

### Features

- Supply Voltage: 1.7 V to 3.6 V
- Low Power: Typical 650 nA at 25°C
- Low Offset Voltage: ±30 μV Maximum at 25°C
- Zero Drift: ±0.025 μV/°C
- Rail-to-Rail Input and Output
- Gain Bandwidth Product: 9 kHz
- Slew Rate: 3 V/ms

### Applications

- Gas Detection
- Battery Current Sensing
- Portable Medical Equipment
- Portable Glucose Monitors
- Portable RFID Readers and Tags

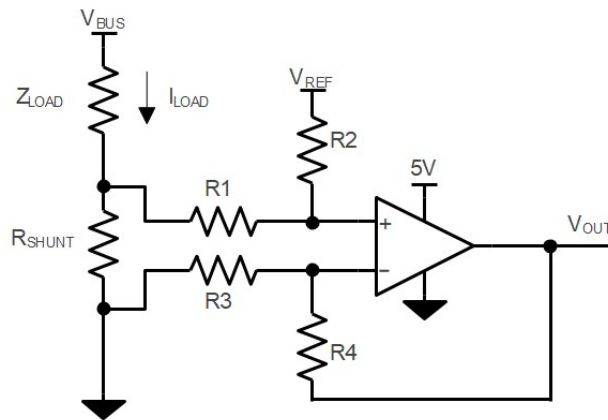
### Description

The TPA551x is the nano-power, zero-drift amplifier with maximum 30-μV low-offset voltage and stable frequency response for the high-precision sensing application that also requires low standby power.

The TPA551x devices provide rail-to-rail input and output. The devices have excellent AC performance with 9-kHz bandwidth, 3-V/ms slew rate while only drawing 650-nA quiescent current per amplifier.

The TPA5511 and TPA5511U (1-ch version) are offered in the SOT23-5 and SC70-5 packages. The TPA5512 (2-ch version) is available in the SOP-8, TSSOP-8, MSOP-8, and DFN-8 packages. All versions can be operated over the industrial temperature range of -40°C to +125°C.

### Typical Application Circuit



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

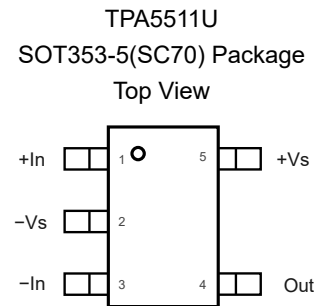
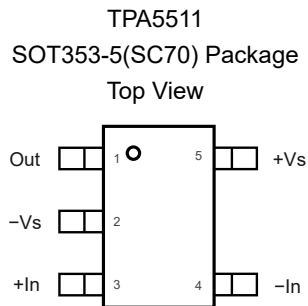
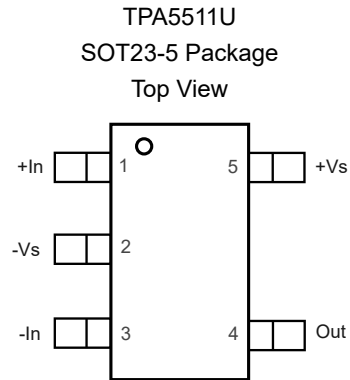
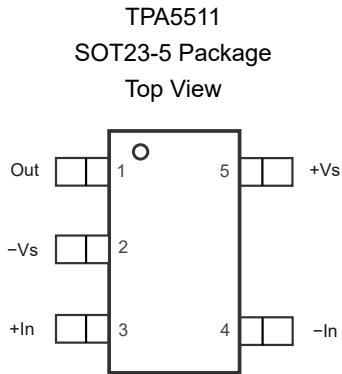
When  $R_3 = R_1, R_2 = R_4, R_{SHUNT} \ll R_1$

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## Revision History

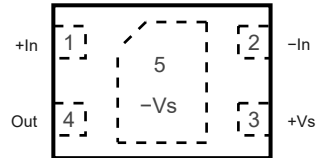
Date	Revision	Notes
2022-12-22	Rev.A.0	Initial version.
2024-01-21	Rev.A.1	Modified the maximum value of IQ at 25 °C from 1500nA to 800nA. Modified the maximum value of IQ at -40 to 125 °C from 1500nA to 1100nA. Modified the mean value of IQ at 25 °C from 650nA to 600nA.
2024-02-06	Rev.A.2	Modified the pin configuration of SOP8. The physical object has not changed, just a correction of hand writing errors.

**Pin Configuration and Functions**

**Table 1. Pin Functions: TPA5511, TPA5511U**

Pin No.		Name	I/O	Description
TPA5511	TPA5511U			
1	4	Out	O	Output
2	2	-Vs	-	Negative power supply
3	1	+In	I	Noninverting input
4	3	-In	I	Inverting input
5	5	+Vs	-	Positive power supply

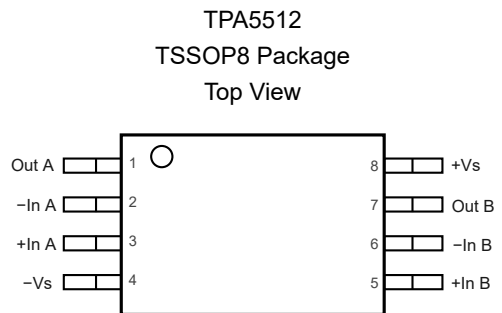
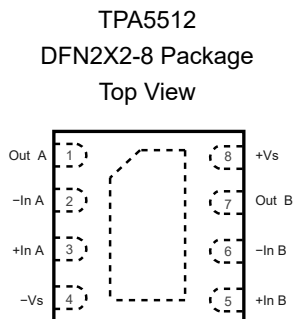
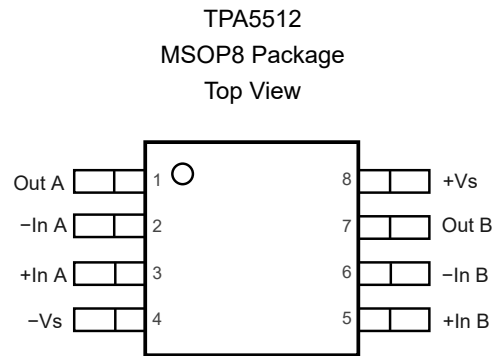
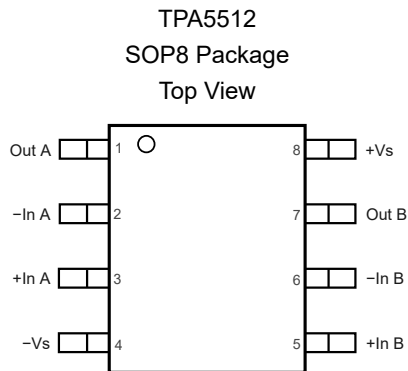
**3.3-V, 9-kHz, Zero-Drift, Nanopower OP Amps**

TPA5511  
DFN1X1.4-4 Package  
Top View



**Table 2. Pin Functions: TPA5511**

Pin No.	Name	I/O	Description
TPA5511			
4	Out	O	Output
5	-Vs	-	Negative power supply
1	+In	I	Noninverting input
2	-In	I	Inverting input
3	+Vs	-	Positive power supply


**Table 3. Pin Functions: TPA5512**

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

## Specifications

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

Over operating ambient temperature, unless otherwise noted.

Parameter	Min	Max	Unit
Supply Voltage, (+V <sub>S</sub> ) – (–V <sub>S</sub> )		4	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 Voltage	(–V <sub>S</sub> ) – 0.3	(+V <sub>S</sub> ) + 0.3	V
Output Short-Circuit Duration <sup>(3)</sup>		Infinite	
Maximum Operating Junction Temperature		150	°C
Operating Temperature Range	–40	125	°C
Storage Temperature Range	–65	150	°C
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 negative power supply. If the input extends more than 300 mV beyond the negative 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	ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	3	kV
CDM	Charged Device Model ESD	ANSI/ESDA/JEDEC JS-002 <sup>(2)</sup>	1.5	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.

