $R_L = 2$ k $\Omega$ , $V_{OUT} = 1$ V <sub>p-p</sub>		0.003		%

**Typical Performance Characteristics**

$V_S = 5\text{ V}$ ,  $V_{CM} = 2.5\text{ V}$ ,  $R_L = \text{Open}$ , unless otherwise specified.



Typical Performance Characteristics (Continued)

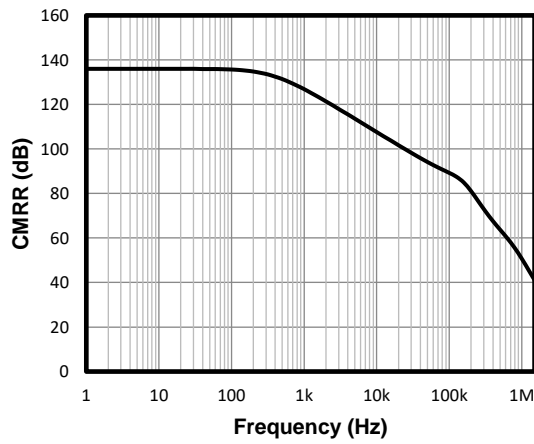


Figure 7. CMRR vs. Frequency

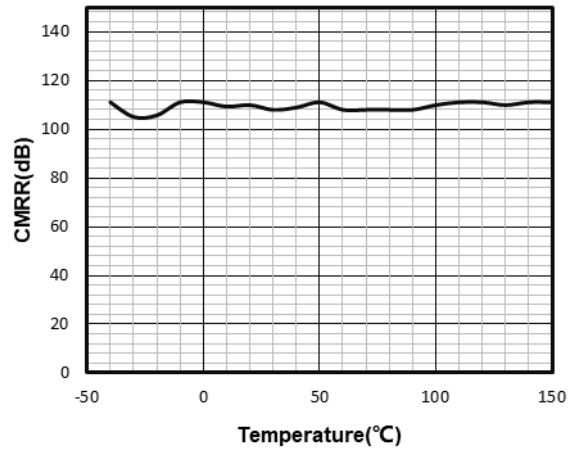


Figure 8. CMRR vs. Temperature

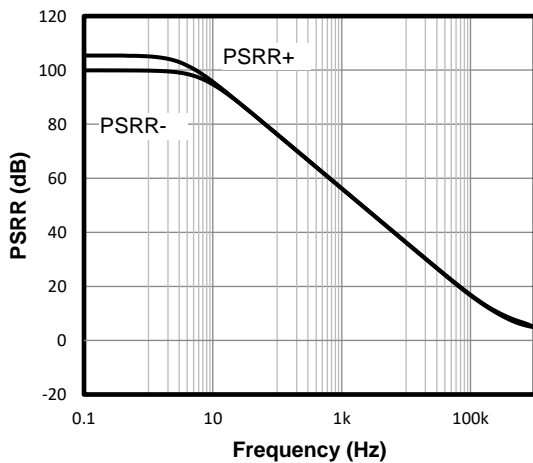


Figure 9. PSRR vs. Frequency

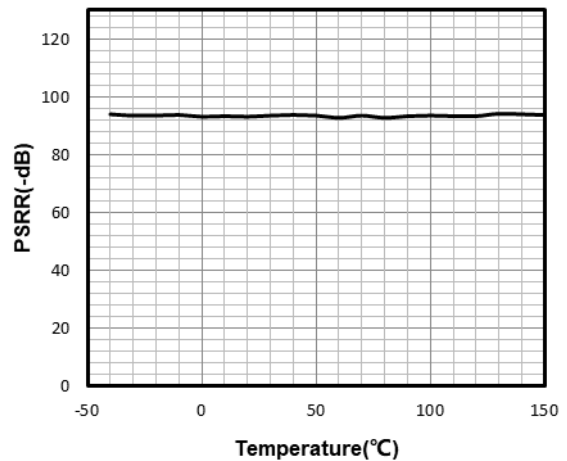


Figure 10. PSRR vs. Temperature

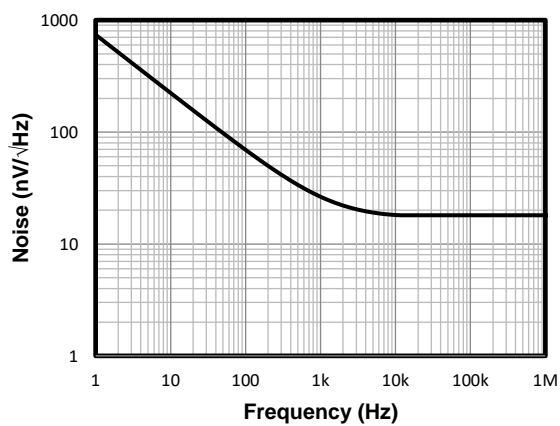


Figure 11. Input Voltage Noise Spectral Density

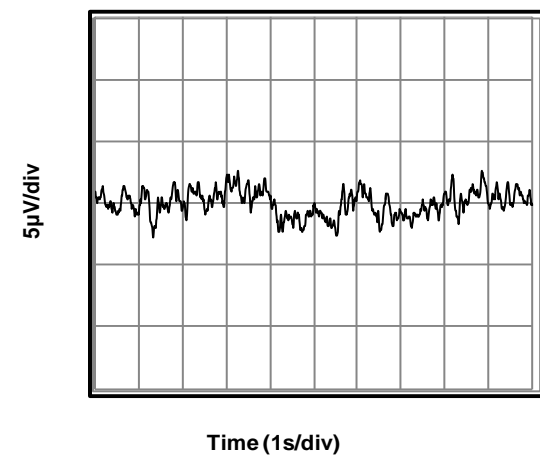


Figure 12. 0.1 Hz to 10 Hz Input Voltage Noise



Typical Performance Characteristics (Continued)

