

## Features

- Supply Voltage: 2.7 V to 5.5 V
- Offset Voltage:  $\pm 20 \mu\text{V}$  Maximum within Temperature Range from  $-40^\circ\text{C}$  to  $125^\circ\text{C}$
- Offset Voltage Drift:  $0.01 \mu\text{V}/^\circ\text{C}$
- Rail-to-Rail Input and Output
- Bandwidth: 3.5 MHz
- Slew Rate:  $4.7 \text{ V}/\mu\text{s}$
- Low Noise:  $12 \text{ nV}/\sqrt{\text{Hz}}$  at 1 kHz

## Applications

- On-Board Charger
- Motor Control
- Current Measurement

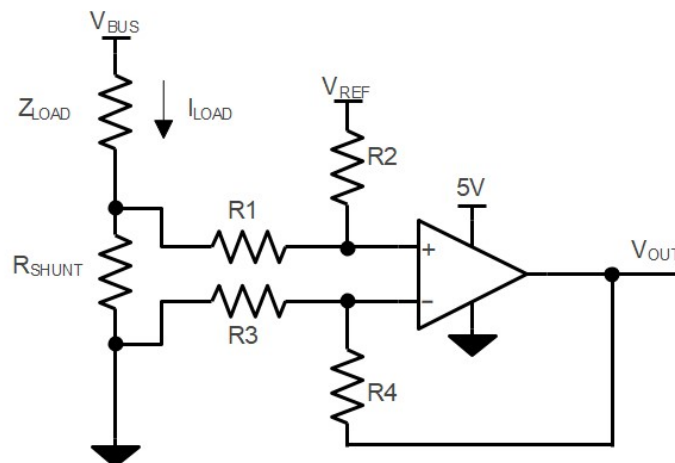
## Description

The TPA5561 and TPA5562 devices are single and dual operational amplifiers. The devices have very low offset voltage within the operating temperature range by the zero-drift technology. The offset voltage of the device is  $\pm 20 \mu\text{V}$  maximum within the temperature range from  $-40^\circ\text{C}$  to  $125^\circ\text{C}$ .

The TPA5561 and TPA5562 devices provide rail-to-rail input and output. The devices have excellent AC performance with 3.5-MHz bandwidth,  $4.7\text{-V}/\mu\text{s}$  slew rate while drawing 0.5-mA quiescent current per amplifier.

The devices can be used in high-accuracy and high-speed signal conditions.

## Typical Application Circuit



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

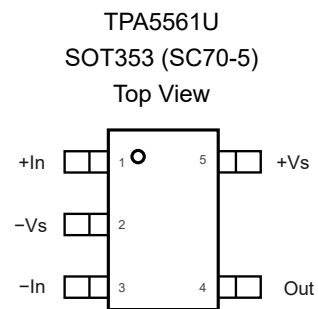
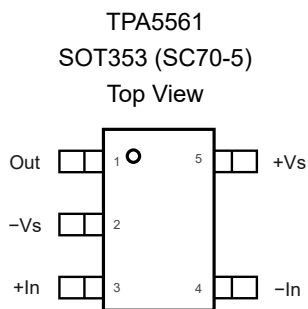
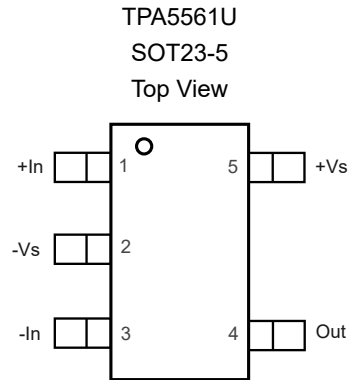
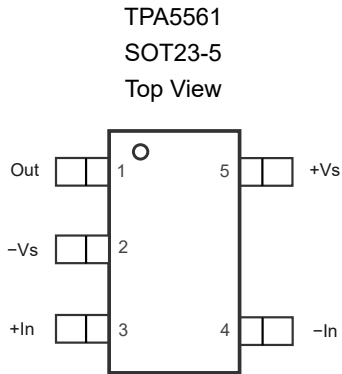
$$\text{When } R_3 = R_1, R_2 = R_4, R_{\text{SHUNT}} \ll R_1$$

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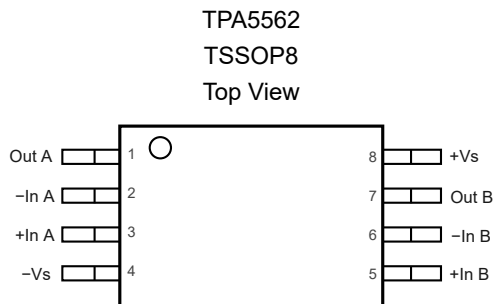
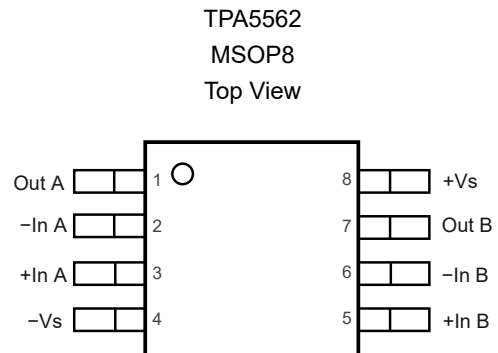
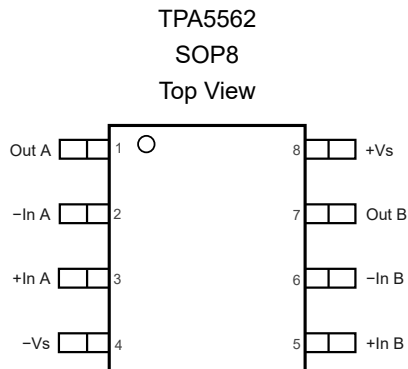
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## Revision History

Date	Revision	Notes
2023-01-03	Rev.A.0	Initial version.
2024-12-18	Rev.A.1	Corrected handwriting errors. The physical object has not changed.

**Pin Configuration and Functions**

**Table 1. Pin Functions: TPA5561, TPA5561U**

Pin No.		Name	I/O	Description
TPA5561	TPA5561U			
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

**5-V, Zero-Drift Operational Amplifiers**

**Table 2. Pin Functions: TPA5562**

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>

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 the 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 rating. This depends on the power dissipation of the application. Thermal resistance varies with the amount of PC board metal connected to the package.

