250-MHz, Precision, Rail-to-Rail I/O, CMOS Operational Amplifier

Features

- Unity-Gain Bandwidth: 250 MHz
- Gain Bandwidth Product: 120 MHz
- High Slew Rate: 180 V/µs
- Offset Voltage: 2 mV Max
- Low Noise: 6.5 nV√Hz
- Rail-to-Rail Input and Output
- High Output Current: >100 mA
- Low Noise: 6 nV/√Hz at 1 kHz
- Excellent Video Performance:
  - Differential Gain: 0.02%
  - Differential Phase: 0.3°
  - 0.1-dB Gain Flatness: 25 MHz
- Low Input Bias Current: 0.3 pA
- Thermal Shutdown
- Supply Range: 2.5 V to 5.5 V
- Operating Temperature Range: −40℃ to 125℃

Applications

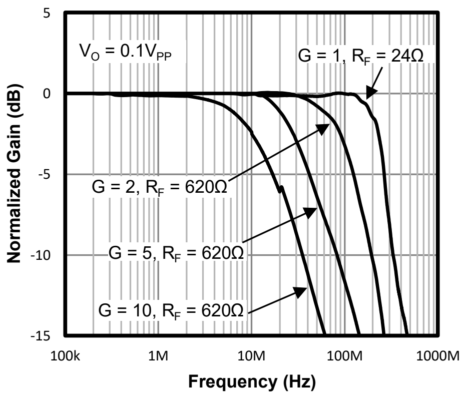
- Low-Voltage, High-Frequency Signal Processing
- Video Processing
- Optical Networking, Tunable Lasers
- Photodiode Trans-Impedance
- Barcode Scanners
- Fast Current-Sensing Amplifiers

Description

The TPH250x is a series of single, dual, or quad low-power, high-speed unity-gain stable rail-to-rail input/output operational amplifiers. On the supply current of only 6.5 mA, the TPH250x series features an impressive 250-MHz gain-bandwidth product, a 180-V/µs slew rate, and a low 6.5-nV/√Hz input-referred noise. The series offers a shutdown current of only 1 µA. The combination of high bandwidth, high slew rate, low power consumption, and low broadband noise makes the TPH250x unique among the rail-to-rail input/output op amps with similar supply currents. It is ideal for low supply-voltage and high-speed signal conditioning systems.

The TPH2501 series maintains high-efficiency performance from supply voltage levels of 2.5 V to 5.5 V, and is fully specified at supplies of 2.7 V and 5.0 V. The TPH2501 family can be used as a plug-in replacement for commercially available op amps to reduce power consumption, extend input/output range, and improve performance.

The TPH2501 series is a single-channel version available in the SOT23-5 package. The TPH2502 series is a dual-channel version available in the SOP8 and MSOP8 packages. The TPH2503 series is in the SOT23-6 package with a shutdown function. The TPH2504 series is a quad-channel version available in the SOP14 and TSSOP14 packages.



Non-Inverting Small-Signal Frequency Response

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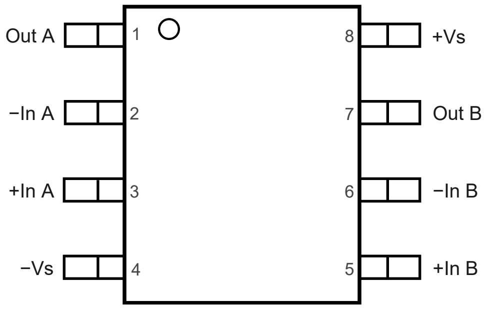
Revision History

Date	Revision	Notes
2018-08-20	Rev.B.0	Updated the full temperature specification.
2018-12-25	Rev.B.1	Corrected the Marking Information of TPH2501L1-TR: from 501" to "50L". Added Power-on Requirement in Application Information.
2019-11-14	Rev.B.2	Updated the unit in Input Bias Current vs. Temperature: from "pA" to "nA"; Added the input logic voltage of shut down.
2019-12-16	Rev.B.3	Corrected the typo in the TPH2503 pin configuration.
2022-04-29	Rev.B.4	Updated Order information.
2024-01-23	Rev.B.5	The following updates are all about the new datasheet formats or typos, and the actual products remain unchanged. Updated the format of Package Outline Dimensions. Updated Tape and Reel Information.
2024-12-18	Rev.B.6	The following updates are all about the new datasheet formats or typos, and the actual products remain unchanged. • Updated to a new datasheet format. • Updated Tape and Reel Information.

Pin Configuration and Functions

TPH2502
SOP8/MSOP8
Top View



TPH2504
SOP14/TSSOP14
Top View

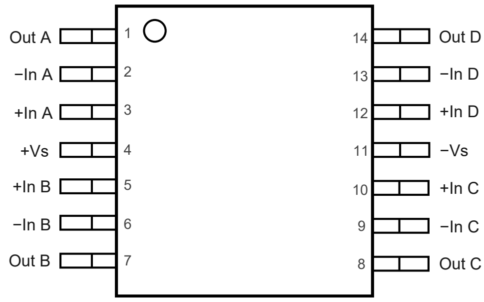
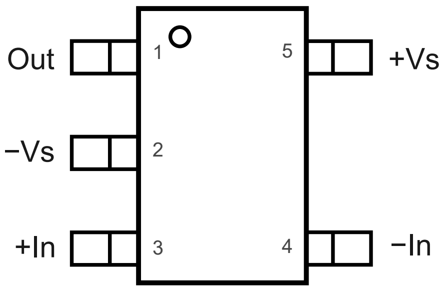


Table 1. Pin Functions: TPH2502, TPH2504

Pin No.		Name	I/O	Description
TPH2502	TPH2504			
1	1	Out A	O	Output. The voltage range extends to within mV of each supply rail.
2	2	−In A	I	Inverting input.
3	3	+In A	I	Non-inverting input.
4	11	$-V_S$	Power Supply	Negative power supply. It is normally tied to GND. It can also be tied to a voltage other than GND when the voltage between V+ and V− is from 2.5 V to 5.5 V. If it is not connected to GND, bypass it with a capacitor of 0.1 mF as close to the part as possible.
5	5	+In B	I	Non-inverting input.
6	6	−In B	I	Inverting input.
7	7	Out B	O	Output. The voltage range extends to within mV of each supply rail.
8	4	$+V_S$	Power Supply	Positive power supply. Typically, the voltage is from 2.5 V to 5.5 V. Split supplies are possible as long as the voltage between V+ and V− is between 2.5 V and 5.5 V. A bypass capacitor of 0.1 mF as close to the part as possible should be used between power supply pins or between supply pins and GND.
	8	Out C	O	Output. The voltage range extends to within mV of each supply rail.
	9	−In C	I	Inverting input.
	10	+In C	I	Non-inverting input.
	12	+In D	I	Non-inverting input.
	13	−In D	I	Inverting input.
	14	Out D	O	Output. The voltage range extends to within mV of each supply rail.