### Recommended Operating Conditions

Parameter		Min	Typ	Max	Unit
V <sub>S</sub>	Supply Voltage, (+V <sub>S</sub> ) – (–V <sub>S</sub> )	1.7		3.6	V
T <sub>A</sub>	Operating Temperature Range	–40		125	°C

### Thermal Information

Package Type	θ <sub>JA</sub>	θ <sub>Jc</sub>	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
DFN1.5X1.5-8	200	100	°C/W
DFN2X2-8	100	60	°C/W



**3.3-V, 9-kHz, Zero-Drift, Nanopower OP Amps**
**Electrical Characteristics**

 Test condition is at  $V_S = 3.3\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$ ,  $C_L = 100\text{ pF}$ , unless otherwise noted

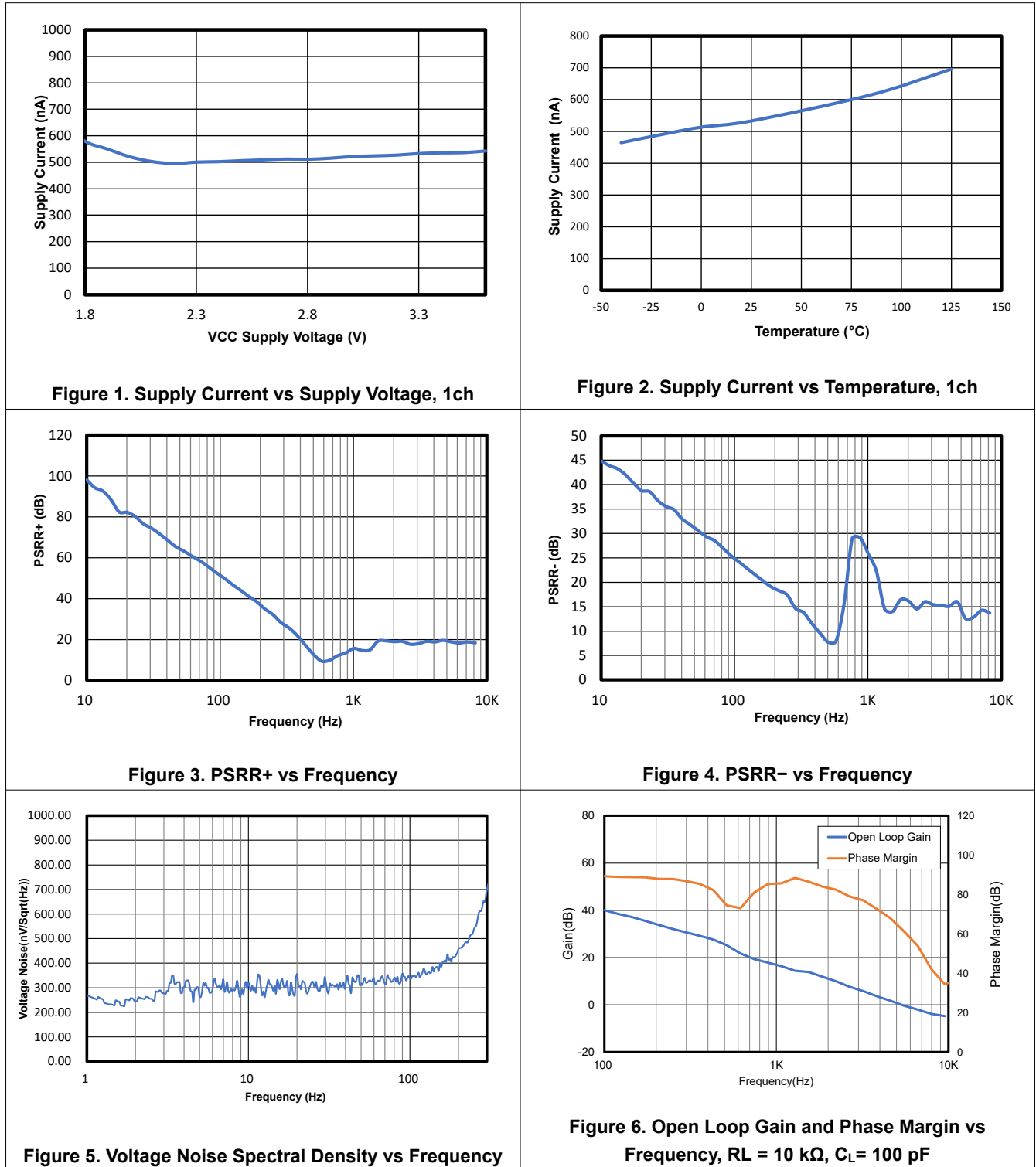
Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>Power Supply</b>						
$V_S$	Supply Voltage Range		1.7		3.6	V
$I_Q$	Quiescent Current per Amplifier	$V_S = 3.3\text{ V}$ , $V_{CM} = 1.65\text{ V}$		600	800	nA
		$V_S = 3.3\text{ V}$ , $V_{CM} = 1.65\text{ V}$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$			1100	nA
PSRR	Power Supply Rejection Ratio	$V_S = 1.7\text{ V}$ to $3.6\text{ V}$ , $V_{CM} = 0\text{ V}$	100	122		dB
		$V_S = 1.7\text{ V}$ to $3.6\text{ V}$ , $V_{CM} = 0\text{ V}$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	100			dB
<b>Input Characteristics</b>						
$V_{OS}$	Input Offset Voltage	$V_S = 1.7$ to $3.6\text{ V}$ , $V_{CM} = 1 / V_S$	-30	1.5	30	$\mu\text{V}$
		$V_S = 1.7$ to $3.6\text{ V}$ , $V_{CM} = 1 / V_S$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	-30		30	$\mu\text{V}$
$V_{OS\ TC}$	Input Offset Voltage Drift	$T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$		0.025		$\mu\text{V}/^\circ\text{C}$
$I_B$	Input Bias Current			20		pA
		$T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	-1100	200	1100	pA
$I_{OS}$	Input Offset Current			16		pA
		$T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	-1300	250	1300	pA
$R_{IN}$				$10^{10}$		$\Omega$
$C_{IN}$	Input Capacitance	Differential Mode		5		pF
		Common Mode		5		pF
$A_v$	Open-loop Voltage Gain	$V_O = 0.1\text{ V}$ to $3.2\text{ V}$	100	130		dB
		$V_O = 0.1\text{ V}$ to $3.2\text{ V}$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	100			dB
$V_{CMR}$	Common-mode Input Voltage Range	$T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	$-V_S$		$+V_S$	V
CMRR	Common-Mode Rejection Ratio	$V_{CM} = 0\text{ V}$ to $3.3\text{ V}$	95	125		dB
		$V_{CM} = 0\text{ V}$ to $3.3\text{ V}$ , $T = -40^\circ\text{C}$ to $125^\circ\text{C}$	90			dB
<b>Output Characteristics</b>						
	Output Voltage Swing from Positive Rail or Negative Rail	$R_{LOAD} = 100\text{ k}\Omega$ to $V_S/2$		1.5	15	mV
		$R_{LOAD} = 100\text{ k}\Omega$ to $V_S/2$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$			15	mV
$I_{SC}$	Output Short-Circuit Current	Sink or Source	10	15		mA
		Sink or Source, $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	10			mA
<b>AC Specifications</b>						

**3.3-V, 9-kHz, Zero-Drift, Nanopower OP Amps**

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
GBW	Gain-Bandwidth Product			9		kHz
SR	Slew Rate	G = 1, 2 V step		3		V/ms
PM	Phase Margin	R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF		60		°
GM	Gain Margin	R <sub>L</sub> = 10 kΩ, C <sub>L</sub> = 100 pF		9.3		dB
	Channel Separation	f = 1 kHz		120		dB
<b>Noise Performance</b>						
E <sub>N</sub>	Input Voltage Noise	f = 0.1 Hz to 10 Hz		5		μV <sub>PP</sub>
e <sub>N</sub>	Input Voltage Noise Density	f = 100Hz		354		nV/√Hz
i <sub>N</sub>	Input Current Noise	f = 100Hz		1		fA/√Hz

Typical Performance Characteristics

All test conditions:  $V_S = 3.3\text{ V}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise noted.



