16-V, 2.5-MHz GBWP, RIRO, Zero-Crossover Operational Amplifiers

Features

- Supply Voltage: 2.7 V to 16 V or ±1.35 V to ±8 V
- Low Power: 0.8 mA per Channel
- Offset Voltage: ±250 µV Maximum at 25°C
- Offset Voltage Drift: 2 µV/°C
- Rail-to-Rail Input and Output
- Gain-Bandwidth Product: 2.5 MHz
- Slew Rate: 2 V/µs
- Zero Crossover
  - Rail-to-Rail Input without Distortion by Input Stage
  - CMRR: 100 dB Minimum at 0-V to 16-V Common-mode Input Range

Applications

- Sensor Signal Conditioning
- Instrumentation
- Industrial Control
- High-Side Current Sensing

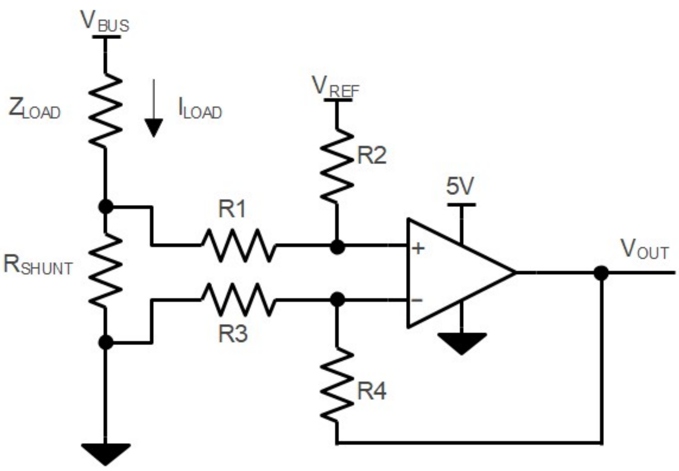
Description

The devices are CMOS single, dual, and quad RRIO op-amps to support 2.7-V to 16-V single supply or ±1.35-V to ±8-V dual supply. They incorporate 3PEAK's proprietary and patented design techniques to achieve excellent DC and AC performance including 250-µV maximum offset voltage at 25°C, 2.5-MHz gain-bandwidth product, and 2-V/µs slew rate.

The devices have a unique zero-crossover input topology to eliminate the input offset transition region, which is brought by the complementary input stage of rail-to-rail input operational amplifiers. The input common-mode range includes both the negative and positive supplies. CMRR is excellent in all common-mode ranges and has no input stage crossover distortion.

The devices are available in standard packages (such as SOT23, SOP, and MSOP). The devices are specified from −40°C to 125°C.

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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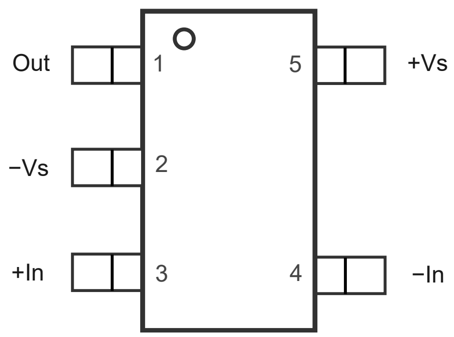
Revision History

Date	Revision	Notes
2024-01-15	Rev.A.0	Initial version.
2024-12-18	Rev.A.1	Changed the status of the TPA3662-SO1R, TPA3664-SO2R to production in the Order Information. Corrected handwriting errors. The physical object has not changed.

Pin Configuration and Functions

TPA3661
SOT23-5
Top View



TPA3661U
SOT23-5
Top View

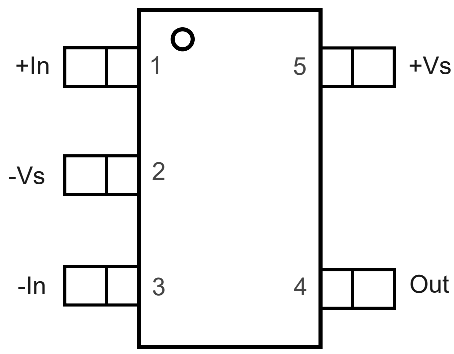
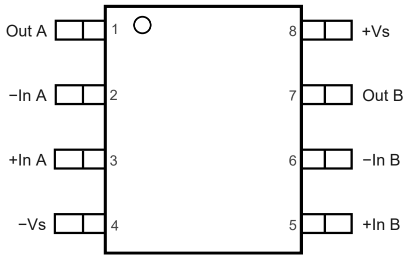


Table 1. Pin Functions: TPA6531, TPA6531U

Pin No.		Name	I/O	Description
TPA3661	TPA3661U			
1	4	Out	O	Output
2	2	$-V_S$	-	Negative power supply
3	1	+In	I	Noninverting input
4	3	−In	I	Inverting input
5	5	$+V_S$	-	Positive power supply

TPA3662
SOP8
Top View



TPA3662
MSOP8
Top View

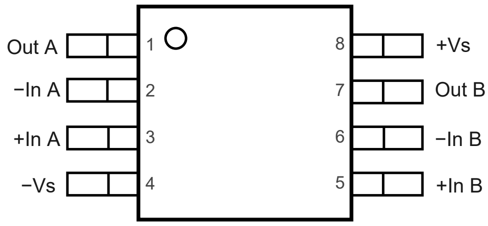
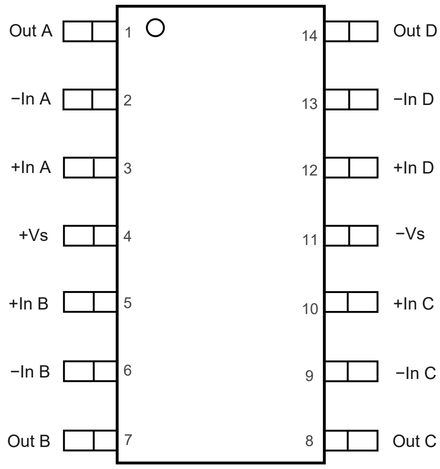