TPH2501
SOT23-5/SOT353 (SC70-5)
Top View



TPA2503
SOT23-6/SOT363 (SC70-6)
Top View

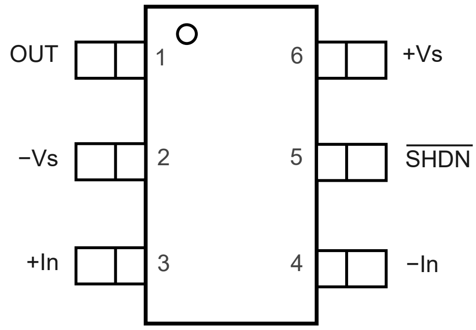


Table 2. Pin Functions: TPH2501, TPH2503

Pin No.		Name	I/O	Description
TPH2501	TPH2503			
1	1	Out	O	Output. The voltage range extends to within mV of each supply rail.
2	2	$-V_S$	Power Supply	Negative power supply. It is normally tied to GND. It can also be tied to a voltage other than GND when the voltage between V+ and V− is from 2.5 V to 5.5 V. If it is not connected to GND, bypass it with a capacitor of 0.1 mF as close to the part as possible.
3	3	+In	I	Non-inverting input.
4	4	−In	I	Inverting input.
5	6	$+V_S$	Power Supply	Positive power supply. Typically, the voltage is from 2.5 V to 5.5 V. Split supplies are possible as long as the voltage between V+ and V− is between 2.5 V and 5.5 V. A bypass capacitor of 0.1 mF as close to the part as possible should be used between power supply pins or between supply pins and GND.
	5	$\overline{SHDN}$		Switch the pin from logic high to logic low to shut down the device. Range: Logic high enables the device and logic low shuts down the device. This pin defaults to logic high if left open.

Specifications

Absolute Maximum Ratings (1)

Parameter		Min	Max	Unit
	Supply Voltage: $(+V_S) – (−V_S)$ (2)		7.0	V
	Input Voltage	$(−V_S) – 0.3$	$(+V_S) + 0.3$	V
	Input Current: +IN, −IN (3)	−20	20	mA
	Output Current: OUT	−160	160	mA
	Output Short-Circuit Duration (4)		Infinite	
	Current at Supply Pins	−60	60	mA
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 op amp supplies must be established, simultaneously with, or before the application of any input signals.
(3) The inputs are protected by ESD protection diodes to each power supply. If the input extends more than 500 mV beyond the power supply, the input current should be limited to less than 10 mA.
(4) 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. The 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

Symbol	Parameter	Condition	Minimum Level	Unit
HBM	Human Body Model ESD	ANSI/ESDA/JEDEC JS-001 (1)	2	kV
CDM	Charged Device Model ESD	ANSI/ESDA/JEDEC JS-002 (2)	1	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.

Thermal Information

Package Type	θ_{JA}	θ_{JC}	Unit
SOT23-5	250	81	°C/W
SOT23-6	170	130	°C/W
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: T_A = +25°C, R_F = 0 Ω, R_L = 1 KΩ, and connected to V_S / 2, unless otherwise noted.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{OS}	Input Offset Voltage	V_{CM} = V_{DD} / 2	−2		2	mV
		V_{CM} = V_{DD} / 2, −40°C to 125°C	−5		5	mV
V_{OS} TC	Input Offset Voltage Drift	−40°C to 125°C		10		μV/°C
I_B	Input Bias Current	T_A = 27 °C		3		pA
		T_A = 85 °C		150		pA
		T_A = 125 °C		300		pA
I_{OS}	Input Offset Current			3		pA
e_n	Input Voltage Noise Density	f = 1 MHz		6.5		nV/√Hz
i_n	Input Current Noise	f = 1 MHz		50		fA/√Hz
C_{IN}	Input Capacitance	Differential mode		2.7		pF
		Common mode		1		pF
CMRR	Common-Mode Rejection Ratio	V_{CM} = 0.7 V to 3.7 V, V_S = 5.4 V	65	85		dB
		V_{CM} = 0 V to 3 V, V_S = 5 V	65	85		dB
		V_{CM} = 0 V to 3 V, V_S = 5 V, −40°C to 125°C	45			dB
V_{CM}	Common-Mode Input Voltage Range		(−V_S) − 0.1		(+V_S) − 0.1	V
PSRR	Power Supply Rejection Ratio	V_S = 2.5 V to 5.5 V	70	120		dB
		V_S = 2.5 V to 5.5 V, −40°C to 125°C	65			dB
A_{VOL}	Open-Loop Large Signal Gain	R_{LOAD} = 2 KΩ	85	110		dB
		R_{LOAD} = 2 KΩ, −40°C to 125°C	75			dB
Frequency Response						
$f_{-3\ dB}$	Small-Signal Bandwidth	G = +1, V_O = 100 mV_{PP}, R_F = 25 Ω		250		MHz
		G = +2, V_O = 100 mV_{PP}		90		MHz
GBW	Gain-Bandwidth Product	G = +10		120		MHz
$f_{0.1\ dB}$	Bandwidth for 0.1-dB Gain Flatness	G = +2, V_O = 100 mV_{PP}		25		MHz
SR	Slew Rate	V_S = +5 V, G = +1, 4-V step		200		V/μs
		V_S = +5 V, G = +1, 2-V step		180		V/μs
		V_S = +3 V, G = +1, 2-V step		160		V/μs
t_F	Rise-and-Fall Time	G = +1, V_O = 200 mV_{PP}, 10% to 90%		2		ns
		G = +1, V_O = 2 V_{PP}, 10% to 90%		7		ns

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
t_S	Settling Time, 0.1%	V_S = +5 V, G = +1, 2-V output step		25		ns
t_S	Settling Time, 0.01%			40		ns
t_R	Overload Recovery Time	V_{IN} × Gain = V_S		50		ns
HD2	Harmonic Distortion, 2nd-Harmonic	G = +1, f = 1 MHz, V_O = 2 V_{PP}, R = 200 Ω, V = 1.5 V		−78		dBc
HD3	Harmonic Distortion, 3rd-Harmonic	G = +1, f = 1 MHz, V_O = 2 V_{PP}, R_L = 200 Ω, V_{CM} = 1.5 V		−90		dBc
GE	Differential Gain Error	NTSC, R_L = 150 Ω		0.02		%
PE	Differential Phase Error	NTSC, R_L = 150 Ω		0.3		°
X_{talk}	Channel-to-Channel Crosstalk TPH2502	f = 5 MHz		−100		dB
	Channel-to-Channel Crosstalk TPH2504			−84		dB
V_{OL}, V_{OH}	Output Swing from Supply Rail	R_{LOAD} = 100 kΩ		2	30	mV
		R_{LOAD} = 100 kΩ, −40°C to 125°C			35	mV
R_I	Input Impedance	Differential mode		10^{13} || 2		Ω || pF
		Common mode		10^{13} || 2		Ω || pF
R_{OUT}	Closed-Loop Output Impedance	G = 1, f = 1 kHz, I_{OUT} = 0		0.01		Ω
R_O	Open-Loop Output Impedance	f = 1 kHz, I_{OUT} = 0		21		Ω
I_{SC}	Output Short-Circuit Current	Sink current	100	160		mA
		Source current	100	290		mA
V_{DD}	Supply Voltage		2.5		5.5	V
I_Q	Quiescent Current per Amplifier	TPH2501		8	10	mA
		TPH2501, −40°C to 125°C			15	mA
		TPH2502, TPH2504		6.5	7.5	mA
		TPH2502, TPH2504, −40°C to 125°C			12	mA
I_{SD}	Shutdown Current (TPH2503)			30		μA
	Input Logic High of Shutdown		1.6			V
	Input Logic Low of Shutdown				0.6	V

Typical Performance Characteristics

All test conditions: V_S = 5 V, G = +1, R_F = 0 Ω, R_L = 1 KΩ, and connected to V_S / 2, unless otherwise noted.