3.3-V, 9-kHz, Zero-Drift, Nanopower OP Amps

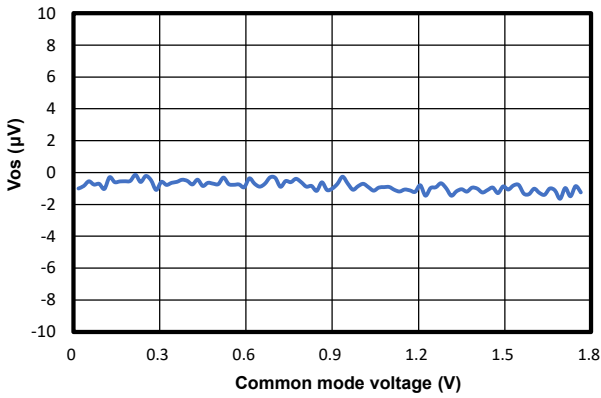


Figure 7.  $V_{OS}$  vs  $V_{CM}$ ,  $V_S = 1.8\text{ V}$

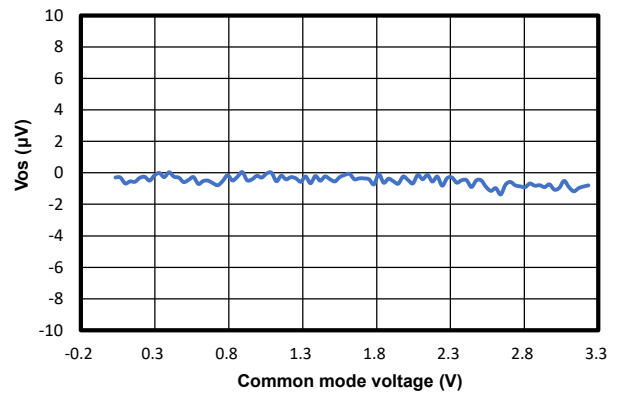


Figure 8.  $V_{OS}$  vs  $V_{CM}$ ,  $V_S = 3.3\text{ V}$

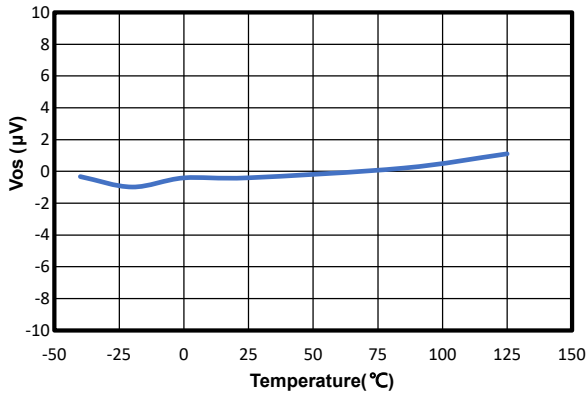


Figure 9.  $V_{OS}$  vs Temperature

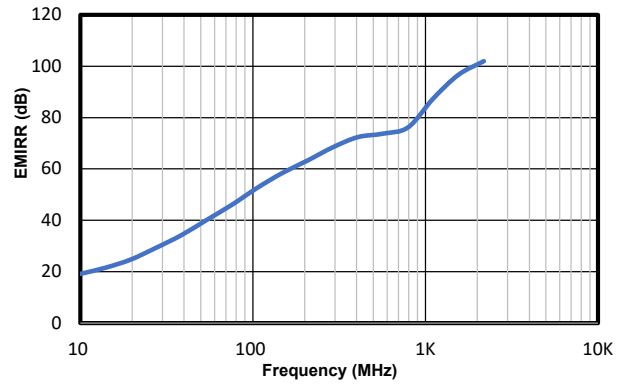


Figure 10. EMIRR vs Frequency

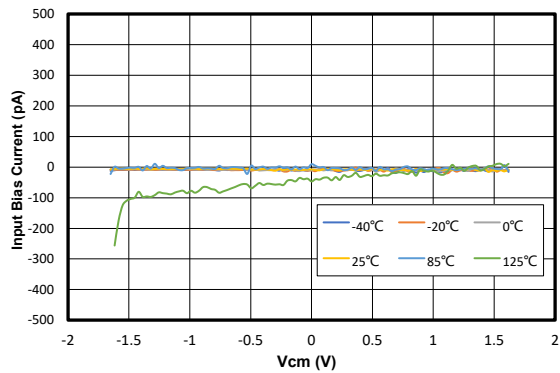


Figure 11.  $I_B$  vs Common-Mode Voltage

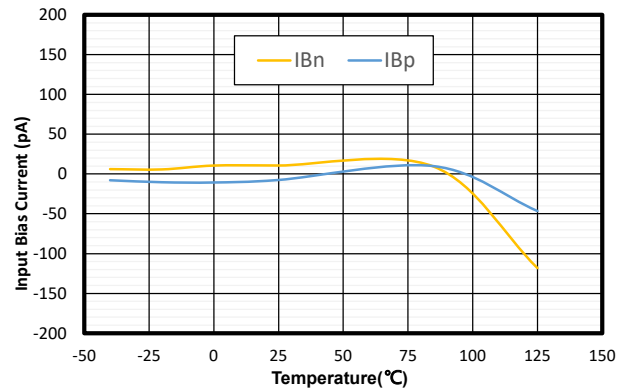


Figure 12.  $I_B$  vs Temperature

3.3-V, 9-kHz, Zero-Drift, Nanopower OP Amps

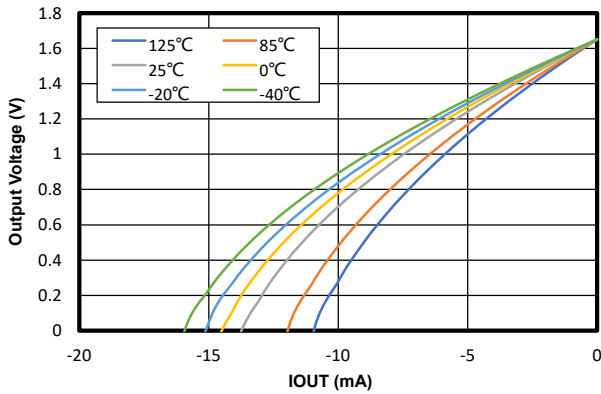


Figure 13. Output Voltage vs Output Current

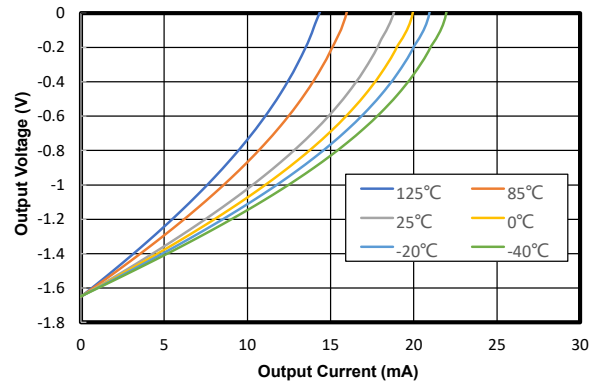


Figure 14. Output Voltage vs Output Current

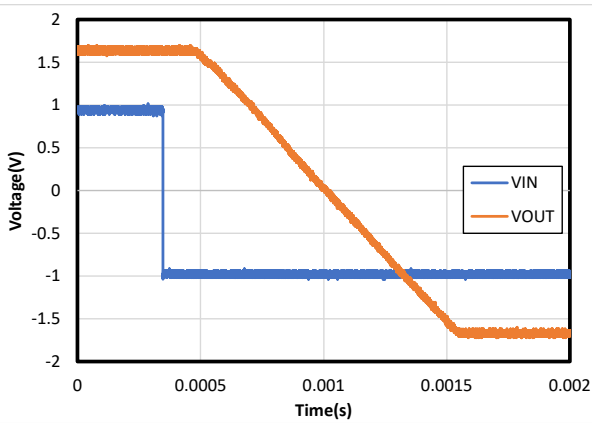


Figure 15. Overload Recovery at Negative Rail

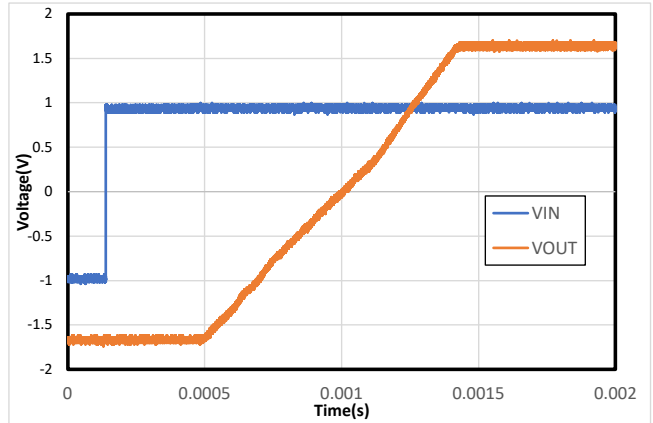


Figure 16. Overload Recovery at Positive Rail

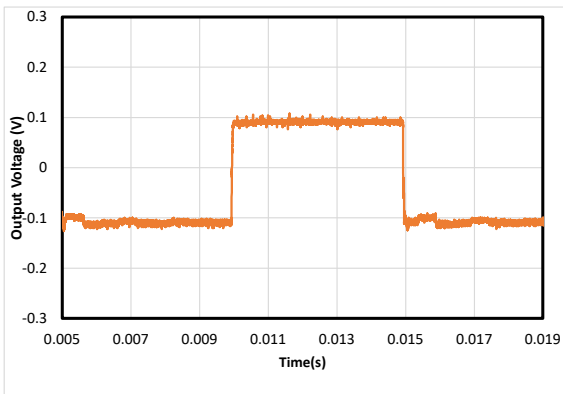


Figure 17. 100-mV Small Signal Step Response Voltage:  
100 mV/div, Time: 20 ms/div

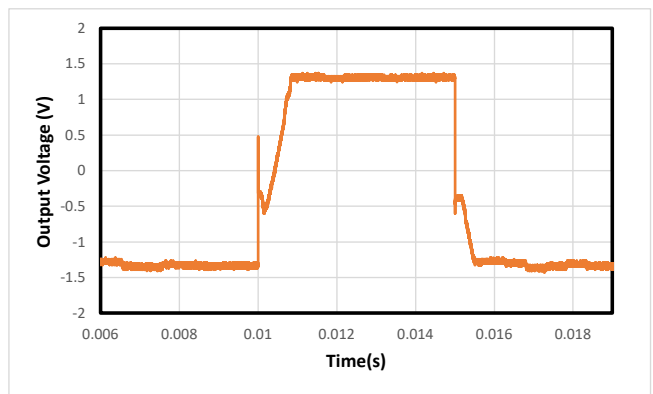
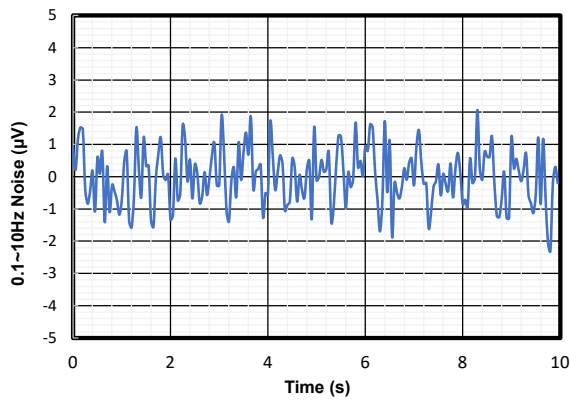


Figure 18. 1-V Large Signal Step Response Voltage: 500  
mV/div, Time: 20 ms/div



**Figure 19. 0.1 to 10 Hz Voltage Noise**

## Detailed Description

### Overview

The TPA551x family of zero-drift amplifiers can operate on a single-supply voltage (1.7 V to 3.6 V), or a split-supply voltage. With the precision auto-calibration technique, these amplifiers achieve low input offset voltage and input offset voltage drift which can achieve outstanding input and output dynamic linearity. The strengths of TPA551x also include 9-kHz bandwidth, no 1/f noise, and only 650-nA quiescent current, making the TPA551x suitable for many precision, low power, and temperature sensitive applications. Parameters that can exhibit variance with regard to operating voltage or temperature are presented in [Typical Performance Characteristics](#).

### Functional Block Diagram

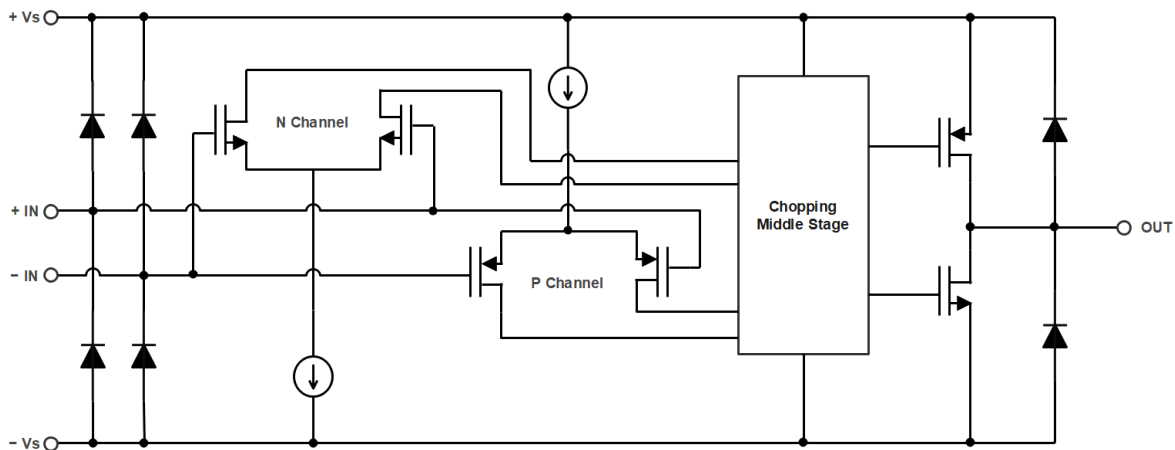


