36-V, 50-MHz, RRO Operational Amplifier

Features

- Supply Voltage: 4.5 V to 36 V
- Unity-Gain Stable
- Offset Voltage: ±1.5 mV Maximum at 25°C
- High Speed:
  - Bandwidth: 50 MHz
  - Slew Rate: 20 V/μs
- Very Low Distortion:
  - THD+N = –119 dBc (f = 1 kHz, BW = 80 kHz)
- Rail-to-Rail Output
- Low Noise: 7 nV/√Hz at 1 kHz

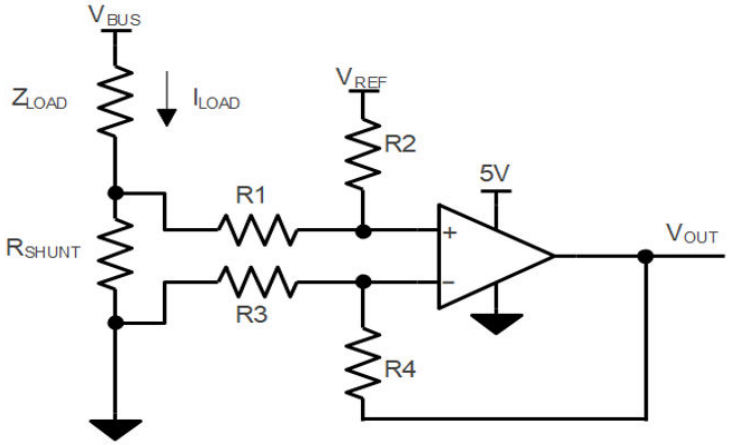
Applications

- Low-noise, Wide-band Amplifier for Industrial Applications
- Active Filters
- Video Amplifiers
- Guitar and other Instrument Amplifier
- Soundbar

Description

The TPA250x is a series of ultra-low voltage noise, high-speed voltage feedback amplifiers. The TPA250x is an excellent choice for applications requiring low voltage noise, including communications and imaging. The TPA250x offers very good AC performance with 50 MHz bandwidth, gain = 1 V/V, 20 V/μs slew rate, and 120 ns settling time (0.1%). These amplifiers draw only 8 mA (Type) supply current per channel at 25℃ under 36 V supply voltage. The TPA250x has a very low noise of 7 nV/√Hz at 1 kHz, which is designed for applications requiring low distortion and low noise, such as buffering analog-to-digital converters.

Typical Application Circuit



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

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

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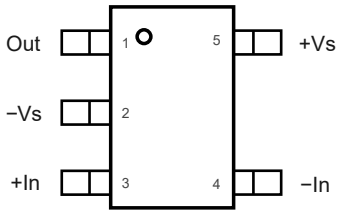
Revision History

Date	Revision	Notes
2025-12-24	Rev.A.0	Initial version.

Pin Configuration and Functions

TPA2501
SOT23-5
Top View



TPA2501
SOP8
Top View

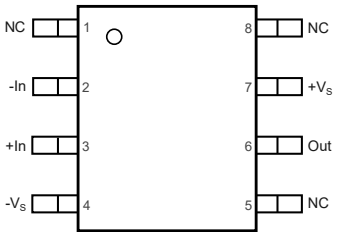
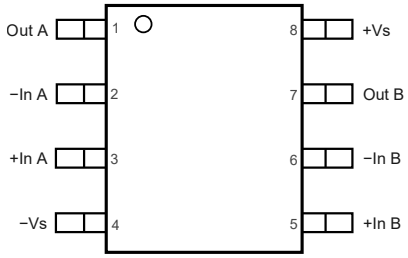


Table 1. Pin Functions: TPA2501

Pin No.		Name	I/O	Description
SOT23-5	SOP8			
1	6	Out	O	Output
2	4	$-V_S$		Negative power supply
3	3	+In	I	Non-inverting input
4	2	−In	I	Inverting input
5	7	$+V_S$		Positive power supply
	1	NC		Not Connected
	5	NC		Not Connected
	8	NC		Not Connected

TPA2502
SOP8
Top View



TPA2502
MSOP8
Top View

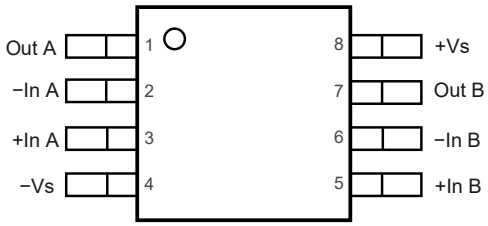
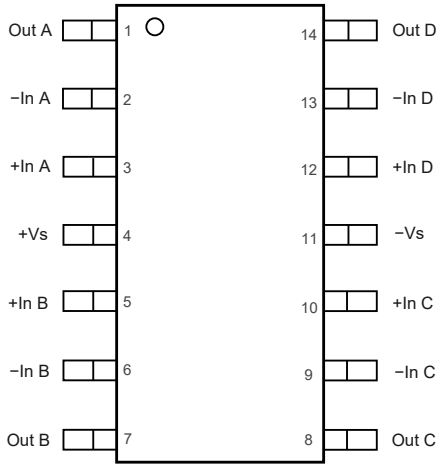


Table 2. Pin Functions: TPA2502

Pin No.		Name	I/O	Description
SOP8	MSOP8			
1	1	Out A	O	Output
2	2	−In A	I	Inverting input
3	3	+In A	I	Non-inverting input
4	4	$-V_S$		Negative power supply
5	5	+In B	I	Non-inverting input
6	6	−In B	I	Inverting input
7	7	Out B	O	Output
8	8	$+V_S$		Positive power supply

TPA2504
SOP14
Top View



TPA2504
TSSOP14
Top View

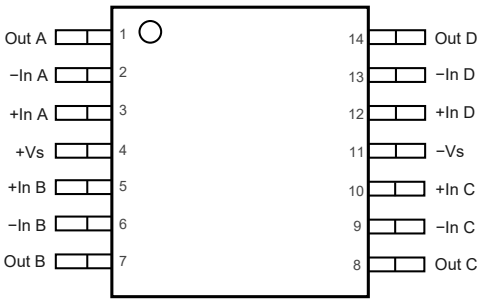


Table 3. Pin Functions: TPA2504

Pin No.		Name	I/O	Description
SOP14	TSSOP14			
1	1	Out A	O	Output
2	2	−In A	I	Inverting input
3	3	+In A	I	Non-inverting input
4	4	$+V_S$		Positive power supply
5	5	+In B	I	Non-inverting input
6	6	−In B	I	Inverting input
7	7	Out B	O	Output
8	8	Out C	O	Output
9	9	−In C	I	Inverting input
10	10	+In C	I	Non-inverting input
11	11	$-V_S$		Negative power supply
12	12	+In D	I	Non-inverting input
13	13	−In D	I	Inverting input
14	14	Out D	O	Output

Specifications

Absolute Maximum Ratings (1)

Parameter		Min	Max	Unit
	Supply Voltage, $(+V_S) - (-V_S)$		40	V
	Input Voltage	$(-V_S) - 0.3$	$(+V_S) + 0.3$	V
	Differential Input Voltage	−1.5	1.5	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	
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. The thermal resistance varies with the amount of PC board metal connected to the package.