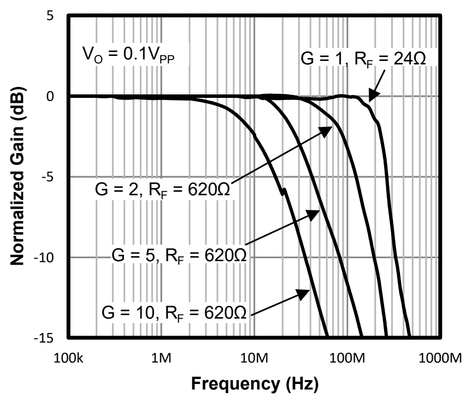


Figure 1. Non-Inverting Small-Signal Frequency Response

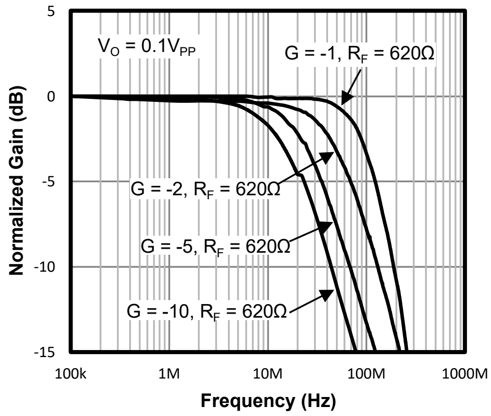


Figure 2. Inverting Small-Signal Frequency Response

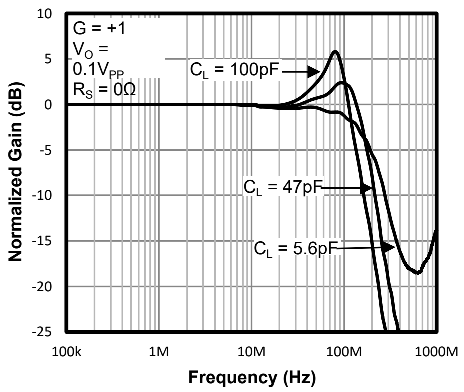


Figure 3. Frequency Response for Various C_L

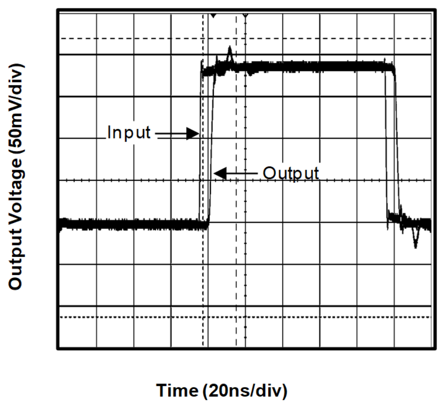


Figure 4. Non-Inverting Small-Signal Step Response

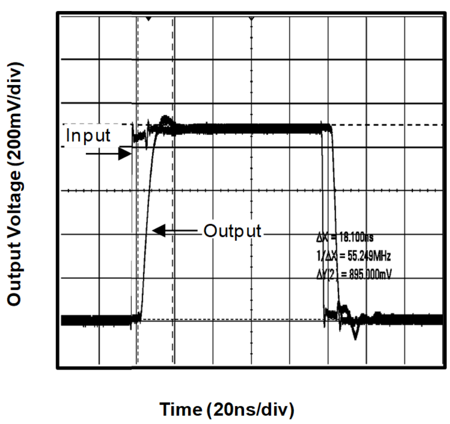


Figure 5. Inverting Large-Signal Step Response

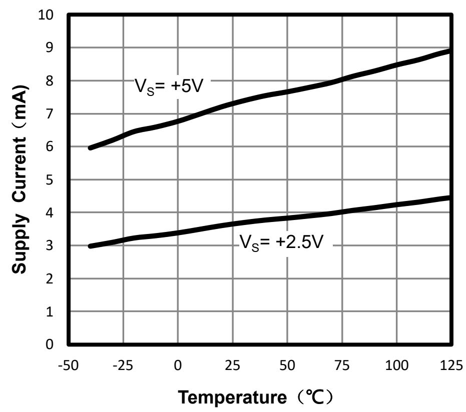


Figure 6. Quiescent Current vs. Temperature

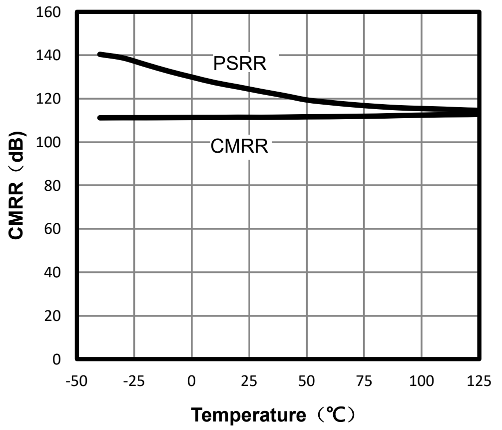


Figure 7. CMRR and PSRR vs. Temperature

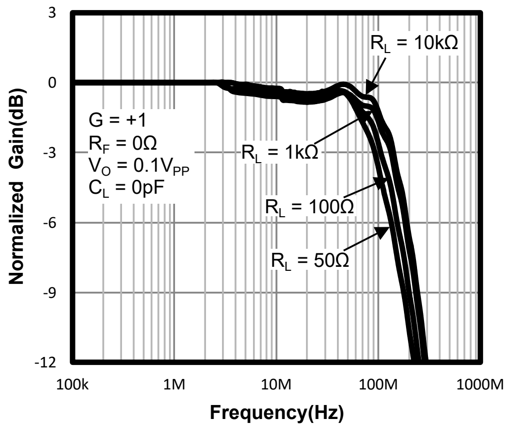


Figure 8. Frequency Response for Various R_L

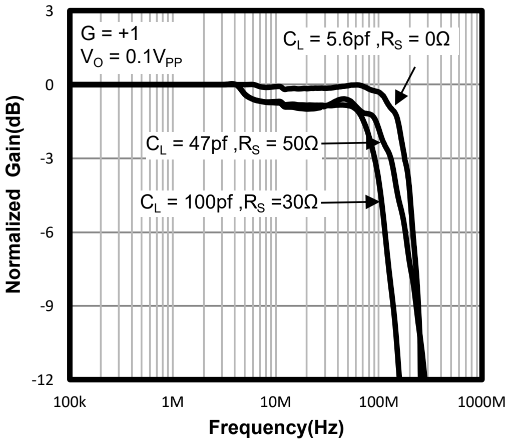


Figure 9. Frequency Response vs. Capacitive Load

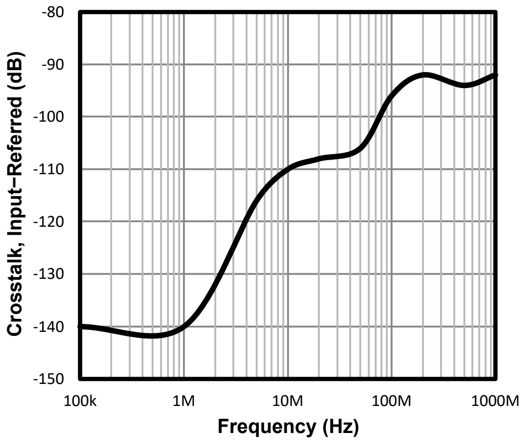


Figure 10. Channel-to-Channel Crosstalk

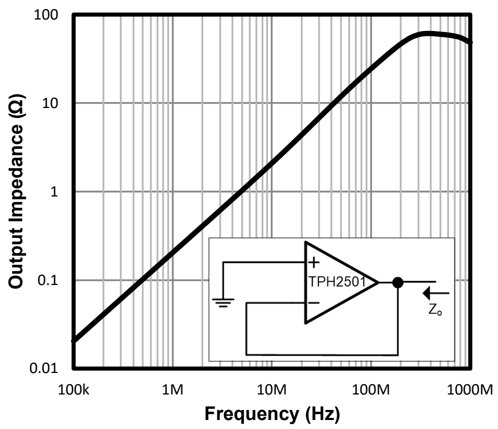


Figure 11. Closed-Loop Output Impedance vs. Frequency

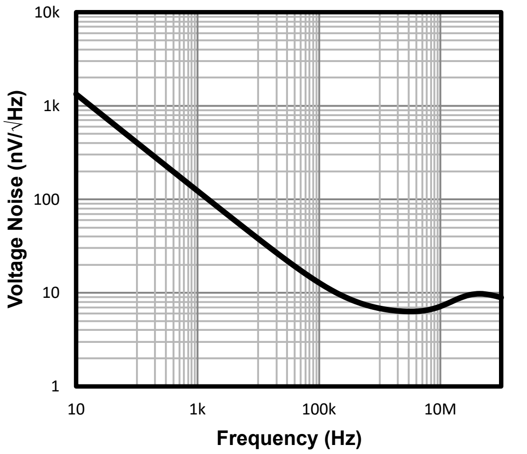


Figure 12. Voltage Spectral Density vs. Frequency

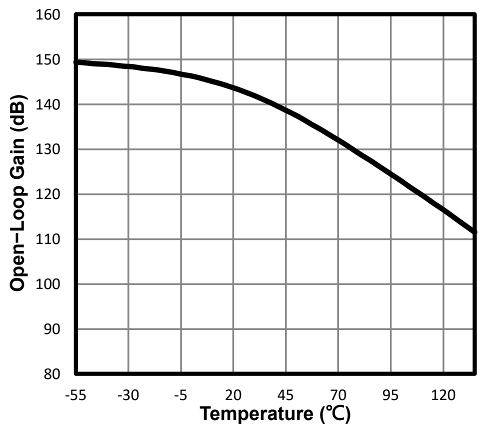


Figure 13. Open-Loop Gain vs. Temperature

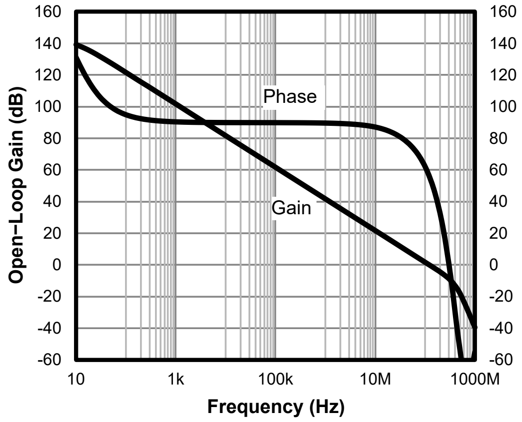


Figure 14. Open-Loop Gain and Phase

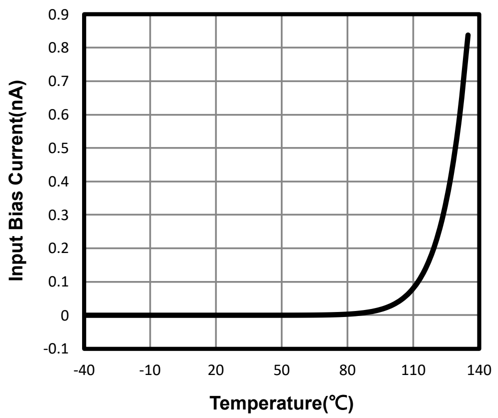


Figure 15. Input Bias Current vs. Temperature

Detailed Description

Overview

The TPH2501/2502/2504 is a series of CMOS, rail-to-rail I/O, high-speed, and voltage-feedback operational amplifiers designed for video, high-speed, and other applications. It is available as a single, dual, or quad op amp. The amplifier features a 250-MHz gain bandwidth and a 180-V/μs slew rate, and it is unity-gain stable and can be operated as a +1-V/V voltage follower. The TPH2501/2502/2504 series is specified over a power-supply range from +2.7 V to +5.5 V (±1.35 V to ±2.75 V). However, the supply voltage may range from +2.5 V to +5.5 V (±1.25 V to ±2.75 V). Supply voltages higher than 7.5 V (absolute maximum) can permanently damage the amplifier. Parameters that vary over the supply voltage or temperature are shown in Typical Performance Characteristics.

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

Power-on Requirement

Generally, the high-speed amplifiers (> 100-MHz GBW) have larger V_{OS} as the input transistors have smaller size to get the lower input capacitance for high speed. The small-size input transistors bring to large V_{OS} for the mismatch of the input transistor pairs. The V_{OS} of the high-speed amplifiers is normally > ±5 mV. In comparison, the low-speed amplifiers have a maximum ±3 mV V_{OS} with larger input transistors.

