36-V, 5-MHz, Bipolar Input, RRIO, Operational Amplifier

Features

- Supply Voltage: 4.5 V to 36 V
- Low Supply Current: 0.9 mA per channel
- Low Offset Voltage: ±1 mV Maximum at 25°C
- Low Input Bias Current: ±30 nA at 25°C
- No ESD Diode to Positive Power Supply
- Gain Bandwidth: 5 MHz
- Slew Rate: 3.5 V/μs
- Low Noise: 62 nV/$\sqrt{Hz}$ at 1 kHz
- Excellent THD + N: 0.001%

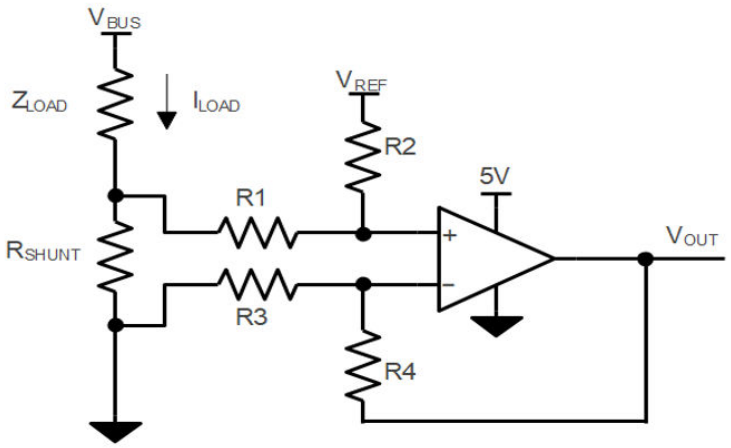
Applications

- Instrumentation
- Active Filters, ASIC Input, and Output Amplifier
- Sensor Interface
- Motor Control
- Industrial Control

Description

The TPA165x is a series of the newest high supply voltage amplifiers with ±1 mV low offset voltage, low noise, and stable high-frequency response. They incorporate proprietary and patented design techniques of the 3PEAK to achieve excellent AC performance with 5-MHz gain-bandwidth, 3.5 V/μs slew rate, and low distortion while drawing only 0.9 mA quiescent current per amplifier. The input common-mode voltage range extends to VCC − 1 V and the outputs swing rail-to-rail.

Typical Application Circuit



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

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

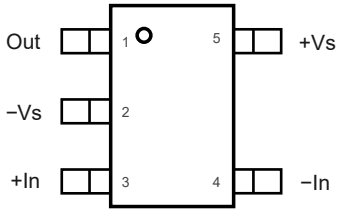
Table of Contents

Revision History

Date	Revision	Notes
2025-08-13	Rev.A.0	Initial Version.

Pin Configuration and Functions

TPA1651
SOT23-5
Top View



TPA1651U
SOT23-5
Top View

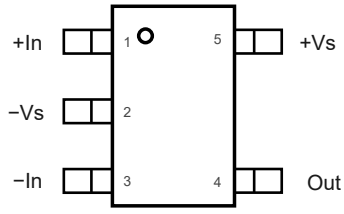
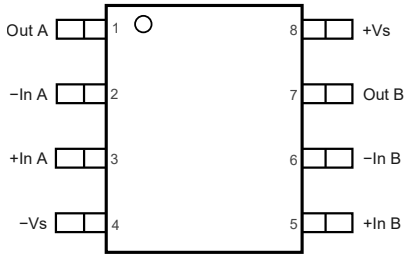


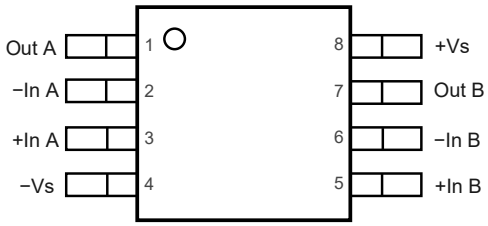
Table 1. Pin Functions: TPA1651/TPA1651U

Pin No.		Name	I/O	Description
TPA1651	TPA1651U			
1	4	Out	O	Output
2	2	$-V_S$	-	Negative power supply
3	1	+In	I	Non-inverting input
4	3	−In	I	Inverting input
5	5	$+V_S$	-	Positive power supply

TPA1652
SOP8
Top View



TPA1652
MSOP8
Top View



TPA1652
TSSOP8
Top View

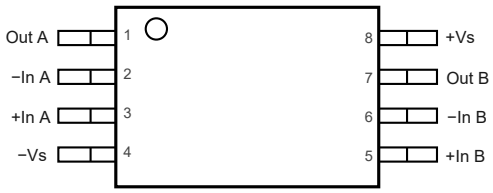
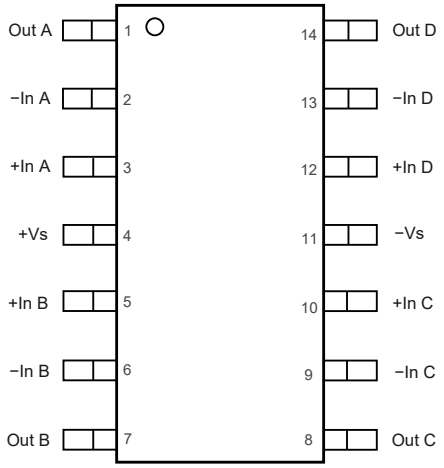


Table 2. Pin Functions: TPA1652

Pin No.			Name	I/O	Description
SOP8	MSOP8	TSSOP8			
1	1	1	Out A	O	Output
2	2	2	−In A	I	Inverting input
3	3	3	+In A	I	Non-inverting input
4	4	4	$-V_S$		Negative power supply
5	5	5	+In B	I	Non-inverting input
6	6	6	−In B	I	Inverting input
7	7	7	Out B	O	Output
8	8	8	$+V_S$		Positive power supply

TPA1654
SOP14
Top View



TPA1654
TSSOP14
Top View

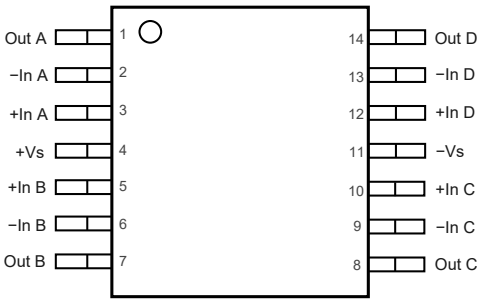


Table 3. Pin Functions: TPA1654

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	$(-V_S) - 0.3$	40	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	
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 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 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)	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.

