5-V, 15-MHz GBW, Zero-Drift Operational Amplifiers

Features

- Supply Voltage: 2.5 V to 5.5 V
- Offset Voltage: ±10 μV Maximum within Temperature Range from −40°C to 125°C
- Offset Voltage Drift: 0.013 μV/°C
- Rail-to-Rail Input and Output
- Bandwidth: 15 MHz
- Slew Rate: 7 V/μs
- Low Noise: 10 nV/$\sqrt{Hz}$ at 1 kHz

Applications

- Server PSU
- Battery Current Sensing
- Precision Signal Condition
- Power System
- Temperature Transmitter
- Medical Instrumentation

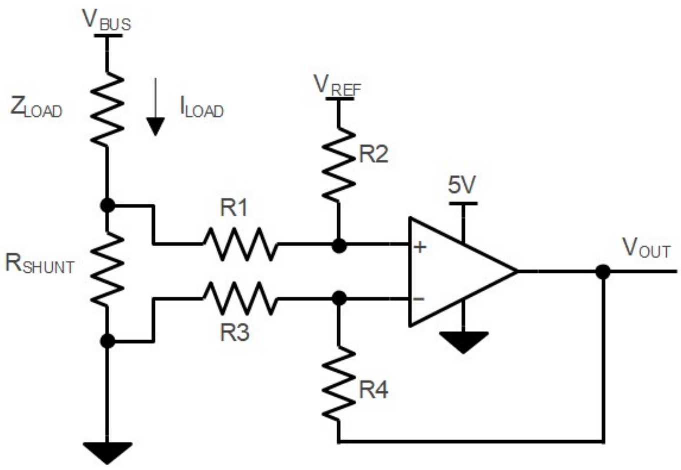
Description

The TPA5601 and TPA5602 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 ±10 μV maximum within the temperature range from −40°C to 125°C.

The TPA5601 and TPA5602 devices provide rail-to-rail input and output. The devices have excellent AC performance with 15-MHz bandwidth and 7-V/μs slew rate while drawing 1.6-mA quiescent current per amplifier.

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

Typical Application Circuit



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

When $R3 = R1$, $R2 = R4$, $R_{SHUNT} << R1$

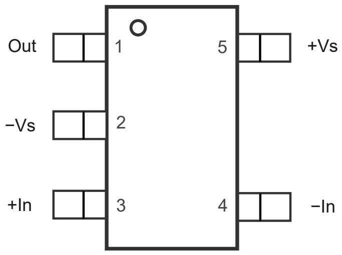
Table of Contents

Revision History

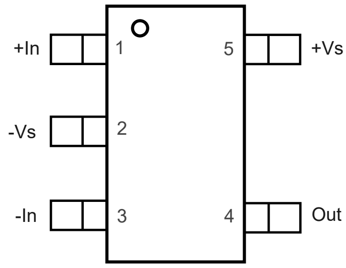
Date	Revision	Notes
2023-09-30	Rev.A.0	Initial version.
2024-12-17	Rev.A.1	Changed the status of the TPA5601-SC5R to production in the Order Information. The following updates are all about the new datasheet formats or typos, and the actual product remains unchanged. • Updated the Tape and Reel Information. • Updated the Order Information.
2025-01-24	Rev.A.2	Changed the status of the TPA5602-SO1R to production in the Order Information.

Pin Configuration and Functions

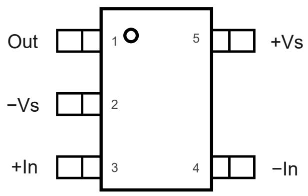
TPA5601
SOT23-5
Top View



TPA5601U
SOT23-5
Top View



TPA5601
SOT353 (SC70-5)
Top View



TPA5601U
SOT353 (SC70-5)
Top View

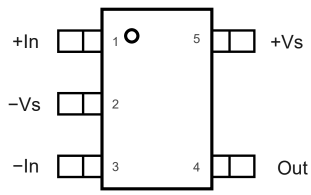
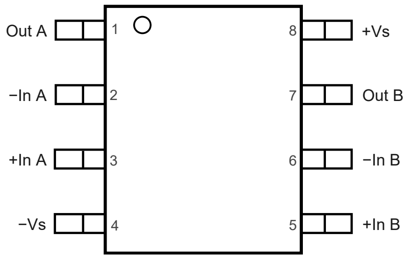


Table 1. Pin Functions: TPA5601, TPA5601U

Pin No.		Name	I/O	Description
TPA5601	TPA5601U			
1	4	Out	O	Output
2	2	$-V_S$	-	Negative power supply
3	1	+In	I	Noninverting input
4	3	−In	I	Inverting input
5	5	$+V_S$	-	Positive power supply

TPA5602
SOP8
Top View



TPA5602
MSOP8
Top View

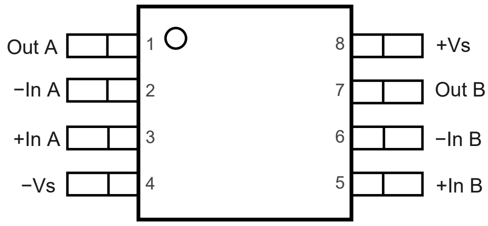


Table 2. Pin Functions: TPA5602

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

Specifications

Absolute Maximum Ratings (1)

