TP1511/TP1512/TP1514

Stable 150-kHz, 4-μA, Rail-to-Rail, Op Amps

Features

- Stable 150 kHz GBWP
- 0.09 V/μs Slew Rate
- Only 4 μA of Supply Current per Amplifier
- Unity Gain Stable
- Offset Voltage: 3.0 mV Maximum
- Offset Voltage Temperature Drift: 0.6 μV/°C
- Input Bias Current: 1 pA Typical
- High CMRR/PSRR: 110 dB
- No Phase Reversal for Overdriven Inputs
- Beyond the Rails Input Common-Mode Range
- Outputs Swing to within 5 mV of Each Rail
- Single +2.1 V to +6.0 V Supply Voltage Range
- –40°C to 125°C Operation Range

Applications

- Sensor Conditioning
- Battery Current Sensing
- IR thermometers
- Digital Scales
- Automotive Keyless Entry
- Toll Booth Tags
- Data Acquisition Equipment
- Battery or Solar Powered Systems
- Active Filters, ASIC Input or Output Amplifier
- Portable Instruments

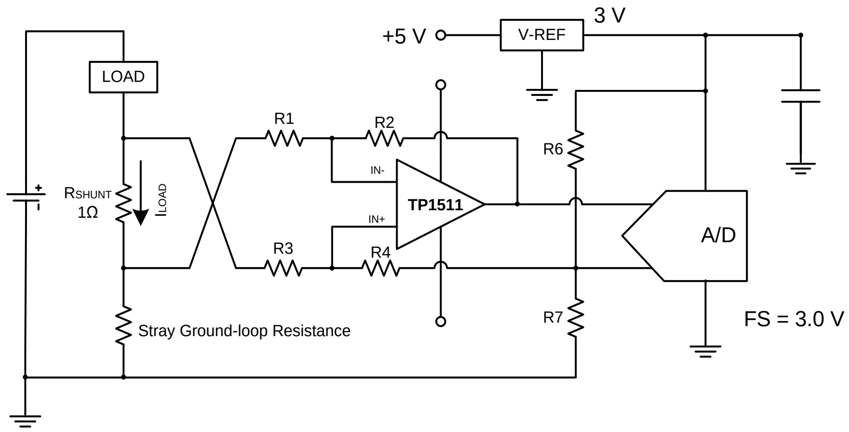
Description

The TP151x family includes CMOS single/dual/quad op-amps with low offset, stable high-frequency response, low power, low supply voltage, and rail-to-rail inputs and outputs. This family incorporates 3PEAK's proprietary and patented design techniques to achieve the best-in-class performance among all micro-power CMOS amplifiers in its power class. The TP151x family can be used as plug-in replacements for many commercially available op-amps to reduce power and improve input/output range and performance.

TP151x family is unity-gain stable with any capacitive load with a constant 150 kHz GBWP, 0.09 V/μs slew rate while consuming only 4 μA of quiescent current per amplifier. Analog trim and calibration routine reduce input offset voltage to below 3.0 mV, and proprietary precision temperature compensation technique makes offset voltage temperature drift at 0.6 μV/°C. Beyond the rails input and rail-to-rail output characteristics allow the full power-supply voltage to be used for signal range.

This combination of features makes the TP151x OPA an ideal choice for battery-powered applications because the TP151x family minimizes errors due to power supply voltage variations over the lifetime of the battery and maintains high CMRR even for a rail-to-rail input op-amp. Battery current monitors, consumer devices, handheld instrumentation, remote battery-powered sensors, hazard detection (for example, smoke, fire, and gas), and patient monitors can benefit from the features of the TP151x op-amps.

Typical Application Circuit



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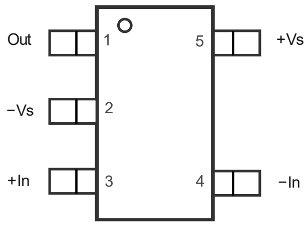
Revision History

Date	Revision	Notes
2022-06-21	Rev.A.3	Updated with new document format. Updated with new package outline dimensions file. Added part number: TP1511-DF1R.
2023-11-02	Rev.A.4	Corrected typo in the header of last page.

Pin Configuration and Functions

TP1511
5-Pin SOT23 Package
Top View



TP1511
DFN1X1-4 (5 Pin) Package
Top View

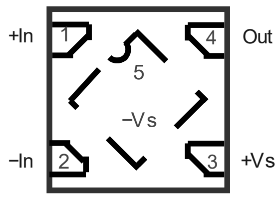
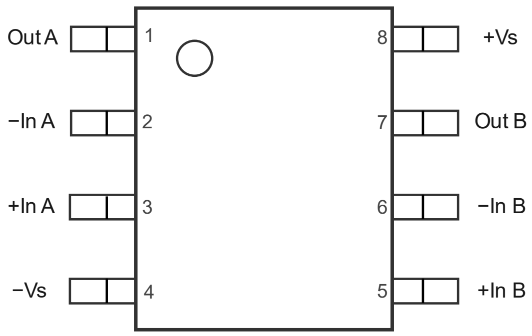


Table 6-1. Pin Functions: TP1511

Pin		Name	I/O	Description
SOT23	DFN1x1			
1	4	Out	Output	Output
2	5	−Vs		Negative power supply
3	1	+In	Input	Noninverting input
4	2	−In	Input	Inverting input
5	3	+Vs		Positive power supply

TP1512
SOP8 Package
Top View



TP1512
MSOP8 Package
Top View

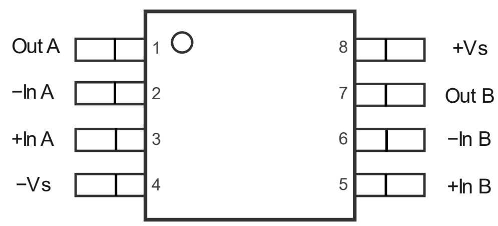
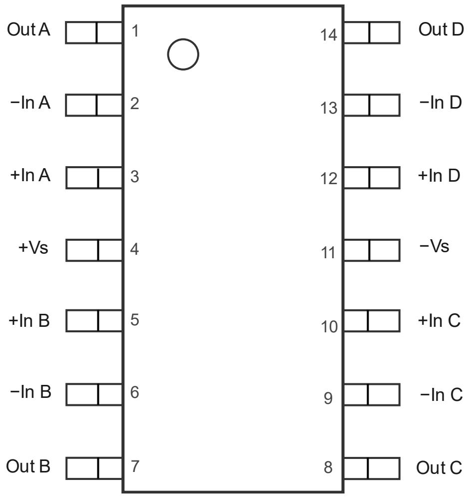


Table 6-2. Pin Functions: TP1512

Pin	Name	I/O	Description
1	Out A	Output	Output
2	−In A	Input	Inverting input
3	+In A	Input	Noninverting input
4	−Vs		Negative power supply
5	+In B	Input	Noninverting input
6	−In B	Input	Inverting input
7	Out B	Output	Output
8	+Vs		Positive power supply