Table 2. Pin Functions: TPA3662

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

TPA3664
SOP14
Top View



TPA3664
TSSOP14
Top View

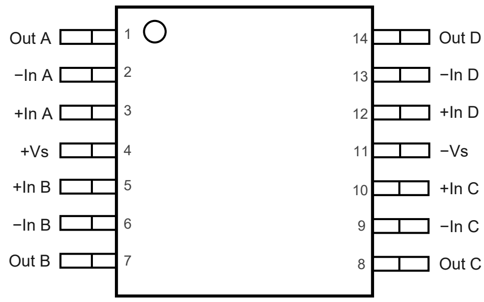


Table 3. Pin Functions: TPA3664

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

Specifications

Absolute Maximum Ratings (1)

Parameter		Min	Max	Unit
	Supply Voltage, $(+V_S) – (−V_S)$		18	V
	Input Voltage	$(−V_S) – 0.3$	$(+V_S) + 0.3$	V
	Differential Input Voltage	$(−V_S) – (+V_S)$	$(+V_S) – (−V_S)$	V
	Input Current: +IN, −IN (2)	−10	+10	mA
	Output Voltage	$(−V_S) – 0.3$	$(+V_S) + 0.3$	V
	Output Short-Circuit Duration (3)		Infinite	
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. This depends on the power supply voltage and how many amplifiers are shorted. Thermal resistance varies with the amount of PC board metal connected to the package. The specified values are for short traces connected to the leads.

ESD, Electrostatic Discharge Protection

Parameter		Condition	Minimum Level	Unit
HBM	Human Body Model ESD	ANSI/ESDA/JEDEC JS-001 (1)	3	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	Single Supply	2.7		16	V
		Dual Supply	±1.35		±8	V
T_A	Operating Temperature Range		−40		125	°C

Thermal Information

Package Type	θ_{JA}	θ_{JC}	Unit
SOT23-5	250	81	°C/W
SOP8	158	43	°C/W
MSOP8	210	45	°C/W
SOP14	120	36	°C/W
TSSOP14	180	35	°C/W

Electrical Characteristics

All test conditions: V_S = 15 V, T_A = 25°C, R_L = 10 kΩ, C_L =100 pF, unless otherwise noted.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Power Supply						
V_S	Supply Voltage Range	$(+V_S) – (−V_S)$	2.7		16	V
I_Q	Quiescent Current per Amplifier	V_S = 2.7 V to 16 V		0.8	1.2	mA
		V_S = 2.7 V to 16 V, T_A = −40°C to 125°C			1.4	mA
PSRR	Power Supply Rejection Ratio	V_S = 2.7 V to 16 V, V_{CM} = 0 V	95	120		dB
		V_S = 2.7 V to 16 V, V_{CM} = 0 V, T_A = −40°C to 125°C	90			dB
Input Characteristics						
V_{OS}	Input Offset Voltage	V_S = 5 V, V_{CM} = 0 V to 5 V	−0.25	±0.1	0.25	mV
		V_S = 5 V, V_{CM} = 0 V to 5 V, T_A = −40°C to 125°C	−1.5		1.5	mV
$V_{OS}TC$	Input Offset Voltage Drift	V_S = 5 V, V_{CM} = 0 V to 5 V, T_A = −40°C to 125°C		2		μV/°C
V_{OS}	Input Offset Voltage	V_{CM} = 0 V to 15 V	−0.25	±0.1	0.25	mV
		V_{CM} = 0 V to 15 V, T_A = −40°C to 125°C	−1.5		1.5	mV
$V_{OS}TC$	Input Offset Voltage Drift	V_{CM} = 0 V to 15 V, T_A = −40°C to 125°C		2		μV/°C
I_B	Input Bias Current	V_{CM} = 7.5 V	−500	10	500	pA
		V_{CM} = 7.5 V, T_A = −40°C to 125°C	−2000	100	2000	pA
I_{OS}	Input Offset Current	V_{CM} = 7.5 V	−500	10	500	pA
		V_{CM} = 7.5 V, T_A = −40°C to 125°C	−2000	100	2000	pA
R_{IN}	Input Resistance	Differential Mode				MΩ
		Common Mode		100		GΩ
C_{IN}	Input Capacitance	Differential Mode		2		pF
		Common Mode		4		pF
A_V	Open-loop Voltage Gain	V_O = 0.1 V to 14.9 V	120	140		dB
		V_O = 0.1 V to 14.9 V, T_A = −40°C to 125°C	115			dB
V_{CMR}	Common-mode Input Voltage Range (1)	T_A = −40°C to 125°C	$(−V_S)$ − 0.1		$(+V_S)$ + 0.1	V
CMRR	Common-Mode Rejection Ratio	V_{CM} = 0 V to 15 V	100	120		dB
		V_{CM} = 0 V to 15 V, T_A = −40°C to 125°C	95			dB
EMIRR	EMI Rejection Ratio	f = 1000 MHz				dB
Output Characteristics						
	Output Voltage Swing from Positive Rail or Negative Rail	V_S = 15 V, R_L = 10 kΩ to V_S / 2		45	70	mV

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
		V_S = 15 V, R_L = 10 kΩ to V_S / 2, T_A = −40°C to 125°C			100	mV
		V_S = 15 V, R_L = 2 kΩ to V_S / 2		200	250	mV
		V_S = 15 V, R_L = 2 kΩ to V_S / 2, T_A = −40°C to 125°C			400	mV
	Output Voltage Swing from Positive Rail or Negative Rail	V_S = 5 V, R_L = 10 kΩ to V_S / 2		15	25	mV
		V_S = 5 V, R_L = 10 kΩ to V_S / 2, T_A = −40°C to 125°C			50	mV
		V_S = 5 V, R_L = 2 kΩ to V_S / 2		65	90	mV
		V_S = 5 V, R_L = 2 kΩ to V_S / 2, T_A = −40°C to 125°C			150	mV
I_{SC}	Output Short-Circuit Current	Source and Sink		40		mA
AC Specifications						
GBW	Gain-Bandwidth Product			2.5		MHz
SR	Slew Rate	G = 1, 2-V step		2		V/μs
t_{OR}	Overload Recovery			800		ns
t_S	Settling Time, 0.1%	G = 1, 2-V step		2		μs
PM	Phase Margin	R_L = 10 kΩ, C_L = 100 pF		60		°
GM	Gain Margin	R_L = 10 kΩ, C_L = 100 pF		8		dB
	Channel Separation	f = 100 kHz		120		dB
Noise Performance						
E_N	Input Voltage Noise	f = 0.1 Hz to 10 Hz		1.5		$μV_{RMS}$
e_N	Input Voltage Noise Density	f = 1 kHz		25		nV/√Hz
i_N	Input Current Noise	f = 1 kHz		2		fA/√Hz
THD+N	Total Harmonic Distortion and Noise	f = 1 kHz, G = 1, R_L = 10 kΩ V_{OUT} = 1 V_{RMS}		0.0005		%

(1) Provided by design simulation.