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
SOP8	158	43	°C/W
MSOP8	210	45	°C/W
TSSOP8	191	44	°C/W
SOP14	120	36	°C/W
TSSOP14	180	35	°C/W

Electrical Characteristics

All test conditions: V_S = 30 V, T_A = 25°C, R_L = 10 kΩ, unless otherwise noted.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Power Supply						
V_S	Supply Voltage Range	$(+V_S) - (-V_S)$	4.5		36	V
I_Q	Quiescent Current per Amplifier	V_S= 5 V	0.6	0.9	1.5	mA
		V_S= 5 V, T_A = −40°C to 125°C		0.9	2	mA
		V_S = 30 V	0.6	0.9	1.5	mA
		V_S = 30 V, T_A = −40°C to 125°C		0.9	2	mA
PSRR	Power Supply Rejection Ratio	V_S = 4.5 V to 36 V	95	103		dB
		V_S = 4.5 V to 36 V, T_A = −40°C to 125°C	93			dB
Input Characteristics						
V_{OS}	Input Offset Voltage	V_S = 4.5 V, V_{CM} = 2.25 V	−1	±0.15	1	mV
		V_S = 4.5 V, V_{CM} = 2.25 V, T_A = −40°C to 125°C	−2.3		2.3	mV
		V_S = 30 V, V_{CM} = 15 V	−1	±0.15	1	mV
		V_S = 30 V, V_{CM} = 15 V, T_A = −40°C to 125°C	−2.3		2.3	mV
V_{OS} TC	Input Offset Voltage Drift	T_A = −40°C to 125°C		4		μV/°C
I_B	Input Bias Current	V_S = 30 V, V_{CM} = 15 V	−30	±8	30	nA
		V_S = 30 V, V_{CM} = 15 V T_A = −40°C to 125°C	−60		60	nA
I_{OS}	Input Offset Current	V_S = 30 V, V_{CM} = 15 V	−800	±100	800	pA
		V_S = 30 V, V_{CM} = 15 V T_A = −40°C to 125°C	−9000		9000	pA
C_{IN}	Input Capacitance	Differential mode		5		pF
		Common mode		5		pF
A_V	Open-Loop Voltage Gain	V_{OUT} = 0.5 V to 29 V	105	115		dB
		V_{OUT} = 0.5 V to 29 V, T_A = −40°C to 125°C	100			dB
V_{CMR}	Common-Mode Input Voltage Range	T_A = −40°C to 125°C	$(-V_S)$ – 0.1		$(+V_S)$ – 1	V
CMRR	Common-Mode Rejection Ratio	V_{CM} = 0 V to 27 V	90	115		dB
		V_{CM} = 0 V to 27 V, T_A = −40°C to 125°C	85			dB
		V_{CM} = 0 V to 29 V	80	100		dB
		V_{CM} = 0 V to 29 V, T_A = −40°C to 125°C	75			dB

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
EMIRR	EMI Rejection Ratio	V_S = 30 V, f = 1000 MHz		60		dB
Output Characteristics						
V_{OH}	Output Swing from Positive Rail	R_L = 10 kΩ to V_S / 2		90	105	mV
		R_L = 10 kΩ to V_S / 2, T_A = −40°C to 125°C			170	mV
		R_L = 2 kΩ to V_S / 2		425	450	mV
		R_L = 2 kΩ to V_S / 2, T_A = −40°C to 125°C			750	mV
V_{OL}	Output Swing from Negative Rail	R_L = 10 kΩ to V_S / 2		55	75	mV
		R_L = 10 kΩ to V_S / 2, T_A = −40°C to 125°C			130	mV
		R_L = 2 kΩ to V_S / 2		215	240	mV
		R_L = 2 kΩ to V_S / 2, T_A = −40°C to 125°C			410	mV
I_{SC}	Output Short-Circuit Current	V_S = 30 V, Source Current		75		mA
		T_A = −40°C to 125°C		75		mA
		V_S = 30 V, Sink Current		70		mA
		T_A = −40°C to 125°C		70		mA
AC Specifications						
GBW	Gain-Bandwidth Product			5		MHz
SR	Slew Rate	G = 1, 10-V step	2.5	3.5		V/μs
t_{OR}	Overload Recovery			400		ns
t_S	Settling Time, 0.1%	G = 1, 2V step		1		μs
	Settling Time, 0.01%			1.5		μs
PM	Phase Margin	R_L= 10 kΩ, C_L= 100 pF		60		°
GM	Gain Margin	R_L= 10 kΩ, C_L= 100 pF		10		dB
X_{TALK}	Crosstalk	f = 100 kHz, Only for 2CH and 4CH		100		dB
Noise Performance						
E_N	Input Voltage Noise	f = 0.1 Hz to 10 Hz		3		μV_{rms}
e_N	Input Voltage Noise Density	f = 1 kHz		62		$nV/\sqrt{Hz}$
i_N	Input Current Noise	f = 1 kHz		200		$fA/\sqrt{Hz}$
THD+N	Total Harmonic Distortion and Noise	f = 1 kHz, G = 1, R_L = 10 kΩ, V_{OUT} = 1 V_{RMS}		0.001		%

(1) Provided by design simulation.