ESD, Electrostatic Discharge Protection

Symbol	Parameter	Condition	Minimum Level	Unit
HBM	Human Body Model ESD	ANSI/ESDA/JEDEC JS-001 (1)	7	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, $(+V_S) - (-V_S)$	4.5		36	V
T_A	Operating Temperature Range	−40		125	℃

Thermal Information

Package Type	θ_{JA}	θ_{JC}	Unit
SOT23-5	250	81	°C/W

Package Type	θ_{JA}	θ_{JC}	Unit
SOP8	158	43	°C/W
MSOP8	210	45	°C/W
SOP14	120	36	°C/W
TSSOP14	180	35	°C/W

Electrical Characteristics

All test conditions: V_S = 36 V, V_{CM} = V_S / 2, T_A = 25°C, R_L = 2 kΩ, unless otherwise noted.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Power Supply						
V_S	Supply Voltage Range	(+V_S) − (−V_S)	4.5		36	V
I_Q	Quiescent Current per Amplifier	V_S = 5 V		5.5	6.5	mA
		V_S = 5 V, T_A = −40°C to 125°C			8.5	mA
		V_S = 36 V		8	9	mA
		V_S = 36 V, T_A = −40°C to 125°C			10.5	mA
PSRR	Power Supply Rejection Ratio	V_S = 4.5 V to 36 V	95	105		dB
		V_S = 4.5 V to 36 V, T_A = −40°C to 125°C	90			dB
Input Characteristics						
V_{OS}	Input Offset Voltage	V_S = 5 V, V_{CM} = 2.5 V	−1	±0.2	1	mV
		V_S = 5 V, T_A = −40°C to 125°C	−1.5		1.5	mV
		V_S = 36 V, V_{CM} = 18 V	−1.5	±0.2	1.5	mV
		V_S = 36 V, T_A = −40°C to 125°C	−2		2	mV
V_{OS} TC	Input Offset Voltage Drift	V_S = 5 V, T_A = −40°C to 125°C		2.5		μV/°C
		V_S = 36 V, T_A = −40°C to 125°C		2.5		μV/°C
I_B	Input Bias Current	V_S = 5 V to 36 V	−2.0	±1.6	2.0	μA
I_{OS}	Input Offset Current	V_S = 4.5 V to 36V		±35		nA
A_V	Open-Loop Voltage Gain	V_{OUT} = 0.4 V to 4.6 V	85	90		dB
		V_{OUT} = 0.4 V to 4.6 V, T_A = −40°C to 125°C	80			dB
V_{CMR}	Common-Mode Input Voltage Range		(−V_S) + 1.3		(+V_S) - 1.5	V
CMRR	Common-Mode Rejection Ratio	V_S = 5 V, V_{CM} = 1.3 V to 3.5 V	90	105		dB
		V_S = 5 V, V_{CM} = 1.3 V to 3.5 V, T_A = −40°C to 125°C	85			dB
		V_S = 36 V, V_{CM} = 1.3 V to 34.5 V	90	105		dB
		V_S = 36 V, V_{CM} = 1.3 V to 34.5 V, T_A = −40°C to 125°C	85			dB
Output Characteristics						
	Output Swing from Positive Rail	V_S = 5 V, R_L = 2 kΩ to V_S / 2		20	40	mV
		V_S = 36 V, R_L = 2 kΩ to V_S / 2		180	200	mV
		V_S = 5 V, Rmo_L = 75 Ω to V_S / 2		410	450	mV
	Output Swing from Negative Rail	V_S = 5 V, R_L = 2 kΩ to V_S / 2		20	40	mV

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
		V_S = 36 V, R_L = 2 kΩ to V_S / 2		160	180	mV
		V_S = 5 V, R_L = 75 Ω to V_S / 2		410	450	mV
I_{SC}	Output Short-Circuit Current	V_S = 5 V, R_L = 75 Ω to V_S, Sink		50		mA
		V_S = 5 V, R_L = 75 Ω to ground, Source		50		mA
AC Specifications						
GBW	Gain-Bandwidth Product	G = 10		50		MHz
PM	Phase Margin	G = 10, R_L= 2 kΩ, C_L= 10 pF		45		°
SR	Slew Rate Up	G = 1, f = 1 kHz, VOUT = 2 V_{PP}		20		V/μs
	Slew Rate Down	G = 1, f = 1 kHz, VOUT = 2 V_{PP}		20		V/μs
t_{OR}	Overload Recovery			150		ns
t_S	Settling Time, 0.1%	G = 1, 2 V step		120		ns
Noise Performance						
e_N	Input Voltage Noise Density	V_S = 5 V, f = 1 kHz		7		nV/√Hz
THD+N	Total Harmonic Distortion and Noise	f = 1 kHz, VOUT= 0.5 V_{PP}, V = ±2.25 V or 4.5 V, BW = 80 kHz		98		dB
		f = 1 kHz, VOUT= 1 V_{PP}, V = ±2.5 V or 5 V, BW = 80 kHz		105		dB
		f = 1 kHz, VOUT= 6 V_{PP}, V = ±5 V or 10 V, BW = 80 kHz		116		dB
		f = 1 kHz, VOUT= 3 V_{RMS}, V = ±12 V or 24 V, BW = 80 kHz		119		dB

Typical Performance Characteristics

All test conditions: V_S = 30 V, T_A = +25℃, R_L= 2 kΩ, unless otherwise noted.

