5-V, Zero-Drift, RRIO, 15-MHz, Precision Op Amp

Features

- Supply Voltage: 2.7 V to 5.5 V or Dual Supply: ±1.35 V to ±2.75 V
- Low Offset Voltage: ±150 μV Maximum
- Zero Drift: ±0.01 μV/°C
- Rail-to-Rail Input and Output
- Gain Bandwidth Product: 15 MHz
- Slew Rate: 5 V/μs
- Low Noise: 10 nV/√Hz at 1 kHz
- AEC-Q100 Qualified for Automotive Applications, Grade 1: −40°C to 125°C

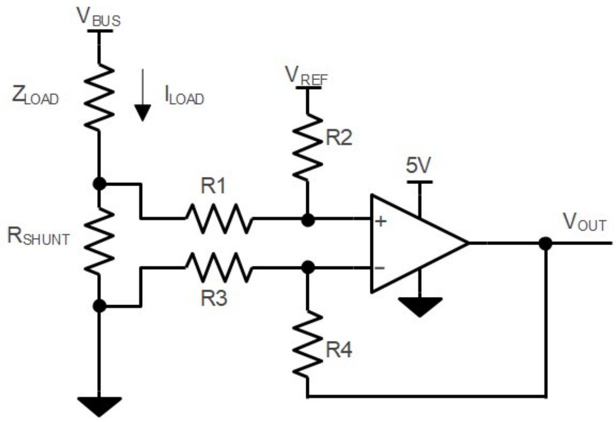
Applications

- On-Board Charger
- Motor Control
- Automotive Current Measurement

Description

The TPA5571Q and TPA5572Q are the newest zero-drift amplifiers with a maximum 150-μV low-offset voltage, low noise, and stable high-frequency response. It incorporates proprietary and patented design techniques to achieve excellent AC performance with 15-MHz bandwidth, 5-V/μs slew rate, and low distortion while drawing 1-mA quiescent current per amplifier. The input common-mode voltage extends to the power rail, and the output swings rail-to-rail. The amplifier can be used as a plug-in replacement for many commercially available op-amps to improve performance. Considering the requirement of the low standby power, there is a shutdown function which is in TPA5571NQ with only 7.5-μA shutdown current.

Typical Application Circuit



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

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

Table of Contents

Revision History

Date	Revision	Notes
2024-5-10	Rev.A.0	Initial version.
2024-7-5	Rev.A.1	The following updates are all about the typo, the actual product remains unchanged. The condition of V_{OS} is modified from V_S = 3.3 V, V_{CM} = 2.5 V, T_A = −40°C to 125°C to V_S = 3.3 V, V_{CM} = 1.65 V, T_A = −40°C to 125°C

Pin Configuration and Functions

TPA5571Q
SOT23-5 Package
Top View

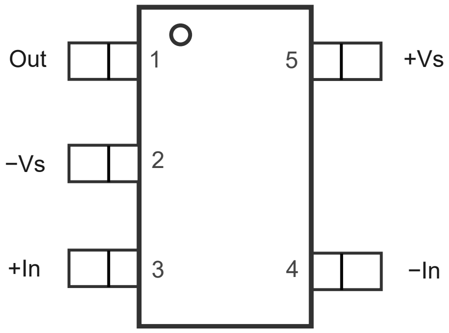


Table 1. Pin Functions: TPA5571Q

Pin No. TPA5571Q	Name	I/O	Description
1	Out	Output	Output
2	$-V_S$		Negative power supply
3	+In	Input	Noninverting input
4	−In	Input	Inverting input
5	$+V_S$		Positive power supply

TPA5571NQ
SOT23-6 Package
Top View

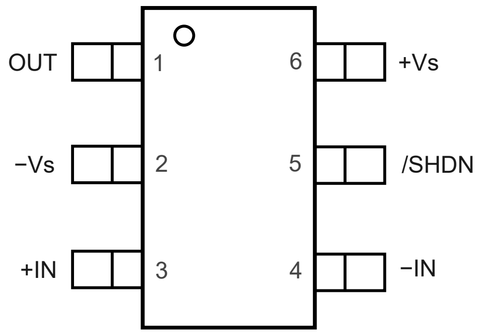
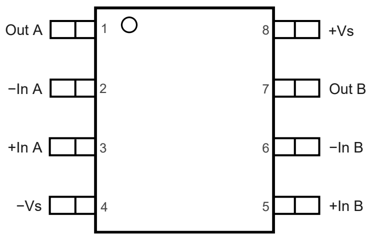


Table 2. Pin Functions: TPA5571NQ

Pin No.	Name	I/O	Description
1	Out	Output	Output
2	$-V_S$		Negative power supply
3	+In	Input	Noninverting input
4	−In	Input	Inverting input
5	/SHDN	Input	Shut down input. The device is shut down when the low-level input voltage is on the input; the device is active when the high-level input voltage is on the input. The device is active in default with a 10-MΩ internal pull-up resistor.
6	$+V_S$		Positive power supply

TPA5572Q
SOP8 Package
Top View



TPA5572Q
MSOP8 Package
Top View

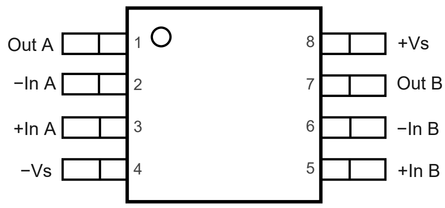


Table 3. Pin Functions: TPA5572Q

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

Specifications

Absolute Maximum Ratings (1)

Over operating ambient temperature, unless otherwise noted.