TP1514
SOP14 Package
Top View



TP1514
TSSOP14 Package
Top View

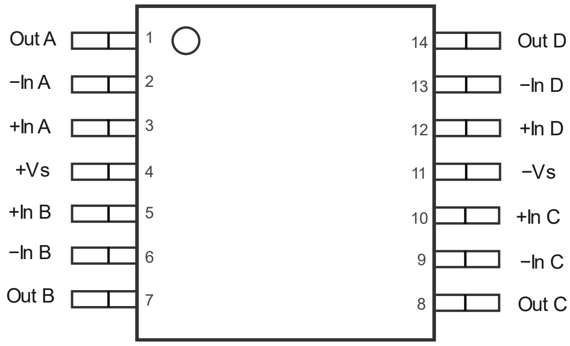


Table 6-3. Pin Functions: TP1514

Pin	Name	I/O	Description
1	Out A	Output	Output
2	−In A	Input	Inverting input
3	+In A	Input	Noninverting input
4	+Vs		Positive power supply
5	+In B	Input	Noninverting input
6	−In B	Input	Inverting input
7	Out B	Output	Output
8	Out C	Output	Output
9	−In C	Input	Inverting input
10	+In C	Input	Noninverting input
11	−Vs		Negative power supply
12	+In D	Input	Noninverting input
13	−In D	Input	Inverting input
14	Out D	Output	Output

Specifications

Absolute Maximum Ratings[1]

Parameter		Min	Max	Unit
	Supply Voltage: $V^+ - V^-$		6	V
	Input Voltage	$V^- - 0.5$	$V^+ + 0.5$	V
	Input Current: +IN, –IN[2]	−10	+10	mA
	Output Current: OUT[2]	−40	+40	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 inputs and outputs are protected by ESD protection diodes to negative power supply. If the input or output extends more than 500 mV beyond the negative power supply, the 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 comparators 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

Symbol	Parameter	Condition	Minimum Level	Unit
HBM	Human Body Model ESD	ANSI/ESDA/JEDEC JS-001[1]	8	kV
CDM	Charged Device Model ESD	ANSI/ESDA/JEDEC JS-002[2]	2	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
DFN1X1-4 (5Pin)	210	110	°C/W
SOT23-5	250	81	°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 condition is at T_A = 27°C. V_{SUPPLY} = 5V, V_{CM} = V_{OUT} = V_{SUPPLY}/2, R_L = 100KΩ, C_L =100pF, V_{SHDN} is unconnected, unless otherwise noted.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{DD}	Supply Voltage		2.1		6.0	V
I_Q	Quiescent Current per Amplifier	T_A = −40°C to 125°C		4	5.6	µA
V_{OS}	Input Offset Voltage	V_{CM} = V_{SUPPLY}/2, T_A = −40°C to 125°C	-3.0	±0.2	+3.0	mV
V_{OS} TC	Input Offset Voltage Drift	T_A = −40°C to 125°C		0.6		µV/°C
PSRR	Power Supply Rejection Ratio	T_A = −40°C to 125°C	80	110		dB
A_{VOL}	Open-Loop Large Signal Gain	V_{OUT} = 2.5V, R_{LOAD} = 100 kΩ, T_A = −40°C to 125°C	80	102		dB
		V_{OUT} = 0.1V to 4.9V, R_{LOAD} = 100 kΩ, T_A = −40°C to 125°C	72	102		dB
I_B	Input Bias Current			1.0		pA
I_{OS}	Input Offset Current			1.0		pA
R_{IN}	Input Resistance		>100			GΩ
C_{IN}	Input Capacitance	Differential Common Mode		1.5 3.0		pF
CMRR	Common Mode Rejection Ratio	V_{CM} = 0.1V to 4.9V, T_A = −40°C to 125°C	80	110		dB
V_{CM}	Common-mode Input Voltage Range	T_A = −40°C to 125°C	(−V_S)− 0.1		(+V_S) + 0.1	V
V_{OL}, V_{OH}	Output Swing from Supply Rail	R_{LOAD} = 100 kΩ		5		mV
R_{OUT}	Closed-Loop Output Impedance	G = 1, f = 1kHz, I_{OUT} = 0		30		Ω
R_O	Open-Loop Output Impedance	f = 1kHz, 10kHz, I_{OUT} = 0		4		kΩ
I_{SC}	Output Short-Circuit Current	Sink or source current		40		mA
PM	Phase Margin	R_{LOAD} = 100kΩ, C_{LOAD} = 100pF		67		°
GBWP	Gain-Bandwidth Product	f = 1kHz		150		kHz
FPBW	Full Power Bandwidth (1)	$2V_{P-P}$		14		kHz
SR	Slew Rate	A_V = 1, V_{OUT} = 1.5 V to 3.5 V, C_{LOAD} = 100 pF, R_{LOAD} = 100 kΩ		0.09		V/µs
t_{OV}	Overload Recovery Time	G = -10		15		µs
t_S	Settling Time, 1.5V to 3.5V, Unity Gain Settling Time, 2.45V to 2.55V, Unity Gain	0.1% 0.01% 0.1% 0.01%		22 26 10 12		µs

Electrical Characteristics (Continued)

All test condition is at T_A = 27°C. V_{SUPPLY} = 5V, V_{CM} = V_{OUT} = $V_{SUPPLY}/2$, R_L = 100KΩ, C_L =100pF, V_{SHDN} is unconnected, unless otherwise noted.

V_n	Input Voltage Noise	f = 0.1Hz to 10Hz		3.6		μV_{PP}
e_n	Input Voltage Noise Density	f = 1kHz f = 10kHz		95 82		nV/√Hz
THD+N	Total Harmonic Distortion and Noise	f = 0.1 kHz, A_V = 1, R_L = 100 kΩ, V_{OUT} = 2 V_{PP} f = 1 kHz, A_V = 1, R_L = 100 kΩ, V_{OUT} = 2 V_{PP}		-94 -70		dB

(1) Full power bandwidth is calculated from the slew rate FPBW = SR/π • VP-P.