Parameter		Min	Max	Unit
	Supply Voltage, $(+V_S) - (-V_S)$		6.5	V
	Input Voltage	$(-V_S) - 0.3$	$(+V_S) + 0.3$	V
	Differential Input Voltage	$(-V_S) - (+V_S)$	$(+V_S) - (-V_S)$	V
	Input Current: +IN, –IN (2)	−10	10	mA
	Output Short-Circuit Duration (3)		Infinite	
T_J	Maximum Junction Temperature		150	°C
T_A	Operating Temperature Range	−40	125	°C
T_{STG}	Storage Temperature Range	−65	150	°C
T_L	Lead Temperature (Soldering 10 sec)		260	°C

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.
(2) The inputs are protected by ESD protection diodes to the 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	Level	Unit
HBM	Human Body Model ESD	ANSI/ESDA/JEDEC JS-001 (1)	4	kV
CDM	Charged Device Model ESD	ANSI/ESDA/JEDEC JS-002 (2)	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_S	Supply Voltage, $(+V_S) - (-V_S)$	2.5 (±1.25)		5.5 (±2.75)	V
T_A	Operating Temperature Range	−40		125	°C

Thermal Information

Package Type	θ_{JA}	θ_{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 V, T_A = 25°C, R_L = 10 kΩ, unless otherwise noted.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Power Supply						
V_S	Supply Voltage Range		2.5		5.5	V
I_Q	Quiescent Current per Amplifier			1.6	2.3	mA
		T_A = −40°C to 125°C			3	mA
PSRR	Power Supply Rejection Ratio	V_S = 2.5 V to 5.5 V	107	132		dB
		V_S = 2.5 V to 5.5 V, T_A = −40°C to 125°C	105			dB
Input Characteristics						
V_{OS}	Input Offset Voltage	V_S = 5 V, V_{CM} = 2.5 V	−6	1	6	μV
		V_S = 5 V, V_{CM} = 2.5 V, T_A = −40°C to 125°C	−8		8	μV
		V_S = 3.3 V, V_{CM} = 1.65 V	−6	1	6	μV
		V_S = 3.3 V, V_{CM} = 1.65 V, T_A = −40°C to 125°C	−10		10	μV
$V_{OS}TC$	Input Offset Voltage Drift	T_A = −40°C to 125°C		0.013		μV/°C
I_B	Input Bias Current (1)	V_{CM} = 2.5 V	−800	30	800	pA
		V_{CM} = 2.5 V, T_A = −40°C to 125°C	−5000		5000	pA
I_{OS}	Input Offset Current (1)	V_{CM} = 2.5 V	−800	30	800	pA
		V_{CM} = 2.5 V, T_A = −40°C to 125°C	−5000		5000	pA
C_{IN}	Input Capacitance	Differential Mode		3.5		pF
		Common Mode		1		pF
A_V	Open-Loop Voltage Gain	V_O = 0.1 V to 4.9 V	110	130		dB
		V_O = 0.1 V to 4.9 V, T_A = −40°C to 125°C	107			dB
V_{CMR}	Common-Mode Input Voltage Range (2)	T_A = −40°C to 125°C	(−V_S) – 0.1		(+V_S) + 0.1	V
CMRR	Common-Mode Rejection Ratio	V_{CM} = 0 V to 5 V	107	127		dB
		V_{CM} = 0 V to 5 V, T_A = −40°C to 125°C	104			dB

(1) Provided by bench tests and design simulation.
(2) Provided by design simulation.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Output Characteristics						
	Output Voltage Swing from Positive Rail or Negative Rail	R_{LOAD} = 10 kΩ to V_S / 2		3	6	mV
		R_{LOAD} = 10 kΩ to V_S / 2, T_A= −40°C to 125°C			10	mV
		R_{LOAD} = 2 kΩ to V_S / 2		13	23	mV
		R_{LOAD} = 2 kΩ to V_S / 2, T_A = −40°C to 125°C			30	mV
I_{SC}	Output Short-Circuit Current	Sink or Source	85	115		mA
		Sink or Source, T_A = −40°C to 125°C	60			mA
AC Specifications						
GBW	Gain-Bandwidth Product			15		MHz
SR	Slew Rate	G = 1, 2-V step		7		V/µs
t_{OR}	Overload Recovery			1		µs
t_S	Settling Time, 0.1% (2)	G = 1, 2-V step		4.6		ns
	Settling Time, 0.01% (2)	G = 1, 2-V step		6		µs
PM	Phase Margin	R_L = 10 kΩ, C_L = 100 pF		56		°
Noise Performance						
E_N	Input Voltage Noise	f = 0.1 Hz to 10 Hz		0.5		μV_{PP}
e_N	Input Voltage Noise Density	f = 1 kHz		10		nV/√Hz
i_N	Input Current Noise Density (2)	f = 1 kHz		100		fA/√Hz
THD+N	Total Harmonic Distortion and Noise (2)	G = 1, f = 10 kHz, V_O = 2 V_{RMS}, R_L = 2 kΩ		0.004		%

(1) Provided by bench tests and design simulation.
(2) Provided by design simulation.