### 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> )	2.7 (±1.35)		5.5 (±2.75)	V
T <sub>A</sub>	Operating Temperature Range	–40		125	°C

**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

**Electrical Characteristics**

 All test conditions:  $V_S = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$ , unless otherwise noted.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>Power Supply</b>						
$V_S$	Supply Voltage Range		2.7		5.5	V
$I_Q$	Quiescent Current per Amplifier	$V_S = 5\text{ V}$		0.5	1	mA
		$V_S = 5\text{ V}$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$			1.2	mA
PSRR	Power Supply Rejection Ratio	$V_S = 2.7\text{ V}$ to $5.5\text{ V}$ , $V_{CM} = 0\text{ V}$	114	124		dB
		$V_S = 2.7\text{ V}$ to $5.5\text{ V}$ , $V_{CM} = 0\text{ V}$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	110			dB
<b>Input Characteristics</b>						
$V_{OS}$	Input Offset Voltage	$V_S = 3.3\text{ V}$ , $V_{CM} = 0$ to $3.3\text{ V}$	-10		10	$\mu\text{V}$
		$V_S = 3.3\text{ V}$ , $V_{CM} = 0$ to $3.3\text{ V}$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	-20		20	$\mu\text{V}$
		$V_S = 5\text{ V}$ , $V_{CM} = 0$ to $5\text{ V}$	-10		10	$\mu\text{V}$
		$V_S = 5\text{ V}$ , $V_{CM} = 0$ to $5\text{ V}$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	-20		20	$\mu\text{V}$
$V_{OSTC}$	Input Offset Voltage Drift	$T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$		0.01		$\mu\text{V}/^\circ\text{C}$
$I_B$	Input Bias Current	$V_S = 5\text{ V}$ , $V_{CM} = 2.5\text{ V}$		200	1000	pA
		$V_S = 5\text{ V}$ , $V_{CM} = 2.5\text{ V}$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$		300	1300	pA
$I_{OS}$	Input Offset Current	$V_S = 5\text{ V}$ , $V_{CM} = 2.5\text{ V}$		100	600	pA
		$V_S = 5\text{ V}$ , $V_{CM} = 2.5\text{ V}$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$			850	pA
$C_{IN}$	Input Capacitance	Differential Mode		5		pF
		Common Mode		2.5		pF
$A_V$	Open-Loop Voltage Gain	$R_{LOAD} = 10\text{ k}\Omega$ , $V_{OUT} = 0.5\text{ V}$ to $4.5\text{ V}$	120	150		dB
		$R_{LOAD} = 10\text{ k}\Omega$ , $V_{OUT} = 0.5\text{ V}$ to $4.5\text{ V}$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	115			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 $5\text{ V}$	115	140		dB
		$V_{CM} = 0\text{ V}$ to $5\text{ V}$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	110			dB



**Electrical Characteristics (Continued)**

 All test conditions:  $V_S = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$ , unless otherwise noted.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>Output Characteristics</b>						
	Output Swing from Positive Rail	$R_{LOAD} = 10\text{ k}\Omega$ to $V_S/2$		10	20	mV
		$R_{LOAD} = 10\text{ k}\Omega$ to $V_S/2$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$			25	mV
		$R_{LOAD} = 2\text{ k}\Omega$ to $V_S/2$		45	100	mV
		$R_{LOAD} = 2\text{ k}\Omega$ to $V_S/2$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$			120	mV
	Output Swing from Negative Rail	$R_{LOAD} = 10\text{ k}\Omega$ to $V_S/2$		10	20	mV
		$R_{LOAD} = 10\text{ k}\Omega$ to $V_S/2$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$			25	mV
		$R_{LOAD} = 2\text{ k}\Omega$ to $V_S/2$		25	50	mV
		$R_{LOAD} = 2\text{ k}\Omega$ to $V_S/2$ , $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$			80	mV
$I_{SC}$	Output Short-Circuit Current	Sink or Source	40	60		mA
		Sink or Source, $T_A = -40^\circ\text{C}$ to $125^\circ\text{C}$	30			mA
<b>AC Specifications</b>						
GBW	Gain-Bandwidth Product			3.5		MHz
SR	Slew Rate	$G = 1$		4.7		V/ $\mu\text{s}$
$t_{OR}$	Overload Recovery			0.8		$\mu\text{s}$
$t_S$	Settling Time, 0.1%	$G = 1$ , 2-V Step		8		$\mu\text{s}$
PM	Phase Margin	$R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$		70		$^\circ$
GM	Gain Margin	$R_L = 10\text{ k}\Omega$ , $C_L = 100\text{ pF}$		15		dB
<b>Noise Performance</b>						
$E_N$	Input Voltage Noise	$f = 0.1\text{ Hz}$ to $10\text{ Hz}$		0.25		$\mu\text{V}_{PP}$
$e_N$	Input Voltage Noise Density	$f = 1\text{ kHz}$		12		nV/ $\sqrt{\text{Hz}}$
$i_N$	Input Current Noise Density	$f = 1\text{ kHz}$		100		fA/ $\sqrt{\text{Hz}}$
THD+N	Total Harmonic Distortion and Noise	$f = 1\text{ kHz}$ , $G = 1$ , $R_L = 2\text{ k}\Omega$ , $V_{OUT} = 1\text{ V}_{RMS}$		0.005		%

Typical Performance Characteristics

All test conditions:  $V_S = 5\text{ V}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise noted.