Typical Performance Characteristics

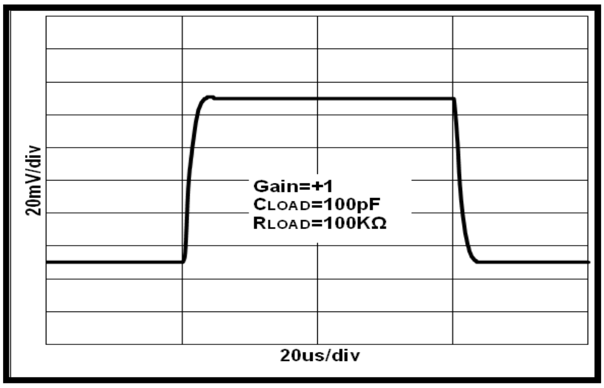


Figure 1. Small-signal Step Response, 100 mV Step

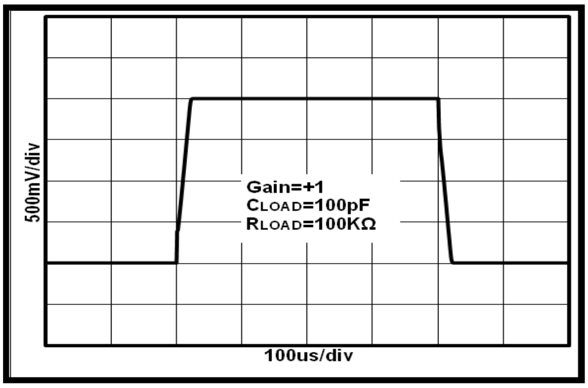


Figure 2. Large-Signal Step Response, 2V Step

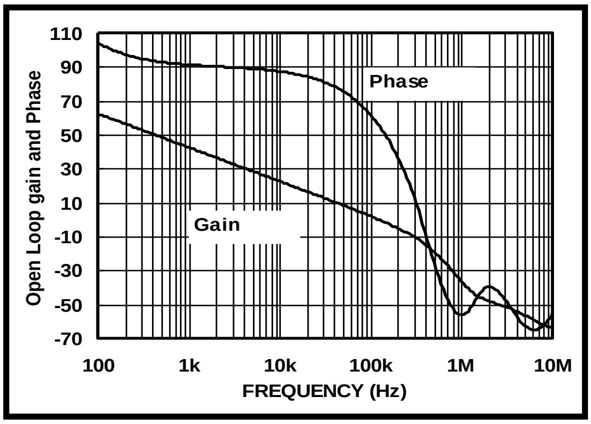


Figure 3. Open-Loop Gain and Phase

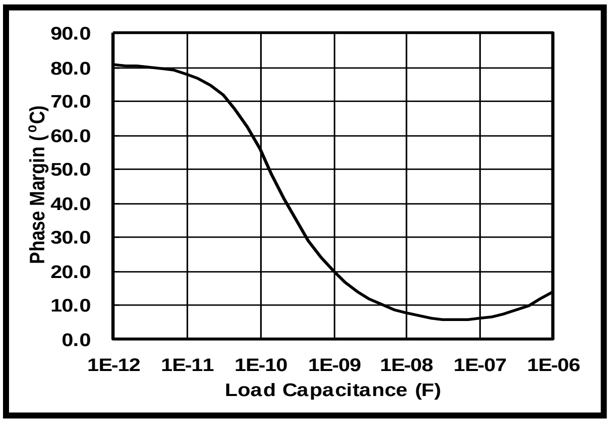


Figure 4. Phase Margin vs. C_{LOAD} (Stable for Any C_{LOAD})