Typical Performance Characteristics

All test conditions: V_S = 5 V, R_L = 10 kΩ, unless otherwise noted.

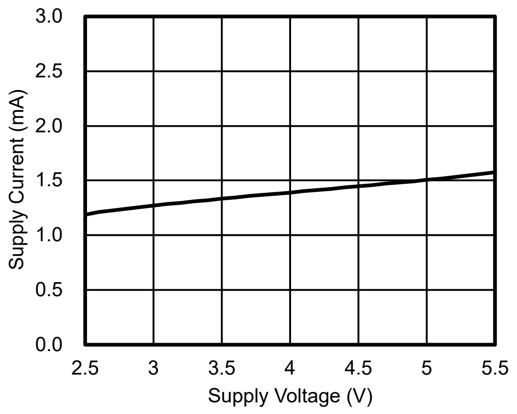


Figure 1. Supply Current vs. Supply Voltage

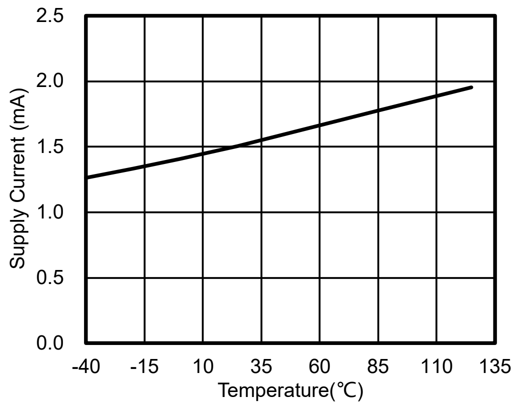


Figure 2. Supply Current vs. Temperature

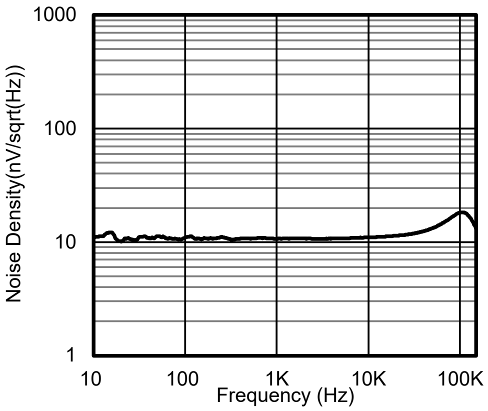


Figure 3. Voltage Noise Spectral Density vs. Frequency

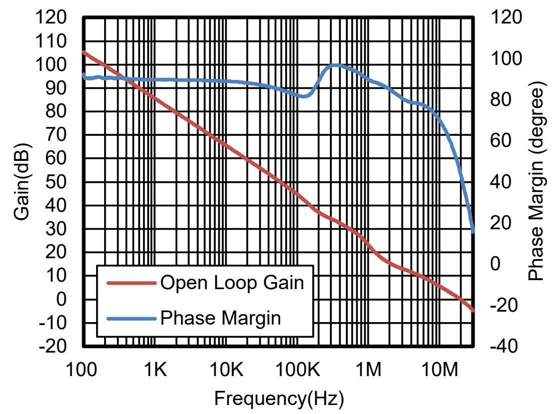


Figure 4. Open-Loop Gain and Phase Margin vs. Frequency, RL = 10 kΩ

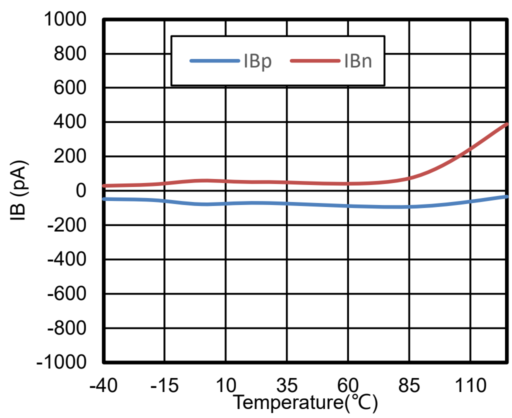


Figure 5. I_B vs. Temperature

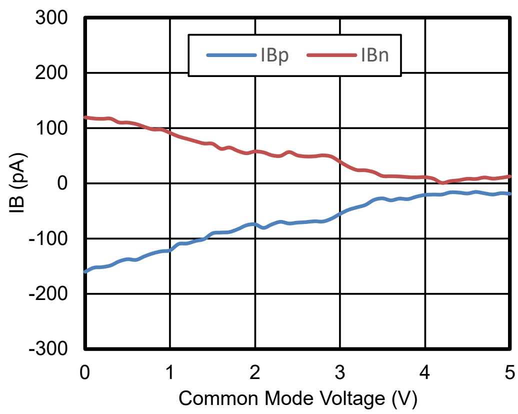


Figure 6. I_B vs. V_{CM}

Figure 7. V_{OS} vs. V_{CM}

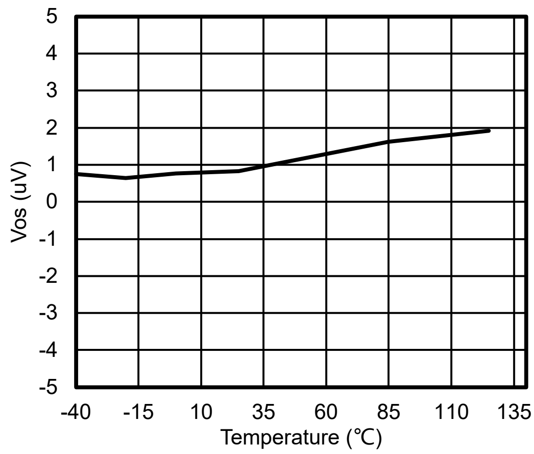


Figure 8. V_{OS} vs. Temperature

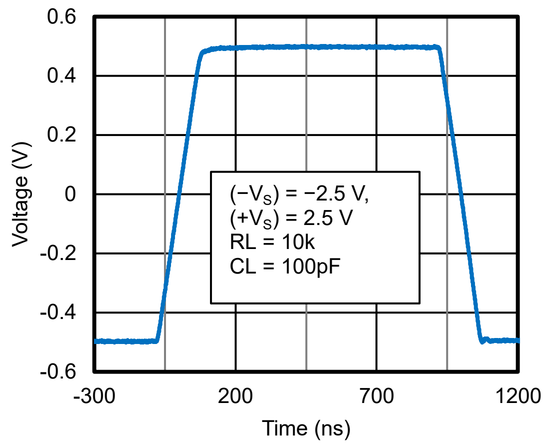


Figure 9. Large-Signal Step Response

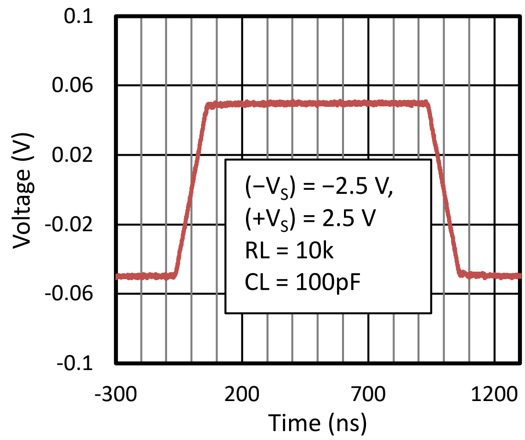


Figure 10. Small-Signal Step Response

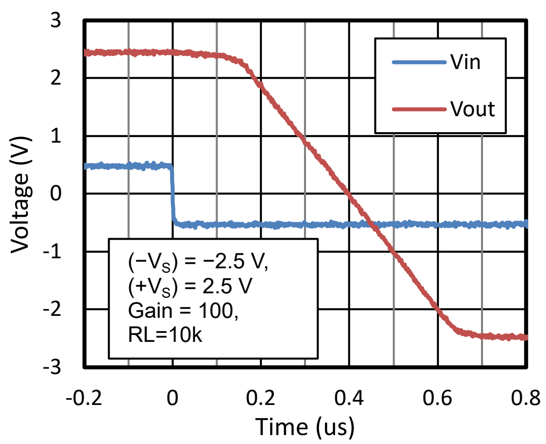


Figure 11. Overload Recovery at Negative Rail

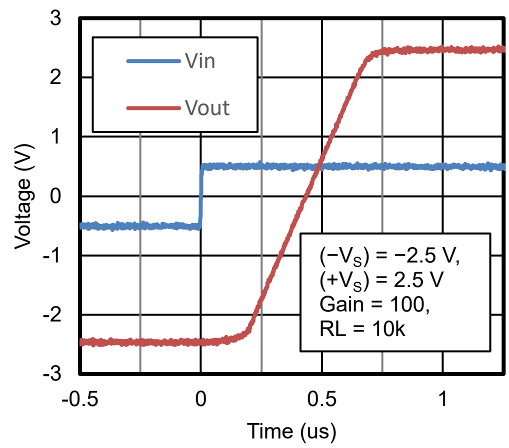


Figure 12. Overload Recovery at Positive Rail