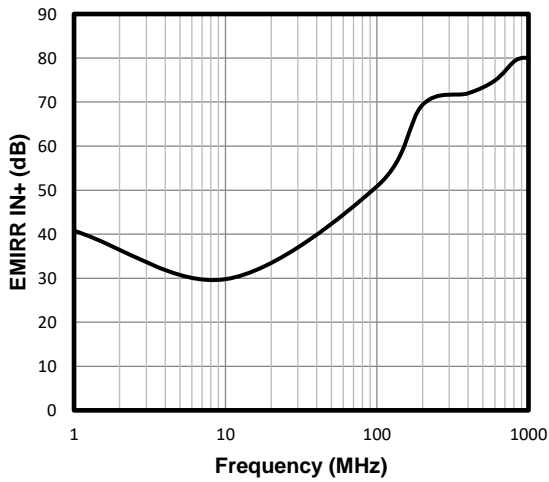


Figure 13. EMIRR IN+ vs. Frequency

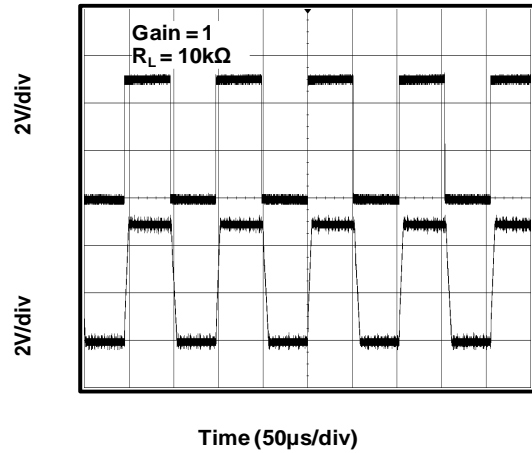


Figure 14. Large-Scale Step Response

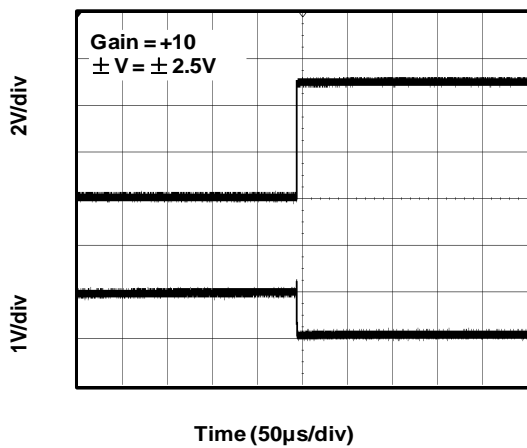


Figure 15. Negative Over-Voltage Recovery

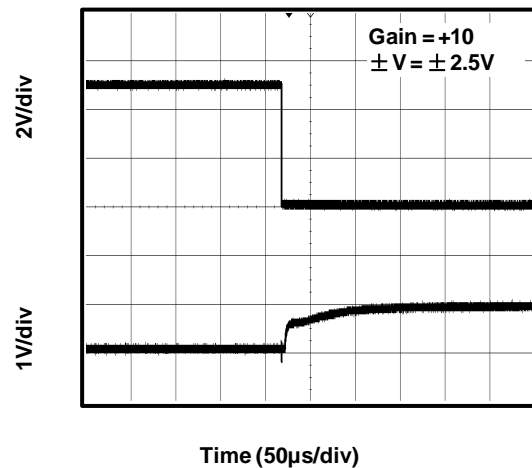


Figure 16. Positive Over-Voltage Recovery

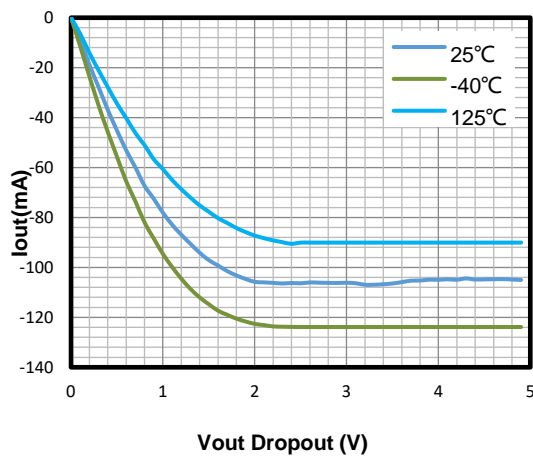


Figure 17. Negative Output Swing vs. Load Current

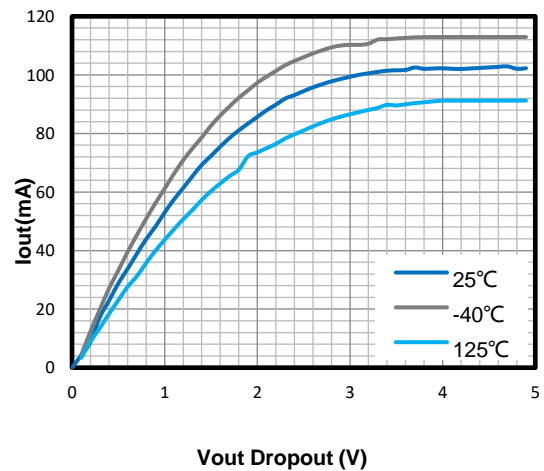


Figure 18. Positive Output Swing vs. Load Current

## Application and Implementation

### NOTE

Information in the following applications 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 TP600X family of operational amplifiers can operate with power supply voltages from 2.1 V to 6.0 V. Each amplifier draws only 80  $\mu$ 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 TP600X family is optimized for wide bandwidth 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 TP600X 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 the 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 current will flow through these diodes.

### Driving Large Capacitive Load

Larger load capacitance decreases the overall phase margin in a feedback system where internal frequency compensation is utilized. As the load capacitance increases, the feedback loop's phase margin decreases, and the closed-loop bandwidth is reduced. This produces gain peaking in the frequency response with overshoot and ringing in output step response. The unity-gain buffer ( $G = +1$  V/V) is the most sensitive to large capacitive loads.

When driving large capacitive loads with the TP600X OPA family (e.g.,  $> 200$  pF when  $G = +1$  V/V), a small series resistor at the output ( $R_{ISO}$  in Figure 19) improves the feedback loop's phase margin and stability by making the output load resistive at higher frequencies.