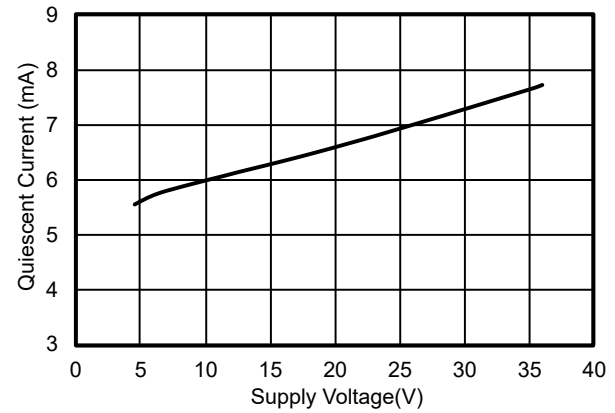


Figure 1. Supply Current vs. Supply Voltage, 1ch

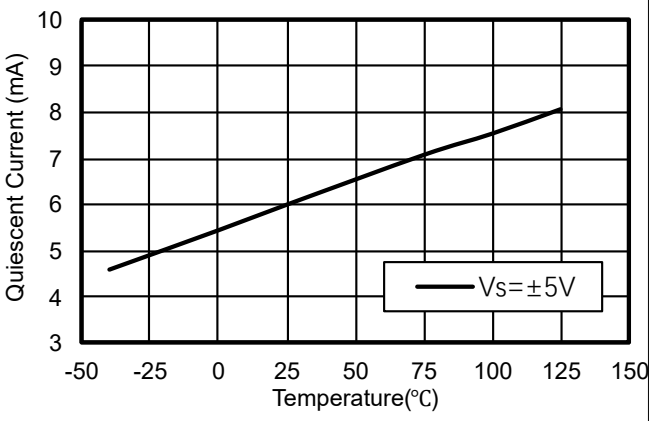


Figure 2. Supply Current vs. Temperature, 1ch

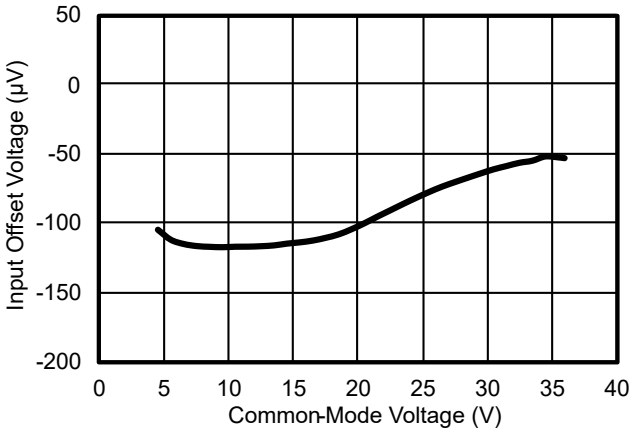


Figure 3. Offset Voltage vs. Supply Voltage

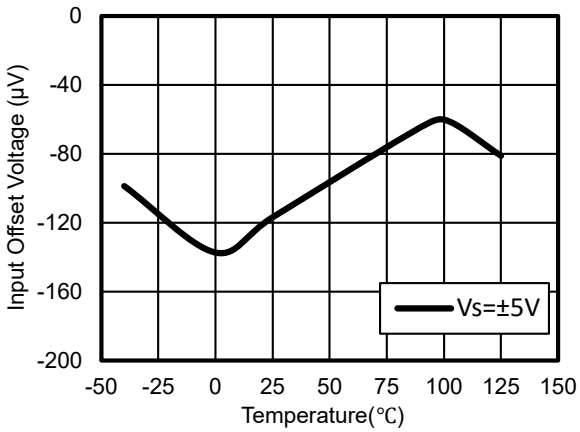


Figure 4. Offset Voltage vs. Temperature

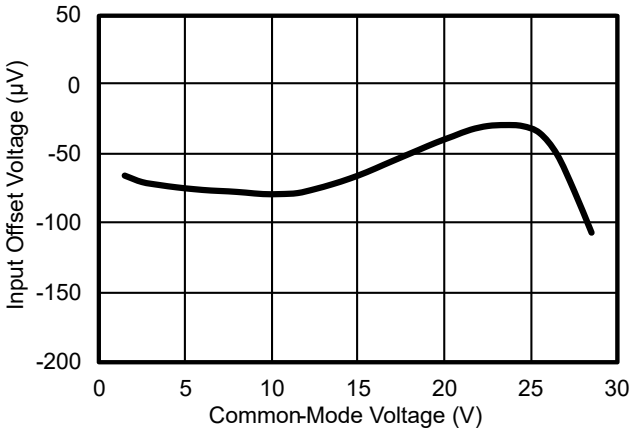


Figure 5. Offset Voltage vs. Common-Mode Voltage

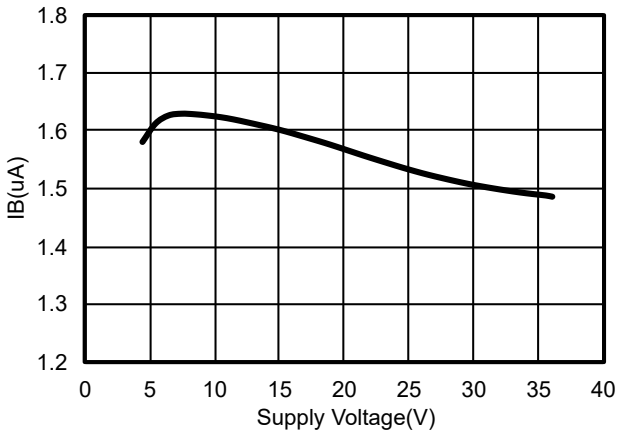


Figure 6. I_B vs. Supply Voltage

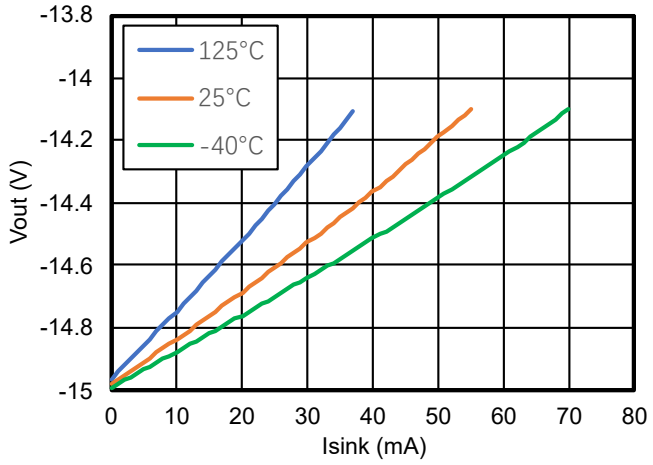


Figure 7. V_{OUT} vs. I_{OUT}, Sink, VCC = ±15 V

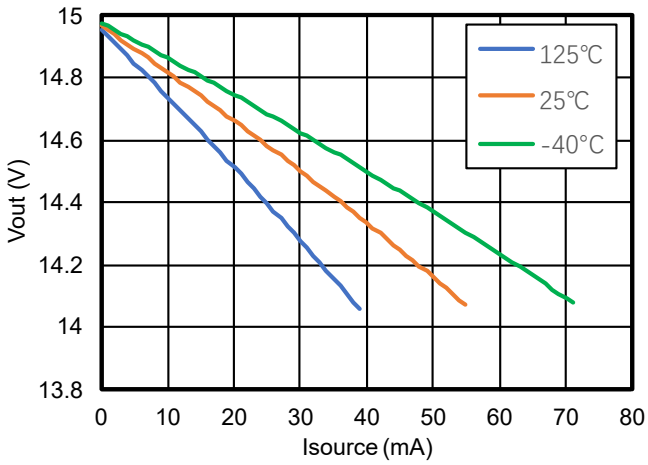


Figure 8. V_{OUT} vs. I_{OUT}, Source, VCC = ±15 V

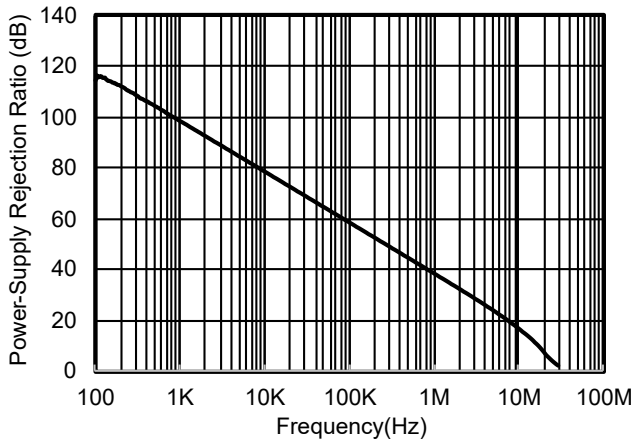


Figure 9. PSRR+ vs. Frequency