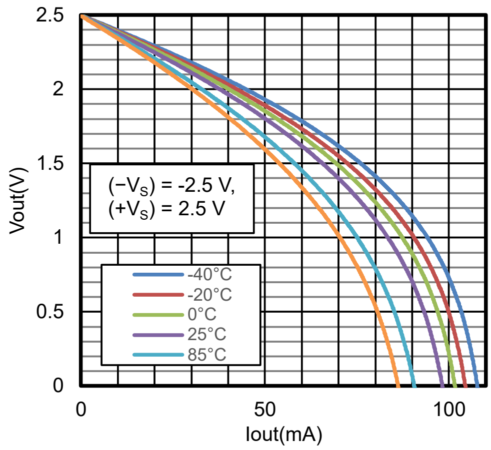


Figure 13. V_{OUT} vs. I_{OUT}, Source

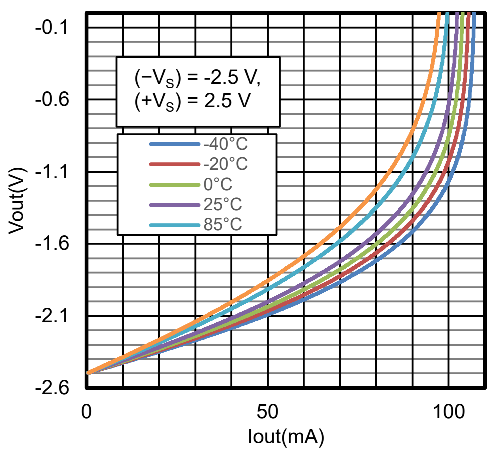


Figure 14. V_{OUT} vs. I_{OUT}, Sink

Detailed Description

Overview

The TPA560x series of op amps can operate on a single-supply voltage (2.5 V to 5.5 V), or a split-supply voltage (±1.25 V to ±2.75 V), making them highly versatile and easy to use. With a 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 TPA558x also include 15-MHz bandwidth, no 1/f noise, 10-nV/√ Hz noise spectral density, and 1.6-mA quiescent current, making the TPA558x suitable for many precision and temperature-sensitive applications. Parameters that can exhibit variance with regard to operating voltage or temperature are presented in Typical Performance Characteristics. The power-supply pins have local bypass ceramic capacitors (typically 0.01 μF to 0.1 μF). These amplifiers are fully specified from 2.5 V to 5.5 V and over the extended temperature range from −40°C to +125°C.

Functional Block Diagram