The TPH250x amplifiers use the internal calibration block to achieve a ±2 mV V_{OS}, which is better than most of the high-speed amplifiers. To guarantee the proper functioning of the calibration block, a good power-on of the amplifier power supply is recommended:

- Fast power-on time is needed to produce the power-on-reset signal of the calibration block. The maximum value of the power-on time is 1 ms.
- The voltage glitch should be avoided reaching the range from 0.4 V to 1 V on the power supply. For example, a power supply that drops to 0.5 V and then recovers to 5 V, may cause errors in the calibration block.

If the power-on signal is not good, the amplifiers have the probability of entering an unexpected status.

Rail-to-Rail Inputs and Outputs

The TPH2501/2502/2504 op amps are designed to be immune to the phase reversal when the input pins exceed the supply voltages, and therefore provide further in-system stability and predictability. Figure 16 shows the input voltage exceeding the supply voltage without any phase reversal.

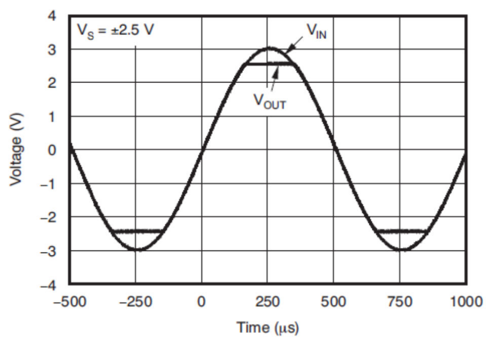


Figure 16. No Phase Reversal

Choice of Feedback Resistor and Gain Bandwidth Product

For applications that require a gain of +1, no feedback resistor is required. Just short the output pin to the inverting input pin. When the gain is greater than +1, the feedback resistor forms a pole with the parasitic capacitance at the inverting input. As this pole becomes smaller, the phase margin of the amplifier is reduced. This causes ringing in the time domain and peaking in the frequency domain. Therefore, R_F has some maximum values that should not be exceeded for optimum performance. If a large value of R_F must be used, a small capacitor in a several-Picofarad range in parallel with R_F helps reduce the ringing and peaking at the expense of reducing the bandwidth. As far as the output stage of the amplifier is concerned, the output stage is also a gain stage with the load. R_F and R_G appear in parallel with R_L for gains other than +1. As this combination gets smaller, the bandwidth falls off. Consequently, R_F also has a minimum value that should not be exceeded for optimum performance. For the gains of +1, R_F = 0 is optimum. For gains other than +1, the optimum response is obtained with R_F between 300 Ω to 1 kΩ.