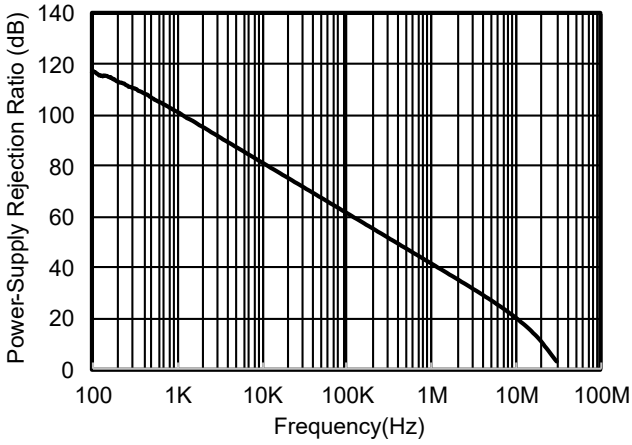


Figure 10. PSRR- vs. Frequency

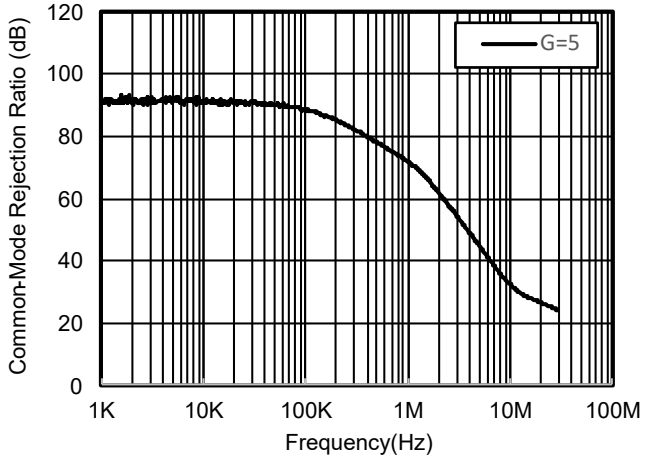


Figure 11. CMRR vs. Frequency

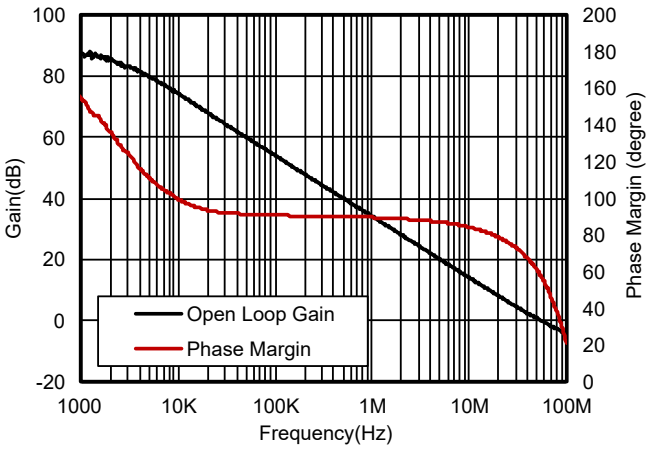


Figure 12. Open-Loop Gain and Phase vs. Frequency, R_L = 2 kΩ

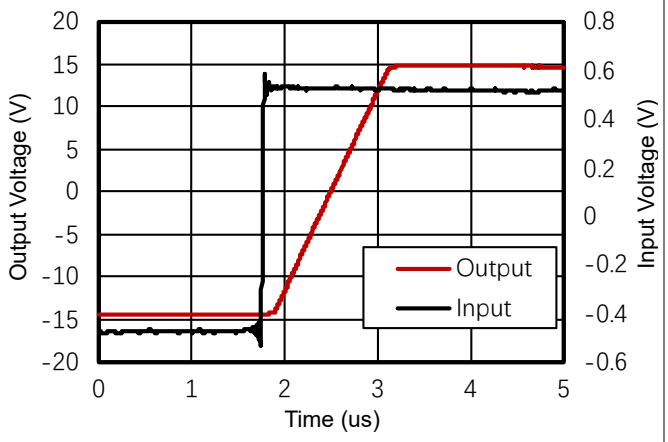


Figure 13. Positive Overload Recovery, G = 5

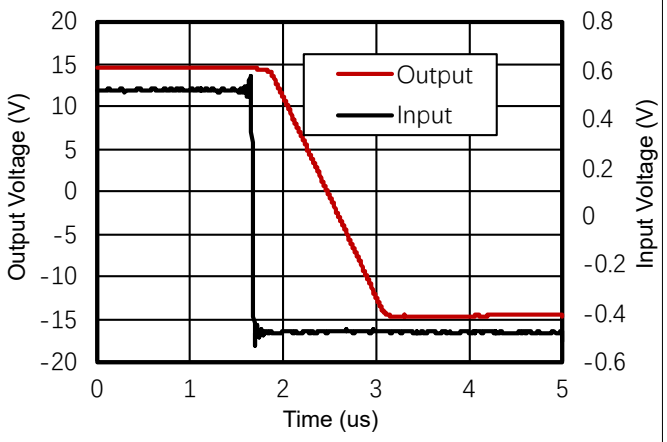


Figure 14. Negative Overload Recovery, G = 5

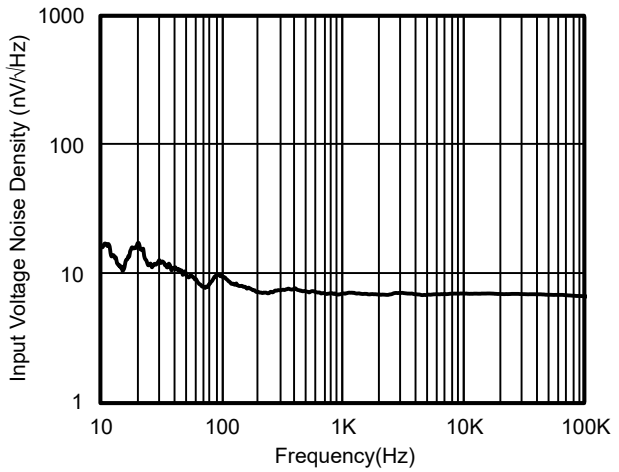


Figure 15. Voltage Noise Spectral Density vs. Frequency

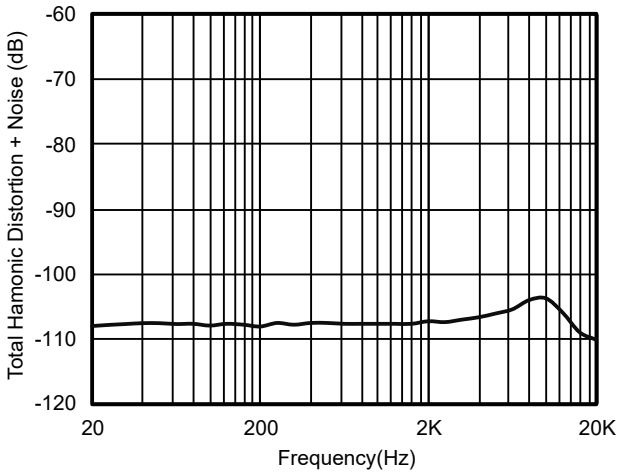


Figure 16. THD+N vs. Frequency, 3 V_{RMS}

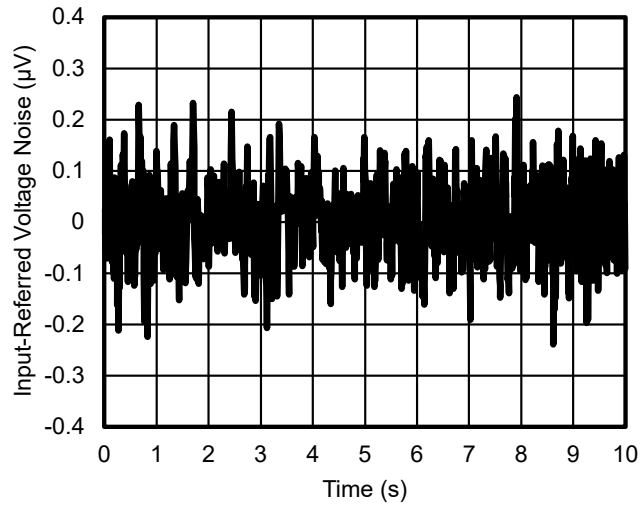


Figure 17. 0.1 Hz to 10 Hz Voltage Noise

Detailed Description

Overview