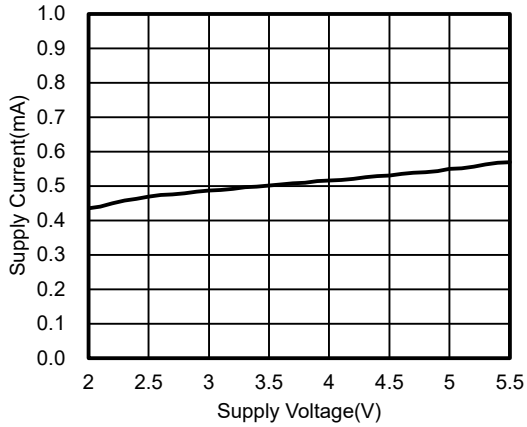


Figure 1. Supply Current vs. Supply Voltage, 1ch

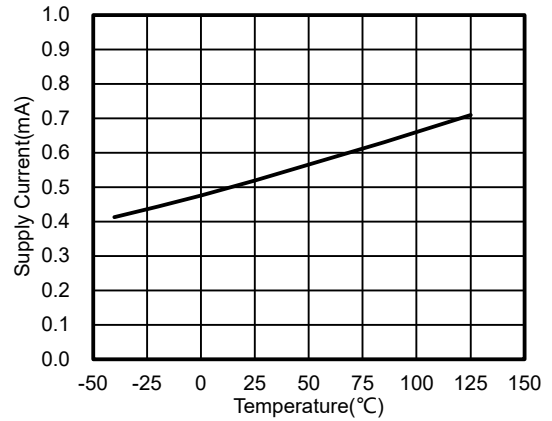


Figure 2. Supply Current vs. Temperature, 1ch

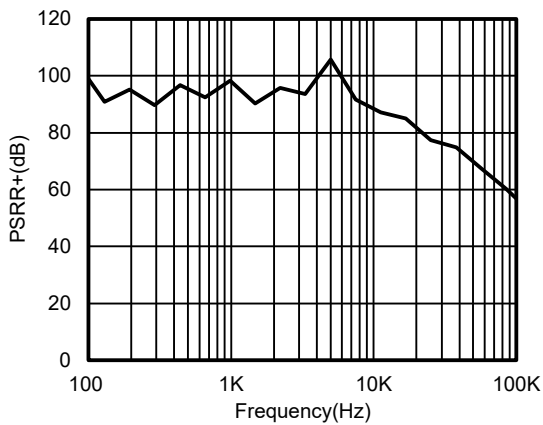


Figure 3. PSRR+ vs. Frequency

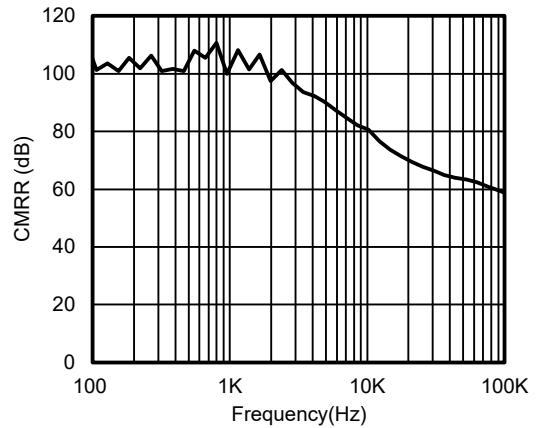


Figure 4. PSRR- vs. Frequency

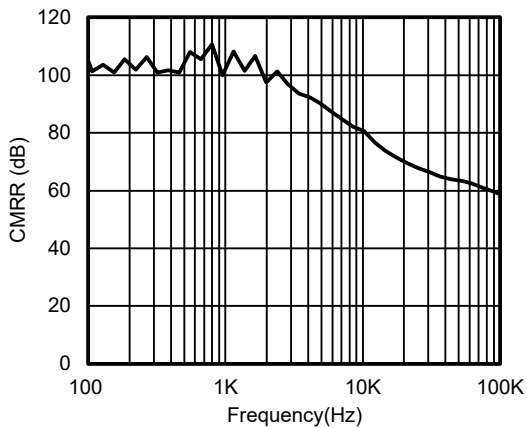


Figure 5. CMRR vs. Frequency

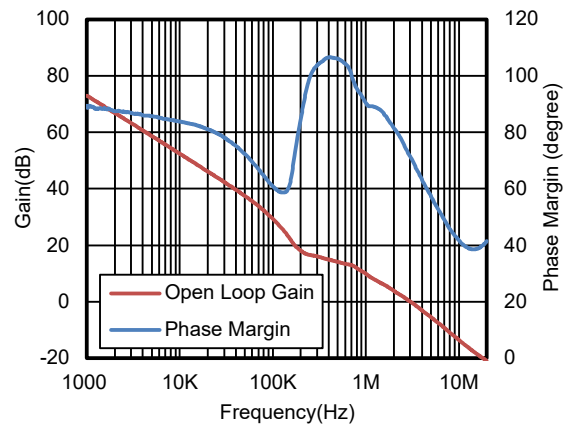


Figure 6. Open-Loop Gain and Phase Margin vs. Frequency,  $R_L = 10\text{ k}\Omega$ ,  $C_L = 100\text{ pF}$

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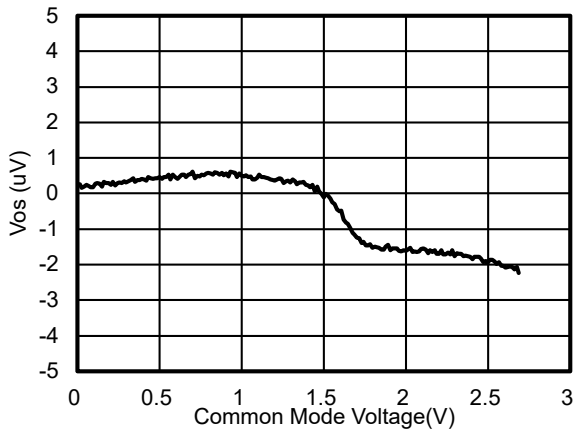