Figure 20. Functional Block Diagram

## Feature Description

### Operating Voltage

The devices are designed for single supply operation from 1.7 V to 3.6 V or dual supply operation from  $\pm 0.85$  V to  $\pm 1.8$  V.

### Ultra Low Offset Voltage and Offset Voltage Drift in Operating Temperature Range

The devices provide 30- $\mu$ V offset voltage within the temperature range from  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ , which is achieved through the chopper stabilized technology. This unique topology allows the devices to maintain their low-offset voltage over a wide temperature range and over their operating lifetime.

### Low 1/f Noise

Flicker noise, as known as 1/f noise, is inherent in semiconductor devices and increases as the frequency decreases. The flicker noise provides higher degrees of error for low-frequency applications. The devices use the chopper stabilized technology to reduce flicker noise. This reduction in 1/f noise allows the devices to have lower noise at dc and low-frequency range compared to the standard amplifier.

**Residual Voltage Ripple**

The chopping technique can be used in the amplifier design due to the internal notch filter. Although the chopping related voltage ripple is suppressed, higher noise spectrum exists at the chopping frequency and its harmonics due to residual ripple.

The devices set the chopping frequency to 1 kHz. If the frequency of input signal is close to the chopping frequency, the signal may be interfered by the residue ripple. To suppress the noise at the chopping frequency, it is recommended that a post filter to be placed at the output of the amplifier.

**Rail-to-Rail Input**

The input common-mode voltage range of the devices extends to the supply rails. This performance is achieved with a complementary input stage: a PMOS input differential pair in parallel with an NMOS input differential pair.

**Rail-to-Rail Output**

The devices deliver rail-to-rail output swing capability with a class-AB output stage. Different load conditions change the ability of the amplifier to swing close to the rails.