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 Voltage	$(-V_S) - 0.3$	$(+V_S) + 0.3$	V
Output Short-Circuit Duration (3)		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 the 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	AEC-Q100-002	3	kV
CDM	Charged Device Model ESD	AEC-Q100-011	1.5	kV

Recommended Operating Conditions

Parameter		Min	Typ	Max	Unit
V_S	Supply Voltage, ($+V_S$) – ($−V_S$)	2.7		5.5	V
T_A	Operating Temperature Range	−40		125	°C

Thermal Information

Package Type	$θ_{JA}$	$θ_{JC}$	Unit
SOT23-5	250	81	°C/W
SOP8	158	43	°C/W
MSOP8	210	45	°C/W

Electrical Characteristics

Test condition is at V_S = 5 V, T_A = 25°C, R_L = 10 kΩ, C_L = 100 pF, unless otherwise noted

Parameter		Conditions	Min	Typ	Max	Unit
Power Supply						
V_S	Supply Voltage Range	Supply Voltage, (+VS) – (−VS), T_A = −40°C to 125°C	2.7		5.5	V
I_Q	Quiescent Current per Amplifier	V_S = 2.7 V to 5.5 V, T_A = −40°C to 125°C		1	1.8	mA
	Shutdown Current	V_S = 2.7 to 5.5 V, /SHDN = 0 V, T_A = −40°C to 125°C		7.5	21	µA
	Input Logic High of Shutdown	T_A = −40°C to 125°C	0.7 × V_S			V
	Input Logic Low of Shutdown	T_A = −40°C to 125°C			0.3 × V_S	V
PSRR	Power Supply Rejection Ratio	V_S = 2.7 V to 5.5 V	114	124		dB
		V_S = 2.7 V to 5.5 V, T_A = −40°C to 125°C	110			dB
Input Characteristics						
V_{OS}	Input Offset Voltage	V_S = 5 V, V_{CM} = 2.5 V, T_A = −40°C to 125°C	−150	10	150	µV
		V_S = 3.3 V, V_{CM} = 1.65 V, T_A = −40°C to 125°C	−150	10	150	µV
V_{OS} TC	Input Offset Voltage Drift	T_A = −40°C to 125°C		0.01		µV/°C
I_B	Input Bias Current	V_S = 5 V, V_{CM} = 2.5 V		200	1000	pA
		V_S = 5 V, V_{CM} = 2.5 V, T_A = −40°C to 125°C			1500	pA
I_{OS}	Input Offset Current	V_S = 5 V, V_{CM} = 2.5 V		100	600	pA
		V_S = 5 V, V_{CM} = 2.5 V, T_A = −40°C to 125°C			1000	pA
R_{IN}		Common Mode		5		GΩ
C_{IN}	Input Capacitance	Differential Mode		2		pF
		Common Mode		5		pF
Av	Open−Loop Voltage Gain	V_O = 0.5 V to 4.5 V	120	150		dB
		V_O = 0.5 V to 4.5 V, T_A = −40°C to 125°C	115			dB
V_{CMR}	Common−Mode Input Voltage Range	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 5V	115	144		dB
		V_{CM} = 0 V to 5 V, T_A= −40°C to 125°C	110			dB
Output Characteristics						

Parameter		Conditions	Min	Typ	Max	Unit
	Output Voltage Swing from Positive Rail or Negative Rail	R_{LOAD} = 10 kΩ to V_S/2, T_A = −40°C to 125°C		5	10	mV
		R_{LOAD} = 2 kΩ to V_S/2, T_A = −40°C to 125°C		22	35	mV
I_{SC}	Output Short−Circuit Current	Sink or Source	128	160		mA
		Sink or Source, T_A = −40°C to 125°C	100			mA
AC Specifications						
GBW	Gain−Bandwidth Product			15		MHz
SR	Slew Rate	G = 1, 2 V step		5		V/μs
t_{OR}	Overload Recovery			5		μs
t_S	Settling Time, 0.1%	G = 1, 2 V step		3		us
	Settling Time, 0.01%			4		μs
PM	Phase Margin	R_L = 10 kΩ, C_L = 100 pF		45		°
GM	Gain Margin	R_L = 10 kΩ, C_L = 100 pF		10		dB
	Channel Separation	f = 100 kHz		120		dB
Noise Performance						
E_N	Input Voltage Noise	f = 0.1 Hz to 10 Hz		0.2		μV_{PP}
e_N	Input Voltage Noise Density	f = 1 kHz		10		nV/√Hz
i_N	Input Current Noise	f = 1 kHz		200		fA/√Hz
THD+N	Total Harmonic Distortion and Noise	G = 1, f = 1 kHz, V_O = 1 V_{RMS}, R_L = 2 kΩ		0.0007		%

Typical Performance Characteristics

All test conditions: V_S = 5 V, T_A = +25°C, the test device is TPA5571QN-S6TR, unless otherwise noted.