Figure 7.  $V_{os}$  vs.  $V_{cm}$ ,  $V_s = 2.7\text{ V}$

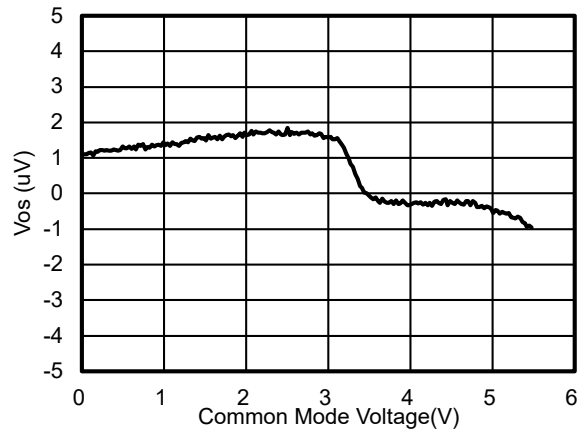


Figure 8.  $V_{os}$  vs.  $V_{cm}$ ,  $V_s = 5.5\text{ V}$

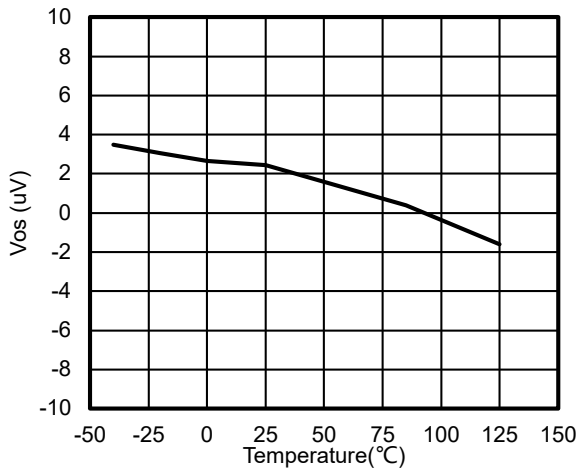


Figure 9.  $V_{os}$  vs. Temperature

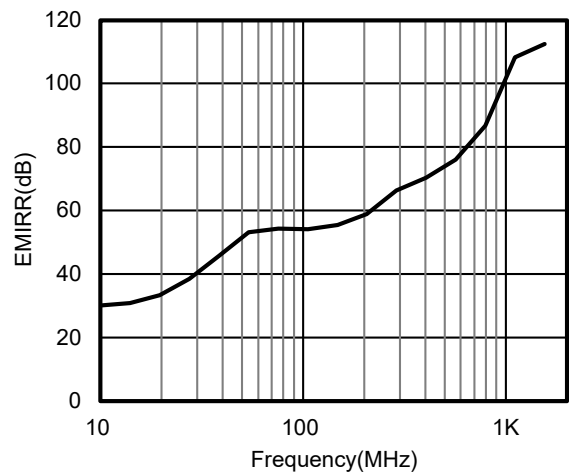


Figure 10. EMIRR vs. Frequency

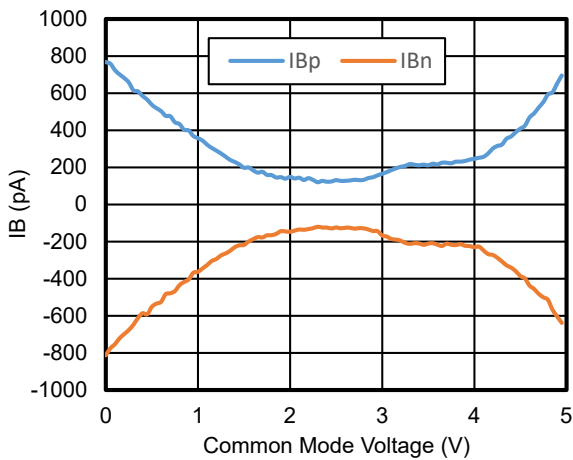


Figure 11.  $I_B$  vs. Common-Mode Voltage

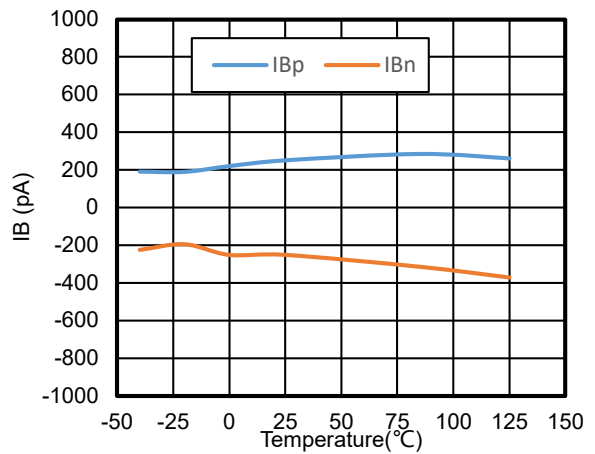


Figure 12.  $I_B$  vs. Temperature

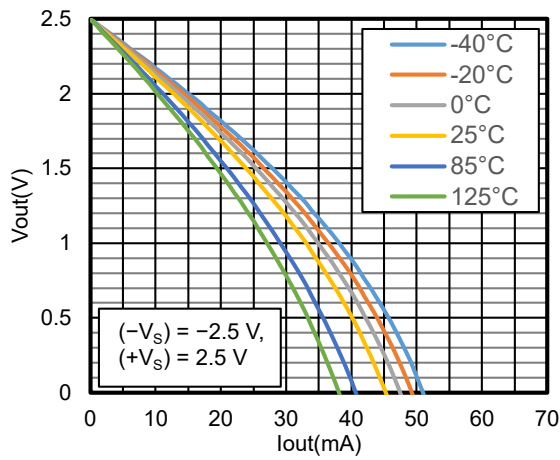


Figure 13. Output Voltage vs. Output Current

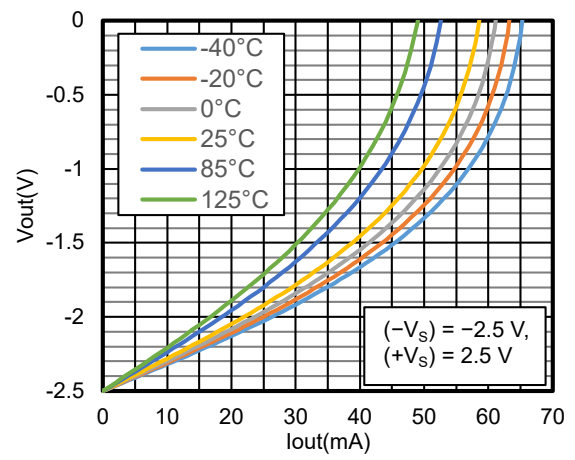


Figure 14. Output Voltage vs. Output Current

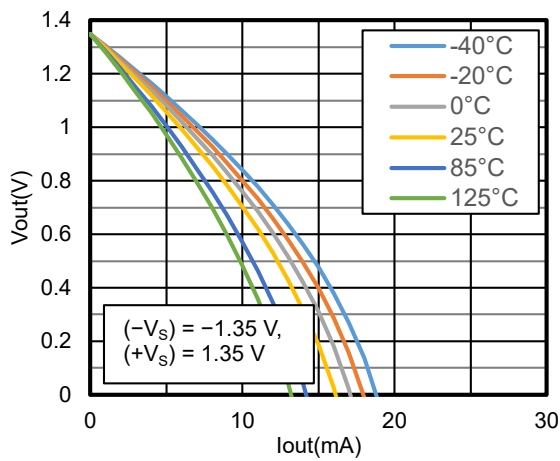


Figure 15. Output Voltage vs. Output Current

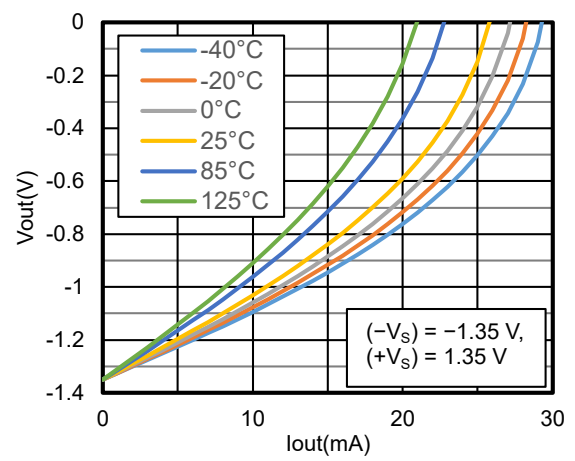


Figure 16. Output Voltage vs. Output Current

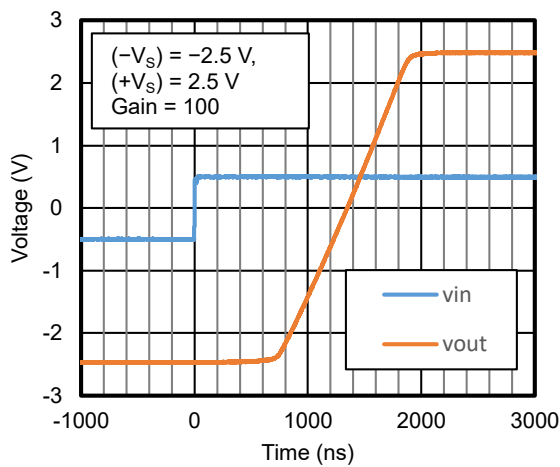


Figure 17. Overload Recovery at Negative Rail

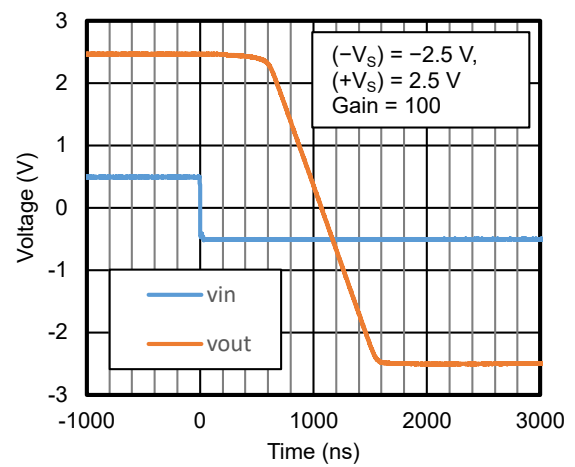