The TPA250x is a series of op amps that operate on a single-supply voltage (4.5 V to 36 V), or a split-supply voltage (±2.25 V to ±18 V), making the series highly versatile and easy to use. The power-supply pins should have local bypass ceramic capacitors (typically 0.01 µF to 0.1 µF). These amplifiers are fully specified from 4.5 V to 36 V and over the extended temperature range from −40°C to +125°C. Parameters that exhibit variance with regard to operating voltage or temperature are presented in Typical Performance Characteristics.

Functional Block Diagram

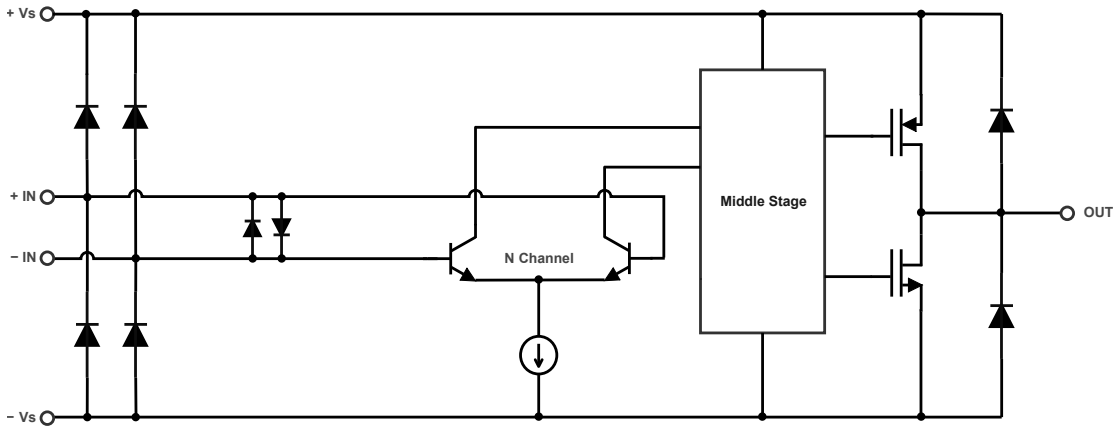


Figure 18. Functional Block Diagram

Feature Description

Operating Voltage

The series is designed for single supply operation from 4.5 V to 36 V or dual supply operation from ±2.25 V to ±18 V.