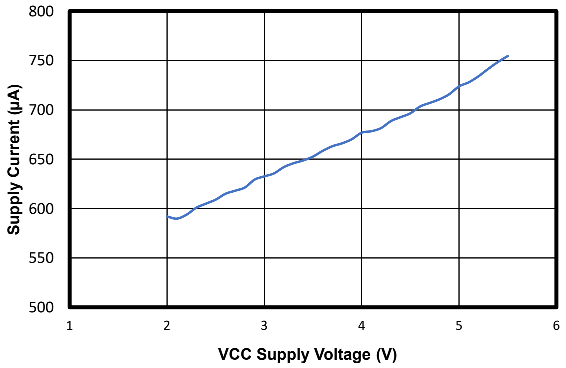


Figure 1. Supply Current vs Supply Voltage

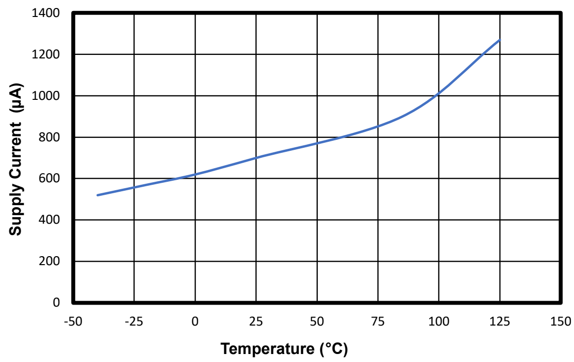


Figure 2. Supply Current vs Temperature

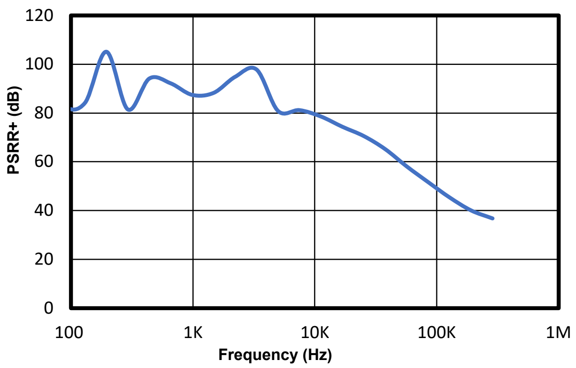


Figure 3. PSRR+ vs Frequency

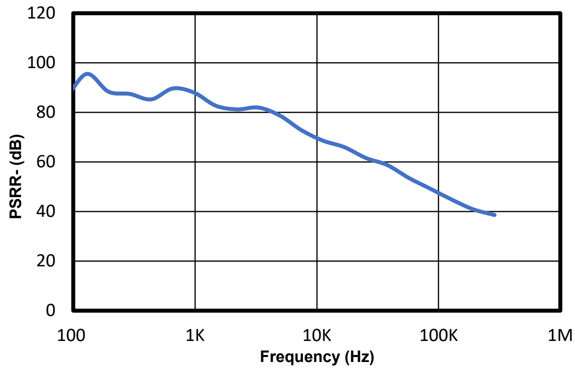


Figure 4. PSRR− vs Frequency

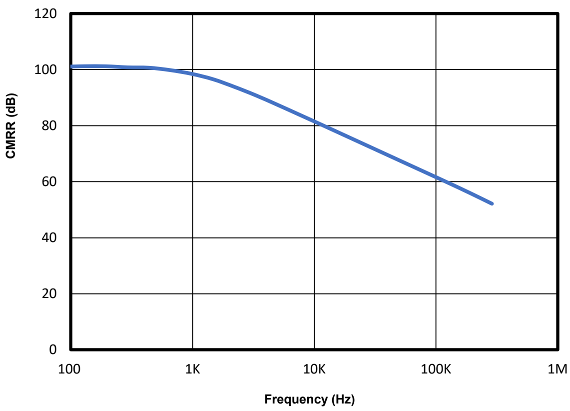


Figure 5. CMRR vs Frequency

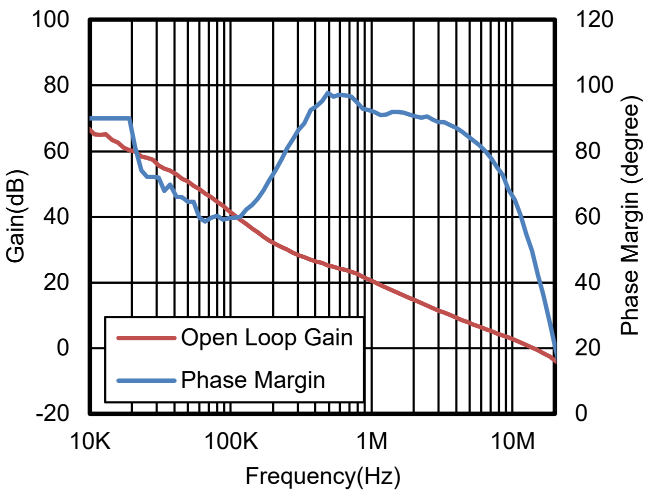


Figure 6. Open Loop Gain and Phase Margin vs Frequency, RL = 10 kΩ, CL = 100 pF

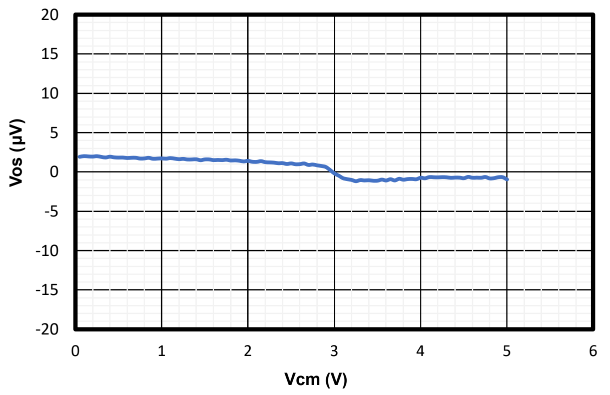


Figure 7. V_{OS} vs V_{CM}, V_S= 5 V

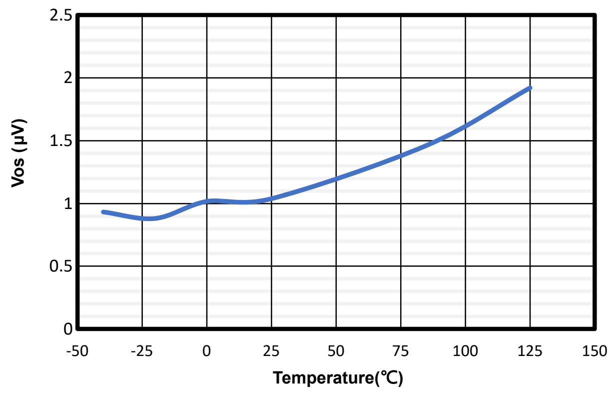


Figure 8. V_{OS} vs Temperature

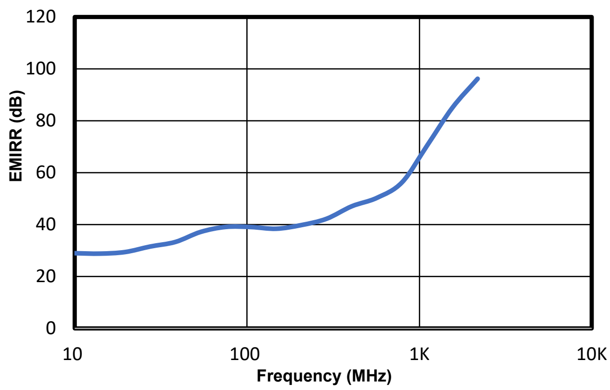


Figure 9. EMIRR vs Frequency