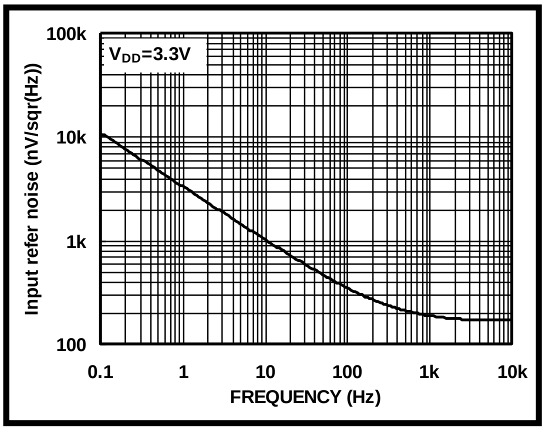


Figure 5. Input Voltage Noise Spectral Density

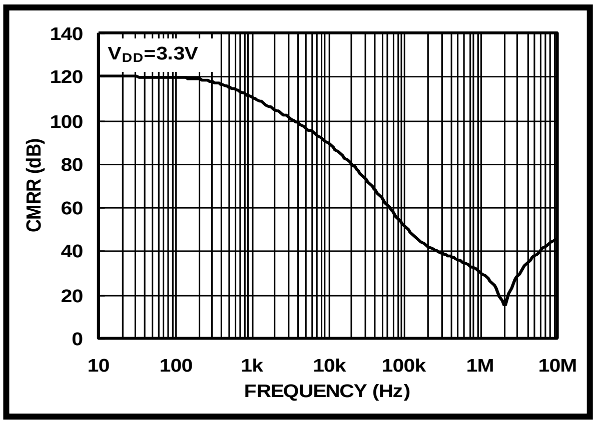


Figure 6. Common-Mode Rejection Ratio

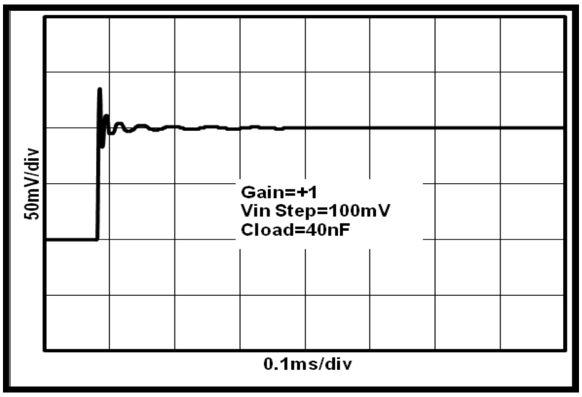


Figure 7. Over-Shoot Voltage, C_{LOAD} = 40nF, Gain = +1

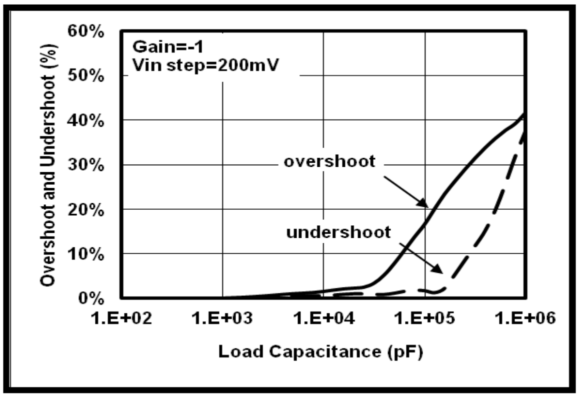


Figure 8. Over-Shoot % vs. C_{LOAD}, Gain = -1, RFB = 20kΩ

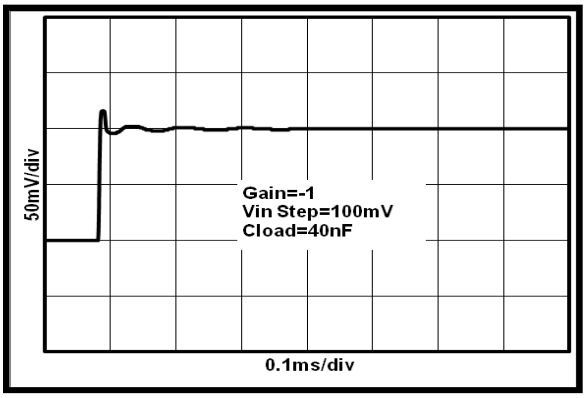


Figure 9. Over-Shoot Voltage, C_{LOAD}=40nF, Gain= -1, RFB=100kΩ

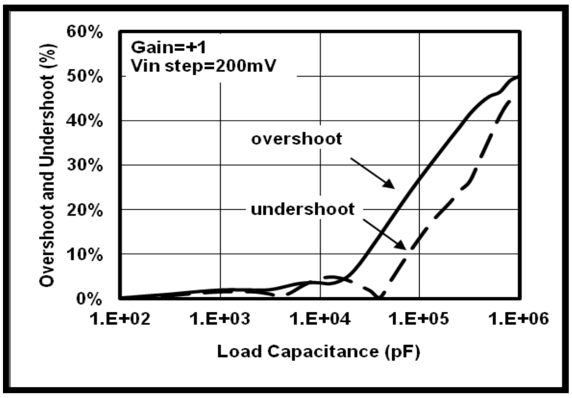


Figure 10. Small-Signal Over-Shoot % vs. C_{LOAD}, Gain = +1

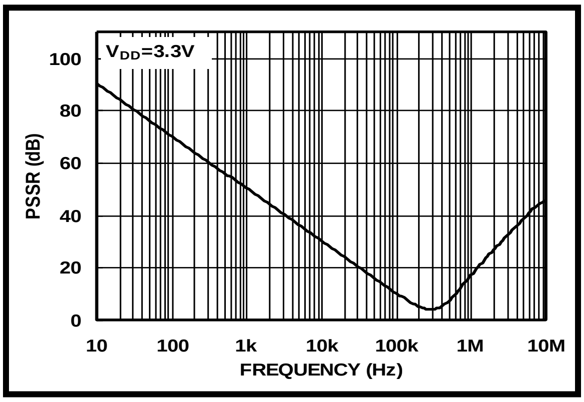


Figure 11. Power-Supply Rejection Ratio

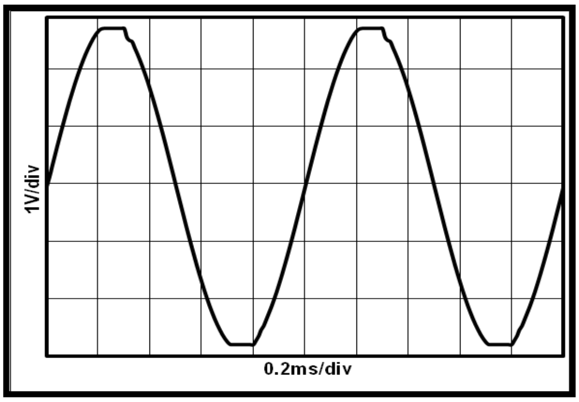


Figure 12. V_{IN} = -0.2V to 5.7V, No Phase Reversal

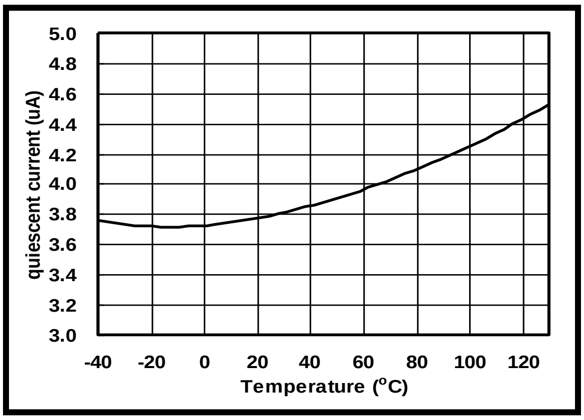


Figure 13. Quiescent Supply Current vs. Temperature

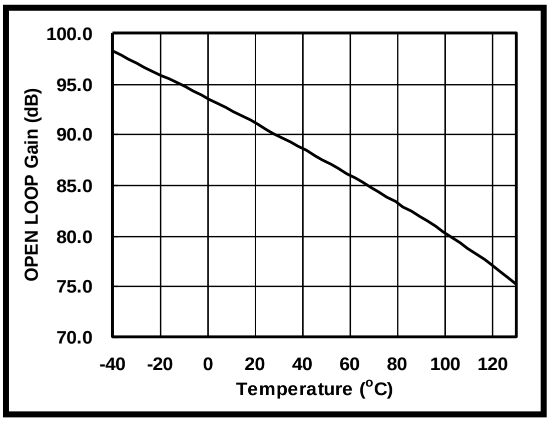


Figure 14. Open-Loop Gain vs. Temperature

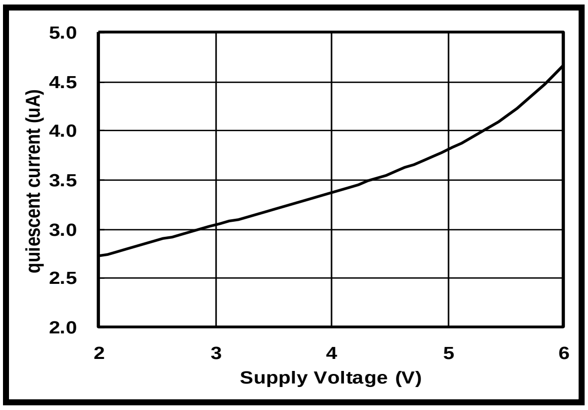


Figure 15. Quiescent Supply Current vs. Supply Voltage

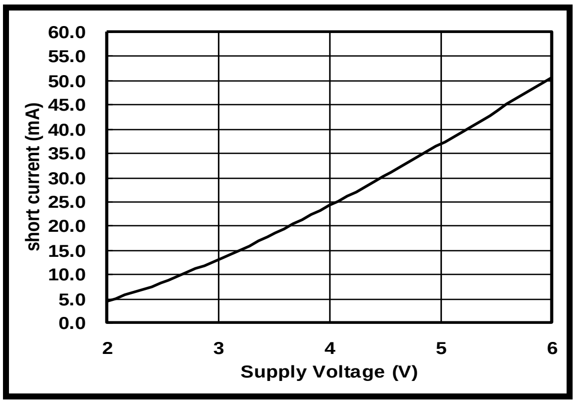


Figure 16. Short-Circuit Current vs. Supply Voltage

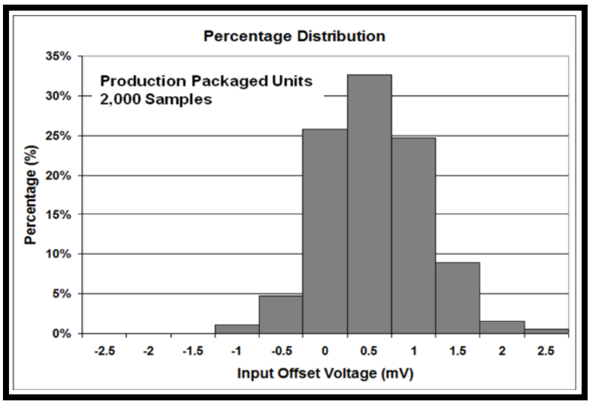


Figure 17. Input Offset Voltage Distribution

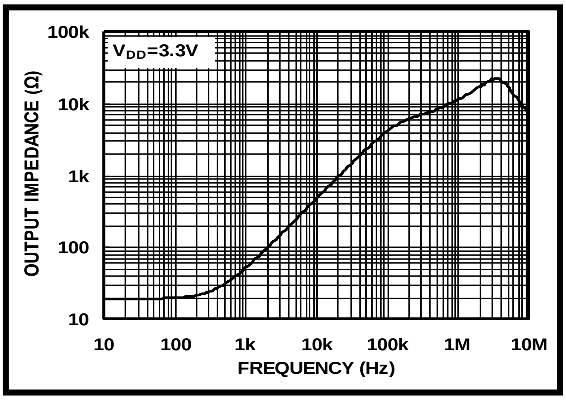


Figure 18. Closed-Loop Output Impedance vs. Frequency

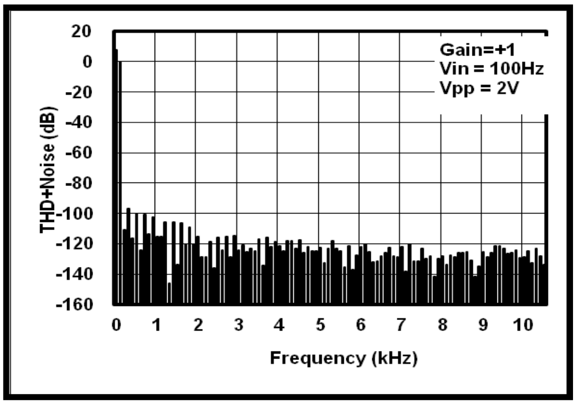


Figure 19. THD + Noise, Gain = +1, V_{IN} = 100Hz, V_{PP} = 2V

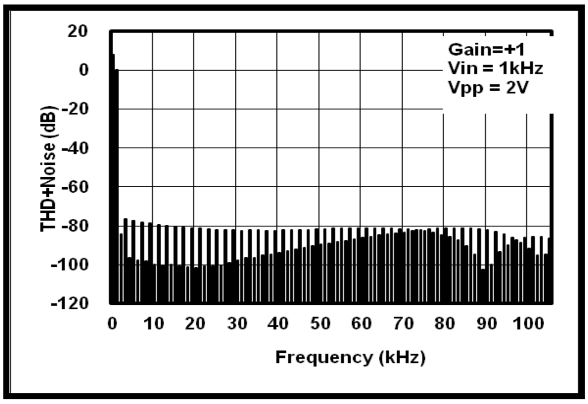


Figure 20. THD + Noise, Gain = +1, V_{IN} = 1kHz, V_{PP} = 2V

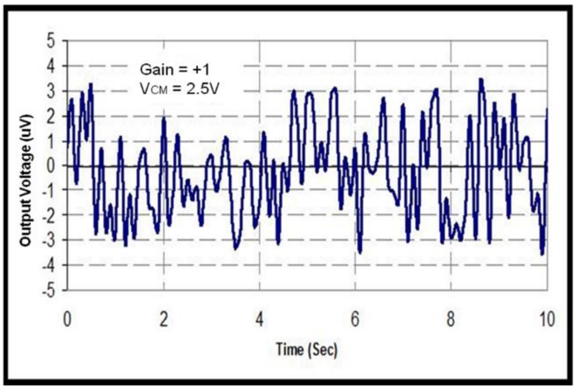


Figure 21. 0.1Hz to 10Hz Time Domain Output Voltage Noise

Detailed Description

Overview