The recommended operating voltage conditions are as follows:

Power supply voltage ($+V_S$) − ($-V_S$): 4.5 V to 36 V. The power supply voltage can support the following three scenarios:

- Single supply;
- Dual supplies with equal voltage values;
- Various voltage configurations, as long as the voltage range of ($+V_S$) − ($-V_S$) is within 4.5 V to 36 V.

For example, if operating with a single supply, ($-V_S$) = 0 V, ($+V_S$) can support 4.5 V to 36 V. If using dual supplies with equal absolute values, the minimum voltage is ±2.25 V, and the maximum voltage is ±18 V. It can even support other voltage configurations, such as ($-V_S$) = −6 V, ($+V_S$) = 30 V and so on.

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.

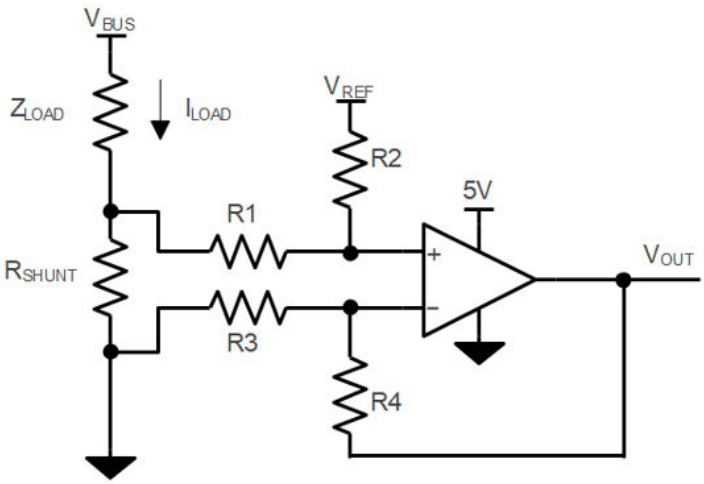
Application and Implementation

> 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 19 shows the devices configured in a low-side current-sensing application. The low-side current-sensing method is to place a sense resistor between the load and the circuit ground. The voltage dropping across the resistor is amplified by different amplifier circuits with the devices. The V_{REF} can be used to add a 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.



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

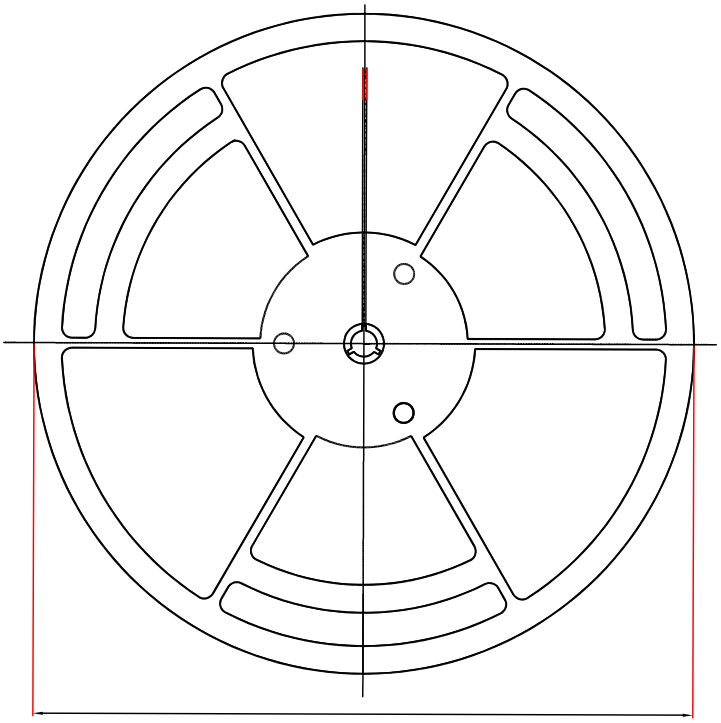
When R3 = R1, R2 = R4, R_{SHUNT} << R1

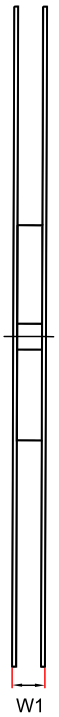
Figure 19. Low-Side Current-Sensing Application