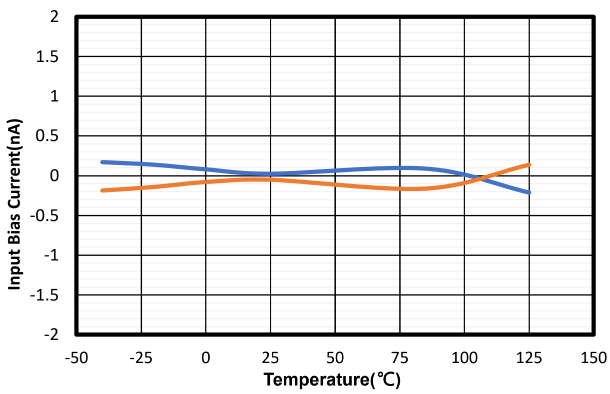


Figure 10. I_B vs Temperature

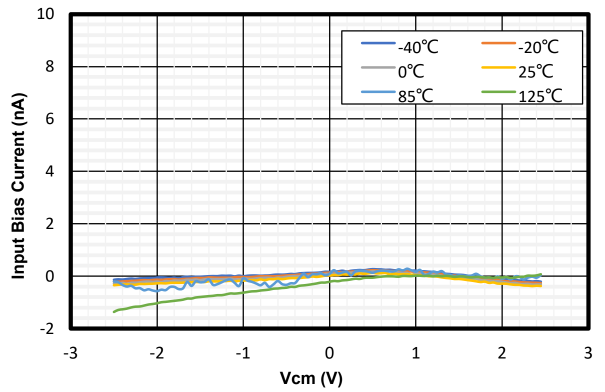


Figure 11. I_B vs Common Voltage, ($-V_S$) = −2.5 V, ($+V_S$) = 2.5 V

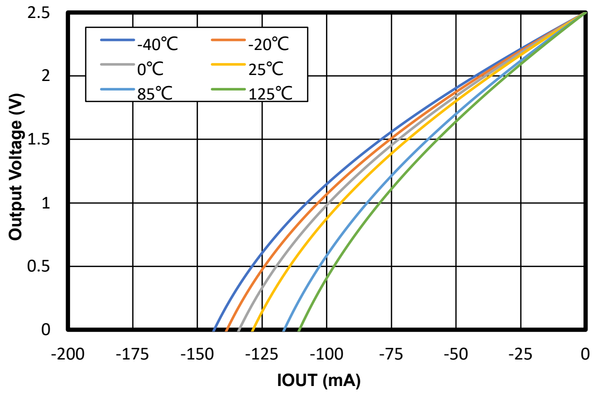


Figure 12. Output Voltage vs Output Current, (−V) = −2.5 V, (+VS) = 2.5 V

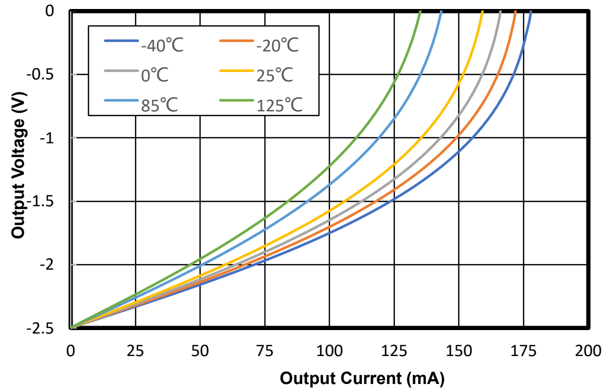


Figure 13. Output Voltage vs Output Current, (−VS) = −2.5 V, (+VS) = 2.5 V

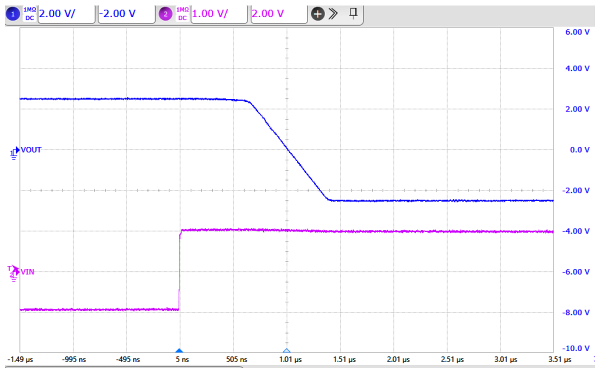


Figure 14. Overload Recovery at Negative Rail

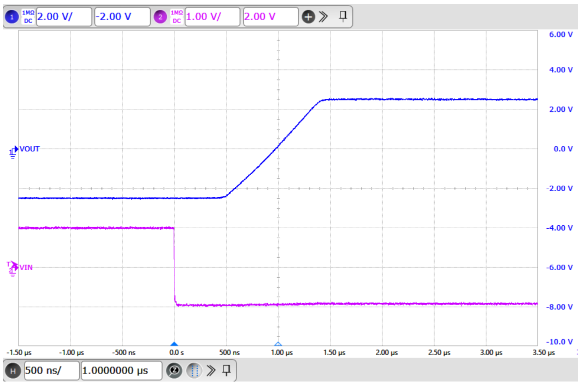


Figure 15. Overload Recovery at Positive Rail

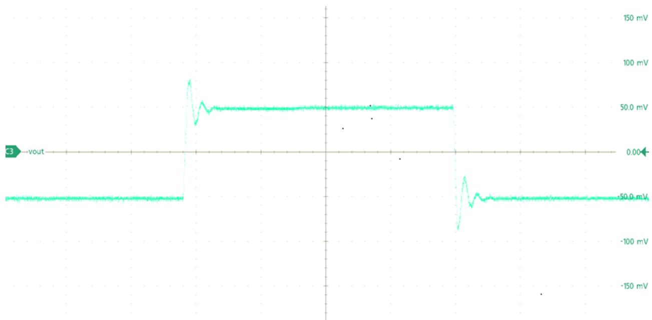


Figure 16. Small Signal Step Response: 50 mV/div, Time: 400 ns/div