## Application and Implementation

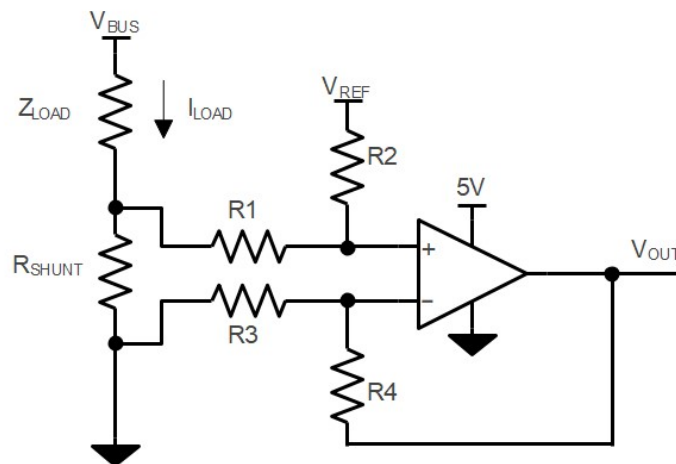
Note

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 Application

Figure 21 shows the device configured in a low-side current sensing application. The low-side current sensing method consists of placing a sense resistor between the load and the circuit ground. The voltage dropping across the resistor is amplified by different amplifier circuits with the device. The  $V_{REF}$  can be used to add bias voltage to the output voltage. Particular attention must be paid to the matching and precision of R1, R2, R3, and R4, to maximize the accuracy of the measurement.



$$V_{OUT} = (I_{LOAD} \times R_{SHUNT}) \times (R2 / R1) + V_{REF}$$

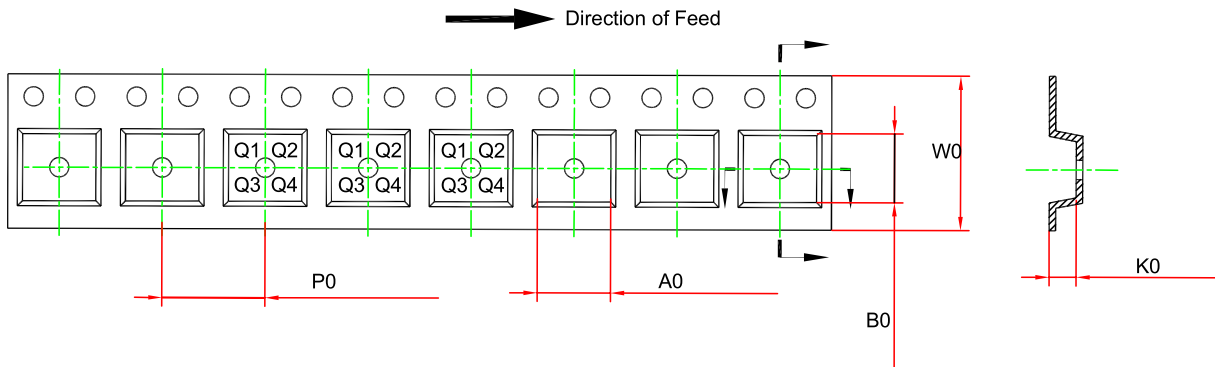
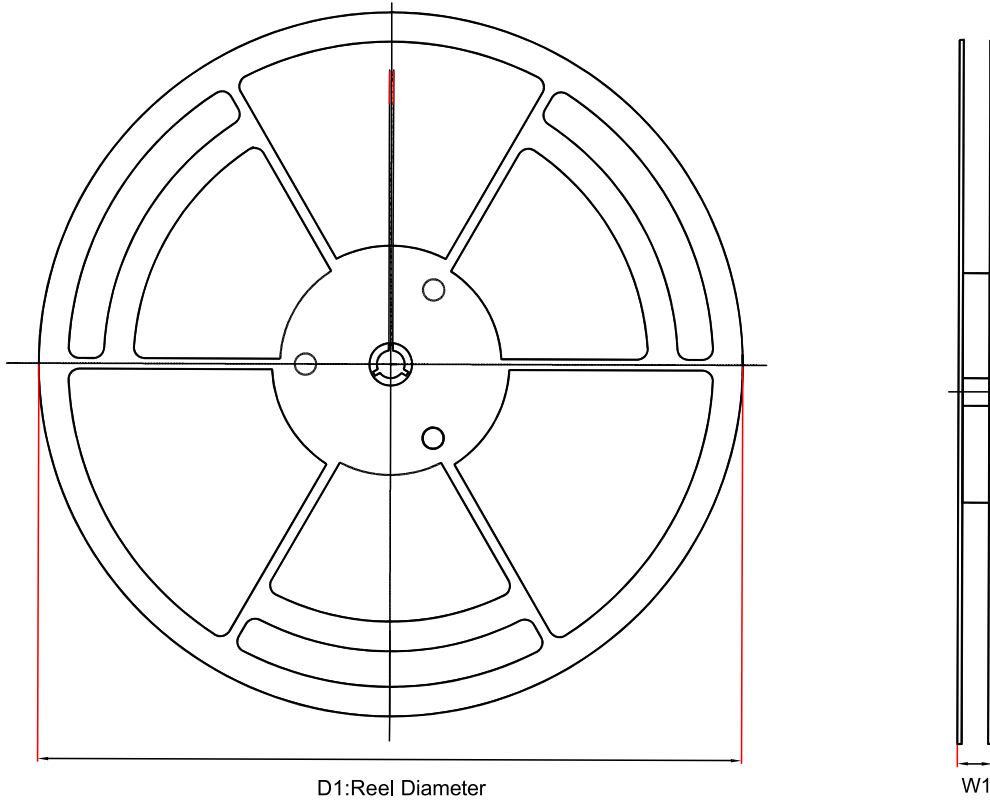
$$\text{When } R3 = R1, R2 = R4, R_{SHUNT} \ll R1$$

Figure 21. Low-Side Current Sensing Application

### Power Supply Recommendations

Place 0.1- $\mu$ F bypass capacitors close to the power supply pins for reducing coupling errors from the noisy or high-impedance power supplies.