Typical Performance Characteristics

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

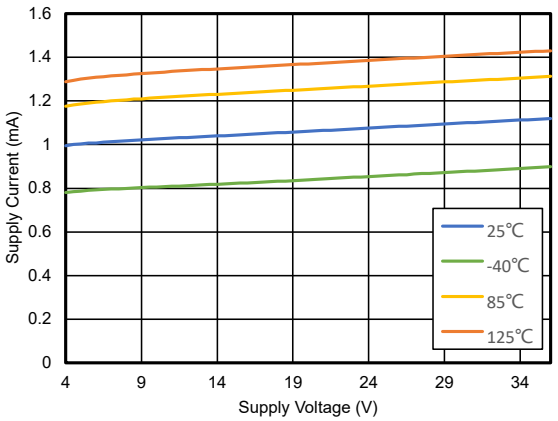


Figure 1. Supply Current vs. Supply Voltage, 1ch

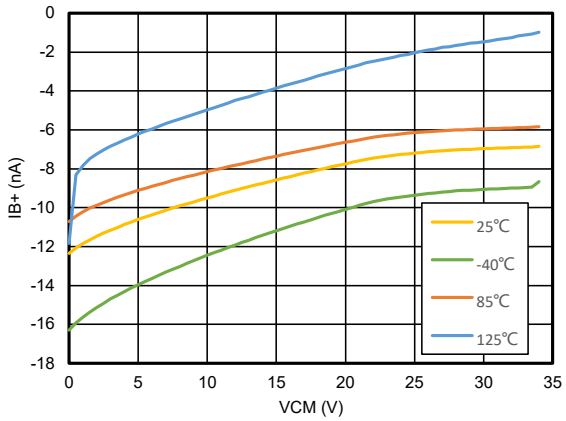


Figure 2. I_{B+} vs. Common-Mode Voltage

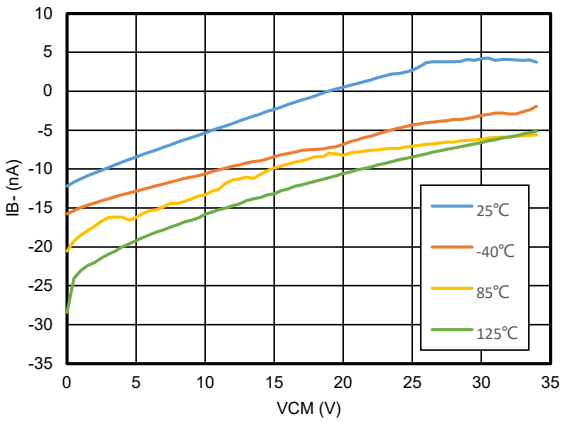


Figure 3. I_{B-} vs. Common-Mode Voltage

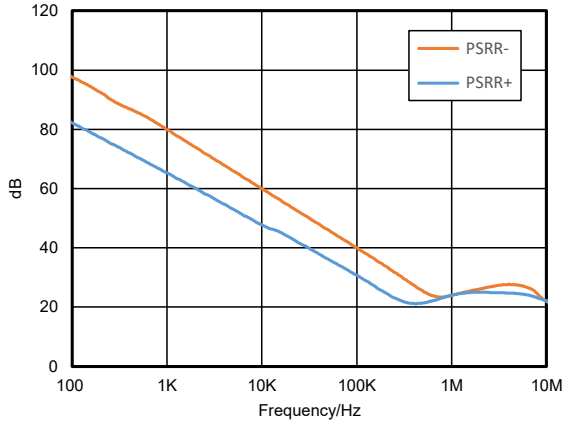


Figure 4. PSRR vs. Frequency

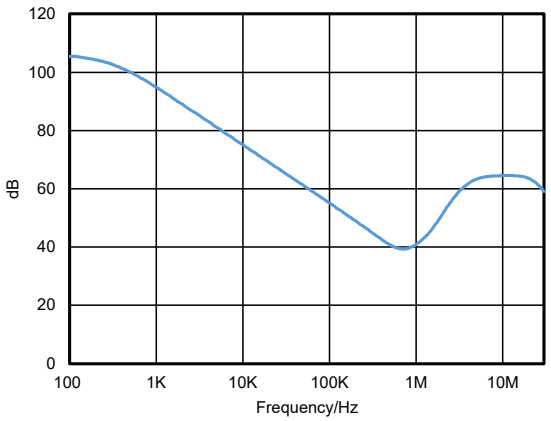


Figure 5. CMRR vs. Frequency

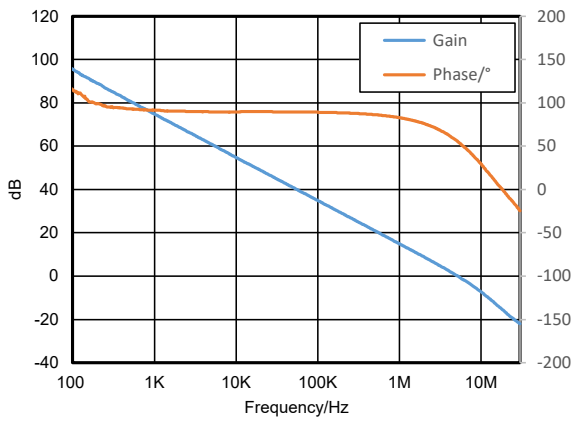


Figure 6. Open-Loop Gain and Phase vs. Frequency

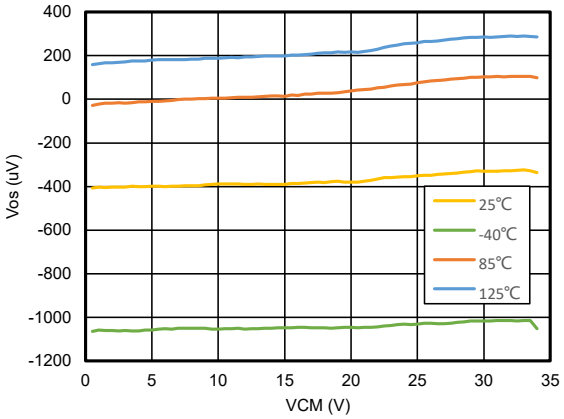


Figure 7. V_{os} vs. Common-Mode Voltage

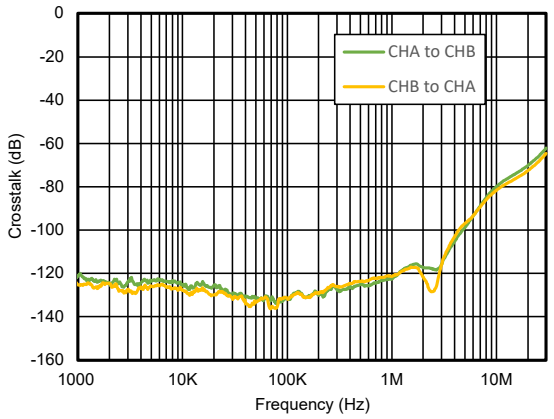


Figure 8. Channel Crosstalk vs Frequency

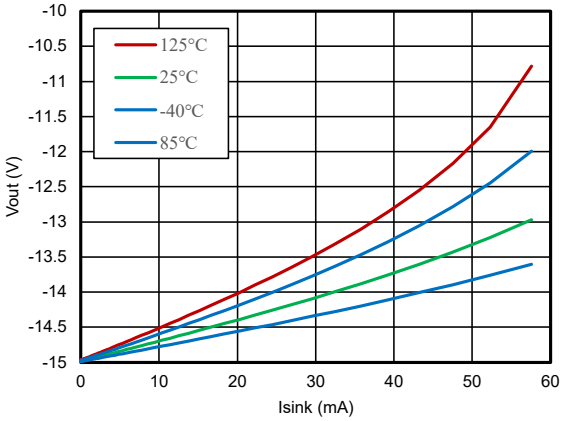


Figure 9. I_{sink} vs. V_{OUT}

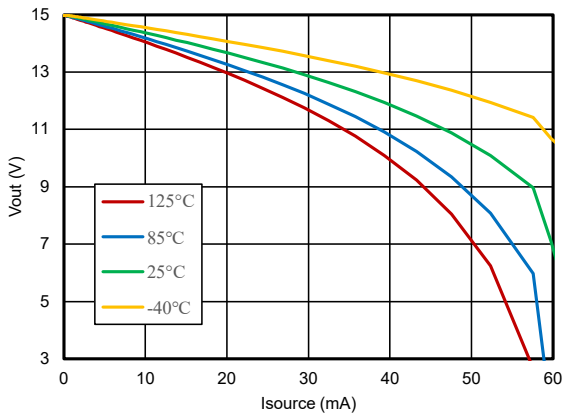