The TPH2501/2502/2504 series has a gain bandwidth product of 120 MHz. For gains ≥ 5, its bandwidth can be predicted by Equation 1:

$$\text{Gain} \times \text{BW} = 120\,\text{MHz} \tag{1}$$

Video Performance

For good video performance, an amplifier is required to maintain the same output impedance and the same frequency response as the DC levels are changed at the output. This is especially difficult when driving a standard video load of 150 Ω because the output current changes with the DC levels. The special circuitry has been incorporated in the TPH2501/2502/2504 series to reduce the variation of the output impedance with the current output. This results in D_g and D_p specifications of 0.03% and 0.3° while driving 150 Ω at a gain of 2. Driving high-impedance loads gives a similar or better D_g and D_p performance.

Driving Capacitive Loads and Cables

The TPH2501/2502/2504 series can drive 10-pF loads in parallel with 1 kΩ with a peaking of less than 5 dB at the gain of +1. If the peaking is desired to be lower in applications, a small series resistor (usually between 5 Ω to 50 Ω) can be placed in series with the output to reduce the peaking. However, this reduces the gain slightly. If the gain setting is greater than 1, the gain resistor R_G can then be chosen to make up for any gain loss that may be created by the additional series resistor at the output. When used as a cable driver, a double-termination arrangement is always recommended for reflection-free performance. For those applications, a back-termination series resistor at the output of the amplifier isolates the amplifier from the cable and allows extensive capacitive drive. However, other applications may have high capacitive loads without a back-termination resistor. Again, a small series resistor at the output helps reduce the peaking.

Output Drive Capability

The output stage of the TPH2501/2502/2504 series can supply a continuous output current of ±100 mA and still provides an output swing of approximately 2.7 V on a 5-V supply. For maximum reliability, it is not recommended to run a continuous DC current over ±100 mA referring to the typical characteristic curve Output Voltage Swing vs. Output Current. For supplying continuous output currents greater than ±100 mA, the TPH250x series may be operated in parallel. The TPH250x series provides peak currents up to 200 mA, which corresponds to the typical short-circuit current. Therefore, an on-chip thermal shutdown circuit is provided to protect the TPH250x series from dangerously high junction temperatures. At 160°C, the protection circuit shuts down the amplifier. Normal operation resumes when the junction temperature cools to below 140°C.

Single-Supply Video-Line Driver

The TPH2501/2502/2504 is a series of wideband rail-to-rail output operational amplifiers with a large output current, excellent D_g and D_p, and low distortion that allow it to drive video signals in low-supply applications. Figure 17 is the single-supply non-inverting and inverting video-line driver configuration. The signal is AC-coupled by C1. R1 and R2 are used to level shift the input and output to provide the largest output swing. R_F and R_G set the AC gain. C2 isolates the virtual ground potential. R_T and R3 are the termination resistors for the line. C1, C2, and C3 are selected big enough to minimize the drop of the luminance signal.

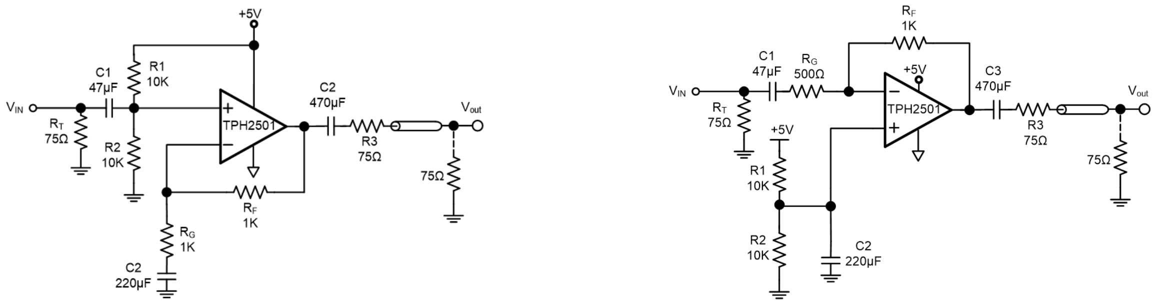


Figure 17. 5-V Single-Supply Non-Inverting and Inverting Video-Line Driver

Power Supply Bypassing and Printed Circuit Board Layout

As with any high-frequency device, a good printed-circuit-board layout is necessary for optimum performance. The lead lengths should be arranged as orderly as possible. The power supply pin must be well bypassed to reduce the risk of oscillation. For the normal single-supply operation where the $V_{S}-$ pin is connected to the ground plane, a single 4.7-mF tantalum capacitor in parallel with a 0.1-mF ceramic capacitor from $+V_S$ to GND is enough. This same capacitor combination should be placed at each supply pin to ground if the split supplies are to be used. In this case, the $-V_S$ pin becomes the negative supply rail. For good AC performance, the parasitic capacitance should be kept minimum. The use of wire-wound resistors should be avoided because of their additional series inductance. The use of sockets should also be avoided if possible. Sockets add parasitic inductance and capacitance, which can result in compromised performance. Minimizing the parasitic capacitance at the inverting input pin of the amplifier is very important. The feedback resistor should be placed very close to the inverting input pin. Strip-line design techniques are recommended for the signal traces.

Video Sync Pulse Remover

Many CMOS analog-to-digital converters have a parasitic latch-up problem when subjected to negative input voltage levels. Since the sync tip contains no useful video information and it is a negative-going pulse, we can chop it off. Figure 18 shows a gain of 2 connections. Figure 18 shows the complete input video signal applied at the input, as well as the output signal with the negative-going sync pulse removed.

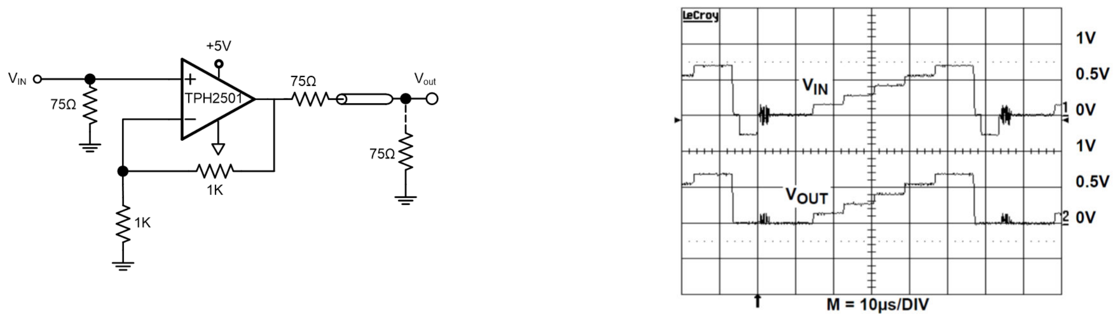


Figure 18. Sync Pulse Remover and Waveform

Input ESD Diode Protection

The TPH250x series incorporates the internal electrostatic discharge (ESD) protection circuits on all pins. In the case of the input and output pins, this protection primarily consists of current-steering diodes connected between the input and power-supply pins. These ESD protection diodes also provide in-circuit input overdrive protection as long as the current is limited to 20 mA as stated in Absolute Maximum Ratings (1). Many input signals are inherently current-limited to less than 20 mA; therefore, the limiting resistor is not required. Figure 19 shows how a series input resistor (R_S) may be added to the driven input to limit the input current. The added resistor contributes to the thermal noise at the amplifier input and the value should be kept minimum in noise-sensitive applications.