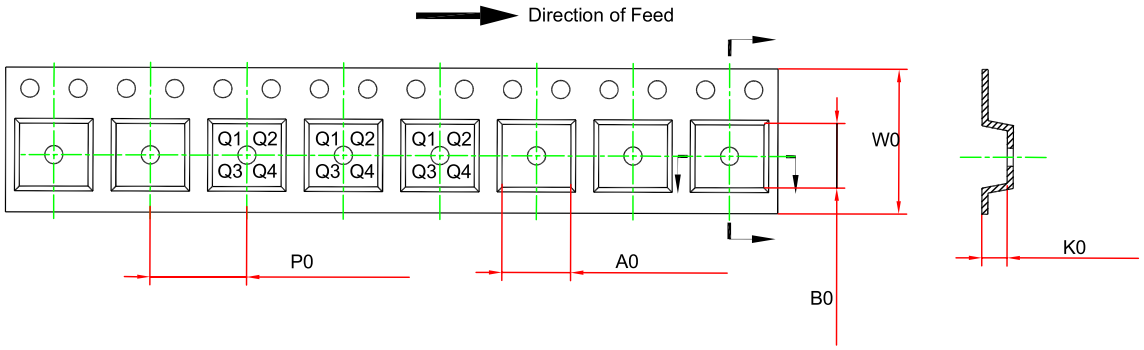
Power Supply Recommendations

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







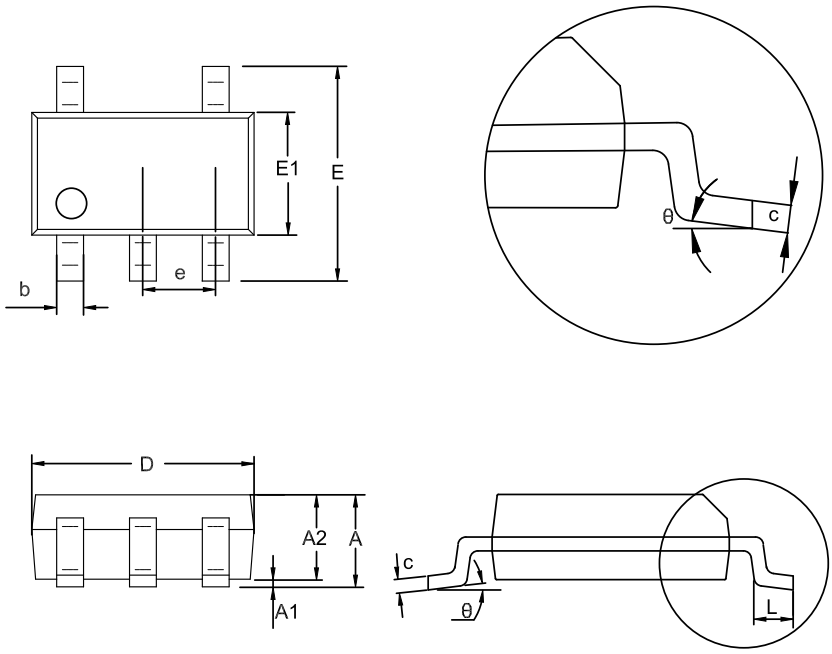
Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm) (1)	B0 (mm) (1)	K0 (mm) (1)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPA2501-S5TR	SOT23-5	180	12	3.3	3.25	1.4	4	8	Q3
TPA2501-SO1R	SOP8	330	17.6	6.5	5.4	2	8	12	Q1
TPA2502-SO1R	SOP8	330	17.6	6.5	5.4	2	8	12	Q1
TPA2502-VS1R	MSOP8	330	17.6	5.3	3.4	1.3	8	12	Q1
TPA2504-SO2R	SOP14	330	21.6	6.5	9.3	2.1	8	16	Q1
TPA2504-TS2R	TSSOP14	330	17.6	6.8	5.5	1.5	8	12	Q1

(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)



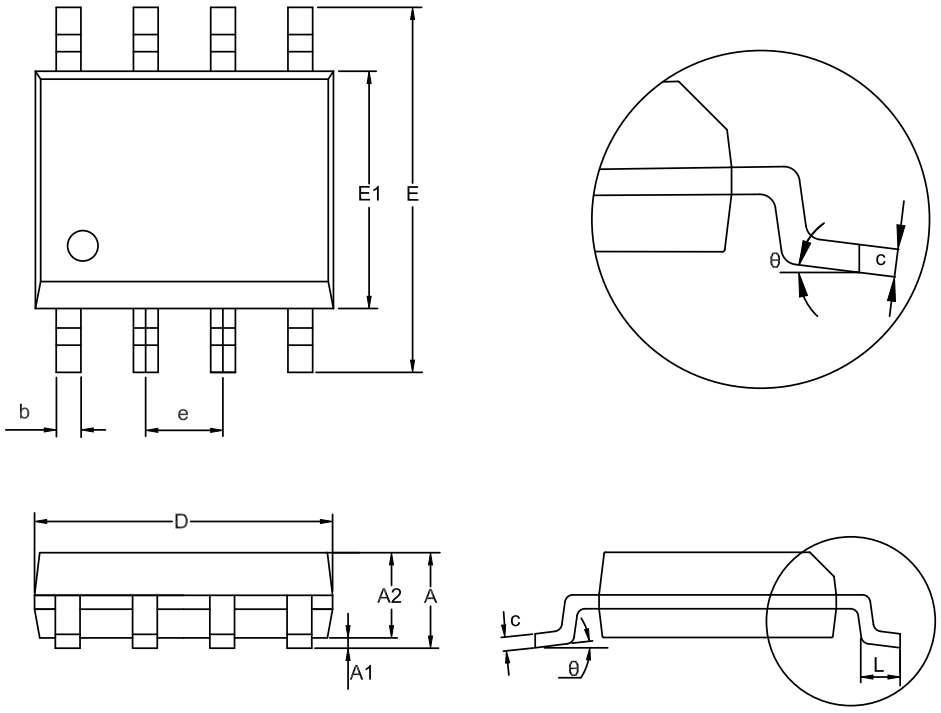
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.150	0.000	0.006
A2	1.000	1.200	0.039	0.047
b	0.280	0.500	0.011	0.020
c	0.100	0.230	0.004	0.009
D	2.820	3.020	0.111	0.119
E	2.600	3.000	0.102	0.118
E1	1.500	1.720	0.059	0.068
e	0.950 BSC		0.037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

SOP8

Package Outline Dimensions SO1(SOP-8-A)



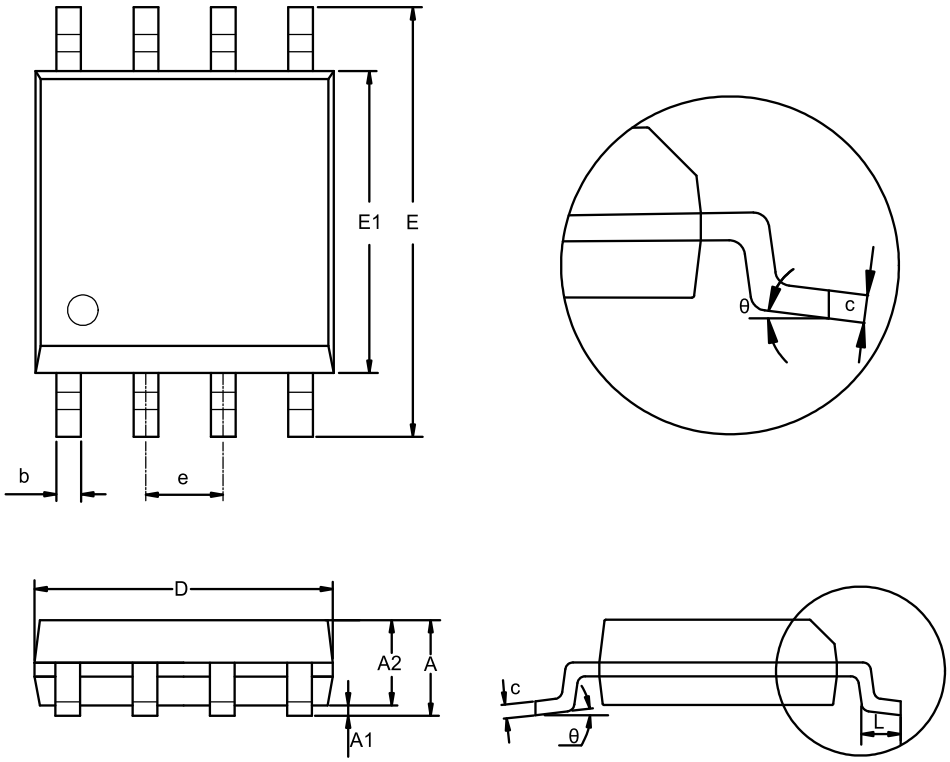
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.550	0.049	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050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