Figure 10. I_{source} vs. V_{OUT}

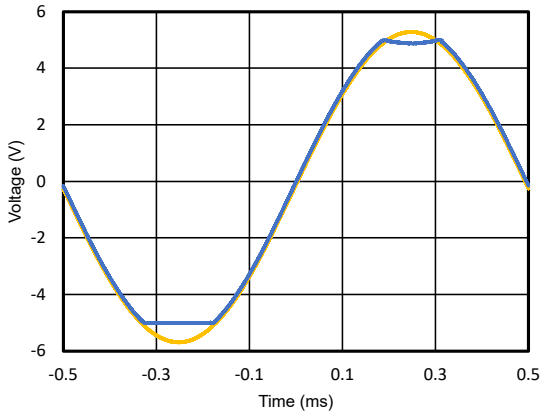


Figure 11. No Phase Reversal

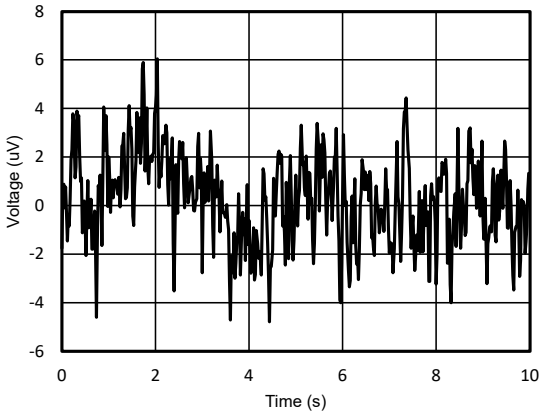


Figure 12. 0.1-Hz to 10-Hz Voltage Noise

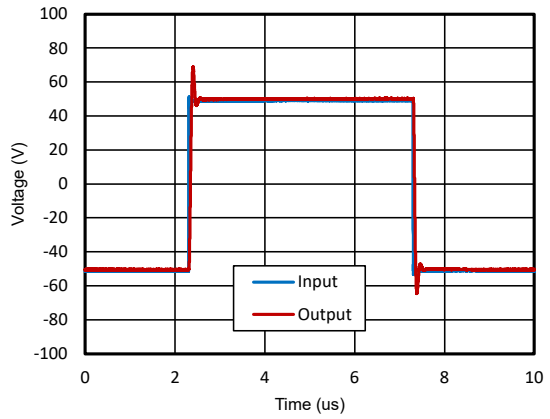


Figure 13. 100-mV Small-Signal Step Response

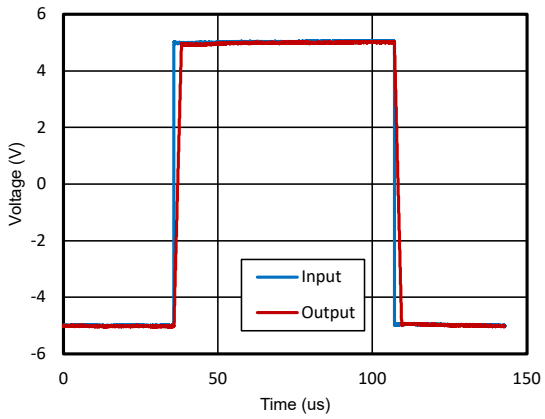


Figure 14. 10-V Large-Signal Step Response

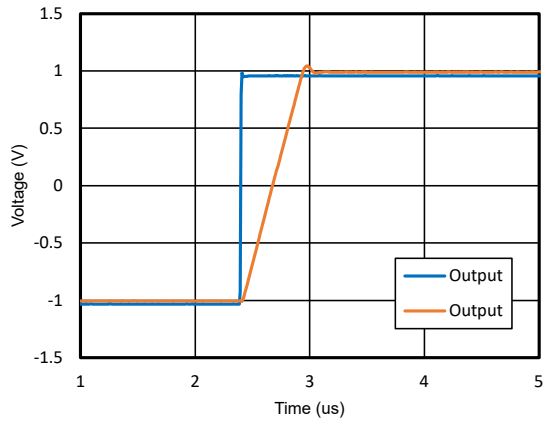


Figure 15. Positive Slew Rate

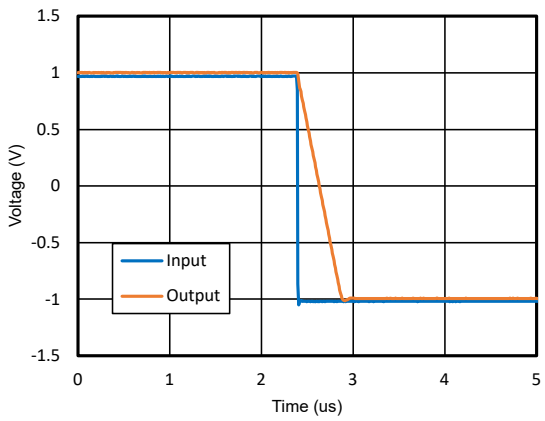


Figure 16. Negative Slew Rate

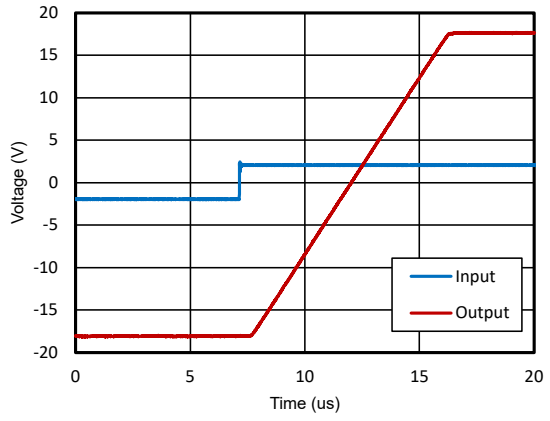


Figure 17. Overload Recovery

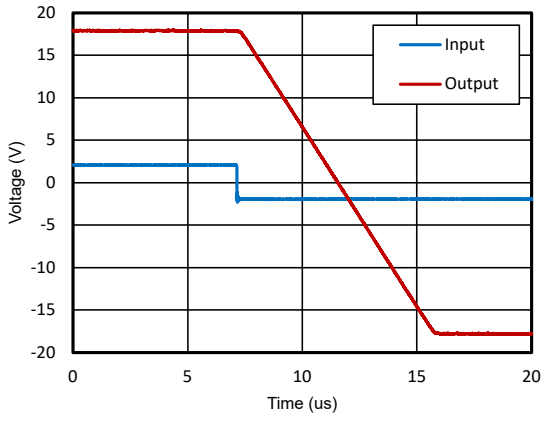


Figure 18. Overload Recovery

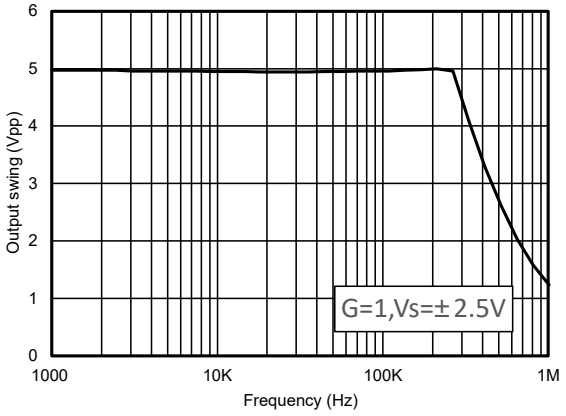


Figure 19. Maximum Output Voltage vs. Frequency

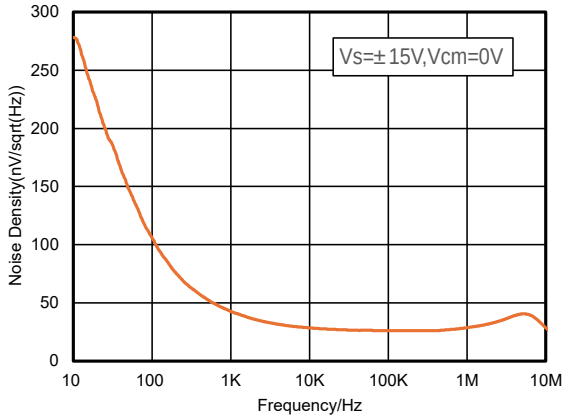


Figure 20. Input Voltage Noise Spectral Density vs. Frequency