Typical Performance Characteristics

All test conditions: V_S = 5 V, T_A = +25°C, unless otherwise noted.

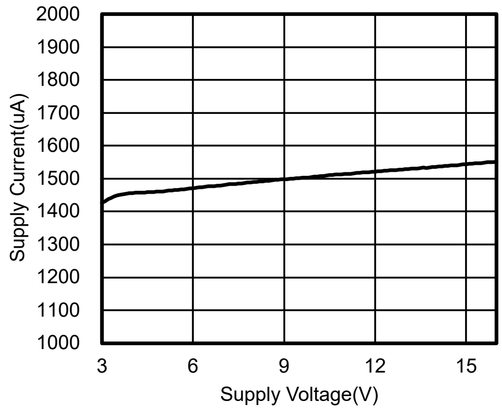


Figure 1. Supply Current vs. Supply Voltage, TPA3662

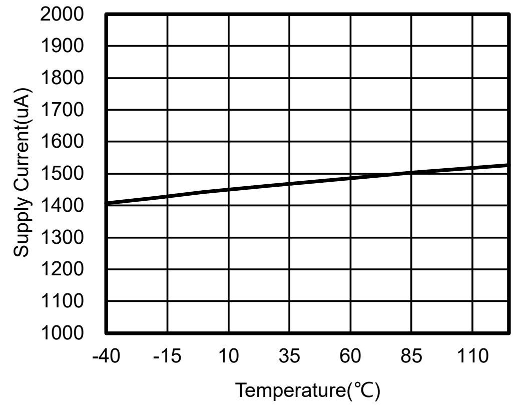


Figure 2. Supply Current vs. Temperature, TPA3662

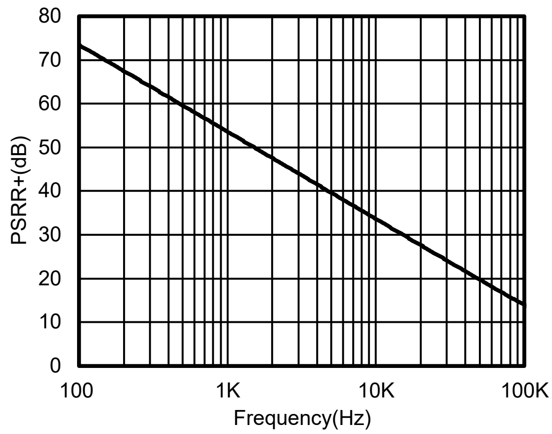


Figure 3. PSRR+ vs. Frequency

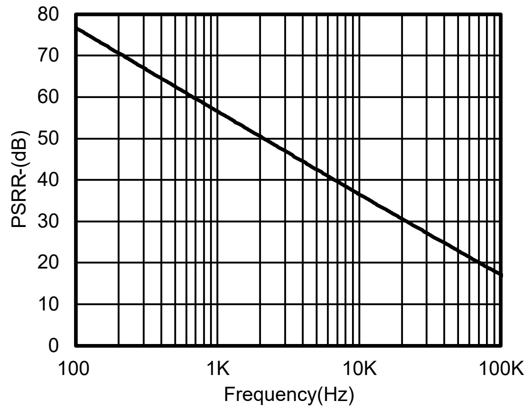


Figure 4. PSRR− vs. Frequency

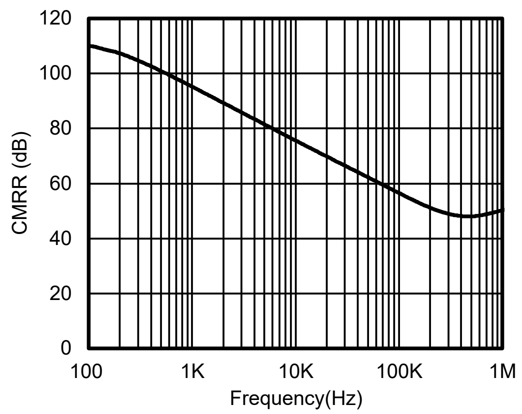


Figure 5. CMRR vs. Frequency, V_S = 16V

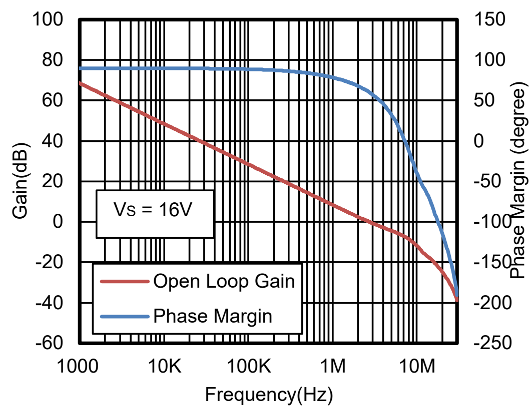


Figure 6. Open-Loop Gain and Phase Margin vs. Frequency, R_L = 10 kΩ, C_L= 100 pF