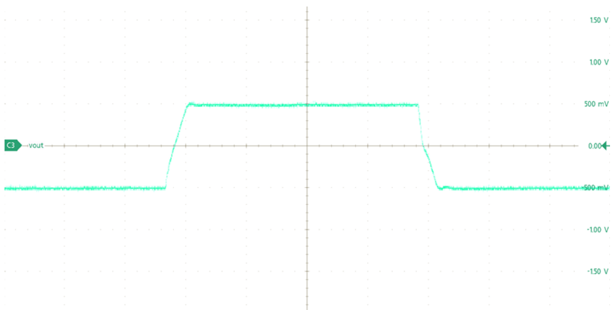


Figure 17. Large Signal Step Response: 500 mV/div, Time: 400 ns/div

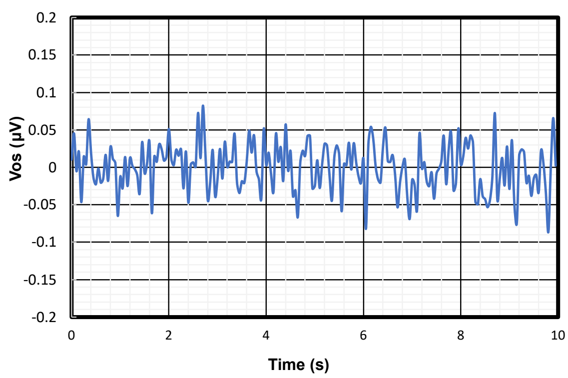


Figure 18. 0.1 to 10 Hz Voltage Noise, V_{CM} = 0 V

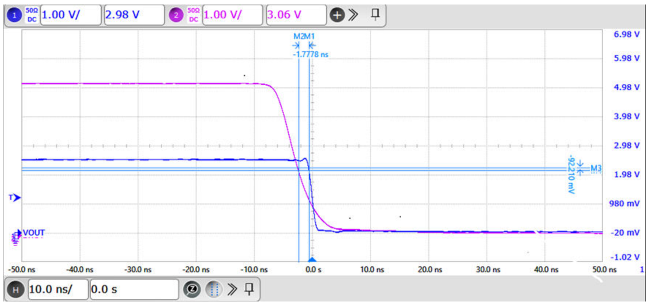


Figure 19. Turnoff Transient

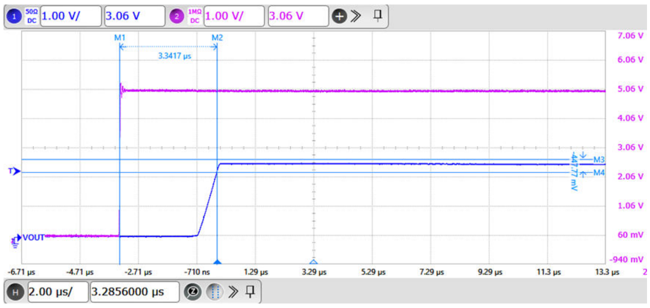


Figure 20. Turnon Transient

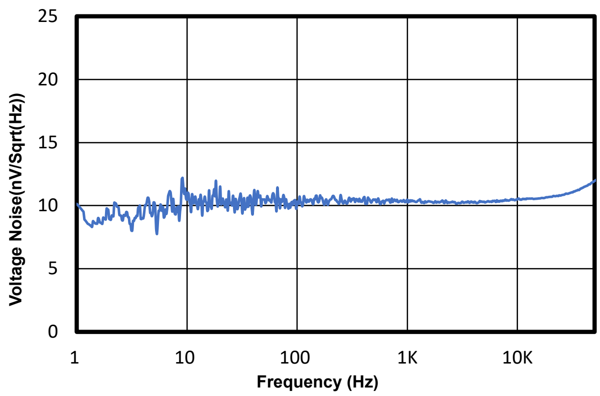


Figure 21. Voltage Noise Spectral Density vs Frequency, V_{CM} = 1 V

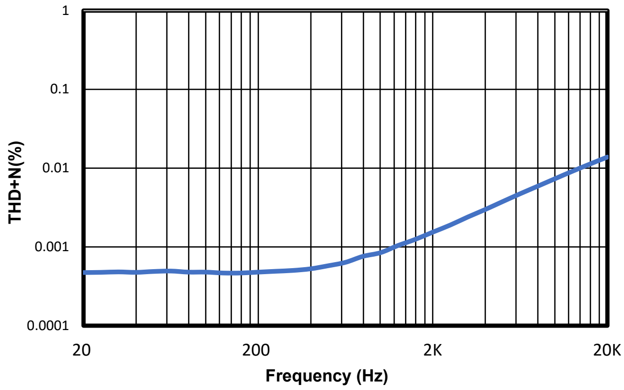


Figure 22. THD vs Frequency, G = 1, V_{IN} = 1 V_{RMS}

Detailed Description

Overview

The TPA557xQ family of zero-drift amplifiers can operate on a single-supply voltage (2.7 V to 5.5 V), or a split-supply voltage (±1.35 V to ±2.75 V).