Detailed Description

Overview

The TPA165x series op amps can operate on a single-supply voltage (4.5 V to 36 V), or a split-supply voltage (±2.25 V to ±18 V), making them highly versatile and easy to use. The power-supply pins should have local bypass ceramic capacitors (typically 0.01 µF to 0.1 µF). Parameters that can exhibit variance with regard to operating voltage or temperature are presented in the Typical Characteristics.

Functional Block Diagram

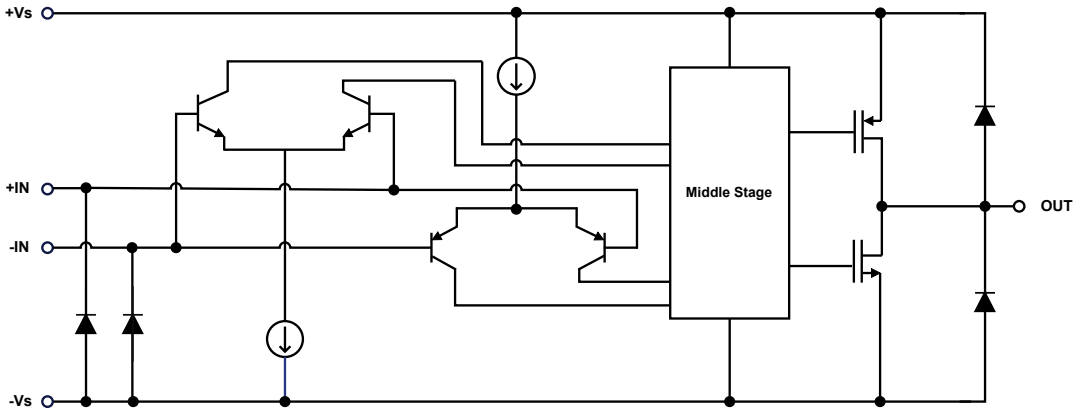


Figure 21. Functional Block Diagram

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 ($-V_S$) = 100 V, ($+V_S$) = 136 V, or ($-V_S$) = −6 V, ($+V_S$) = 30 V, and so on.

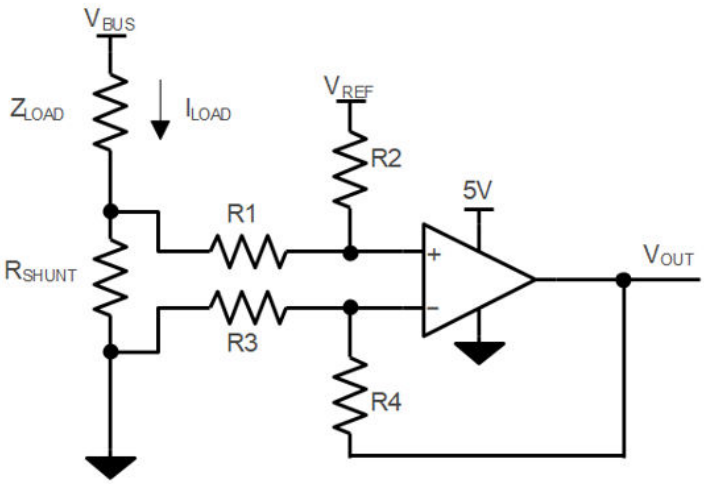
Application and Implementation

> 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 22 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.