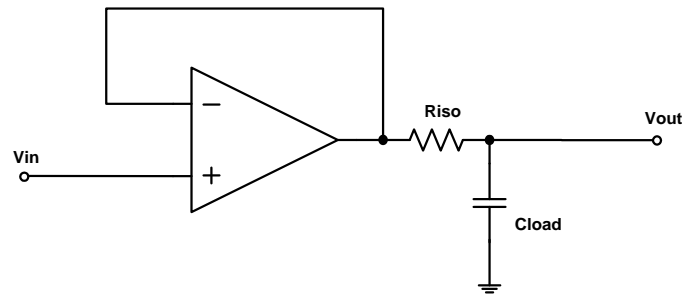
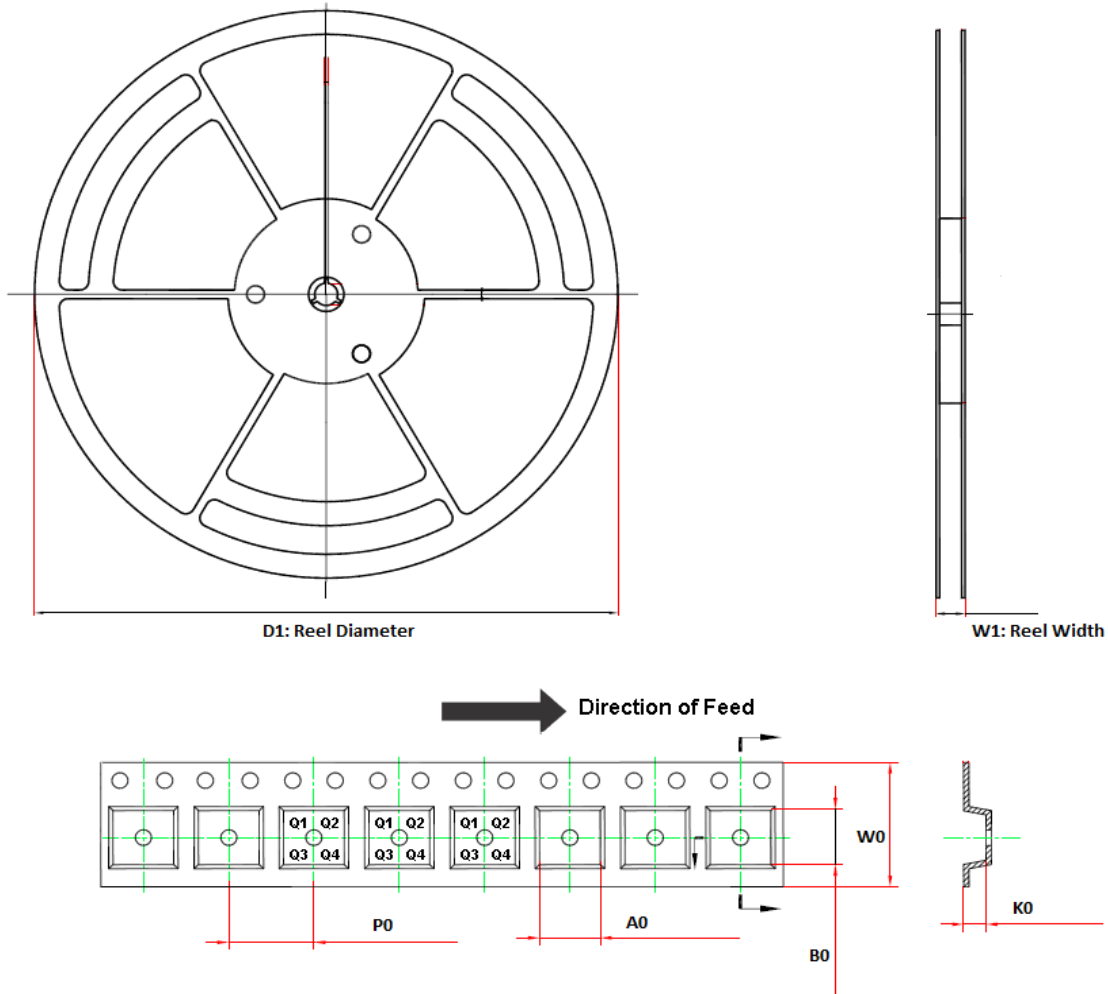