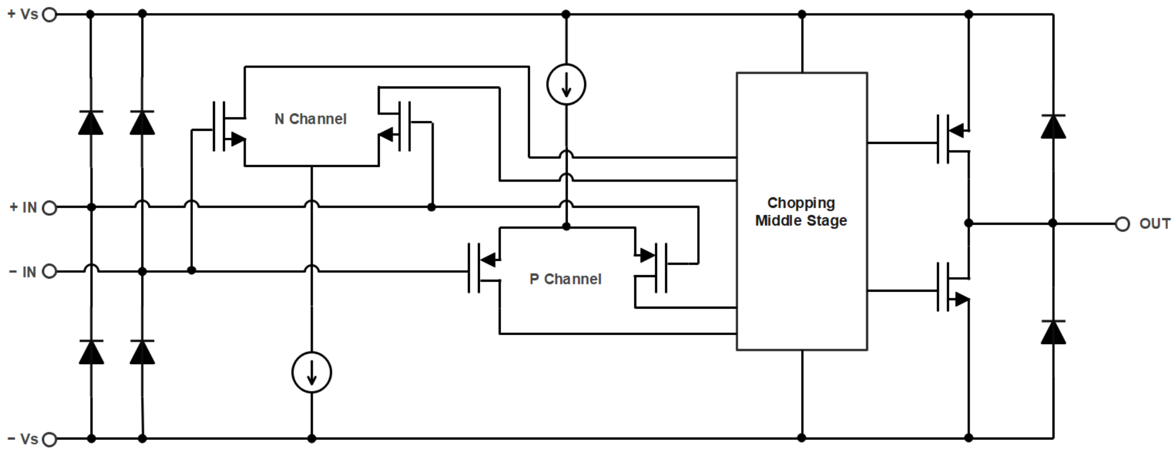


Figure 15. Functional Block Diagram

Feature Description

Operating Voltage

The devices are designed for single supply operation from 2.5 V to 5.5 V or dual supply operation from ±1.25 V to ±2.75 V.

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

The devices provide low offset voltage within the temperature range from −40°C to 125°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, also 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 amplifiers.

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.

The devices set the chopping frequency to 560 kHz. If the frequency of the input signal is close to the chopping frequency, the signal may be interfered with by the residue ripple. To suppress the noise at the chopping frequency, it is recommended that a post filter 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.

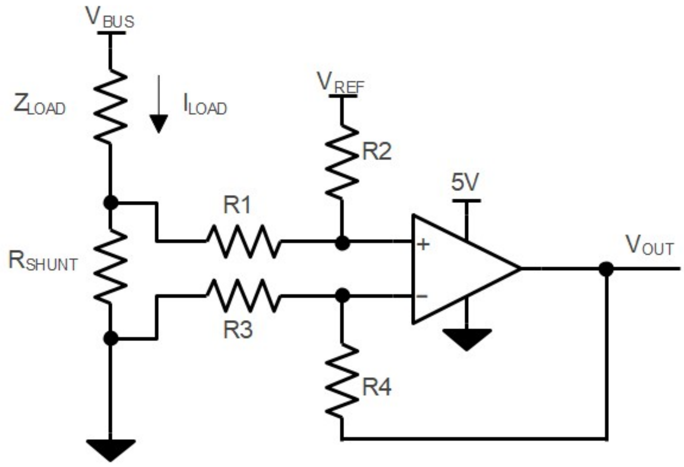
Application and Implementation

> 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 16 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.