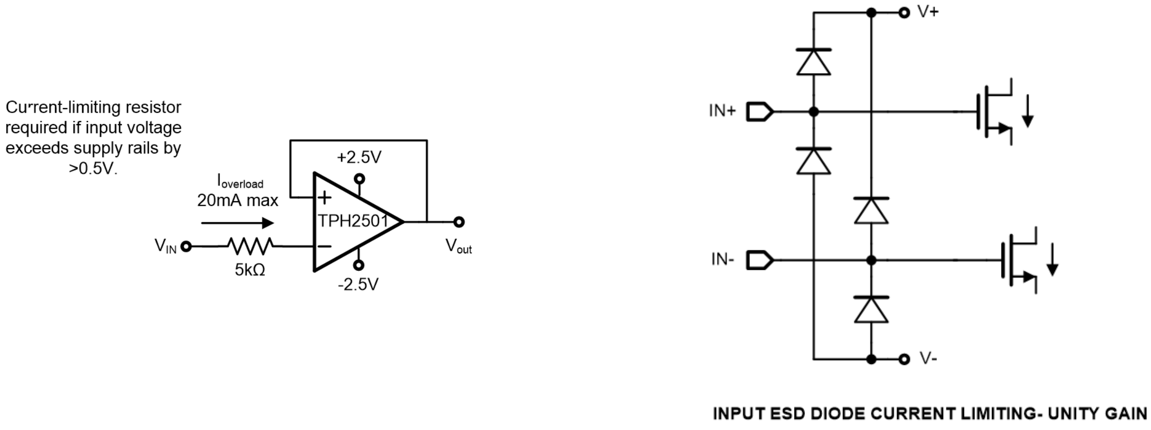
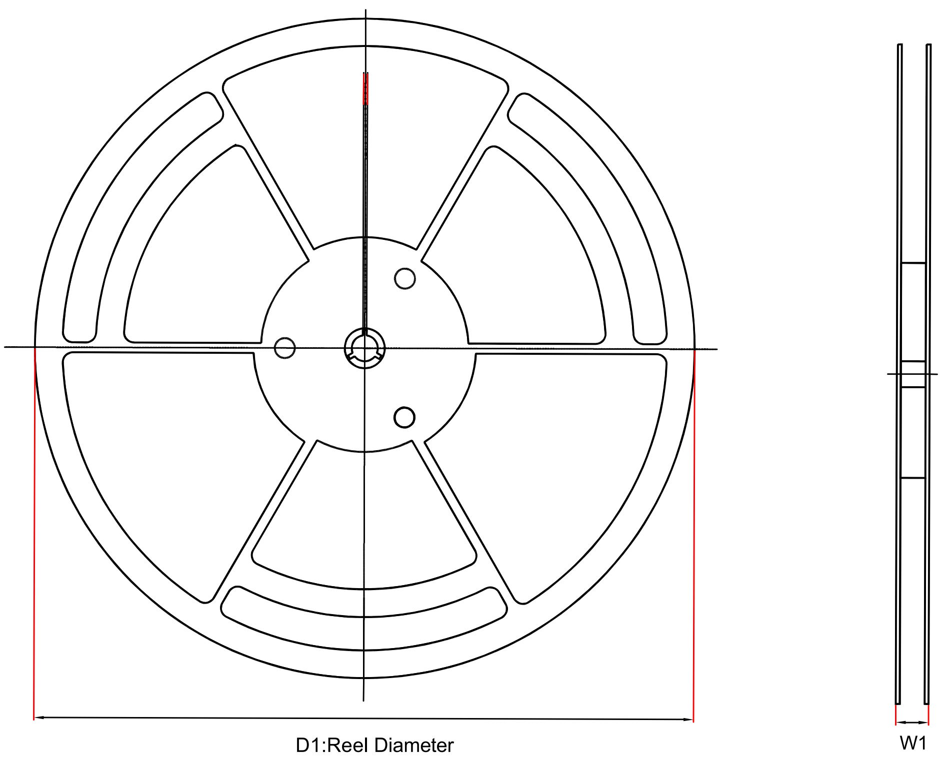
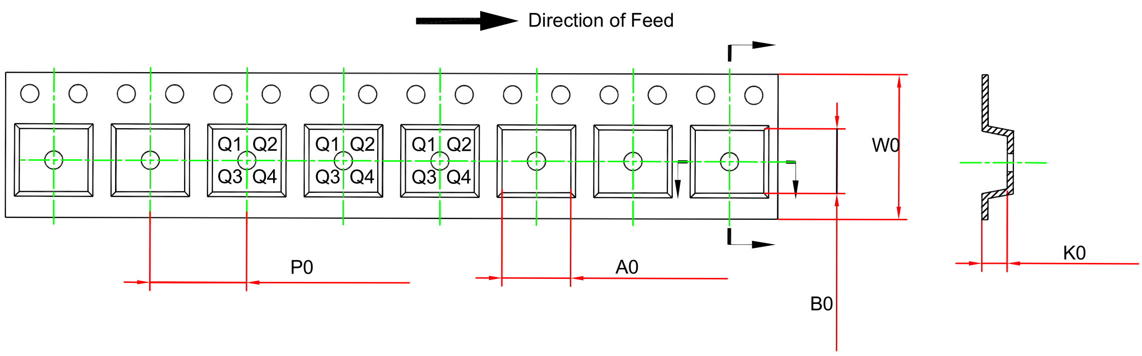