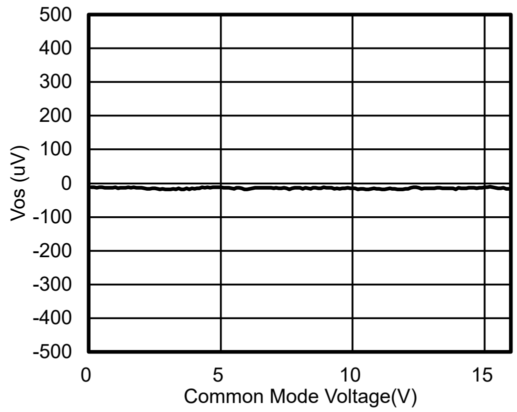


Figure 7. V_{OS} vs. V_{CM}, V_S = 16 V

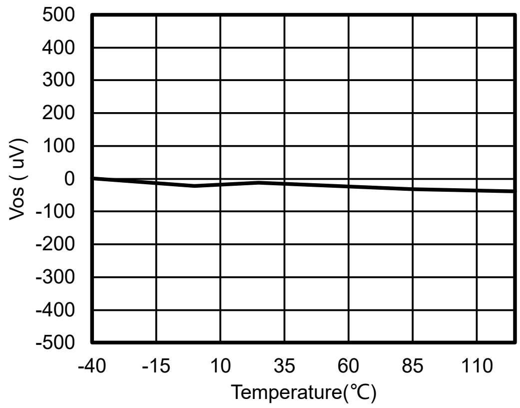


Figure 8. V_{OS} vs. Temperature

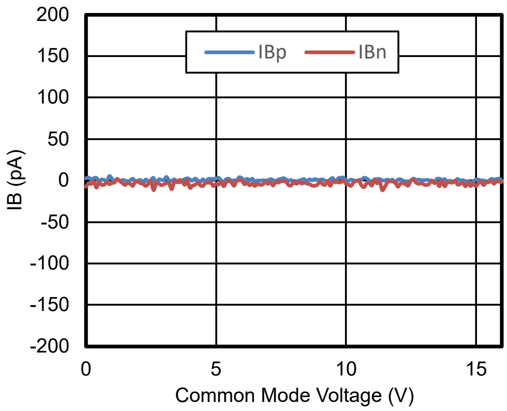


Figure 9. I_B vs. Common Voltage, V_S = 16 V

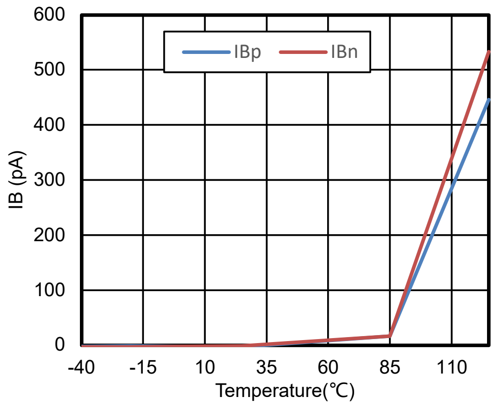


Figure 10. I_B vs. Temperature, V_S = 16 V, V_{CM} = 8 V

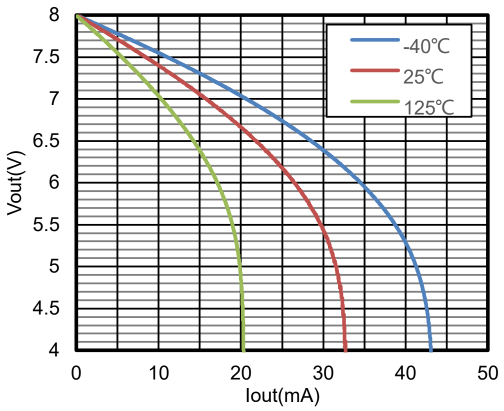


Figure 11. Output Voltage vs. Output Current, Source, $(-V_S)$ = −8 V, $(+V_S)$ = 8 V

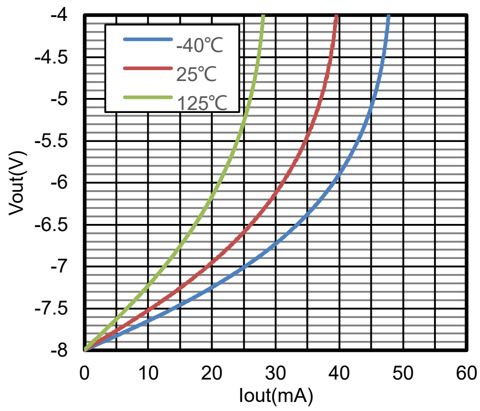


Figure 12. Output Voltage vs. Output Current, Sink, $(-V_S)$ = −8 V, $(+V_S)$ = 8 V