The TP151x family input signal range extends beyond the negative and positive power supplies. The output can even extend all the way to the negative supply. The input stage is comprised of two CMOS differential amplifiers, a PMOS stage and NMOS stage that are active over different ranges of common-mode input voltage. The Class-AB control buffer and output bias stage uses a proprietary compensation technique to take full advantage of the process technology to drive very high capacitive loads. This is evident from the transient over shoot measurement plots in the Typical Performance Characteristics.

Functional Block Diagram

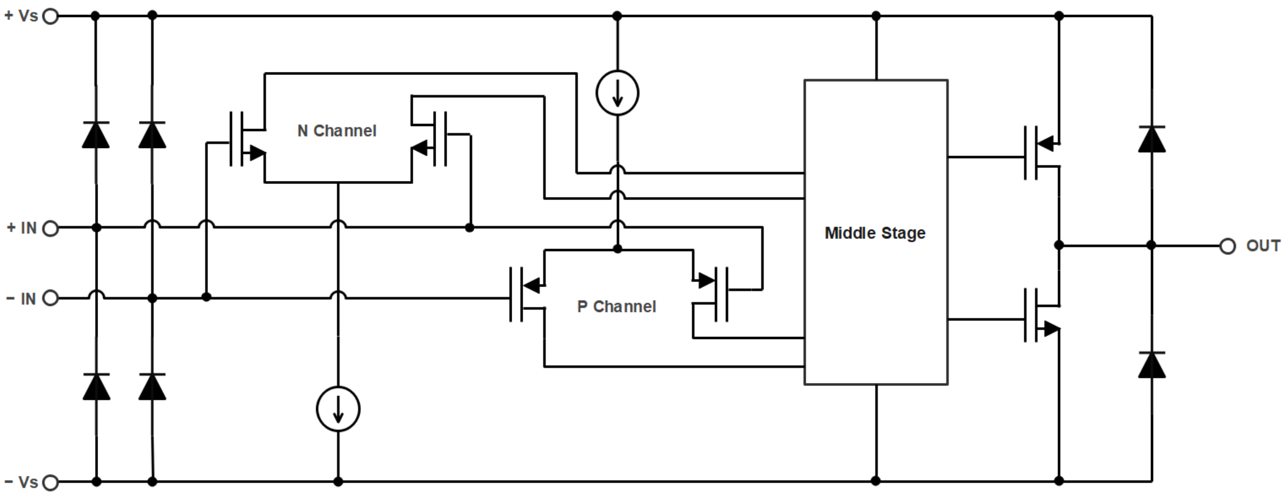


Figure 22. Functional Block Diagram

Application and Implementation

NOTE

Information in the following applications 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 Supply Voltage and Low Power Consumption

The TP151x family of operational amplifiers can operate with power supply voltages from 2.1 V to 6.0 V. Each amplifier draws only 4 μA quiescent current. The low supply voltage capability and low supply current are ideal for portable applications demanding high capacitive load driving capability and stable wide bandwidth. The TP151x family is optimized for wide-bandwidth and low-power applications. The TP151x family has an industry leading high GBW to power ratio and is unity gain stable for any capacitive load. When the load capacitance increases, the increased capacitance at the output pushes the non-dominant pole to lower frequency in the open loop frequency response, lowering the phase and gain margin. Higher gain configurations tend to have better capacitive drive capability than lower gain configurations due to lower closed loop bandwidth and hence higher phase margin.

Low Input Bias Current

The TP151x family is a CMOS OPA family and features very low input bias current in pA range. The low input bias current allows the amplifiers to be used in applications with high resistance sources. Care must be taken to minimize PCB surface leakage.

Typical Application

Low-Side Current Monitor Application

As shown in Figure 4. Please be noted: 1% resistors provide adequate common-mode rejection at small ground-loop errors.