Figure 18. Overload Recovery at Positive Rail

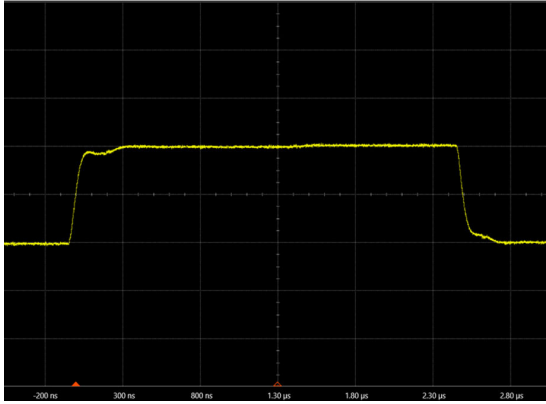


Figure 19. 100-mV Small-Signal Step Response Voltage:  
50 mV/div, Time: 500 ns/div

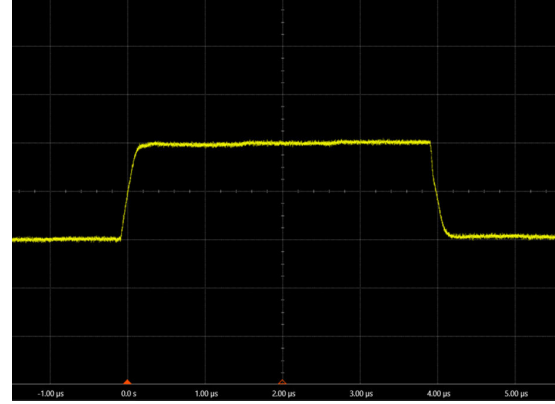


Figure 20. 1-V Large-Signal Step Response Voltage: 500  
mV/div, Time: 1 μs/div

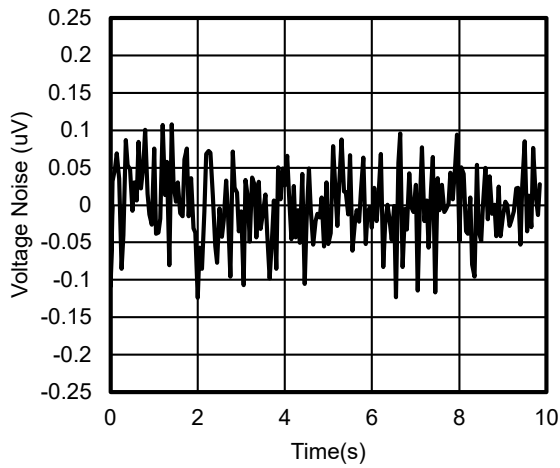


Figure 21. 0.1-Hz to 10-Hz Voltage Noise

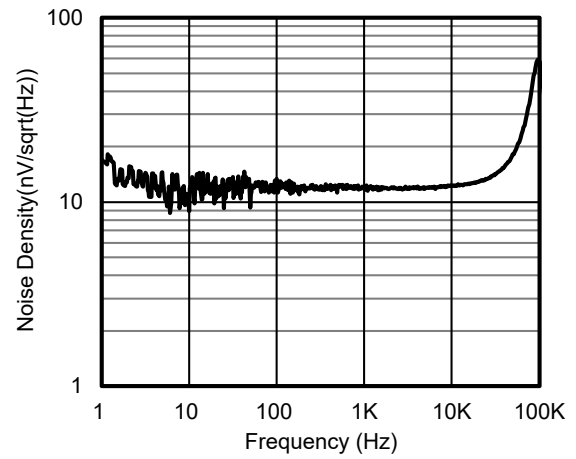


Figure 22. Voltage Noise Spectral Density vs. Frequency

## Detailed Description

### Overview

The TPA556x is a series of operational amplifiers which can operate on a single-supply voltage (2.7 V to 5.5 V), or a split-supply voltage ( $\pm 1.35$  V to  $\pm 2.75$  V), making them highly versatile and easy to use. The power-supply pins have local bypass ceramic capacitors (typically 0.01  $\mu$ F to 0.1  $\mu$ F). These amplifiers are fully specified from 2.7 V to 5.5 V and over the extended temperature range from  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