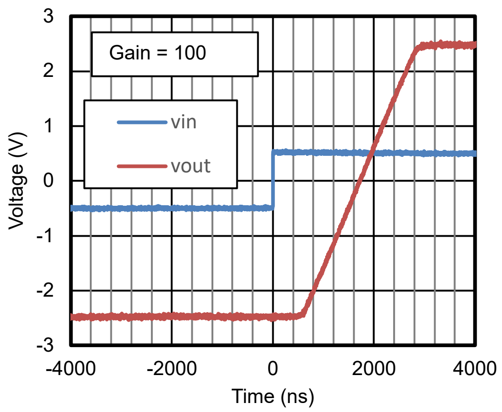


Figure 13. Overload Recovery at Negative Rail

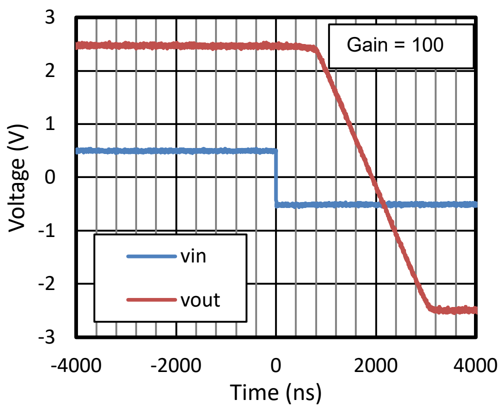


Figure 14. Overload Recovery at Positive Rail

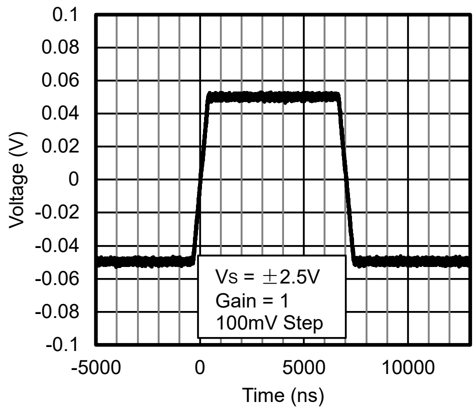


Figure 15. 100-mV Small-Signal Step Response

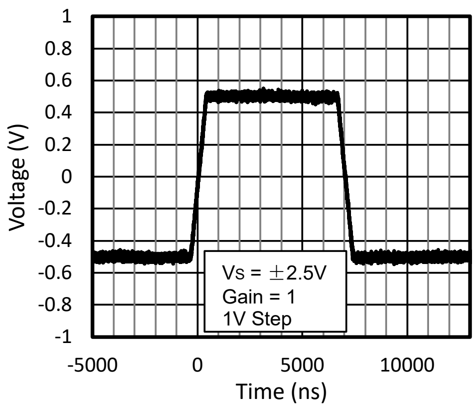


Figure 16. 1-V Large-Signal Step Response

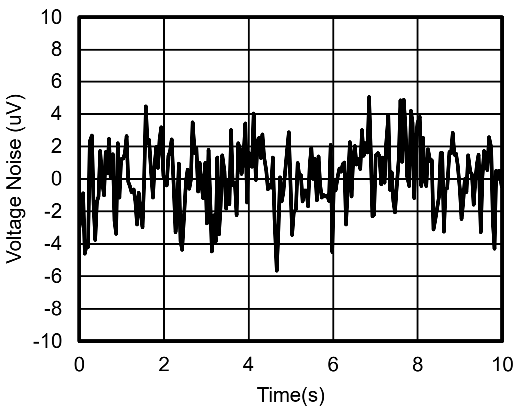


Figure 17. 0.1-Hz to 10-Hz Voltage Noise

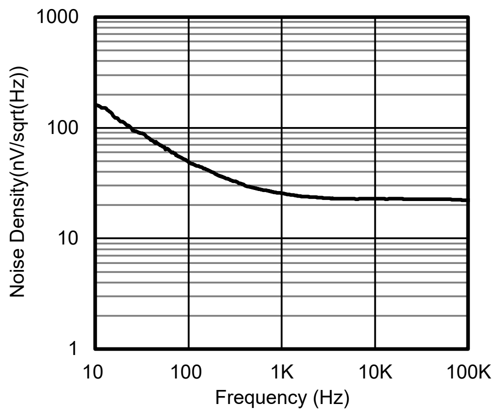


Figure 18. Voltage Noise Spectral Density vs. Frequency

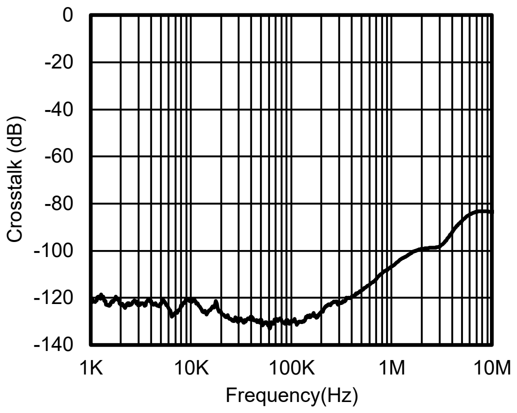


Figure 19. Crosstalk vs. Frequency, TPA3662

Detailed Description

Overview

The TPA366x op amps can operate on a single-supply voltage (2.7 V to 16 V), or a split supply voltage (±1.35 V to ±8 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). These devices are specified from 2.7 V to 16 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 the Typical Performance Characteristics.

Functional Block Diagram

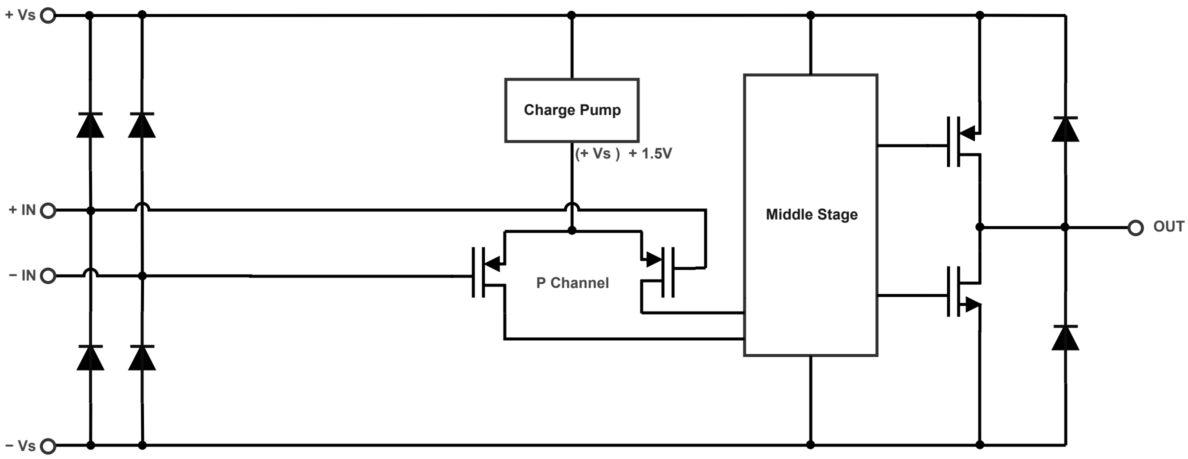


Figure 20. Functional Block Diagram

Feature Description

Operating Supply Voltage

The devices are designed for single supply operation from 2.7 V to 16 V or dual supply operation from ±1.35 V to ±8 V.

The recommended operating voltage conditions are as follows:

Power supply voltage $(+V_S) − (−V_S)$: 2.7 V to 16 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 2.7 V to 16 V

For example, if operating with a single supply, $(−V_S)$ = 0 V, then $(+V_S)$ can support 2.7 V to 16 V. If using dual supplies with equal absolute values, the minimum voltage is ±1.35 V and the maximum voltage is ±8 V. It can even support other voltage configurations, such as $(−V_S)$ = 100 V, $(+V_S)$ = 116 V, or $(−V_S)$ = −6 V, $(+V_S)$ = 10 V, and so on.

Rail-to-Rail Input

The devices have a unique zero-crossover input topology to eliminate the input offset transition region, which is brought by the complementary input stage of rail-to-rail input operational amplifiers. The input common-mode range includes both the negative and positive supplies. CMRR is excellent in all common-mode ranges and has no input stage crossover distortion.

When driving ADCs, the highly linear common-mode range of the devices ensures that the signal conditional system linearity performance is not compromised.

Rail-to-Rail Output

The device delivers rail-to-rail output swing capability with a class-AB output stage. Different load conditions change the ability of the amplifier to swing close to the rails.