Tape and Reel Information



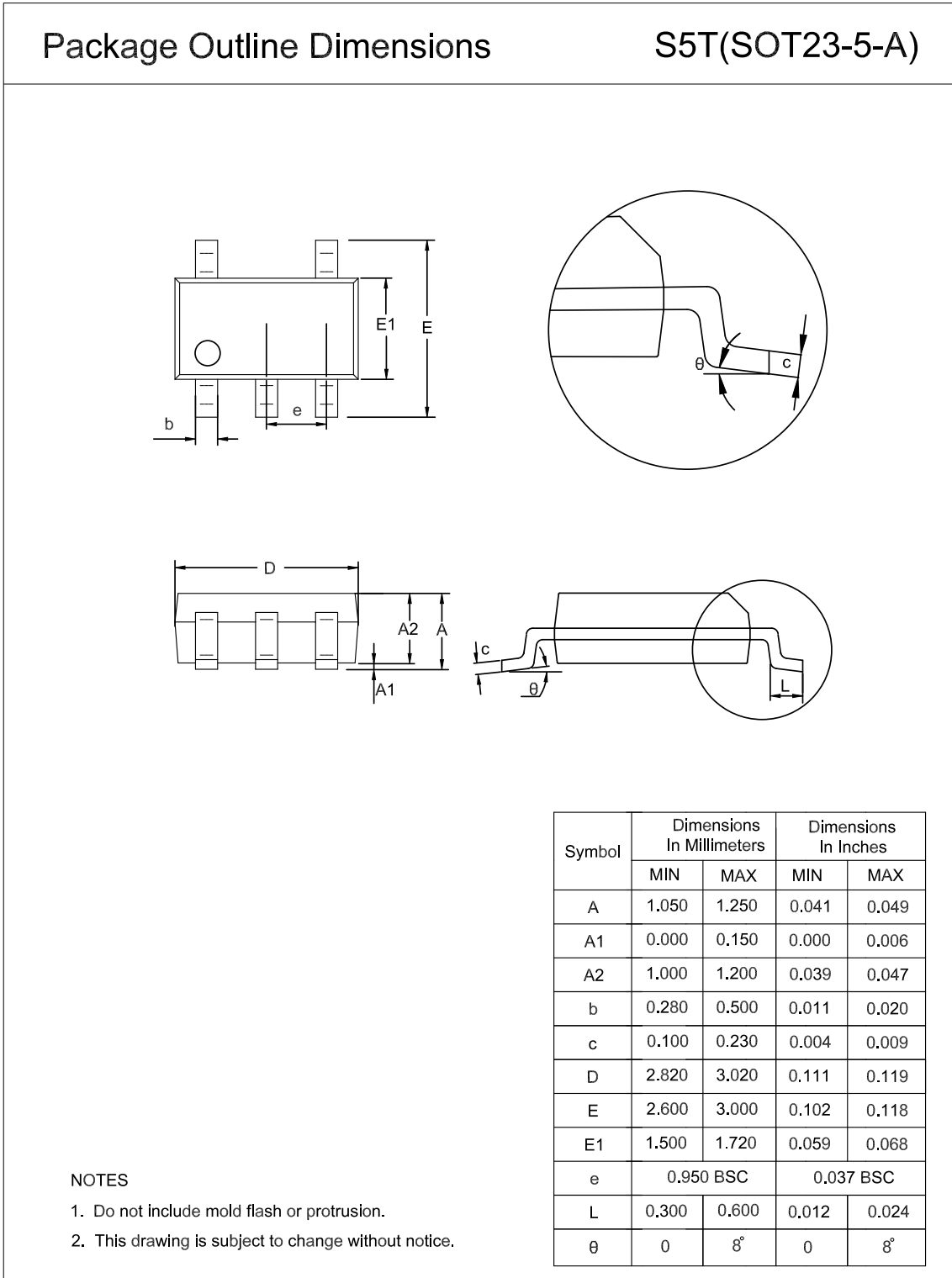
Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPA5511-SC5R	SOT353 (SC70-5)	178.0	12.3	2.4	2.5	1.2	4.0	8.0	Q3
TPA5511U-SC5R	SOT353 (SC70-5)	178.0	12.3	2.4	2.5	1.2	4.0	8.0	Q3
TPA5511-S5TR	SOT23-5	180.0	13.1	3.2	3.2	1.4	4.0	8.0	Q3
TPA5511-DFPR	DFN1.4X1-4	180.0	10.0	1.15	1.6	0.5	4.0	8.1	Q1
TPA5511U-S5TR	SOT23-5	180.0	13.1	3.2	3.2	1.4	4.0	8.0	Q3
TPA5512-SO1R	SOP8	330.0	17.6	6.4	5.4	2.1	8.0	12.0	Q1

**3.3-V, 9-kHz, Zero-Drift, Nanopower OP Amps**

Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPA5512-DFGR	DFN2X2-8	180.0	13.1	2.3	2.3	1.1	4.0	8.0	Q1
TPA5512-DFSR	DFN1.5X1.5-8	180.0	12.3	1.7	1.7	0.75	4.0	8.0	Q2
TPA5512-TS1R	TSSOP8	330.0	17.6	6.8	3.3	1.2	8.0	12.0	Q1
TPA5512-VS1R	MSOP8	330.0	17.6	5.4	3.3	1.5	8.0	12.0	Q1

Package Outline Dimensions

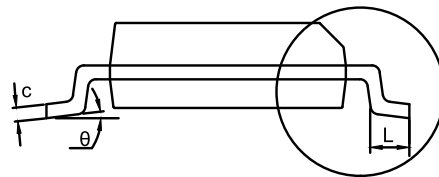
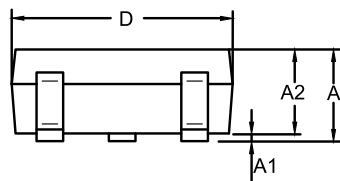
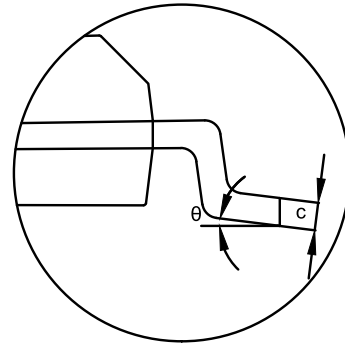
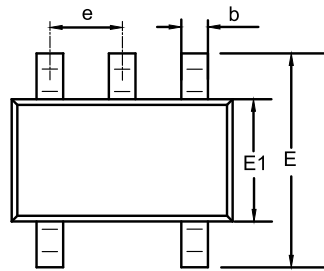
SOT23-5



SOT353-5

Package Outline Dimensions

SC5(SOT353-5-A)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.850	1.100	0.033	0.043
A1	0.000	0.100	0.000	0.004
A2	0.800	1.000	0.031	0.039
b	0.150	0.350	0.006	0.014
c	0.110	0.230	0.004	0.009
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 BSC		0.026 BSC	
L	0.260	0.460	0.010	0.018
θ	0	8°	0	8°

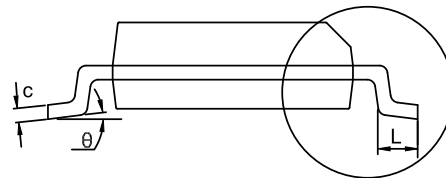
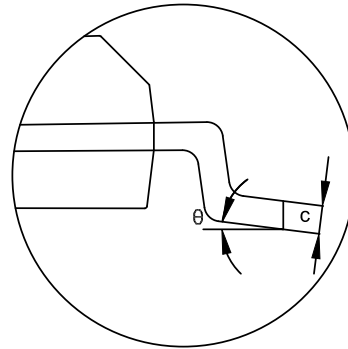
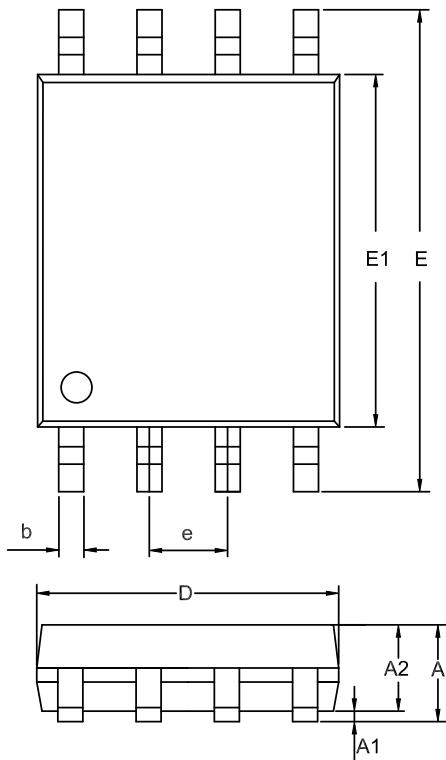
NOTES

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
$\theta$	0	8°	0	8°

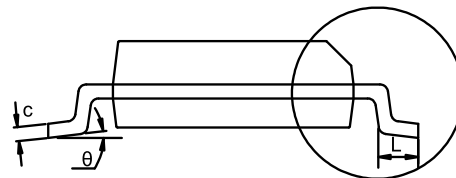
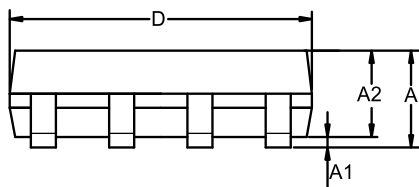
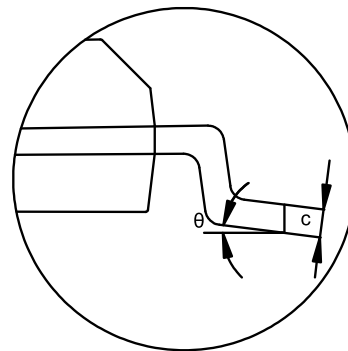
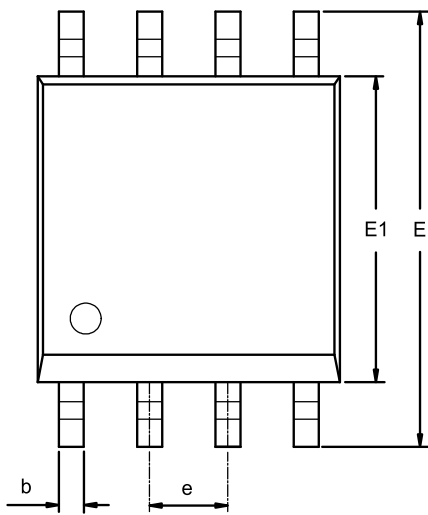
NOTES