Figure 19. Drive Large Capacitive Load

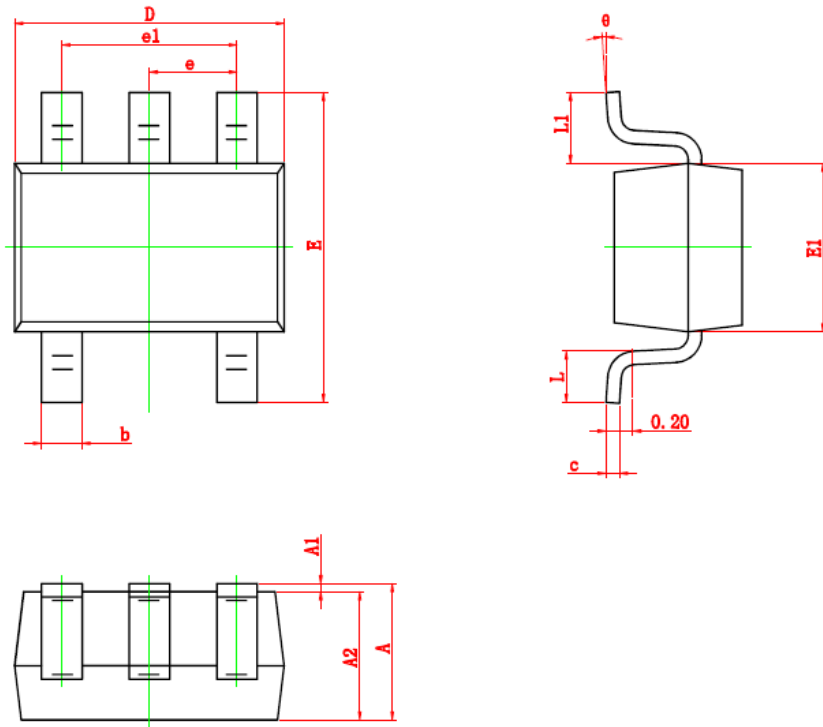
### Tape and Reel Information



Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TP6001-CR	SOT353 (SC70-5)	178.0	12.3	2.4	2.5	1.2	4.0	8.0	Q3
TP6001U-CR	SOT353 (SC70-5)	178.0	12.3	2.4	2.5	1.2	4.0	8.0	Q3
TP6001-TR	SOT23-5	180.0	13.1	3.2	3.2	1.4	4.0	8.0	Q3
TP6001R-TR	SOT23-5	180.0	13.1	3.2	3.2	1.4	4.0	8.0	Q3
TP6002-SR	SOP8	330.0	17.6	6.4	5.4	2.1	8.0	12.0	Q1
TP6002-VR	MSOP8	330.0	17.6	5.2	3.3	1.5	8.0	12.0	Q1
TP6002-TSR	TSSOP8	330.0	17.6	6.8	3.3	1.2	8.0	12.0	Q1
TP6002-FR	DFN2X2-8	180.0	13.1	2.3	2.3	1.1	4.0	8.0	Q1
TP6004-SR	SOP14	330.0	21.6	6.5	9.0	2.1	8.0	16.0	Q1
TP6004-TR	TSSOP14	330.0	17.6	6.8	5.4	1.2	8.0	12.0	Q1

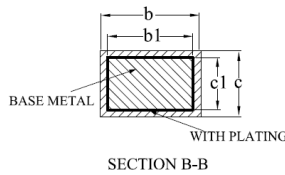
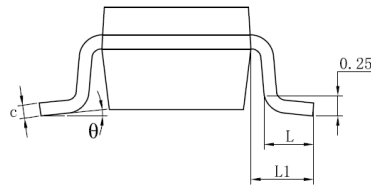
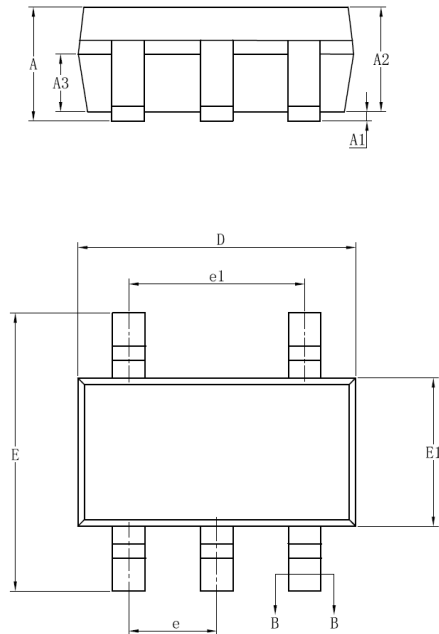
## Package Outline Dimensions

### SOT353 (SC70-5)



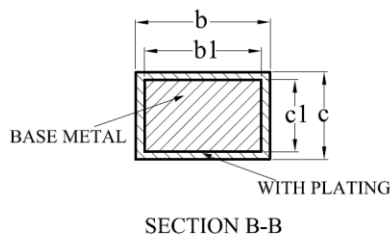
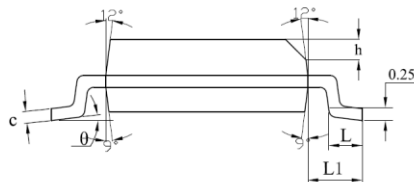
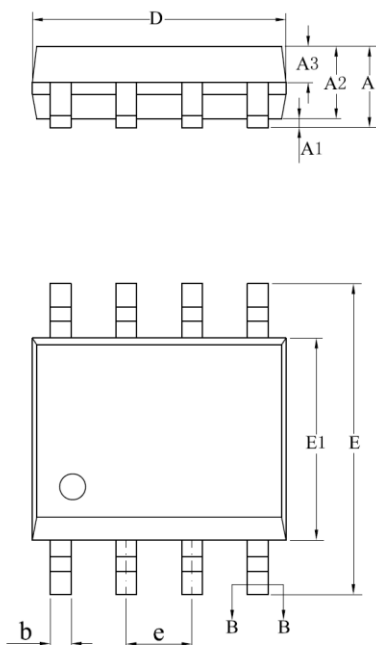
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.900	1.100	0.035	0.043
A1	0.000	0.100	0.000	0.004
A2	0.900	1.000	0.035	0.039
b	0.150	0.350	0.006	0.014
c	0.110	0.175	0.004	0.007
D	2.000	2.200	0.079	0.087
E	2.150	2.450	0.085	0.096
E1	1.150	1.350	0.045	0.053
e	0.650 TYP.		0.026 TYP.	
e1	1.200	1.400	0.047	0.055
L	0.260	0.460	0.010	0.018
L1	0.525 REF.		0.021 REF.	
$\theta$	0°	8°	0°	8°