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

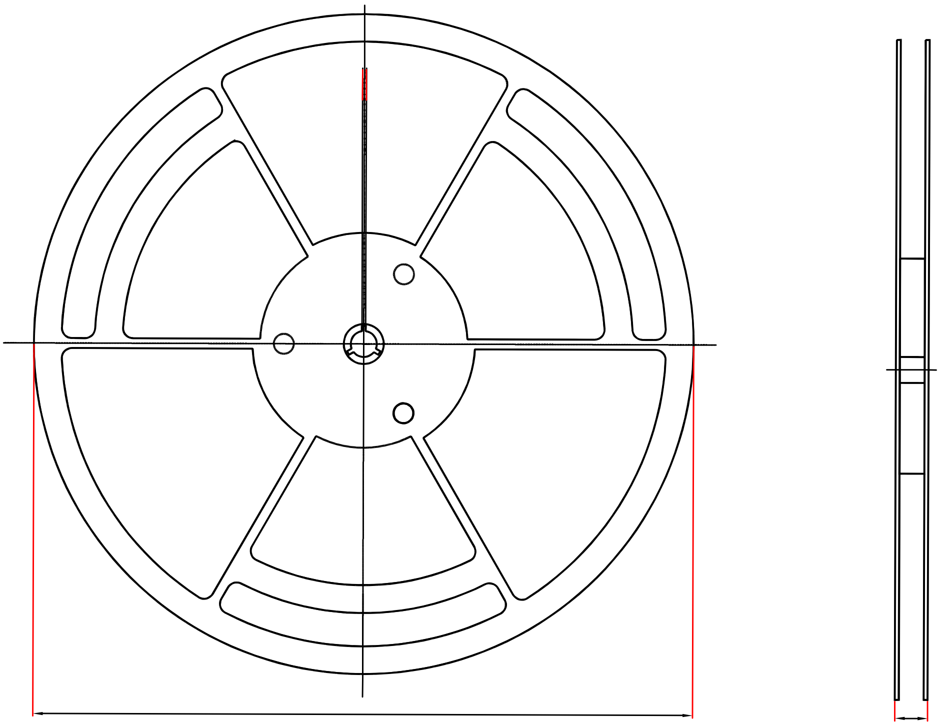
When $R3 = R1$, $R2 = R4$, $R_{SHUNT} << R1$

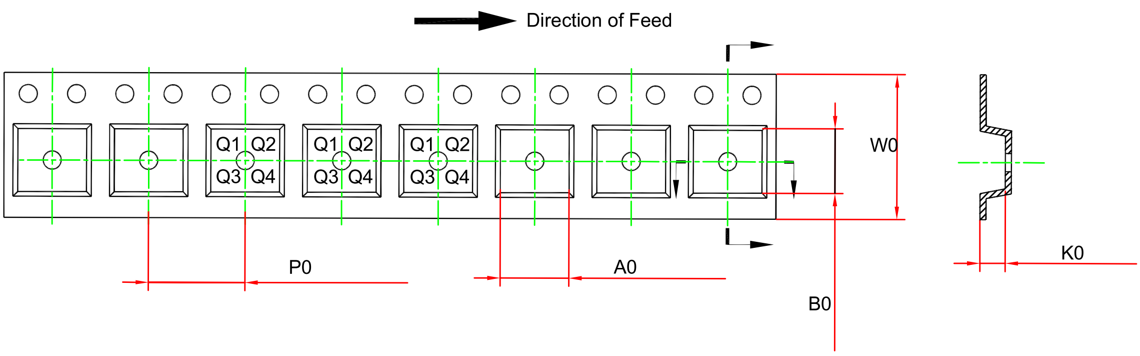
Figure 16. Low-Side Current-Sensing Application