Functional Block Diagram

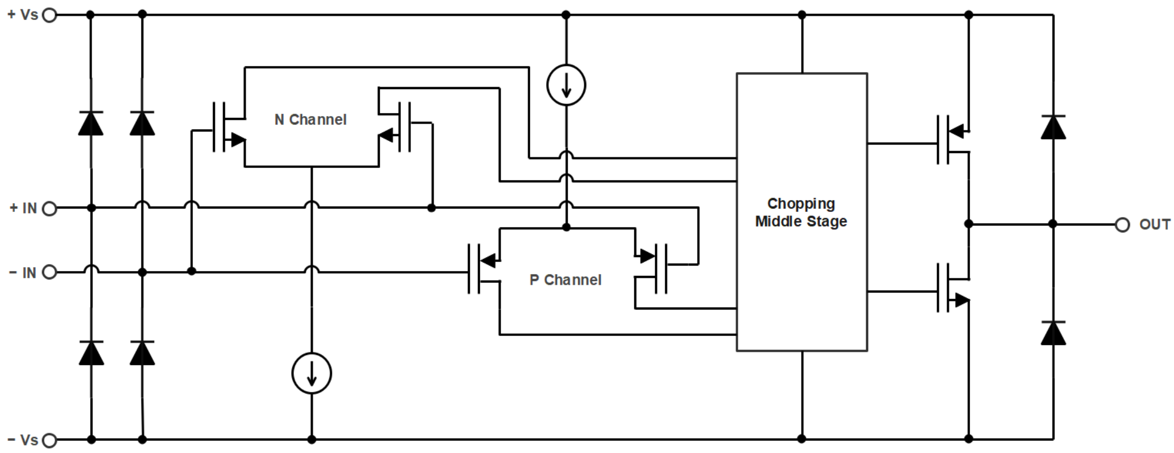


Figure 23. Functional Block Diagram

Feature Description

Operating Voltage

The TPA557xQ family of op amplifiers is designed for single supply operation from 2.7 V to 5.5 V or dual supply operation from ±1.35 V to ±2.75 V.

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 the residual ripple.

The devices set the chopping frequency to 400 kHz. If the frequency of the 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 be placed at the output of the amplifier.

Rail-to-Rail Input

The input common-mode voltage range of the TPA557xQ family extends 100 mV beyond the supply rails. This performance is achieved with a complementary input stage: a P-channel input differential pair in parallel with an N-channel differential pair. The P-channel pair is active for inputs from 100 mV below the negative supply to approximately (+V_S) – 1.5 V, whereas the N-channel pair is active for input voltages close to the positive rail, typically (+V_S) – 1.5 V to 100 mV above the positive supply. There is around 200-mV transition region at (+V_S) – 1.5 V where both pairs are on. Within this transition region, PSRR, CMRR, offset voltage, offset drift, and THD can degrade compared to that operating outside this region.

Rail-to-Rail Output

The TPA557x family delivers 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.

Shutdown Function

The shutdown function is available in the TPA557xNQ. The operational amplifier is enabled with a valid high voltage and shut down by a valid low voltage. A valid high level is defined as 0.7 × V_S and a valid low level is defined as 0.3 × V_S , the valid voltage level refers to the voltage on ($-V_S$) . The pin of SHDN is internally pulled up to a valid high level when this pin is left float, so the amplifier is enabled initially if the shutdown pin is floated. The output state of the amplifier is high-impedance state when it is shut down.

Application and Implementation

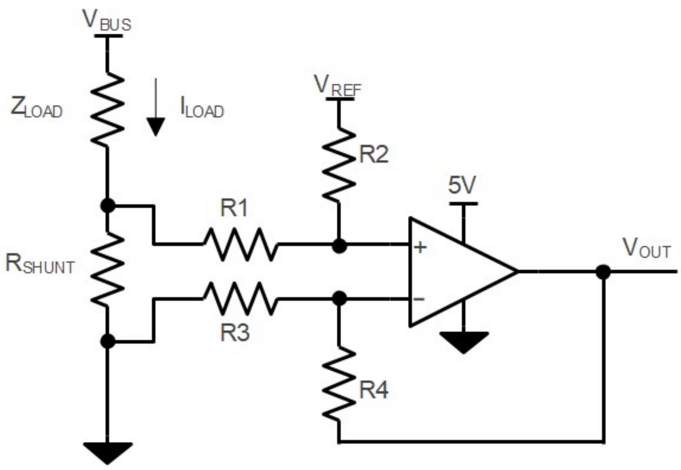
Note

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. 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.