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

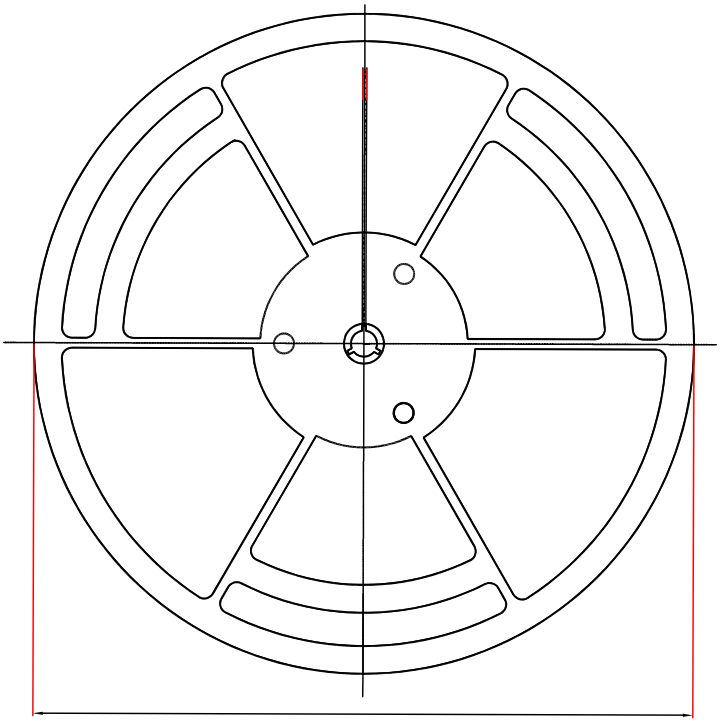
When R3 = R1, R2 = R4, R_{SHUNT} << R1

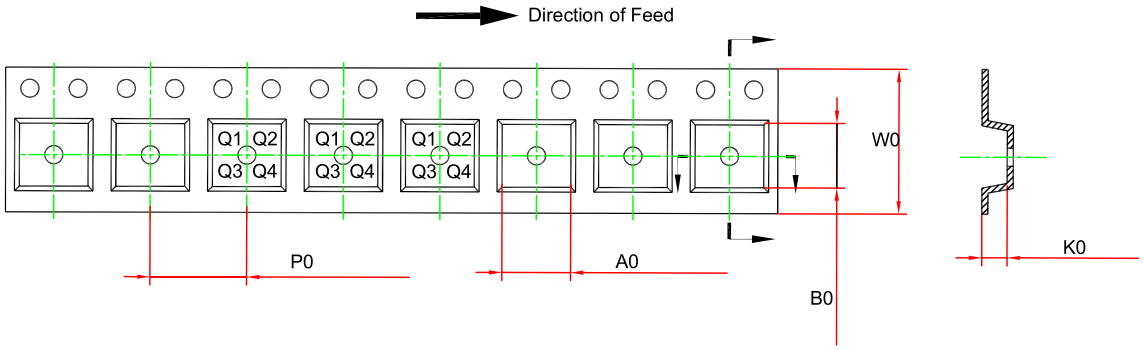
Figure 22. Low-Side Current-Sensing Application

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





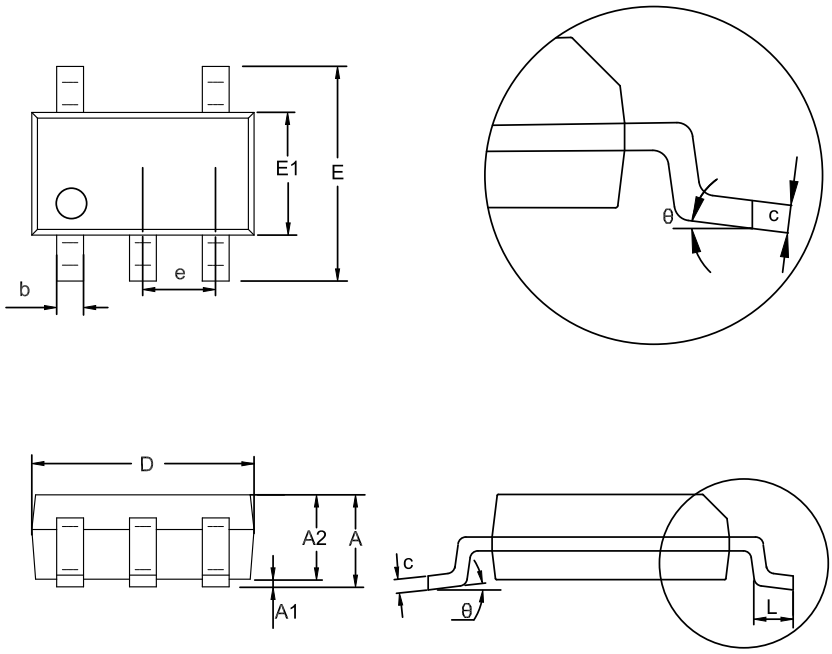
Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm) (1)	B0 (mm) (1)	K0 (mm) (1)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPA1651-S5TR	SOT23-5	180	12	3.3	3.25	1.4	4	8	Q3
TPA1651U-S5TR	SOT23-5	180	12	3.3	3.25	1.4	4	8	Q3
TPA1652-SO1R	SOP8	330	17.6	6.5	5.4	2	8	12	Q1
TPA1652-VS1R	MSOP8	330	17.6	5.3	3.4	1.3	8	12	Q1
TPA1652-TS1R	TSSOP8	330	17.6	6.8	3.4	1.8	8	12	Q1
TPA1654-SO2R	SOP14	330	21.6	6.5	9.3	2.1	8	16	Q1
TPA1654-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)