SOT23-5



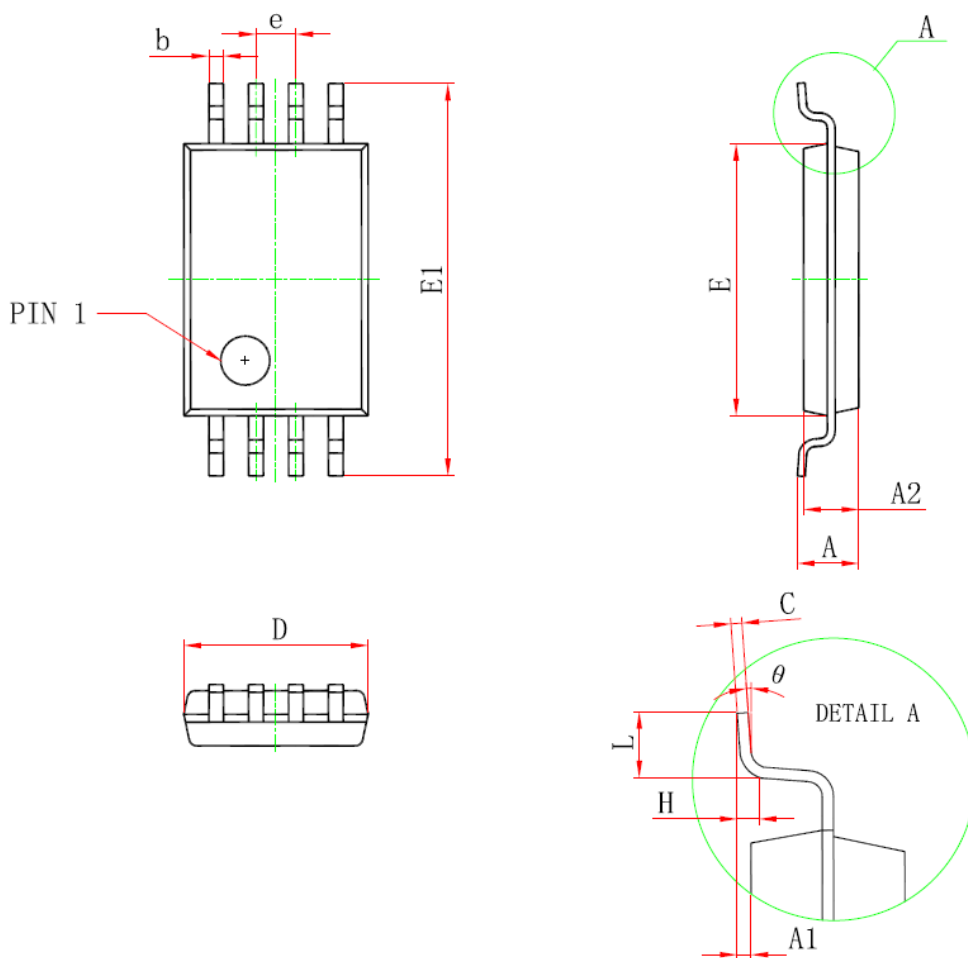
SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	—	—	1.25
A1	0.04	—	0.10
A2	1.00	1.10	1.20
A3	0.60	0.65	0.70
b	0.33	—	0.41
b1	0.32	0.35	0.38
c	0.15	—	0.19
c1	0.14	0.15	0.16
D	2.82	2.92	3.02
E	2.60	2.80	3.00
E1	1.50	1.60	1.70
e	0.95BSC		
e1	1.90BSC		
L	0.30	—	0.60
L1	0.60REF		
$\theta$	0	—	8°

SOIC-8



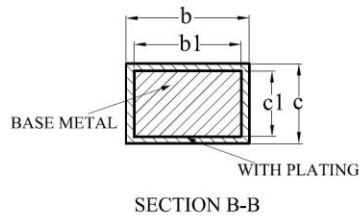
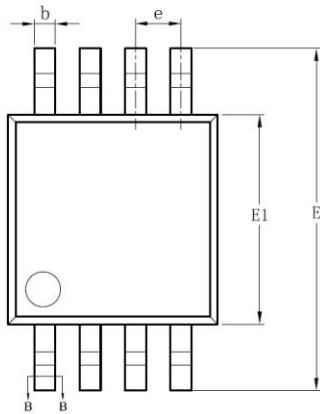
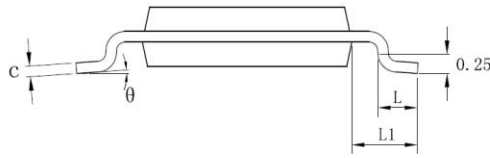
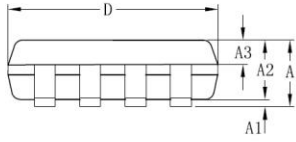
SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	—	—	1.75
A1	0.10	—	0.225
A2	1.30	1.40	1.50
A3	0.60	0.65	0.70
b	0.39	—	0.47
b1	0.38	0.41	0.44
c	0.20	—	0.24
c1	0.19	0.20	0.21
D	4.80	4.90	5.00
E	5.80	6.00	6.20
E1	3.80	3.90	4.00
e	1.27BSC		
h	0.25	—	0.50
L	0.50	—	0.80
L1	1.05REF		
$\theta$	0	—	8°