Power Supply Recommendations

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

Tape and Reel Information





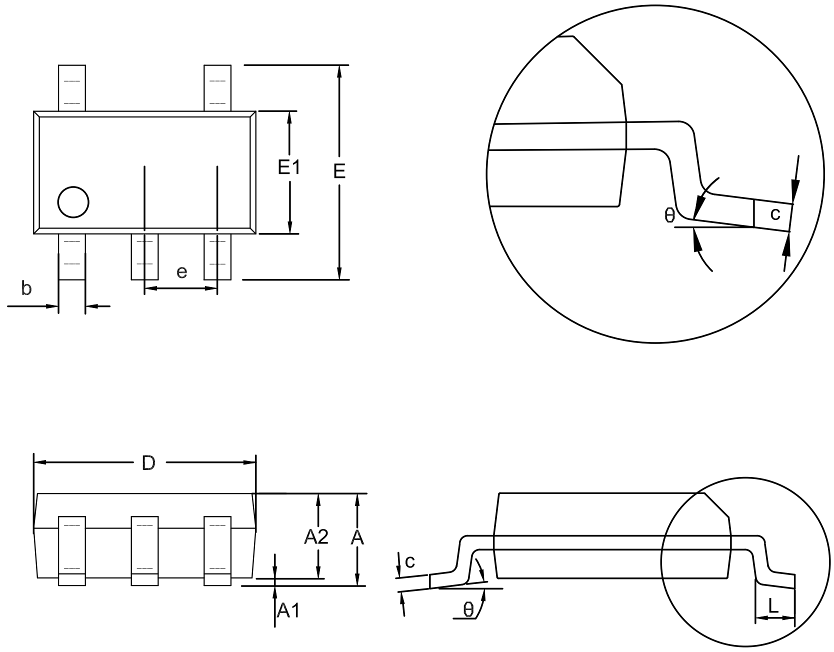
Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm) (1)	B0 (mm) (1)	K0 (mm) (1)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPA5602-SO1R	SOP8	330	17.6	6.5	5.4	2	8	12	Q1
TPA5602-VS1R	MSOP8	330	17.6	5.3	3.4	1.3	8	12	Q1
TPA5601-SC5R	SOT353 (SC70-5)	178	12.1	2.4	2.5	1.2	4	8	Q3
TPA5601-S5TR	SOT23-5	180	12	3.3	3.25	1.4	4	8	Q3
TPA5601U-SC5R	SOT353 (SC70-5)	178	12.1	2.4	2.5	1.2	4	8	Q3
TPA5601U-S5TR	SOT23-5	180	12	3.3	3.25	1.4	4	8	Q3

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

Package Outline Dimensions

SOT23-5

Package Outline Dimensions S5T(SOT23-5-A)



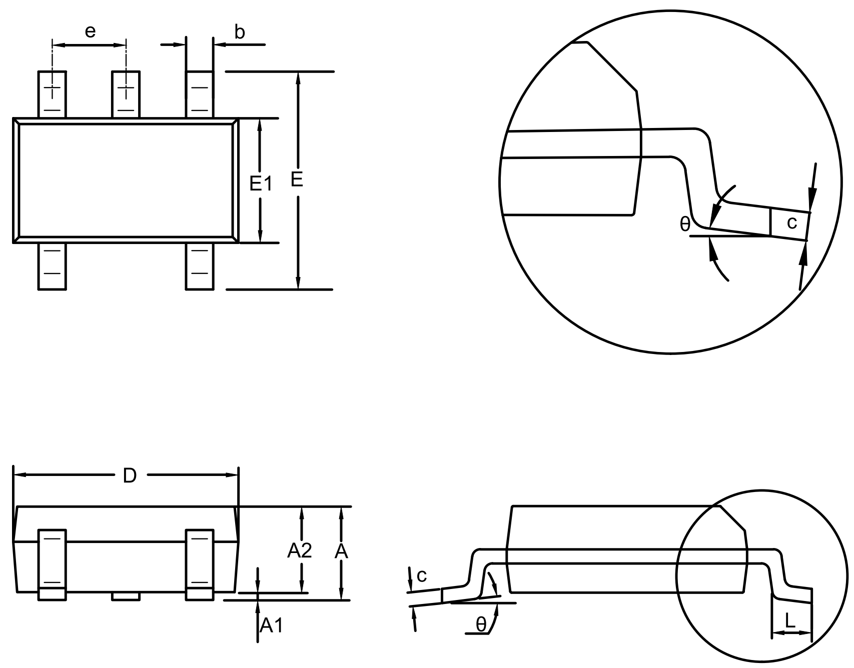
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.150	0.000	0.006
A2	1.000	1.200	0.039	0.047
b	0.280	0.500	0.011	0.020
c	0.100	0.230	0.004	0.009
D	2.820	3.020	0.111	0.119
E	2.600	3.000	0.102	0.118
E1	1.500	1.720	0.059	0.068
e	0.950 BSC		0.037 BSC	
L	0.300	0.600	0.012	0.024
θ	0	8°	0	8°

NOTES

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

SOT353 (SC70-5)

Package Outline Dimensions SC5(SOT353-5-A)