### Functional Block Diagram

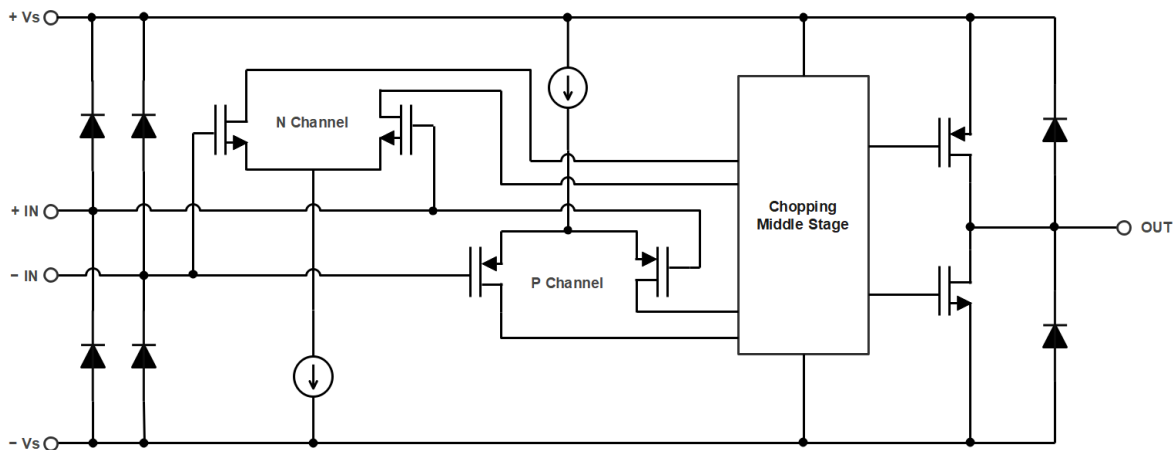


Figure 23. Functional Block Diagram

## Feature Description

### Operating Voltage

The devices are designed for single supply operation from 2.7 V to 5.5 V or dual supply operation from  $\pm 1.35$  V to  $\pm 2.75$  V.

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

The devices provide 45- $\mu$ 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 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 standard amplifier.

### Residual Voltage Ripple

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

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The devices set the chopping frequency to 450 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 100 mV beyond 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

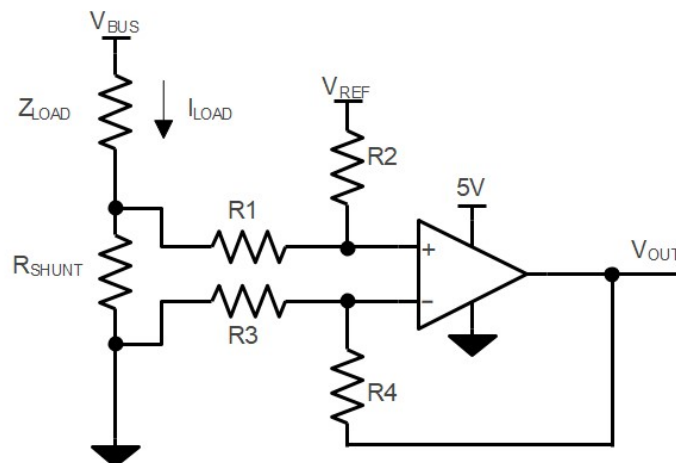
### Note

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 24 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.  $V_{REF}$  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.



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

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

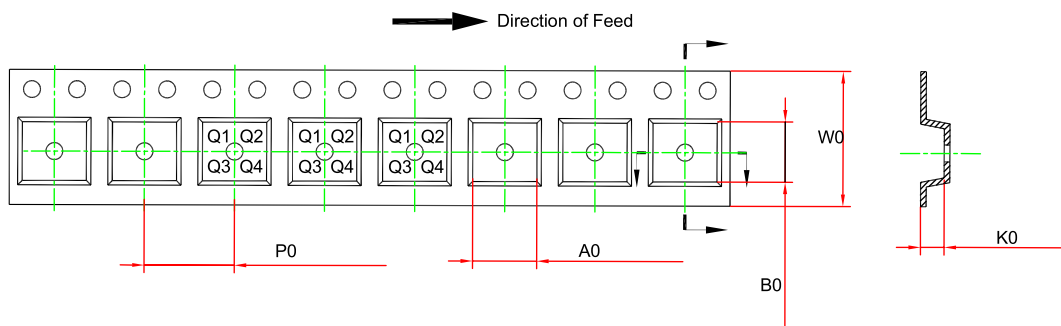
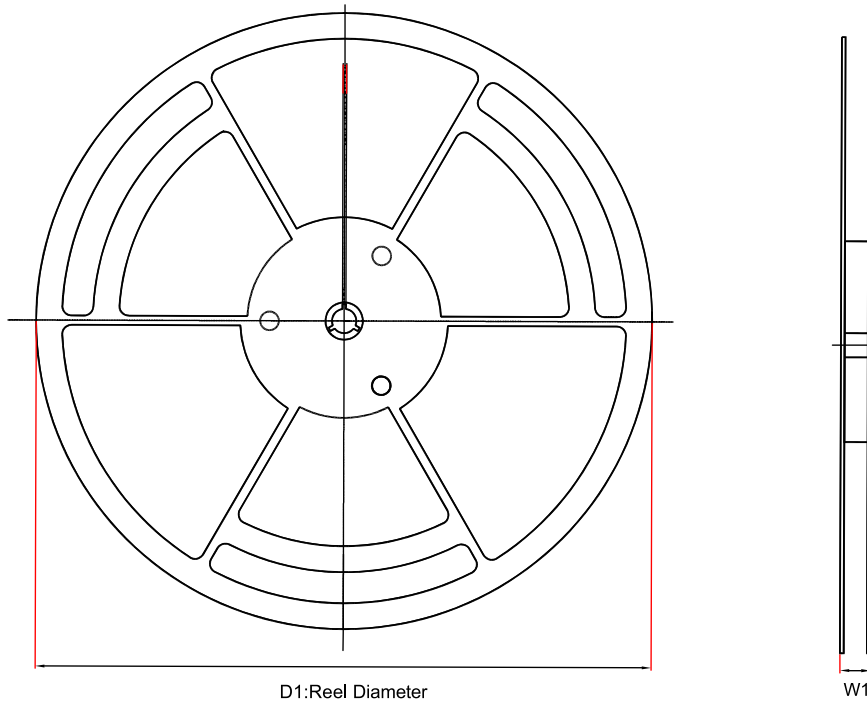
**Figure 24. Low-Side Current-Sensing Application**