**TSSOP8**



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
D	2.900	3.100	0.114	0.122
E	4.300	4.500	0.169	0.177
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
E1	6.250	6.550	0.246	0.258
A		1.200		0.047
A2	0.800	1.000	0.031	0.039
A1	0.050	0.150	0.002	0.006
e	0.65 (BSC)		0.026 (BSC)	
L	0.500	0.700	0.020	0.028
H	0.25(TYP)		0.01(TYP)	
$\theta$	1°	7°	1°	7°

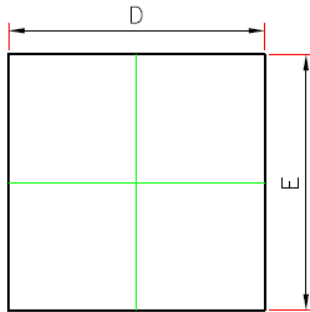
**MSOP-8**



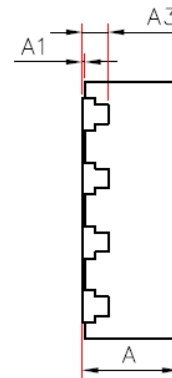
SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	—	—	1.10
A1	0.05	—	0.15
A2	0.75	0.85	0.95
A3	0.30	0.35	0.40
b	0.28	—	0.36
b1	0.27	0.30	0.33
c	0.15	—	0.19
c1	0.14	0.15	0.16
D	2.90	3.00	3.10
E	4.70	4.90	5.10
E1	2.90	3.00	3.10
e	0.65BSC		
L	0.40	—	0.70
L1	0.95REF		
$\theta$	0	—	8°