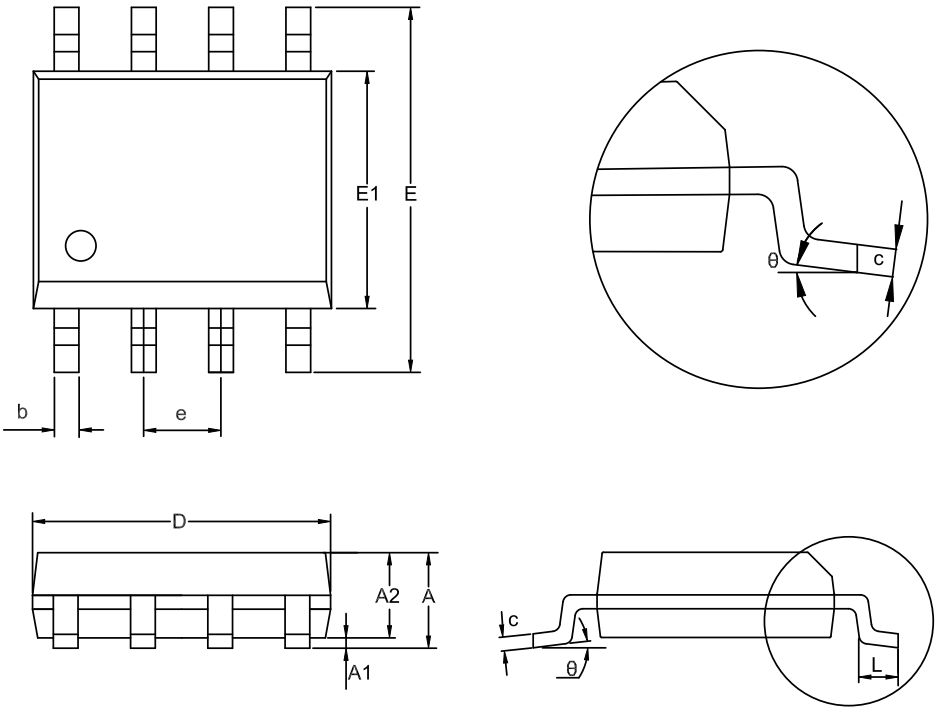
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.150	0.000	0.006
A2	1.000	1.200	0.039	0.047
b	0.280	0.500	0.011	0.020
c	0.100	0.230	0.004	0.009
D	2.820	3.020	0.111	0.119
E	2.600	3.000	0.102	0.118
E1	1.500	1.720	0.059	0.068
e	0.950 BSC		0.037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



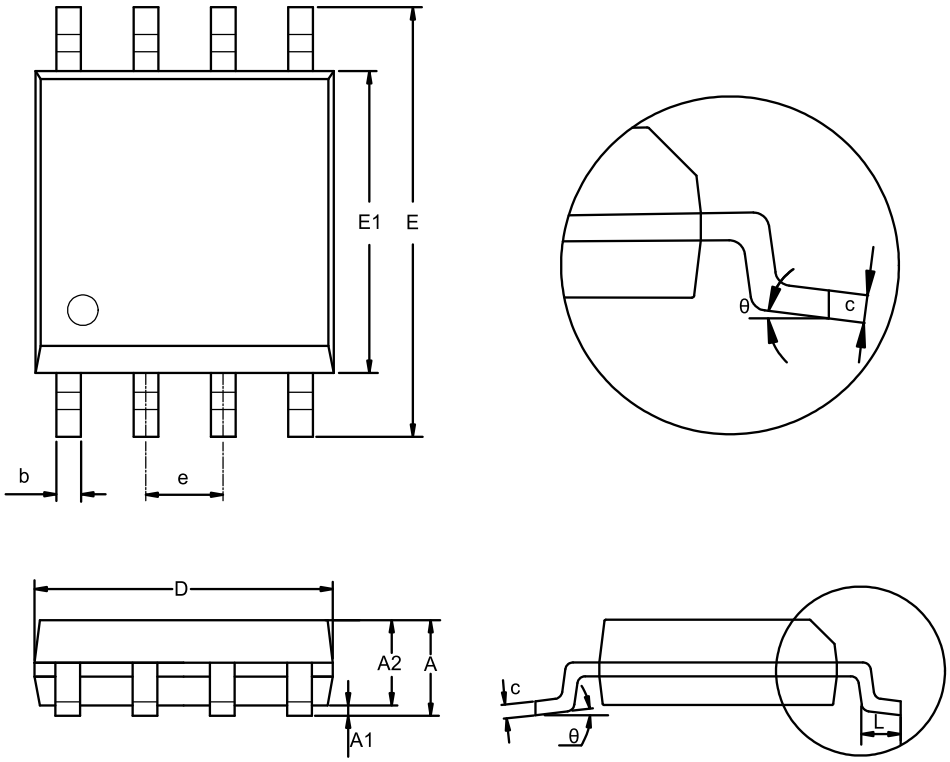
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.550	0.049	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050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



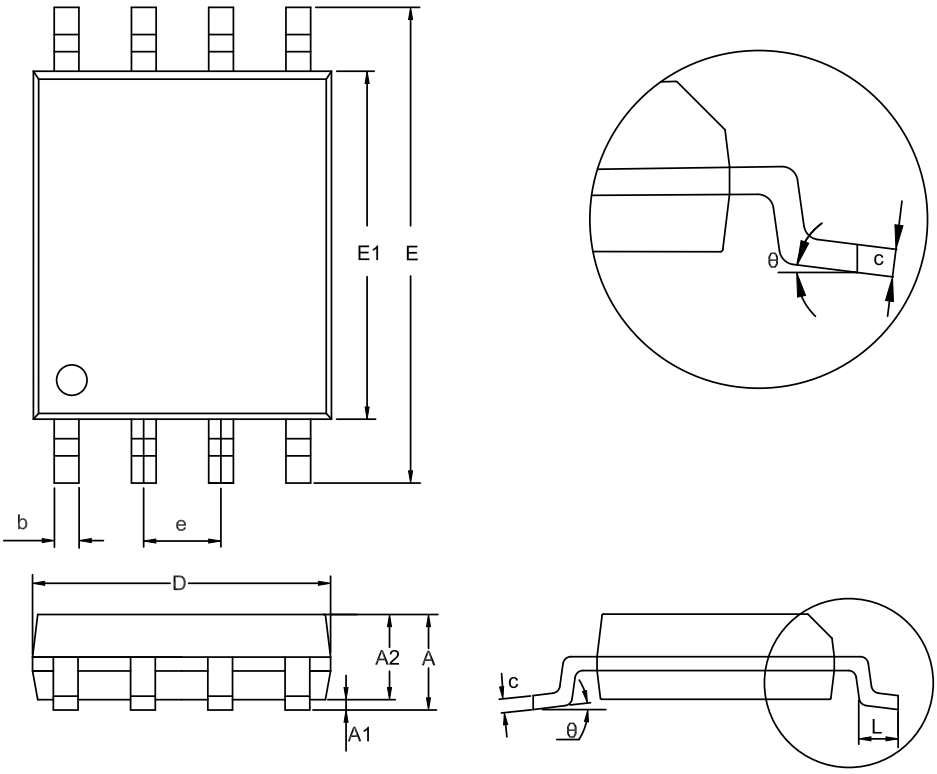
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.800	1.100	0.031	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	4.700	5.100	0.185	0.201
E1	2.900	3.100	0.114	0.122
e	0.650 BSC		0.026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