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

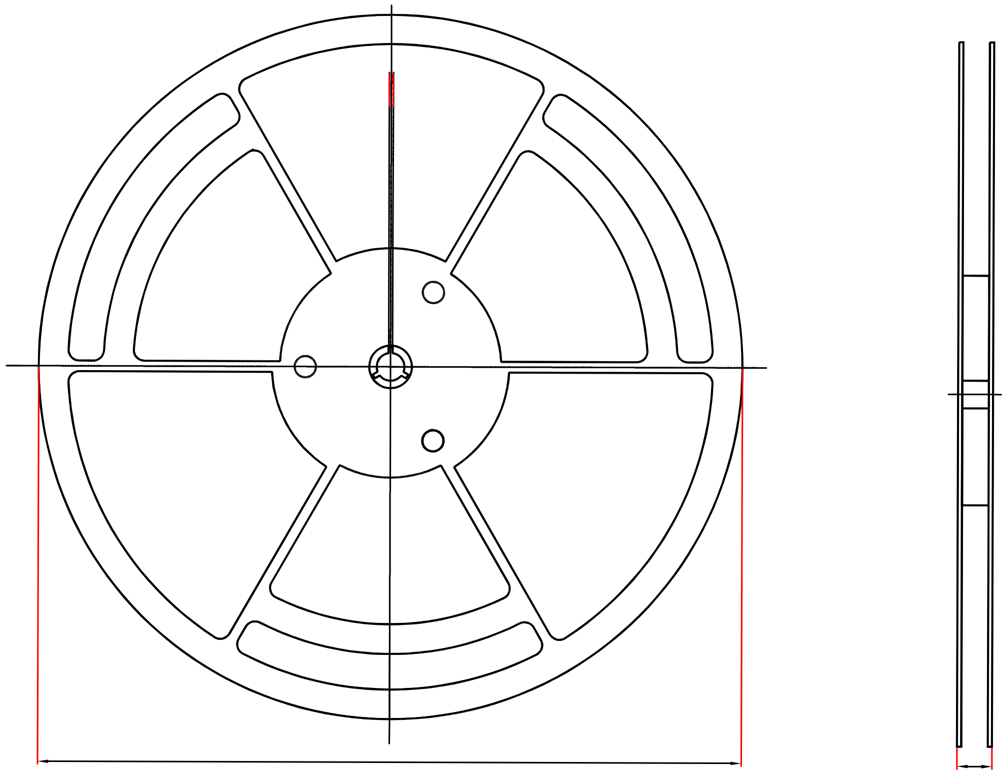
When R3 = R1, R2 = R4, R_{SHUNT} << R1

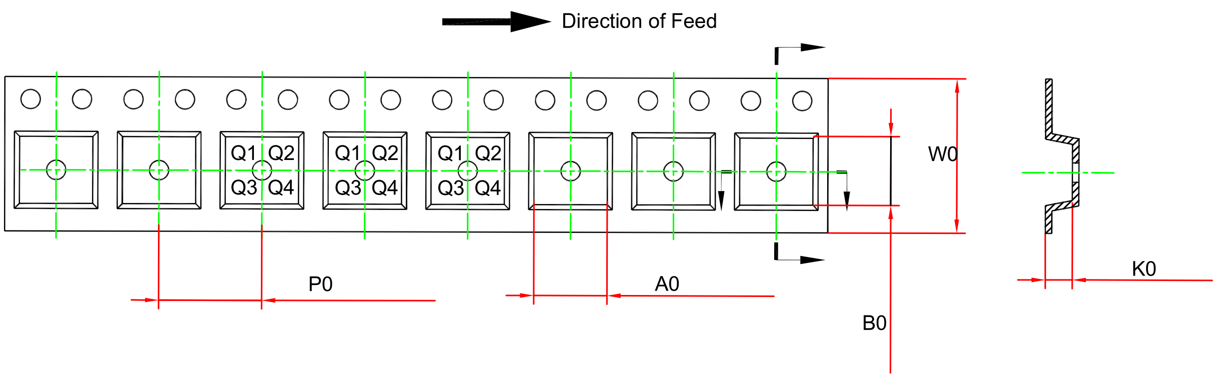
Figure 24. Low-Side Current Sensing Application

Power Supply Recommendations

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

Tape and Reel Information



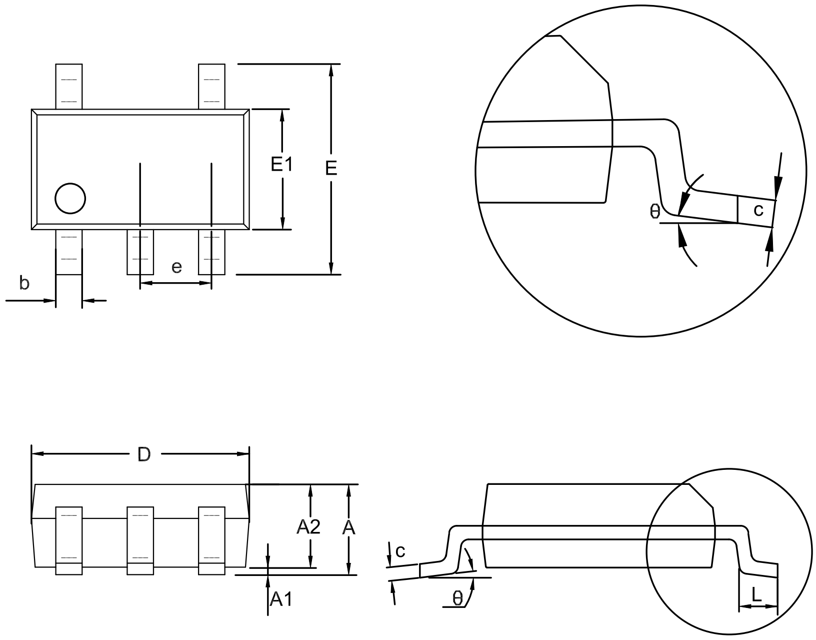


Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPA5571NQ-S6TR-S	SOT23-6	180.0	12	3.3	3.25	1.4	4.0	8.0	Q3
TPA5571Q-S5TR-S	SOT23-5	180.0	12	3.3	3.25	1.4	4.0	8.0	Q3
TPA5572Q-SO1R-S	SOP8	330.0	17.6	6.5	5.4	2.0	8.0	12.0	Q1
TPA5572Q-VS1R-S	MSOP8	330.0	17.6	5.3	3.4	1.3	8.0	12.0	Q1

Package Outline Dimensions

SOT23-5

Package Outline Dimensions S5T(SOT23-5-A)



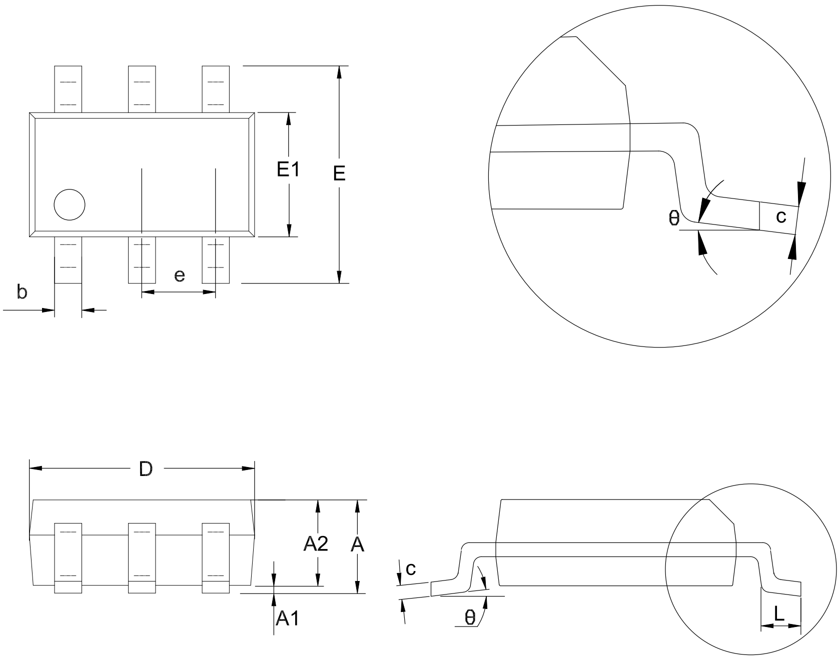
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.150	0.000	0.006
A2	1.000	1.200	0.039	0.047
b	0.280	0.500	0.011	0.020
c	0.100	0.230	0.004	0.009
D	2.820	3.020	0.111	0.119
E	2.600	3.000	0.102	0.118
E1	1.500	1.720	0.059	0.068
e	0.950 BSC		0.037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