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°

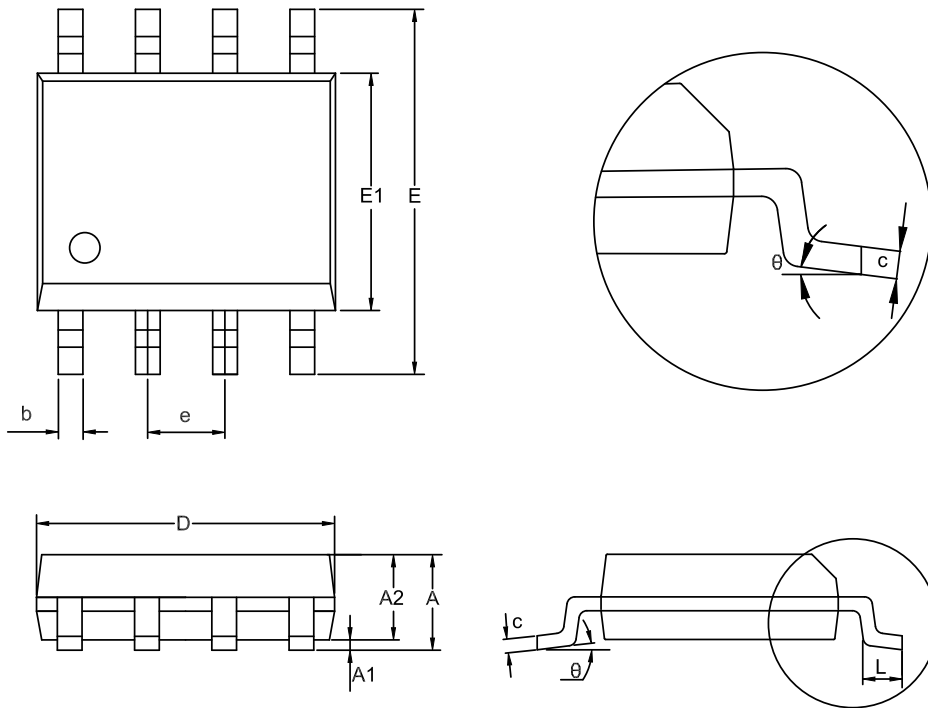
NOTES

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

SOP8

Package Outline Dimensions

SO1(SOP-8-A)



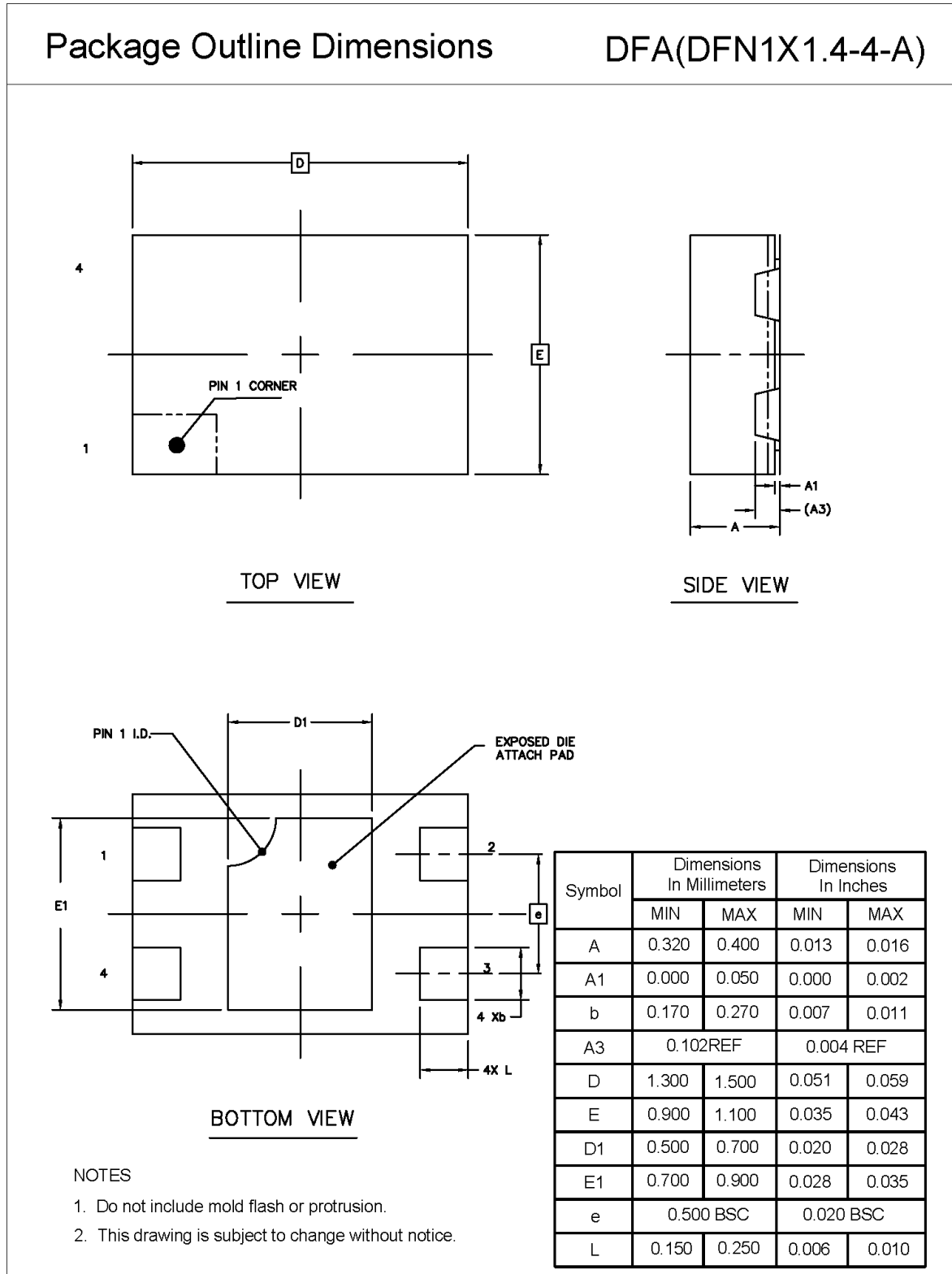
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.550	0.049	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050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