### Power Supply Recommendations

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



### Tape and Reel Information

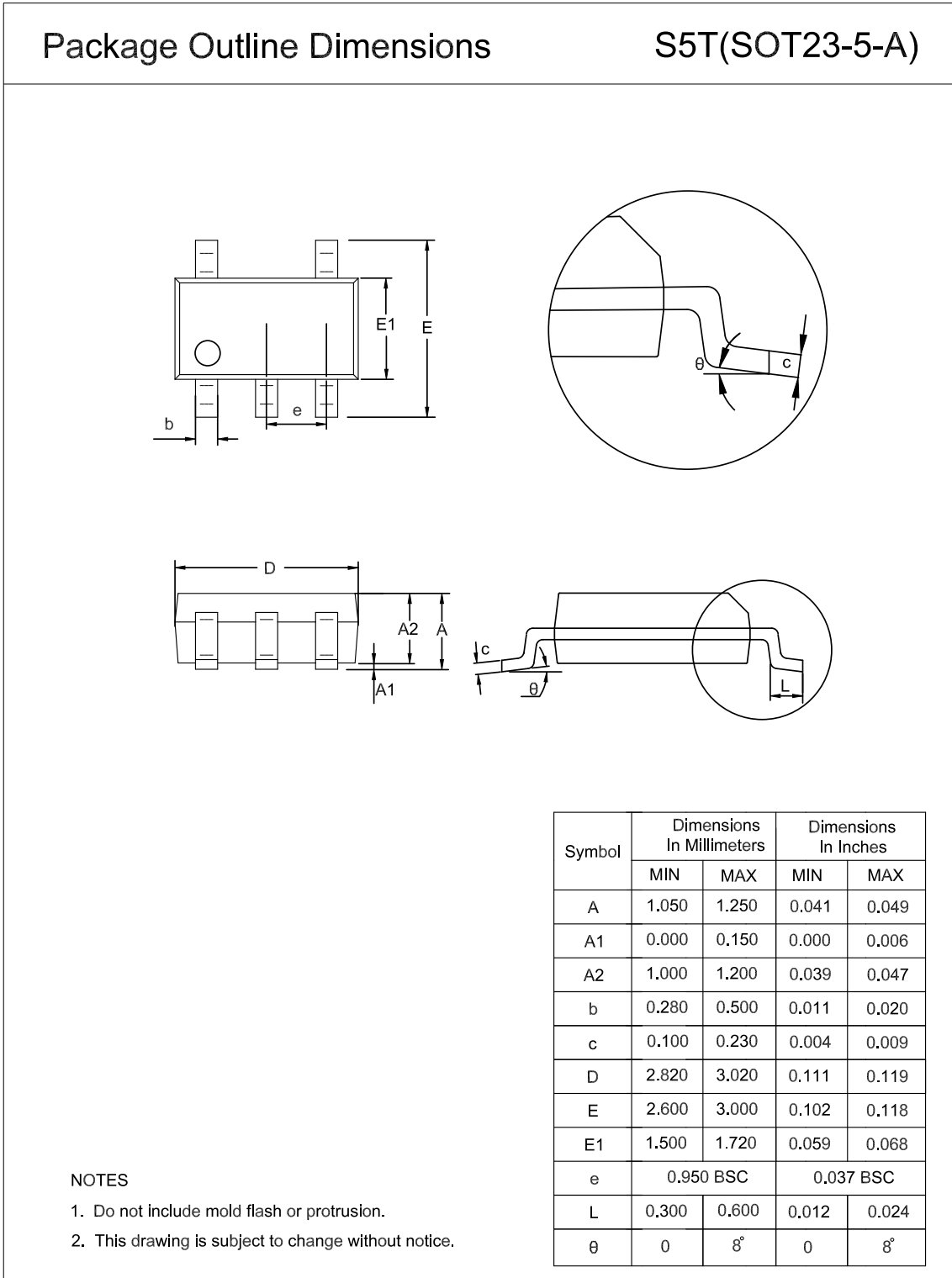


Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm) <sup>(1)</sup>	B0 (mm) <sup>(1)</sup>	K0 (mm) <sup>(1)</sup>	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPA5561-SC5R	SOT353 (SC70-5)	178.0	12.3	2.4	2.5	1.2	4.0	8.0	Q3
TPA5561U-SC5R	SOT353 (SC70-5)	178.0	12.3	2.4	2.5	1.2	4.0	8.0	Q3
TPA5561-S5TR	SOT23-5	178.0	11.4	3.3	3.2	1.4	4.0	8.0	Q3
TPA5561U-S5TR	SOT23-5	178.0	11.4	3.3	3.2	1.4	4.0	8.0	Q3
TPA5562-SO1R	SOP8	330.0	16.8	6.5	5.4	2	8.0	12.0	Q1
TPA5562-TS1R	TSSOP8	330.0	17.6	6.8	3.3	1.2	8.0	12.0	Q1
TPA5562-VS1R	MSOP8	330.0	17.6	5.2	3.3	1.5	8.0	12.0	Q1

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

Package Outline Dimensions

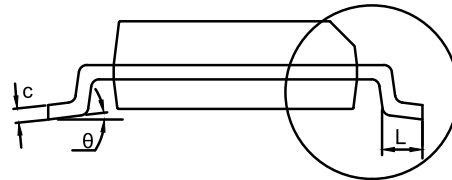
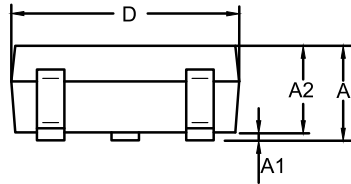
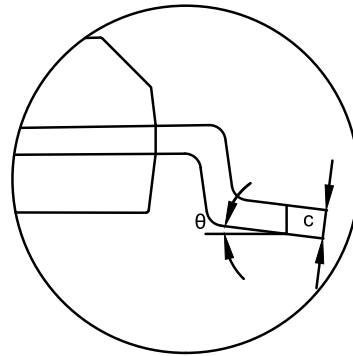
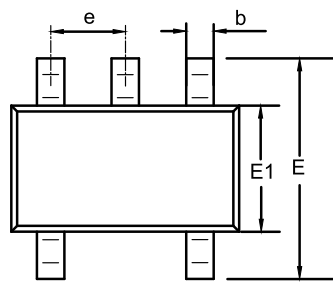
SOT23-5



SOT353 (SC70-5)