MSOP8

Package Outline Dimensions VS1(MSOP-8-A)



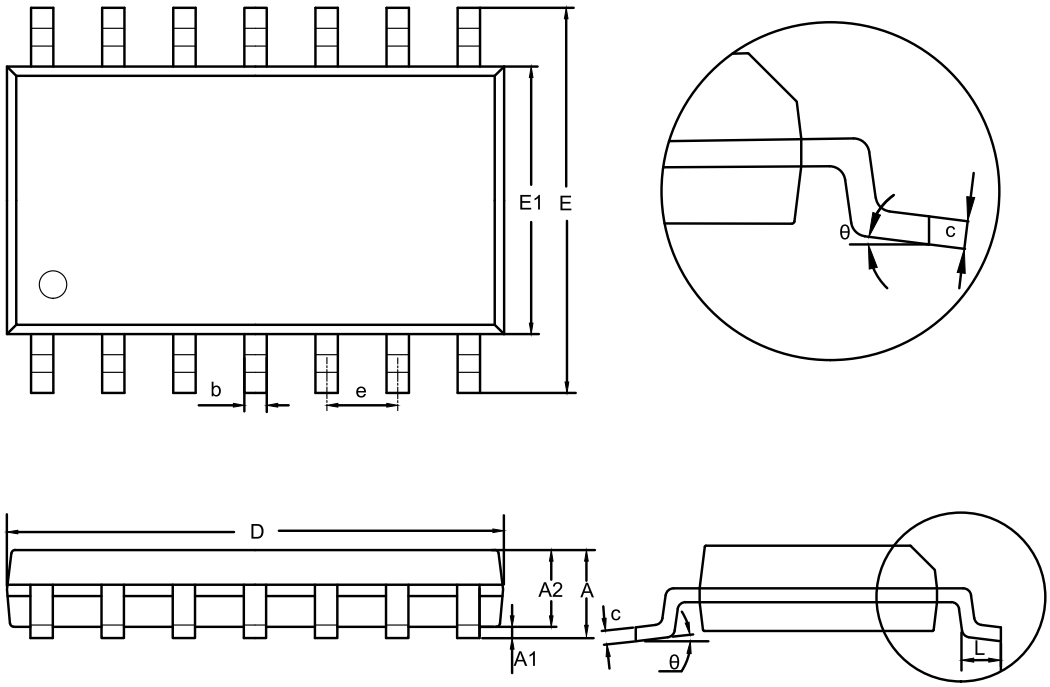
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.800	1.100	0.031	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	4.700	5.100	0.185	0.201
E1	2.900	3.100	0.114	0.122
e	0.650 BSC		0.026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

SOP14

Package Outline Dimensions SO2(SOP-14-A)



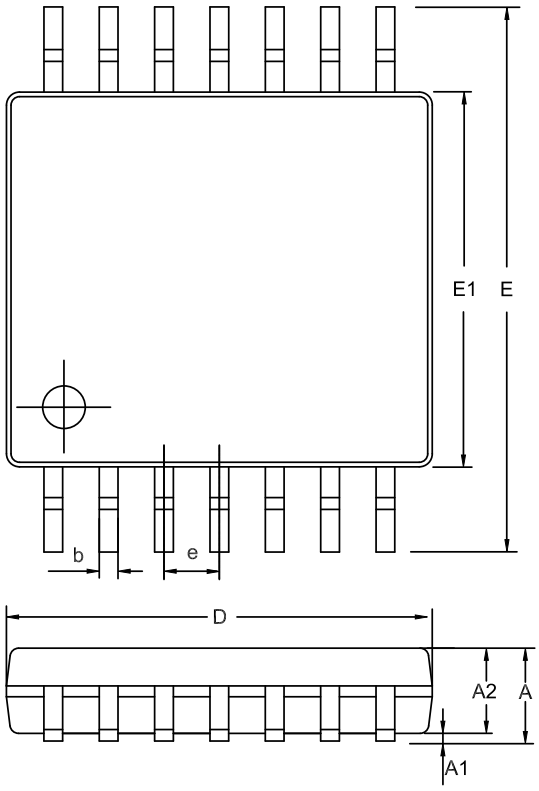
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.650	0.049	0.065
b	0.310	0.510	0.012	0.020
c	0.100	0.250	0.004	0.010
D	8.450	8.850	0.333	0.348
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050 BSC	
L	0.400	1.270	0.016	0.050
θ	0	8°	0	8°

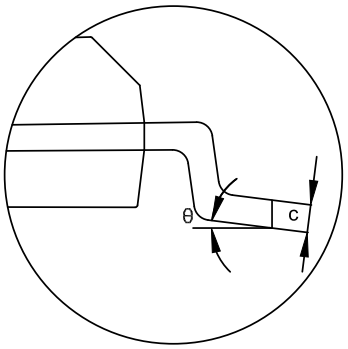
NOTES

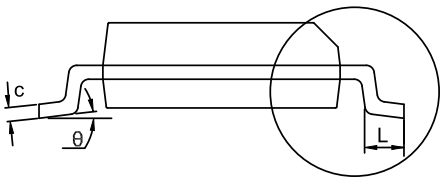
1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

TSSOP14

Package Outline Dimensions TS2(TSSOP-14-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	4.900	5.100	0.193	0.201
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
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
TPA2501-S5TR (1)	−40 to 125°C	SOT23-5	AA7	1	Tape and Reel, 3000	Green
TPA2501-SO1R (1)	−40 to 125°C	SOP8	A2501	1	Tape and Reel, 4000	Green
TPA2502-SO1R	−40 to 125°C	SOP8	A2502	1	Tape and Reel, 4000	Green
TPA2502-VS1R (1)	−40 to 125°C	MSOP8	A2502	1	Tape and Reel, 3000	Green
TPA2504-SO2R (1)	−40 to 125°C	SOP14	A2504	1	Tape and Reel, 2500	Green
TPA2504-TS2R (1)	−40 to 125°C	TSSOP14	A2504	3	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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