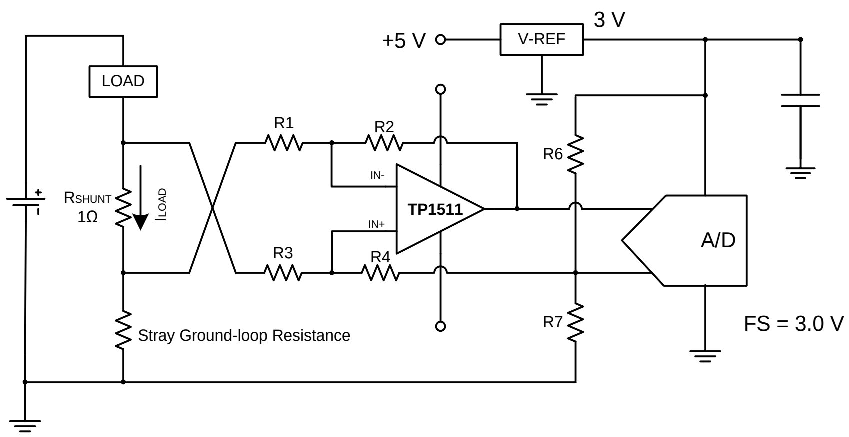
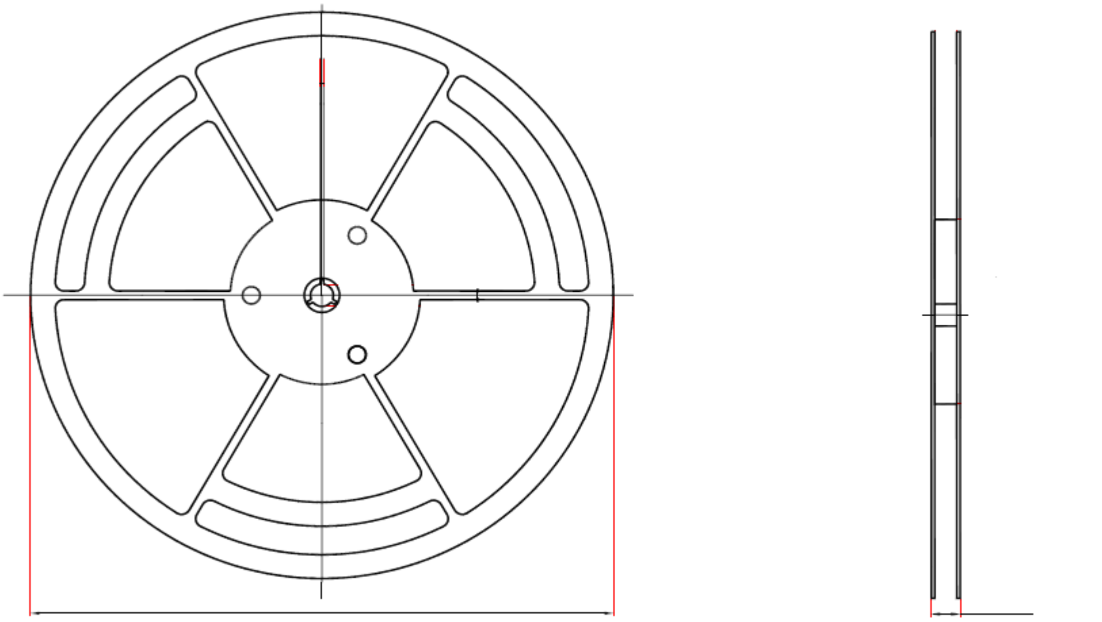
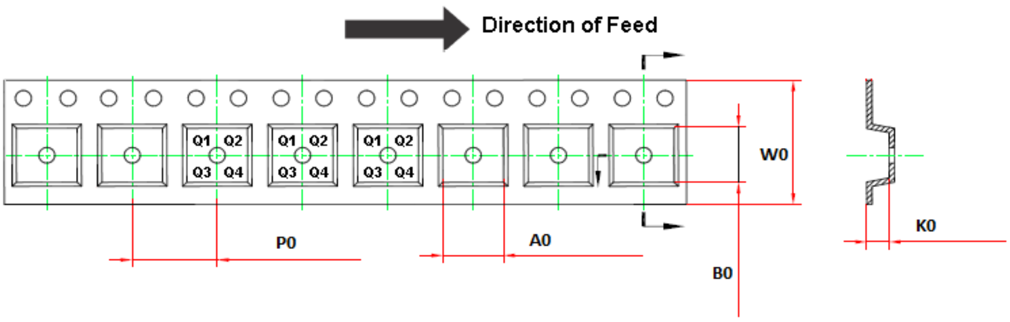


Figure 23. Low-Side Current Monitor Application

Tape and Reel Information



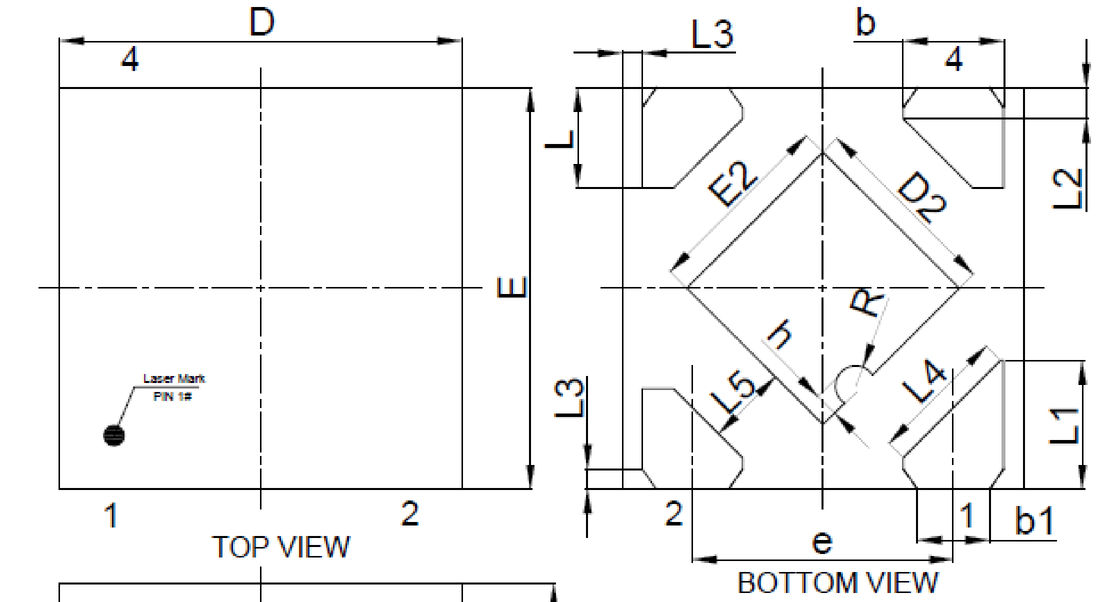


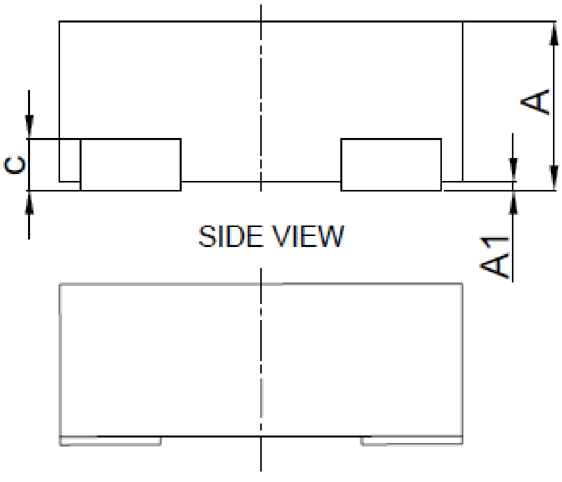
Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TP1511-TR	SOT23-5	180.0	13.1	3.2	3.2	1.4	4.0	8.0	Q3
TP1511-DF1R	DFN1X1-4 (5 Pin)	180	10.0	1.16	1.16	0.5	2.0	8.0	Q1
TP1512-SR	SOP8	330.0	17.6	6.4	5.4	2.1	8.0	12.0	Q1
TP1512-VR	MSOP8	330.0	17.6	5.2	3.3	1.5	8.0	12.0	Q1
TP1514-SR	SOP14	330.0	21.6	6.5	9.0	2.1	8.0	16.0	Q1
TP1514-TR	TSSOP14	330.0	17.6	6.8	5.4	1.2	8.0	12.0	Q1