SOT23-6

Package Outline Dimensions S6T(SOT23-6-A)



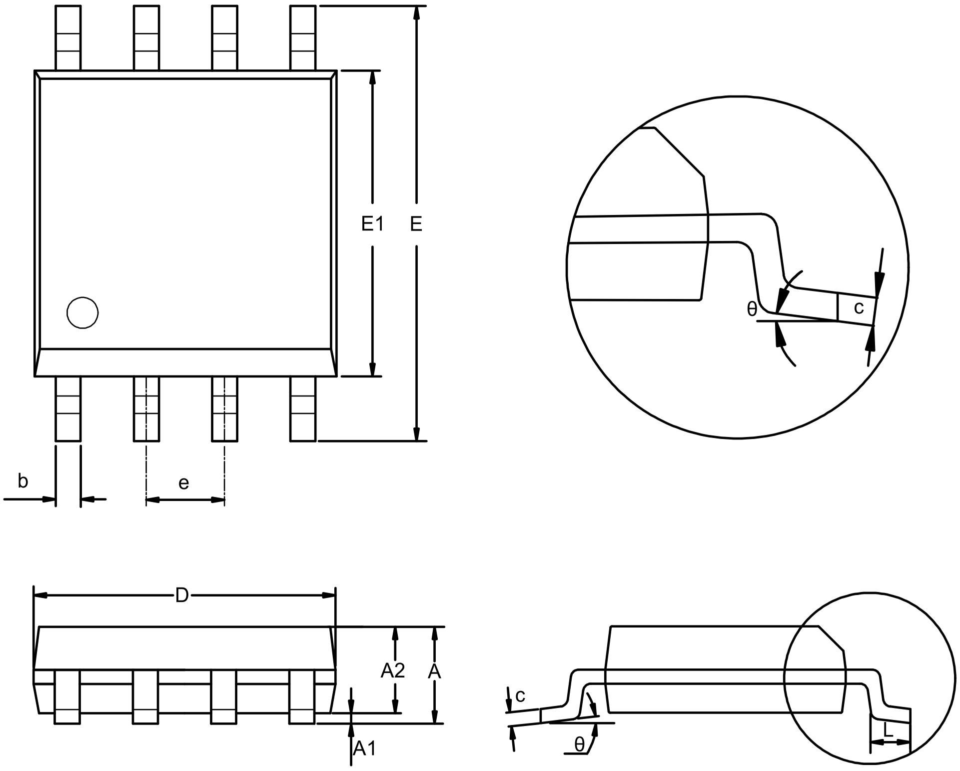
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.150	0.000	0.006
A2	1.000	1.200	0.039	0.047
b	0.280	0.500	0.011	0.020
c	0.100	0.230	0.004	0.009
D	2.820	3.020	0.111	0.119
E	2.600	3.000	0.102	0.118
E1	1.500	1.720	0.059	0.068
e	0.950 BSC		0.037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

MSOP8

Package Outline Dimensions VS1(MSOP-8-A)



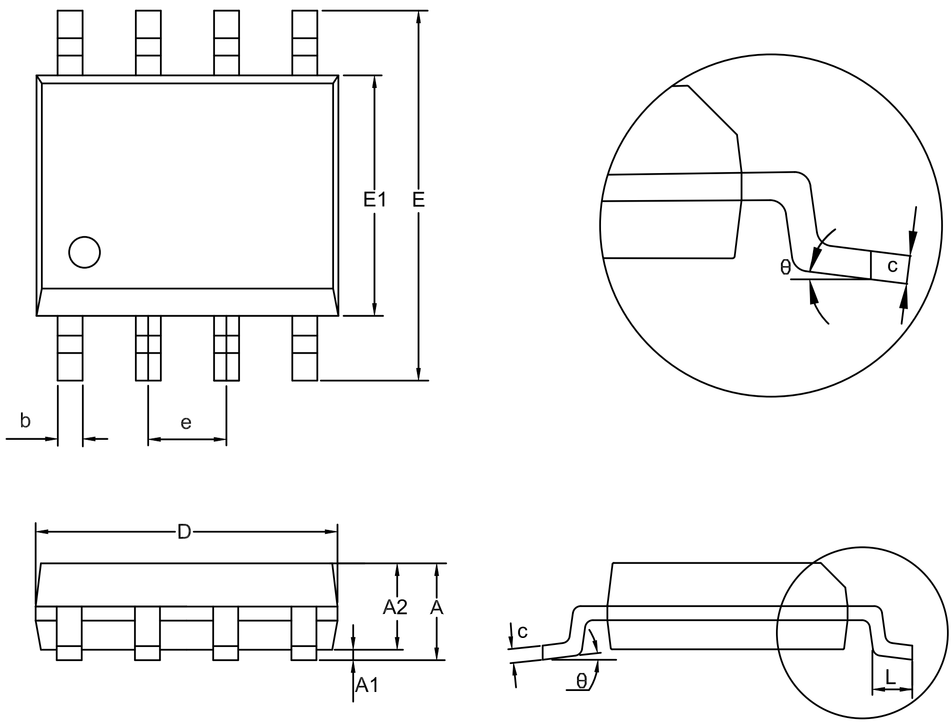
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.800	1.100	0.031	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	4.700	5.100	0.185	0.201
E1	2.900	3.100	0.114	0.122
e	0.650 BSC		0.026 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
TPA5571NQ-S6TR-S	−40 to 125°C	SOT23-6	A51	1	Tape and Reel, 3000	Green
TPA5571Q-S5TR-S	−40 to 125°C	SOT23-5	A50	1	Tape and Reel, 3000	Green
TPA5572Q-SO1R-S	−40 to 125°C	SOP8	5572Q	1	Tape and Reel, 4000	Green
TPA5572Q-VS1R-S	−40 to 125°C	MSOP8	5572Q	1	Tape and Reel, 3000	Green

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

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