Application and Implementation

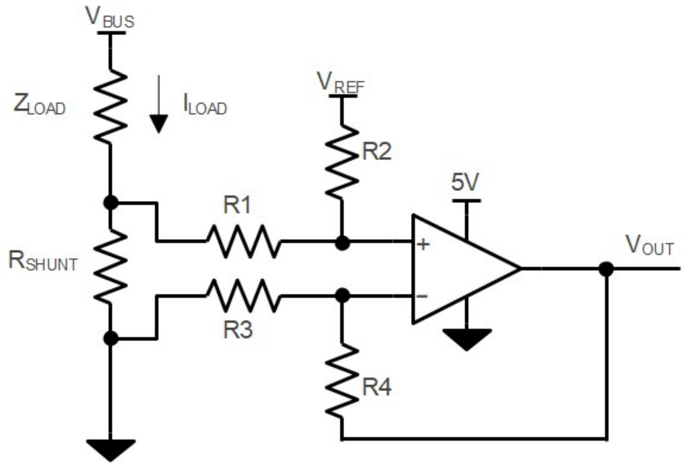
Note

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 21 shows the device configured in a low-side current sensing application. The low-side current sensing method consists of placing a sense resistor between the load and the circuit ground. The voltage dropping across the resistor is amplified by different amplifier circuits with the device. V_{REF} can be used to add bias voltage to the output voltage. Particular attention must be paid to the matching and precision of R1, R2, R3, and R4, to maximize the accuracy of the measurement.



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

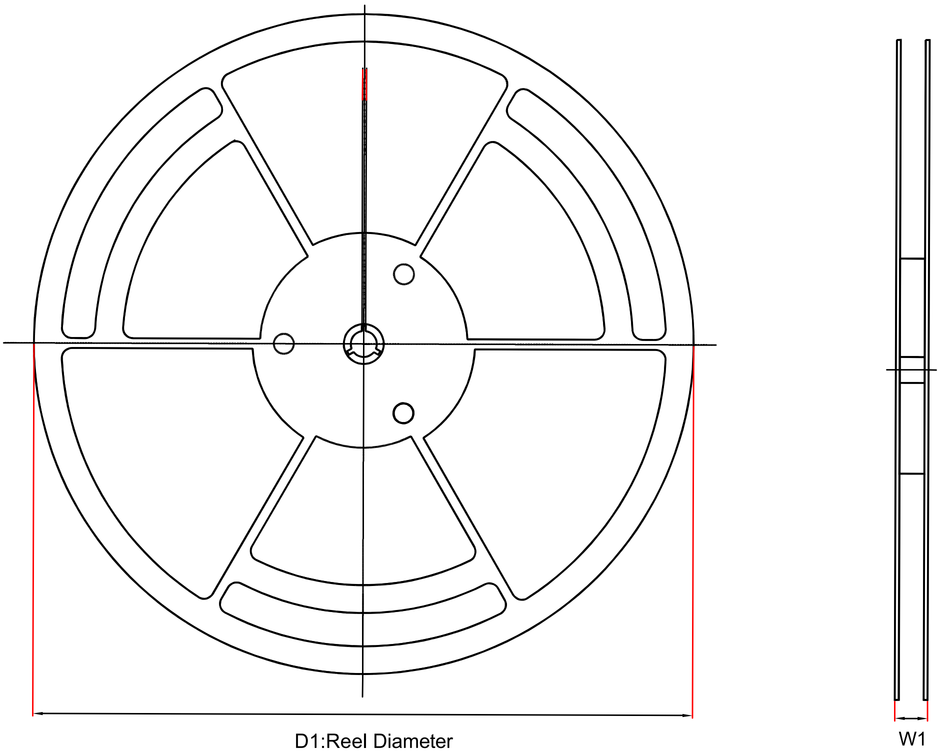
When $R3 = R1$, $R2 = R4$, $R_{SHUNT} << R1$

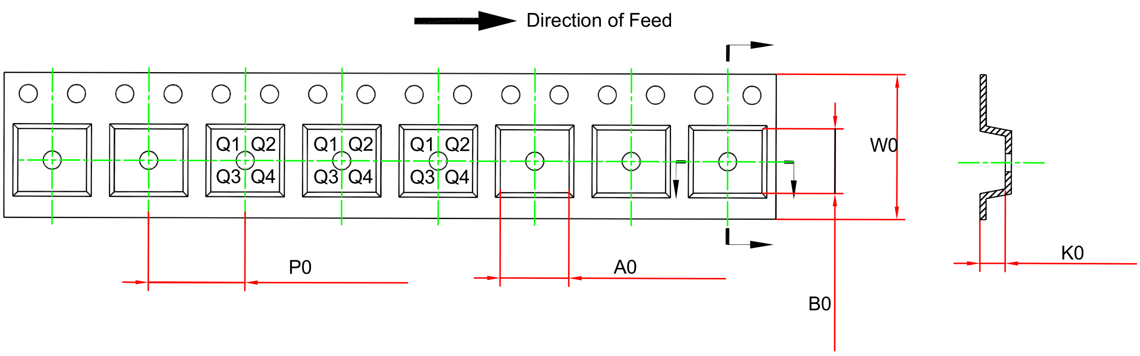
Figure 21. Low-Side Current-Sensing Application