Package Outline Dimensions

DFN1X1-4 (5 Pin)

Package Outline Dimensions DF1(DFN1X1-4-A)





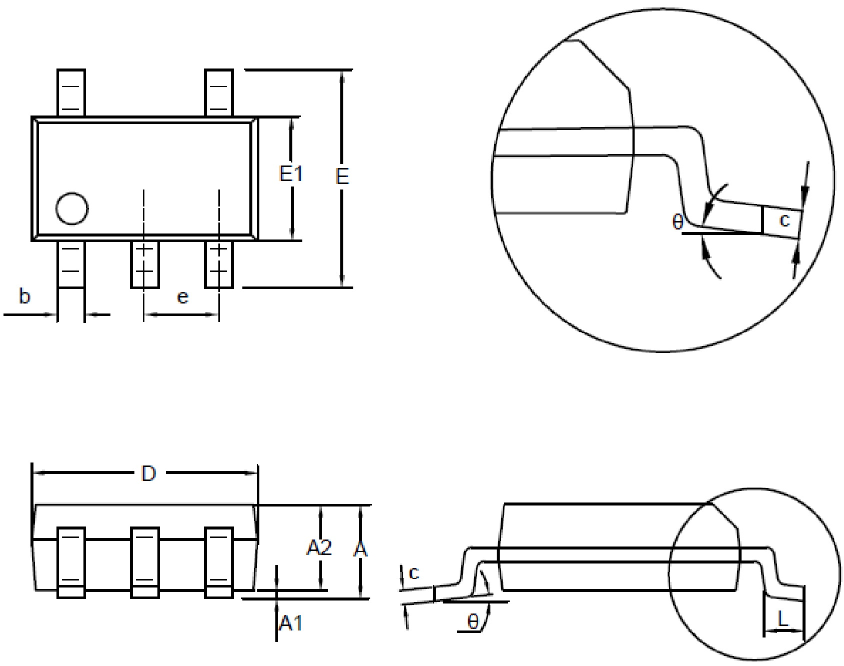
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.350	0.400	0.014	0.016
A1	0.000	0.050	0.000	0.002
b	0.200	0.300	0.008	0.012
c	0.070	0.170	0.003	0.007
D	0.950	1.050	0.037	0.041
D2	0.430	0.530	0.017	0.021
E	0.950	1.050	0.037	0.041
E2	0.430	0.530	0.017	0.021
e	0.650 BSC		0.026 BSC	
L	0.200	0.300	0.008	0.012
L1	0.270	0.370	0.011	0.015
L2	0.077 BSC		0.003 BSC	
L3	0.050 BSC		0.002 BSC	
L4	0.340 BSC		0.013 BSC	
L5	0.200 BSC		0.008 BSC	

NOTES

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

SOT23-5

Package Outline Dimensions	S5T(SOT23-5-A)

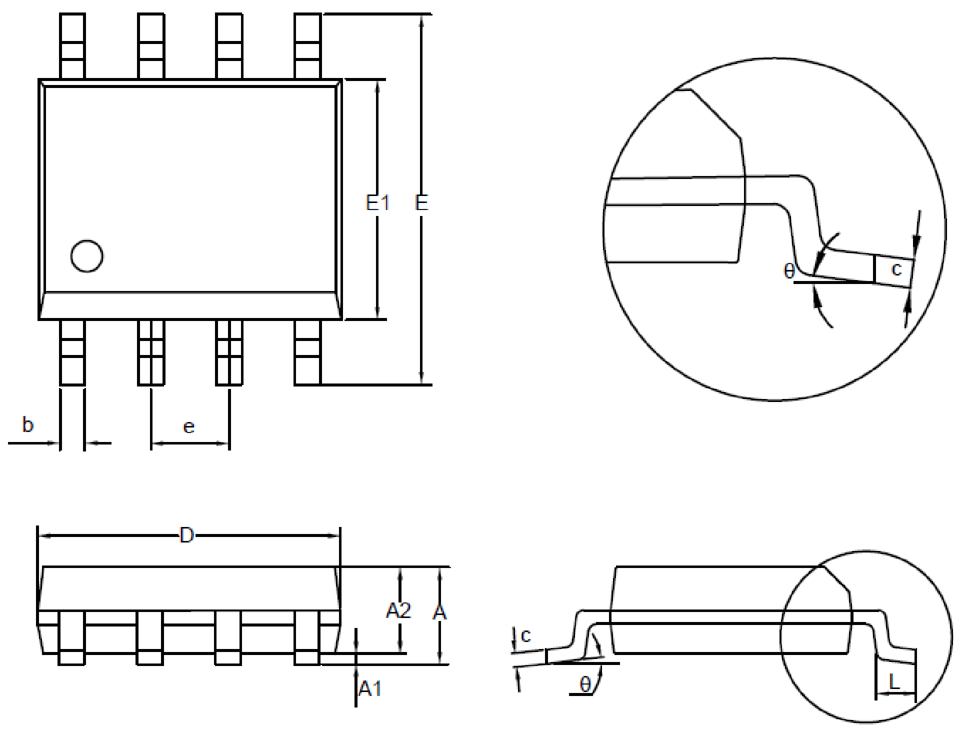


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.150	0.000	0.006
A2	1.000	1.200	0.039	0.047
b	0.280	0.500	0.011	0.020
c	0.100	0.230	0.004	0.009
D	2.820	3.020	0.111	0.119
E	2.600	3.000	0.102	0.118
E1	1.500	1.720	0.059	0.068
e	0.950 BSC		0.037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



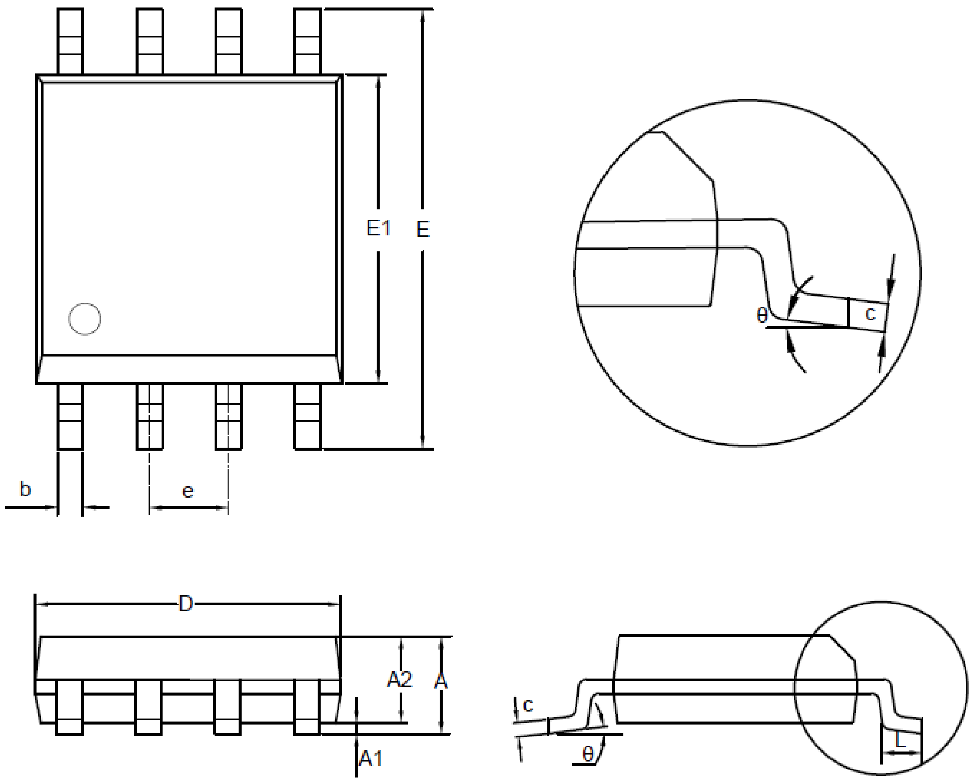
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.550	0.049	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050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