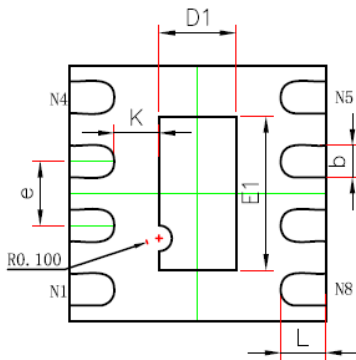
DFN-8 2\*2



TOP VIEW



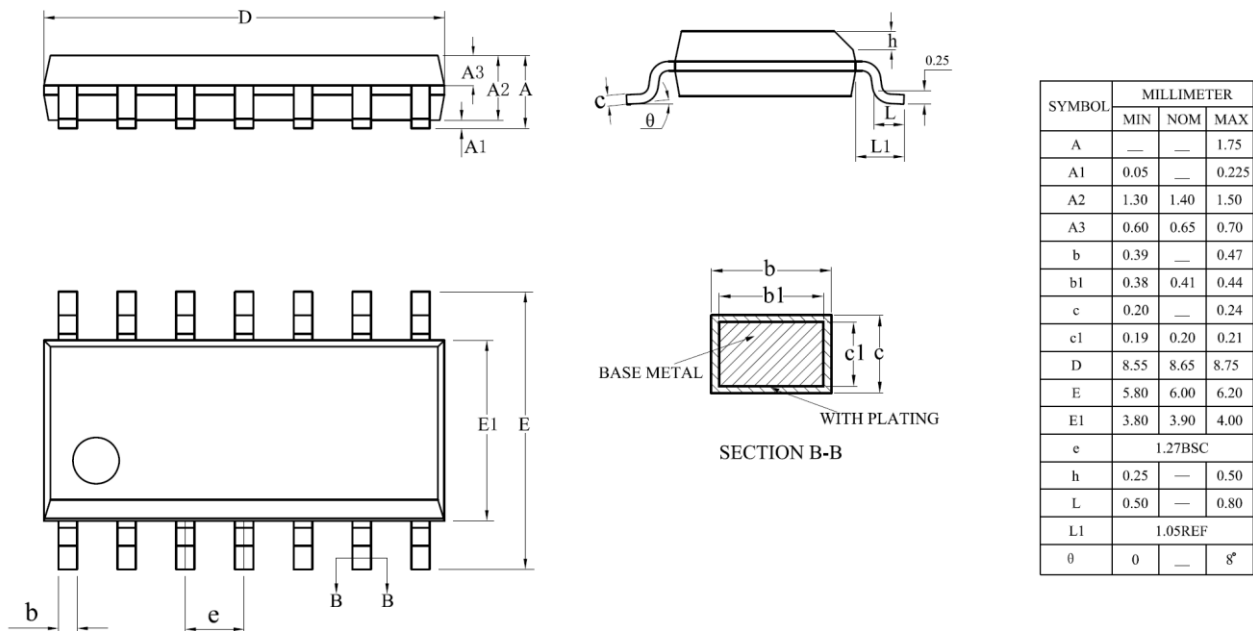
SIDE VIEW



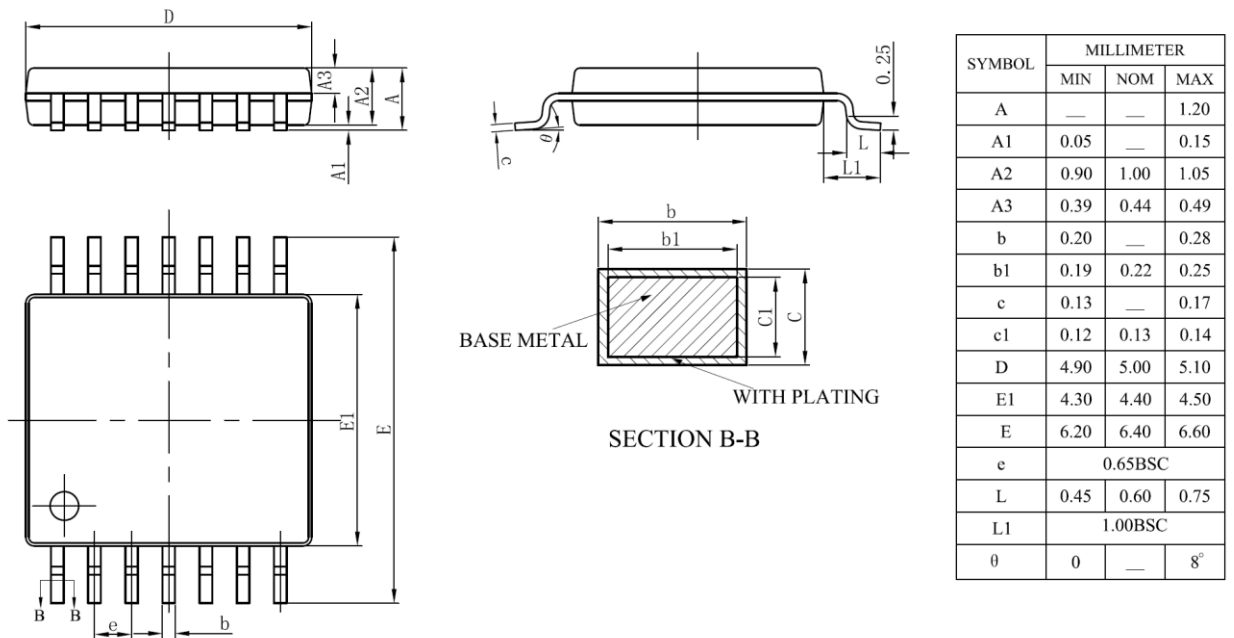
BOTTOM VIEW

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.203REF.		0.008REF.	
D	1.900	2.100	0.075	0.083
E	1.900	2.100	0.075	0.083
D1	0.500	0.700	0.020	0.028
E1	1.100	1.300	0.043	0.051
k	0.350REF.		0.014REF.	
b	0.200	0.300	0.008	0.012
e	0.500BSC.		0.020BSC.	
L	0.274	0.426	0.011	0.017

**SOIC-14**



**TSSOP-14**



### Order Information

Order Number	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TP6001-CR	-40 to 125°C	SOT353 (SC70-5)	601	MSL1	Tape and Reel, 3000	Green
TP6001U-CR	-40 to 125°C	SOT353 (SC70-5)	60U	MSL1	Tape and Reel, 3000	Green
TP6001-TR	-40 to 125°C	SOT23-5	601	MSL3	Tape and Reel, 3000	Green
TP6001R-TR	-40 to 125°C	SOT23-5	60R	MSL3	Tape and Reel, 3000	Green
TP6002-SR	-40 to 125°C	SOP8	6002	MSL3	Tape and Reel, 4000	Green
TP6002-TSR	-40 to 125°C	TSSOP8	6002	MSL3	Tape and Reel, 3000	Green
TP6002-VR	-40 to 125°C	MSOP8	6002	MSL3	Tape and Reel, 3000	Green
TP6002-FR	-40 to 125°C	DFN2X2-8	602	MSL3	Tape and Reel, 3000	Green
TP6004-SR	-40 to 125°C	SOP14	6004	MSL3	Tape and Reel, 2500	Green
TP6004-TR	-40 to 125°C	TSSOP14	6004	MSL3	Tape and Reel, 3000	Green

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

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