Figure 19. Input ESD Diode

Tape and Reel Information





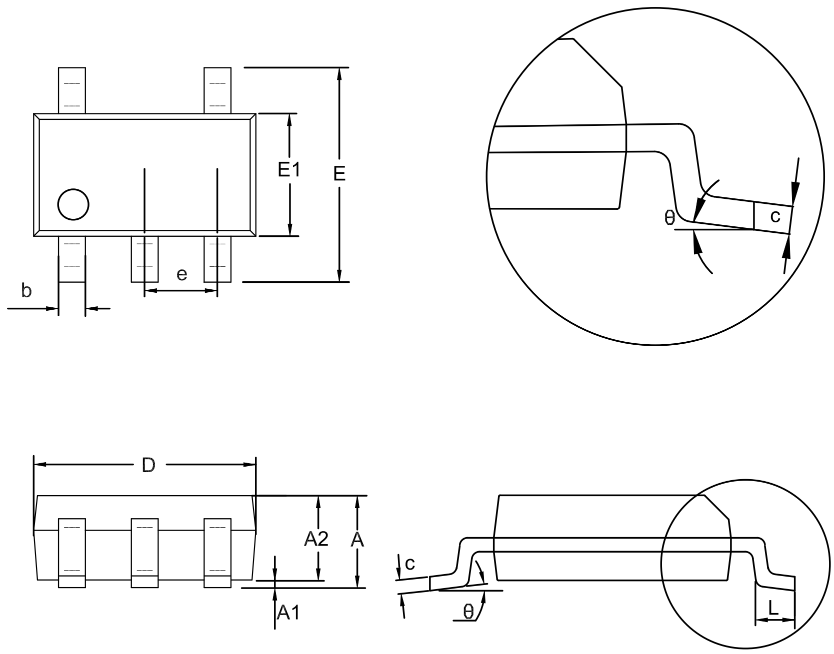
Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm) (1)	B0 (mm) (1)	K0 (mm) (1)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPH2501-TR	SOT23-5	180	12	3.3	3.25	1.4	4	8	Q3
TPH2502-SR	SOP8	330	17.6	6.5	5.4	2	8	12	Q1
TPH2502-VR	MSOP8	330	17.6	5.3	3.4	1.3	8	12	Q1
TPH2503-TR	SOT23-6	180	12	3.3	3.2	1.4	4	8	Q3
TPH2504-SR	SOP14	330	21.6	6.5	9.15	1.8	8	16	Q1
TPH2504-TR	TSSOP14	330	17.6	6.8	5.5	1.3	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)

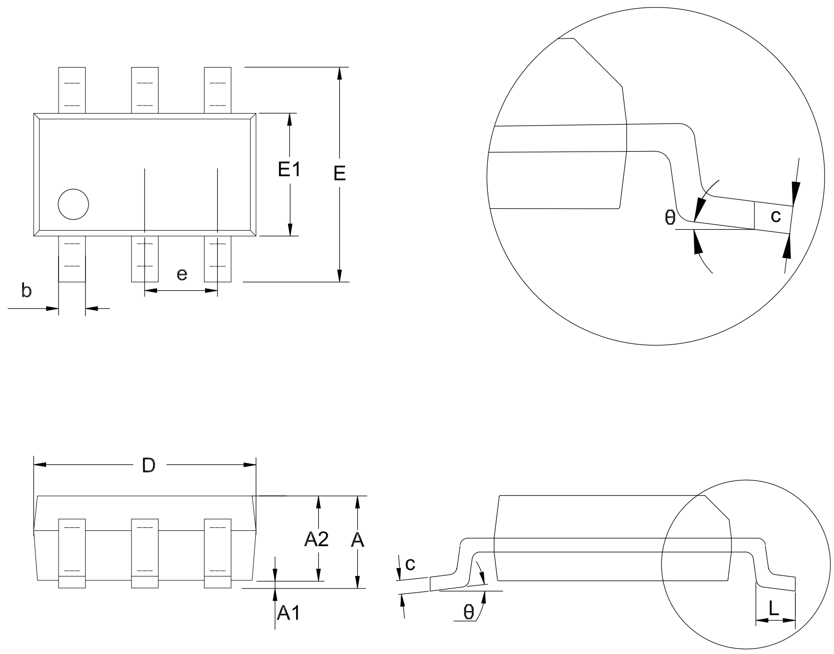


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.150	0.000	0.006
A2	1.000	1.200	0.039	0.047
b	0.280	0.500	0.011	0.020
c	0.100	0.230	0.004	0.009
D	2.820	3.020	0.111	0.119
E	2.600	3.000	0.102	0.118
E1	1.500	1.720	0.059	0.068
e	0.950 BSC		0.037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

SOT23-6

Package Outline Dimensions S6T(SOT23-6-A)



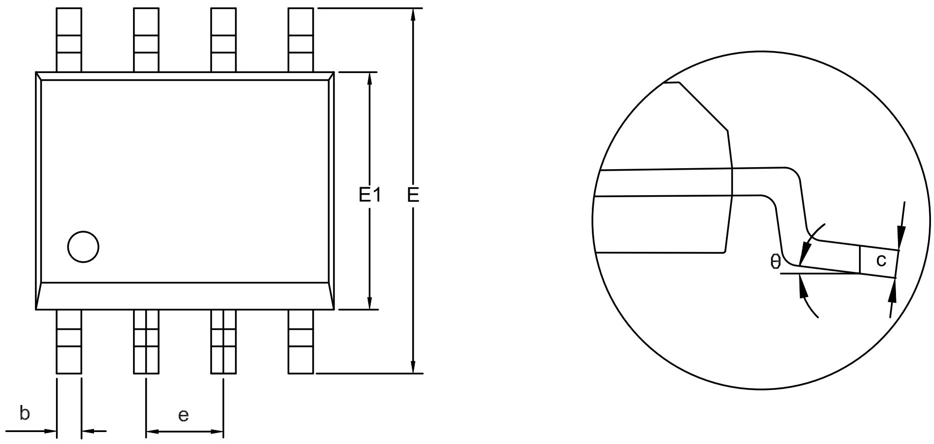
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.150	0.000	0.006
A2	1.000	1.200	0.039	0.047
b	0.280	0.500	0.011	0.020
c	0.100	0.230	0.004	0.009
D	2.820	3.020	0.111	0.119
E	2.600	3.000	0.102	0.118
E1	1.500	1.720	0.059	0.068
e	0.950 BSC		0.037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

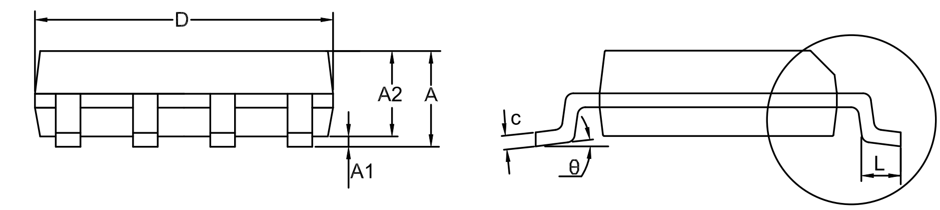
NOTES

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

SOP8

Package Outline Dimensions SO1(SOP-8-A)