TSSOP8

Package Outline Dimensions TS1(TSSOP-8-A)



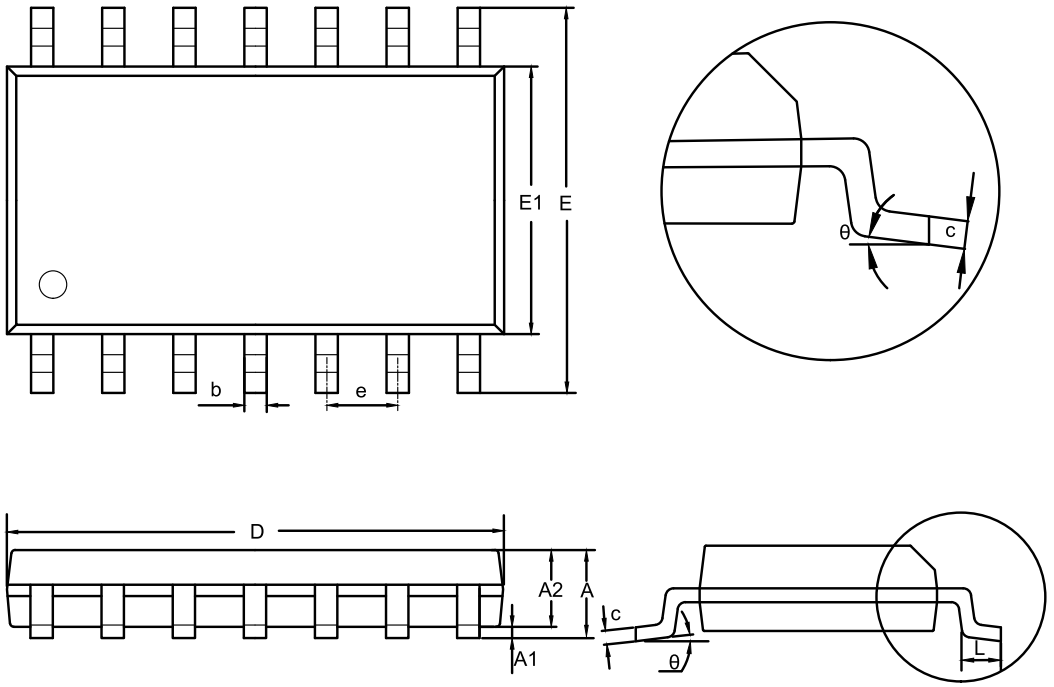
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.900	1.200	0.035	0.047
A1	0.050	0.150	0.002	0.006
A2	0.800	1.050	0.031	0.041
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
D	2.900	3.100	0.114	0.122
E	6.200	6.600	0.244	0.260
E1	4.300	4.500	0.169	0.177
e	0.650 BSC		0.026 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.

SOP14

Package Outline Dimensions SO2(SOP-14-A)



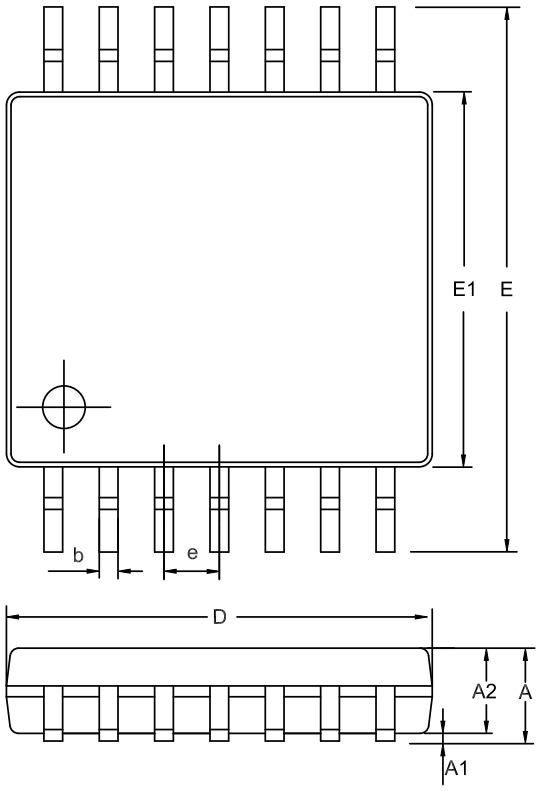
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.650	0.049	0.065
b	0.310	0.510	0.012	0.020
c	0.100	0.250	0.004	0.010
D	8.450	8.850	0.333	0.348
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050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

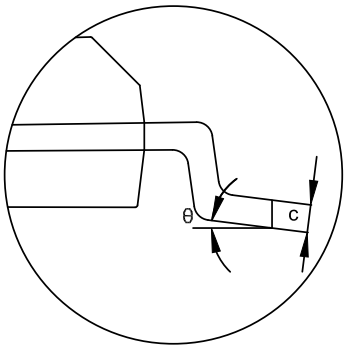
NOTES

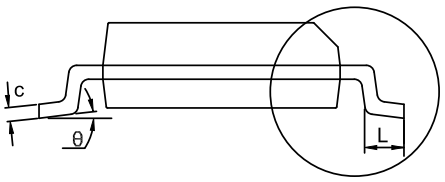
1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

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
TPA1651-S5TR (1)	−40 to 125°C	SOT23-5	AA1	1	Tape and Reel, 3000	Green
TPA1651U-S5TR (1)	−40 to 125°C	SOT23-5	AA2	1	Tape and Reel, 3000	Green
TPA1652-SO1R	−40 to 125°C	SOP8	A1652	1	Tape and Reel, 4000	Green
TPA1652-VS1R	−40 to 125°C	MSOP8	A1652	1	Tape and Reel, 3000	Green
TPA1652-TS1R (1)	−40 to 125°C	TSSOP8	A1652	1	Tape and Reel, 3000	Green
TPA1654-SO2R (1)	−40 to 125°C	SOP14	A1654	1	Tape and Reel, 2500	Green
TPA1654-TS2R (1)	−40 to 125°C	TSSOP14	A1654	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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