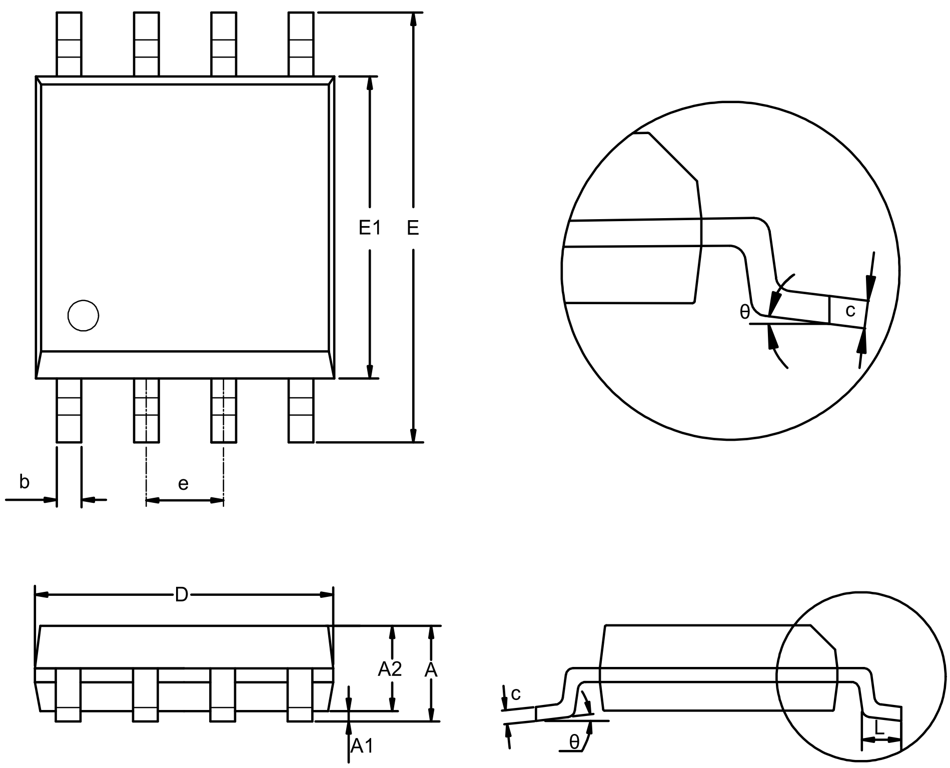
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.850	1.100	0.033	0.043
A1	0.000	0.100	0.000	0.004
A2	0.800	1.000	0.031	0.039
b	0.150	0.350	0.006	0.014
c	0.110	0.230	0.004	0.009
D	2.000	2.200	0.079	0.087
E	2.150	2.450	0.085	0.096
E1	1.150	1.350	0.045	0.053
e	0.650 BSC		0.026 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.

MSOP8

Package Outline Dimensions VS1(MSOP-8-A)



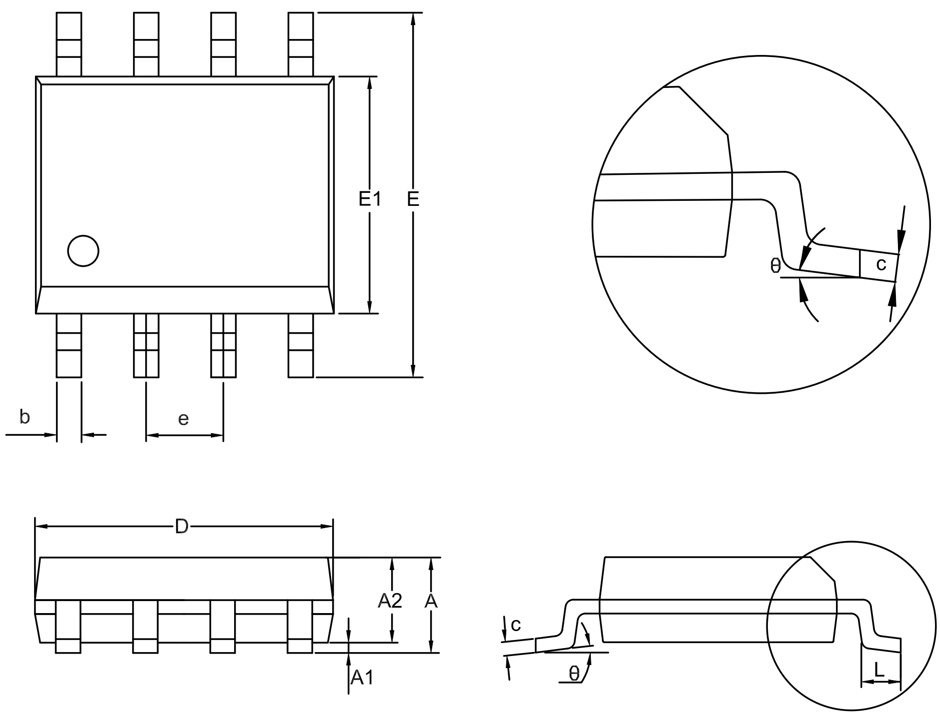
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.800	1.100	0.031	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	4.700	5.100	0.185	0.201
E1	2.900	3.100	0.114	0.122
e	0.650 BSC		0.026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

NOTES

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

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.

Order Information

Order Number	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TPA5601-SC5R	−40 to 125°C	SOT353 (SC70-5)	A01	1	Tape and Reel,3000	Green
TPA5601-S5TR	−40 to 125°C	SOT23-5	A01	1	Tape and Reel,3000	Green
TPA5601U-SC5R (1)	−40 to 125°C	SOT353 (SC70-5)	A02	1	Tape and Reel,3000	Green
TPA5601U-S5TR (1)	−40 to 125°C	SOT23-5	A02	2	Tape and Reel,3000	Green
TPA5602-SO1R	−40 to 125°C	SOP8	A5602	1	Tape and Reel,4000	Green
TPA5602-VS1R (1)	−40 to 125°C	MSOP8	A5602	2	Tape and Reel,3000	Green

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

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

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Performance Information. Performance tests or performance range contained in this document/material are either results of design simulation or actual tests conducted under designated testing environment. Any variation in testing environment or simulation environment, including but not limited to testing method, testing process or testing temperature, may affect actual performance of the product.

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