NOTES

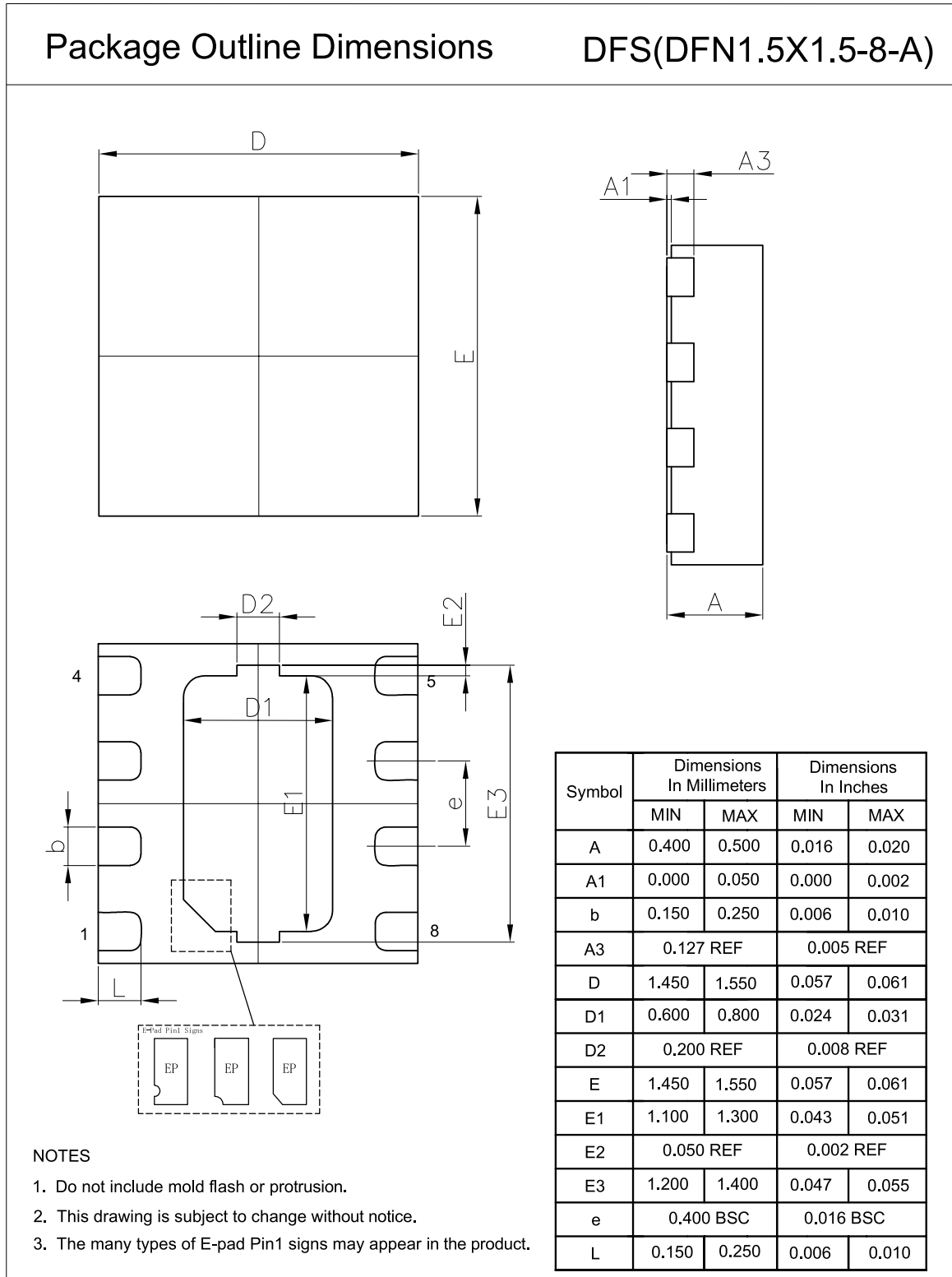
1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.



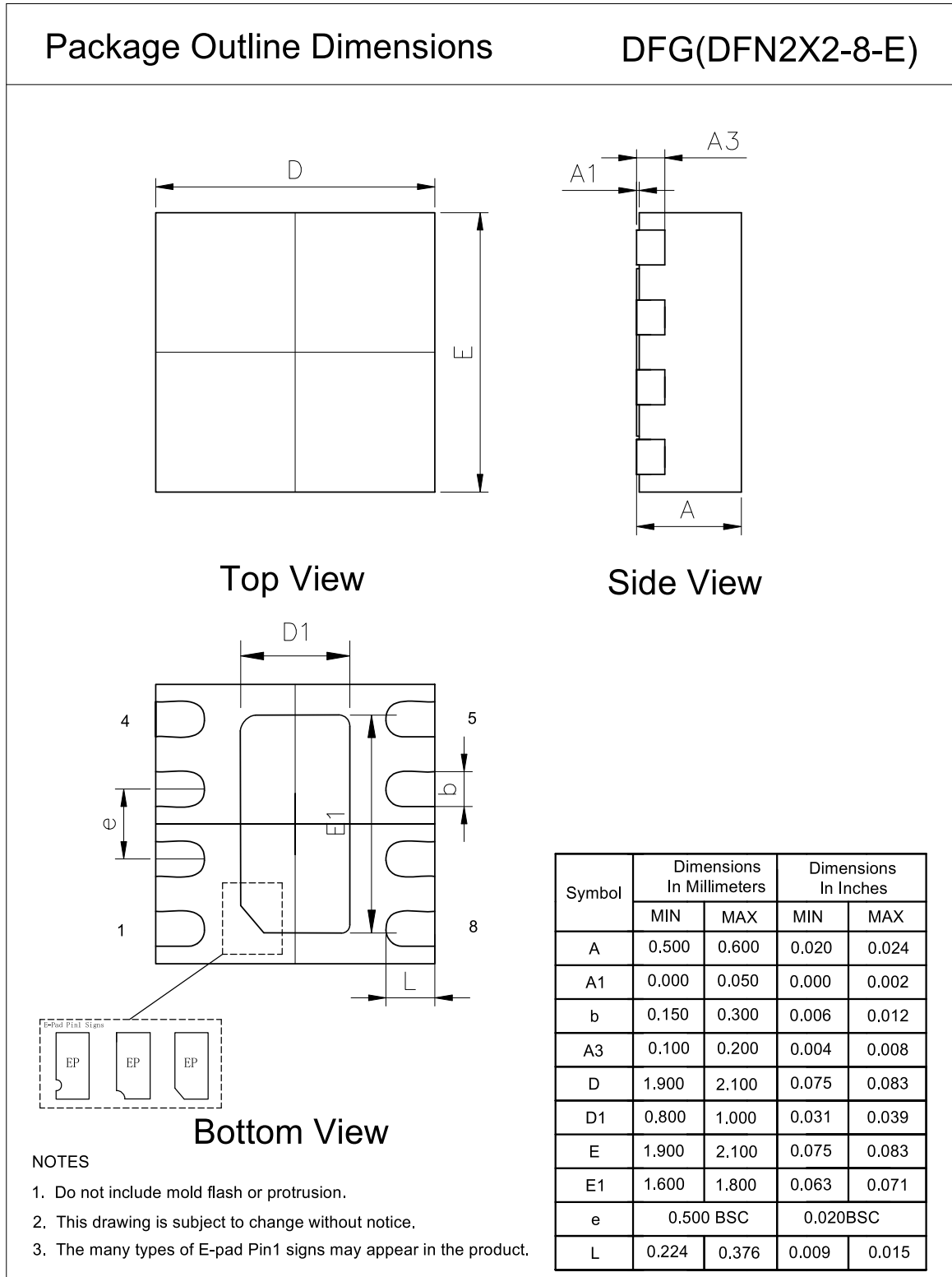
DFN1X1.4-4



DFN1.5X1.5-8



DFN2X2-8



**Order Information**

Order Number	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TPA5511-DFPR	-40 to 125°C	DFN1.4X1-4	51	3	Tape and Reel, 4000	Green
TPA5511-SC5R <sup>(3)</sup>	-40 to 125°C	SOT353 (SC70-5)	511	3	Tape and Reel, 3000	Green
TPA5511U-SC5R <sup>(3)</sup>	-40 to 125°C	SOT353 (SC70-5)	51U	3	Tape and Reel, 3000	Green
TPA5511-S5TR	-40 to 125°C	SOT23-5	511	3	Tape and Reel, 3000	Green
TPA5511U-S5TR <sup>(3)</sup>	-40 to 125°C	SOT23-5	51U	3	Tape and Reel, 3000	Green
TPA5512-DFSR <sup>(3)</sup>	-40 to 125°C	DFN1.5X1.5-8	51	3	Tape and Reel, 4000	Green
TPA5512-SO1R	-40 to 125°C	SOP8	A5512	3	Tape and Reel, 4000	Green
TPA5512-DFGR	-40 to 125°C	DFN2X2-8	551	3	Tape and Reel, 3000	Green
TPA5512-TS1R <sup>(3)</sup>	-40 to 125°C	TSSOP8	A5512	3	Tape and Reel, 3000	Green
TPA5512-VS1R	-40 to 125°C	MSOP8	A5512	3	Tape and Reel, 3000	Green

(1) The sample will be ready in 1 month.

(2) The sample will be ready in 2 months after manufacture starts.

(3) 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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