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





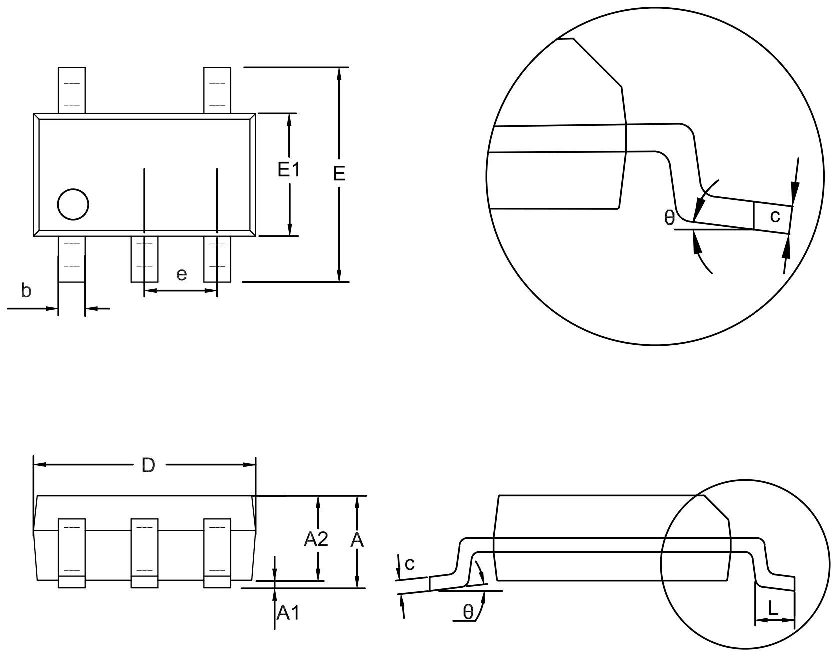
Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm) (1)	B0 (mm) (1)	K0 (mm) (1)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPA3661-S5TR	SOT23-5	180.0	12.0	3.3	3.25	1.4	4.0	8.0	Q3
TPA3661U-S5TR	SOT23-5	180.0	12.0	3.3	3.25	1.4	4.0	8.0	Q3
TPA3662-SO1R	SOP8	330.0	17.6	6.5	5.4	2.0	8.0	12.0	Q1
TPA3662-VS1R	MSOP8	330.0	17.6	5.3	3.3	1.3	8.0	12.0	Q1
TPA3664-SO2R	SOP14	330.0	21.6	6.5	9.15	1.8	8.0	16.0	Q1
TPA3664-TS2R	TSSOP14	330.0	17.6	6.8	5.5	1.7	8.0	12.0	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)



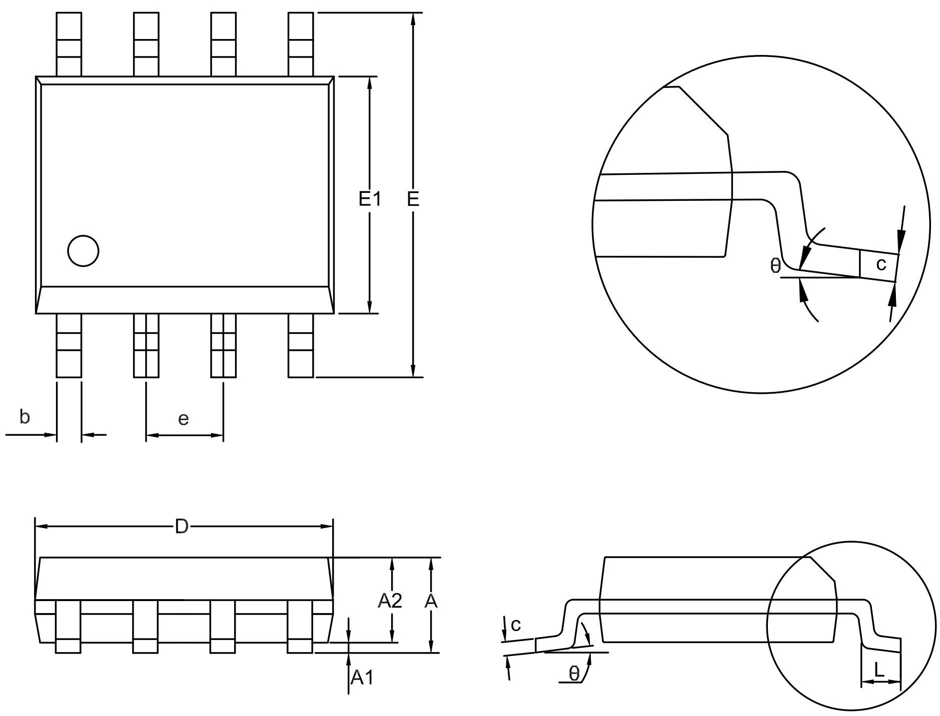
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.150	0.000	0.006
A2	1.000	1.200	0.039	0.047
b	0.280	0.500	0.011	0.020
c	0.100	0.230	0.004	0.009
D	2.820	3.020	0.111	0.119
E	2.600	3.000	0.102	0.118
E1	1.500	1.720	0.059	0.068
e	0.950 BSC		0.037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



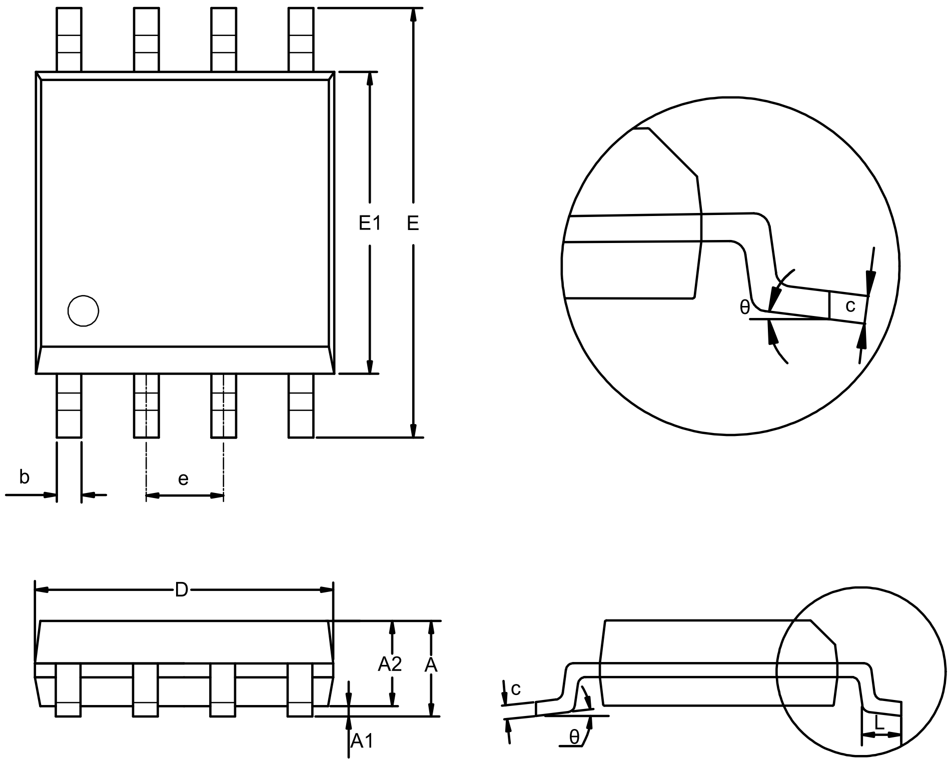
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.550	0.049	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050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