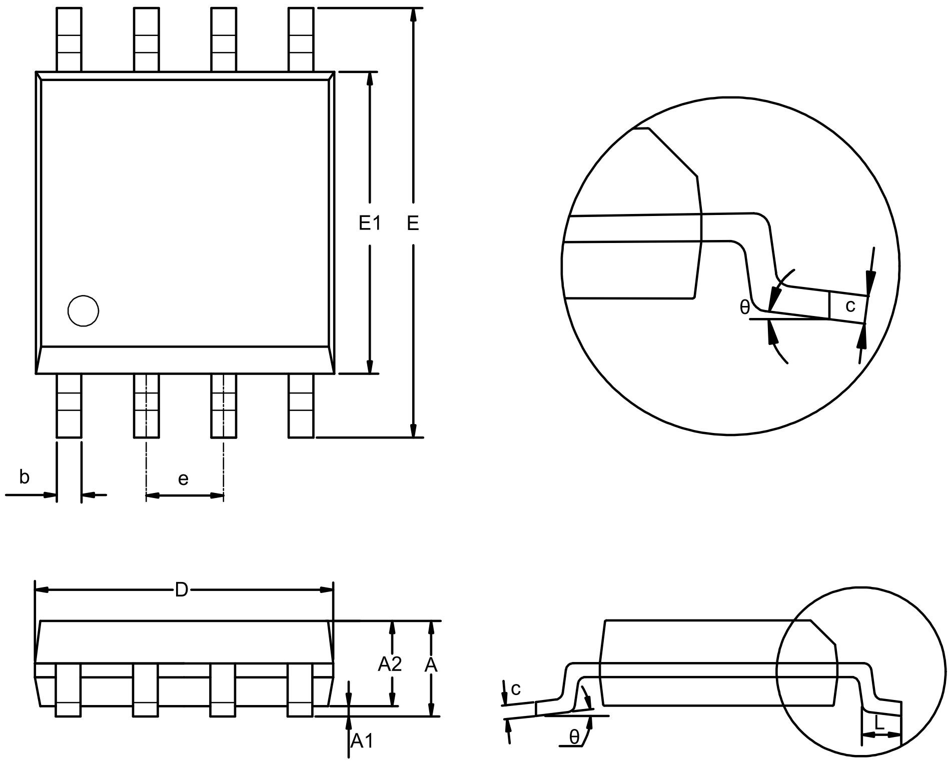
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.550	0.049	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050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



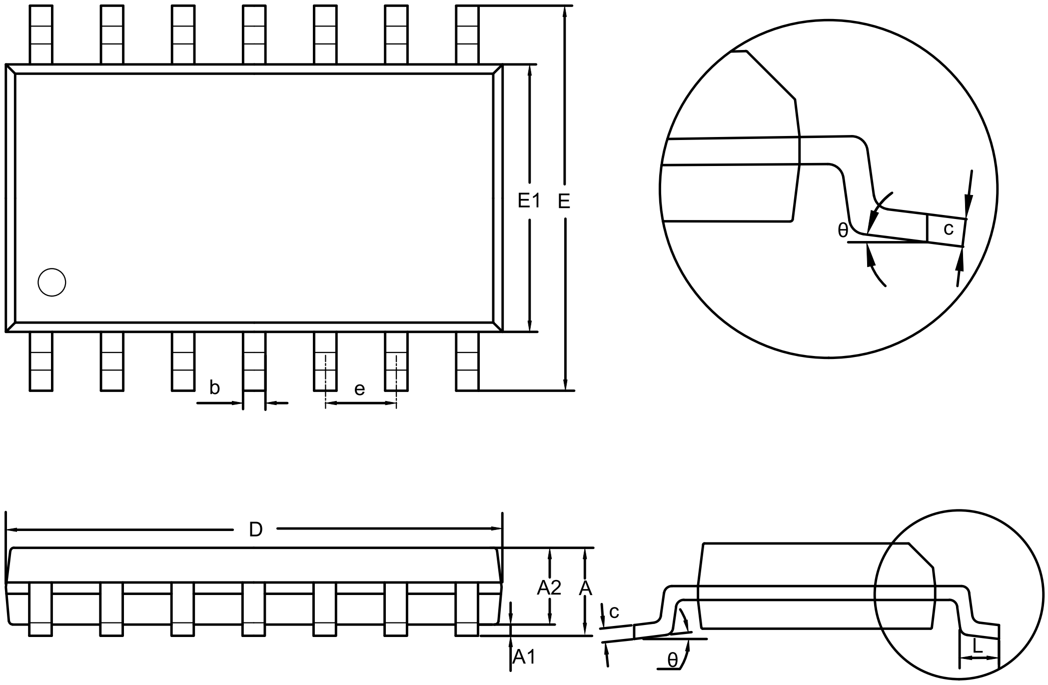
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.800	1.100	0.031	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	4.700	5.100	0.185	0.201
E1	2.900	3.100	0.114	0.122
e	0.650 BSC		0.026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



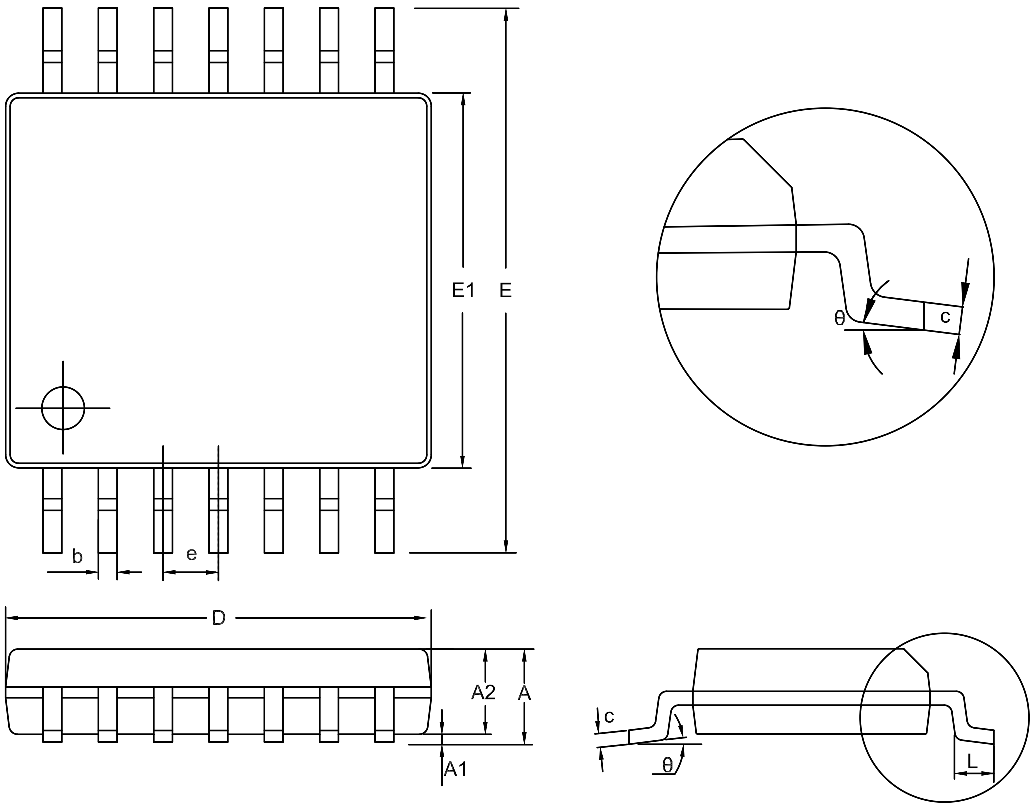
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.650	0.049	0.065
b	0.310	0.510	0.012	0.020
c	0.100	0.250	0.004	0.010
D	8.450	8.850	0.333	0.348
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050 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
TPH2501-TR	−40 to 125°C	SOT23-5	501	3	Tape and Reel, 3,000	Green
TPH2502-SR	−40 to 125°C	SOP8	TPH2502	3	Tape and Reel, 4,000	Green
TPH2502-VR	−40 to 125°C	MSOP8	TPH2502	3	Tape and Reel, 3,000	Green
TPH2503-TR	−40 to 125°C	SOT23-6	503	3	Tape and Reel, 3,000	Green
TPH2504-SR	−40 to 125°C	SOP14	TPH2504	3	Tape and Reel, 2,500	Green
TPH2504-TR	−40 to 125°C	TSSOP14	TPH2504	3	Tape and Reel, 3,000	Green

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

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