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°

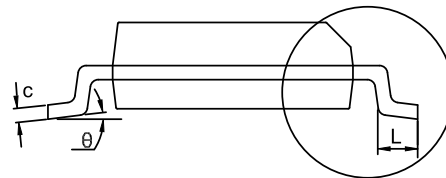
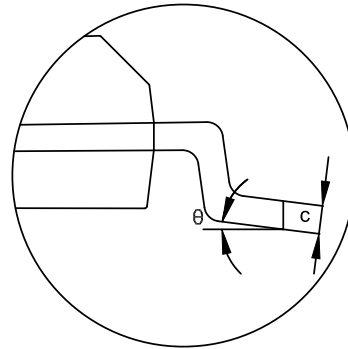
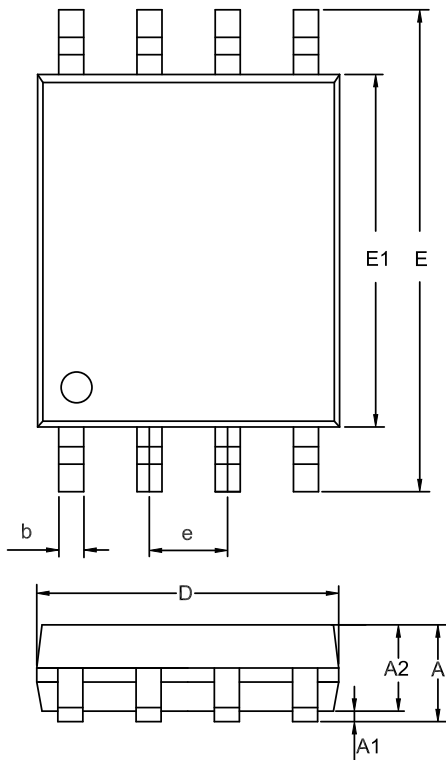
NOTES

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°

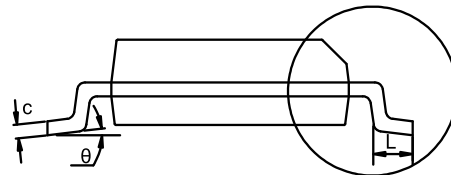
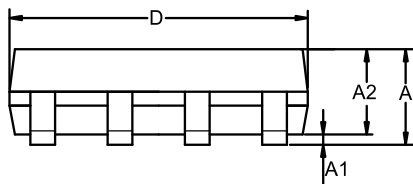
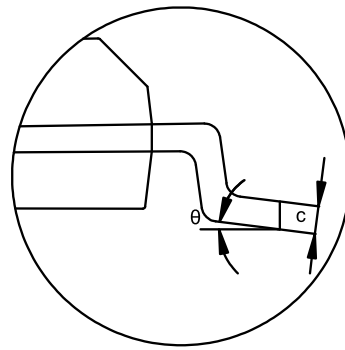
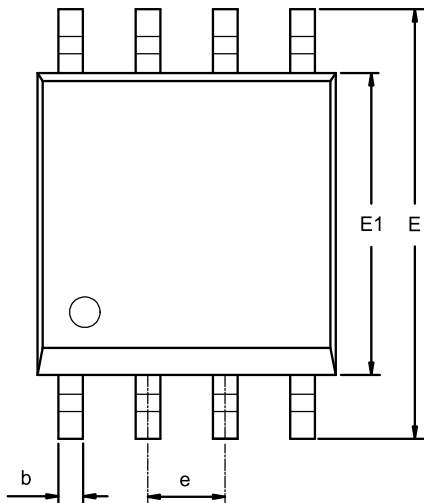
NOTES

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°

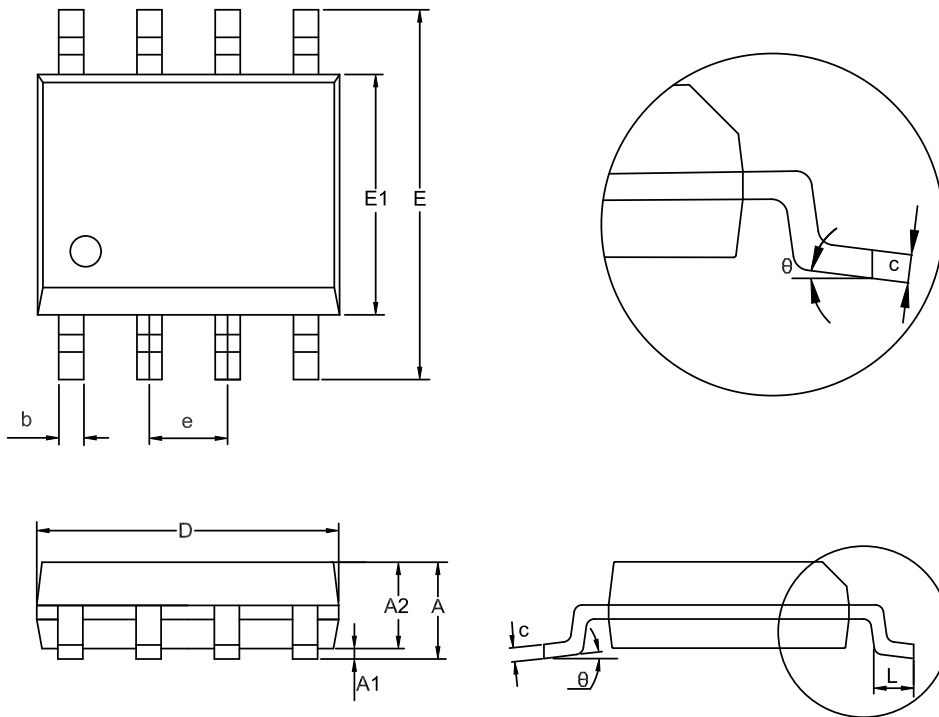
NOTES

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
theta	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
TPA5561-SC5R	-40 to 125°C	SOT353 (SC70-5)	561	3	Tape and Reel, 3000	Green
TPA5561U-SC5R	-40 to 125°C	SOT353 (SC70-5)	56U	3	Tape and Reel, 3000	Green
TPA5561-S5TR	-40 to 125°C	SOT23-5	561	3	Tape and Reel, 3000	Green
TPA5561U-S5TR	-40 to 125°C	SOT23-5	56U	3	Tape and Reel, 3000	Green
TPA5562-SO1R	-40 to 125°C	SOP8	A5562	3	Tape and Reel, 4000	Green
TPA5562-TS1R	-40 to 125°C	TSSOP8	A5562	3	Tape and Reel, 3000	Green
TPA5562-VS1R	-40 to 125°C	MSOP8	A5562	3	Tape and Reel, 3000	Green

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

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