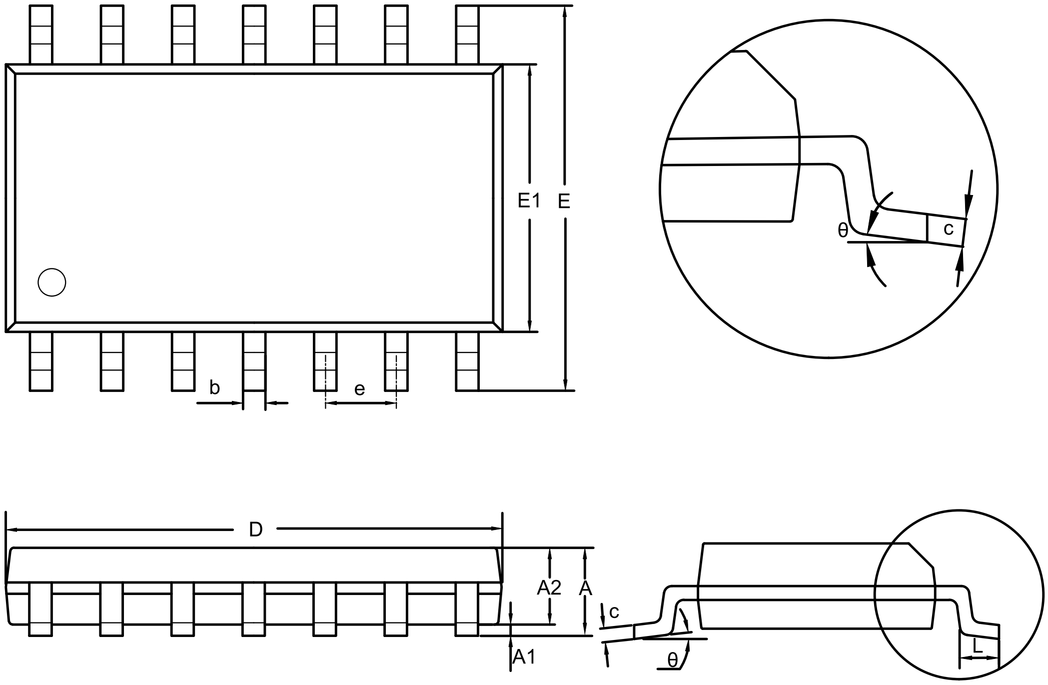
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.800	1.100	0.031	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	4.700	5.100	0.185	0.201
E1	2.900	3.100	0.114	0.122
e	0.650 BSC		0.026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



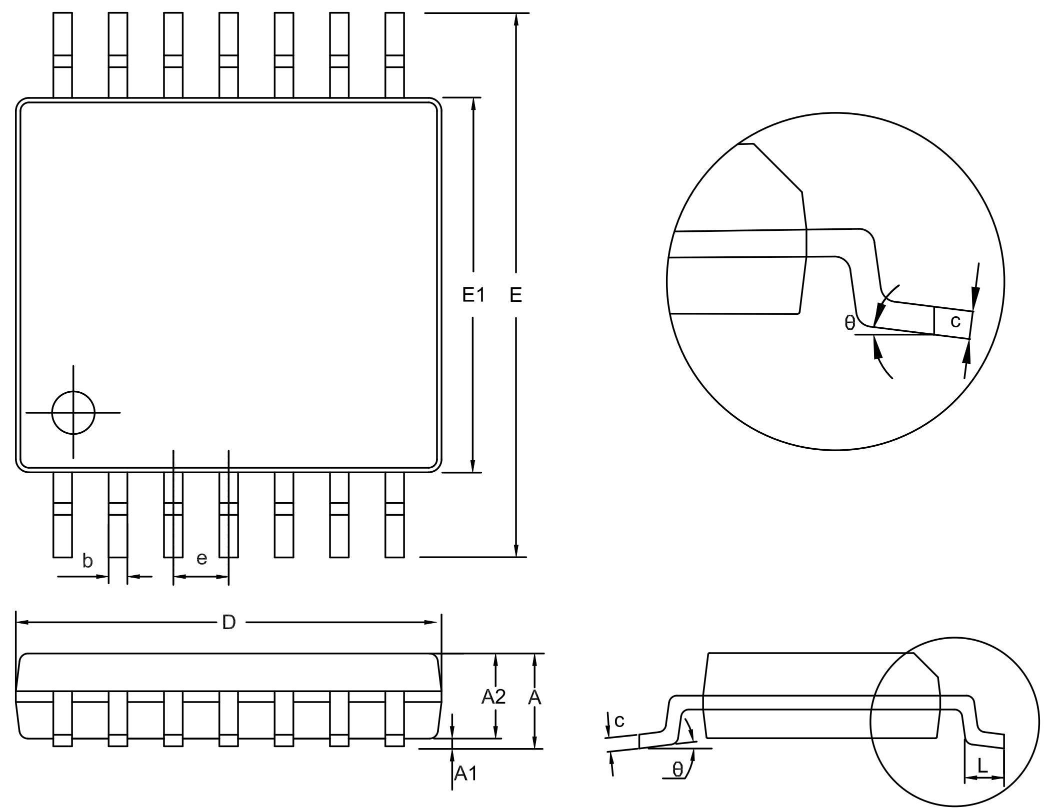
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.650	0.049	0.065
b	0.310	0.510	0.012	0.020
c	0.100	0.250	0.004	0.010
D	8.450	8.850	0.333	0.348
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050 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
TPA3661-S5TR (1)	−40 to 125°C	SOT23-5	361	3	Tape and Reel, 3000	Green
TPA3661U-S5TR (1)	−40 to 125°C	SOT23-5	36U	3	Tape and Reel, 3000	Green
TPA3662-SO1R	−40 to 125°C	SOP8	A3662	3	Tape and Reel, 4000	Green
TPA3662-VS1R	−40 to 125°C	MSOP8	A3662	3	Tape and Reel, 3000	Green
TPA3664-SO2R	−40 to 125°C	SOP14	A3664	3	Tape and Reel, 2500	Green
TPA3664-TS2R (1)	−40 to 125°C	TSSOP14	A3664	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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