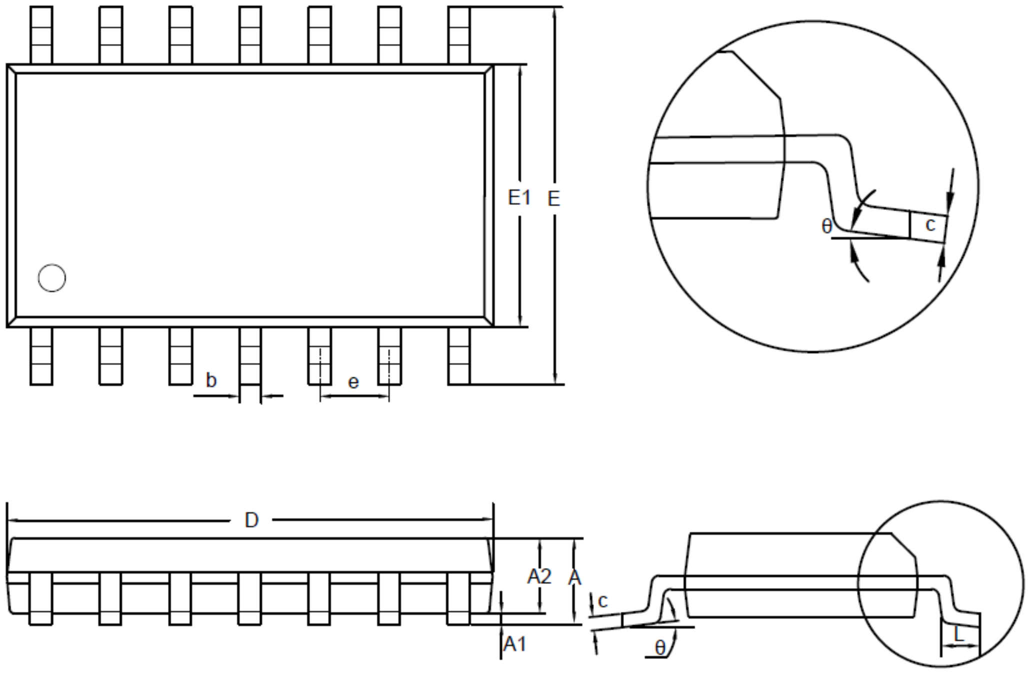


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.800	1.100	0.031	0.043
A1	0.050	0.150	0.002	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	4.700	5.100	0.185	0.201
E1	2.900	3.100	0.114	0.122
e	0.650 BSC		0.026 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)



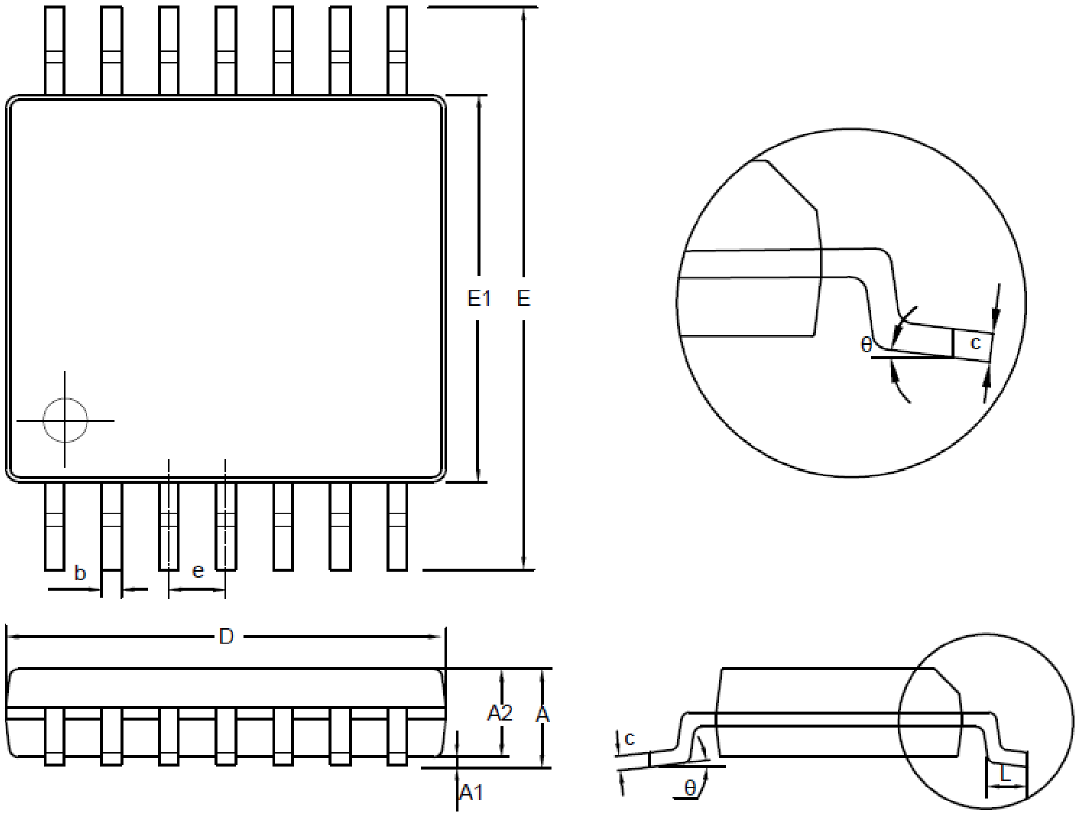
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.650	0.049	0.065
b	0.310	0.510	0.012	0.020
c	0.100	0.250	0.004	0.010
D	8.450	8.850	0.333	0.348
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050 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
TP1511-TR	−40 to 125°C	5-Pin SOT23	A1T	3	Tape and Reel, 3000	Green
TP1511-DF1R	−40 to 125°C	DFN1X1-4 (5 Pin)	15	3	Tape and Reel, 12000	Green
TP1512-SR	−40 to 125°C	SOP8	1512S	3	Tape and Reel, 4000	Green
TP1512-VR	−40 to 125°C	MSOP8	1512S	3	Tape and Reel, 3000	Green
TP1514-SR	−40 to 125°C	SOP14	A14S	3	Tape and Reel, 2500	Green
TP1514-TR(1)	−40 to 125°C	TSSOP14	A14T	3	Tape and Reel, 3000	Green

(1) Future product, contact 3PEAK factory for more information and sample.

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

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