

## Features

- Supply Voltage: 2.7 V to 16 V or  $\pm 1.35$  V to  $\pm 8$  V
- Low Power: 0.8 mA per Channel
- Offset Voltage:  $\pm 250$   $\mu$ V Maximum at 25°C
- Offset Voltage Drift: 2  $\mu$ V/°C
- Rail-to-Rail Input and Output
- Gain-Bandwidth Product: 2.5 MHz
- Slew Rate: 2 V/ $\mu$ s
- 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

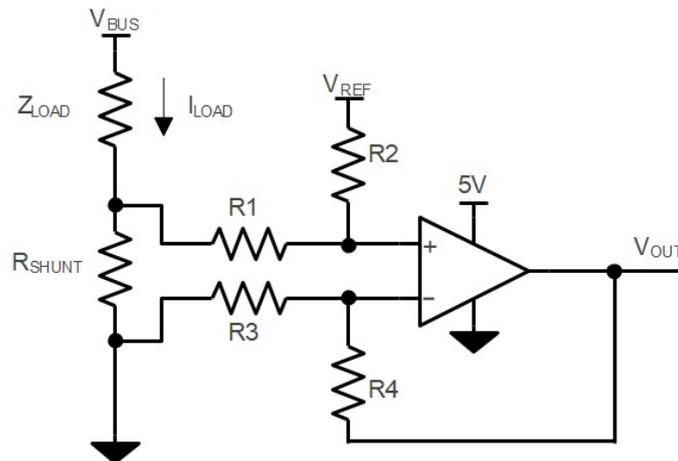
## Description

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



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

$$\text{When } R3 = R1, R2 = R4, R_{SHUNT} \ll R1$$

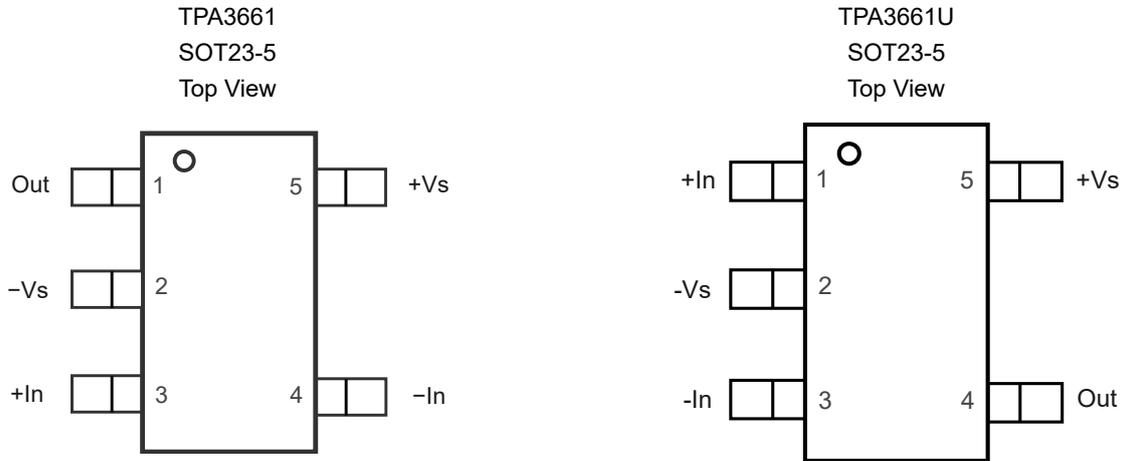
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## Revision History

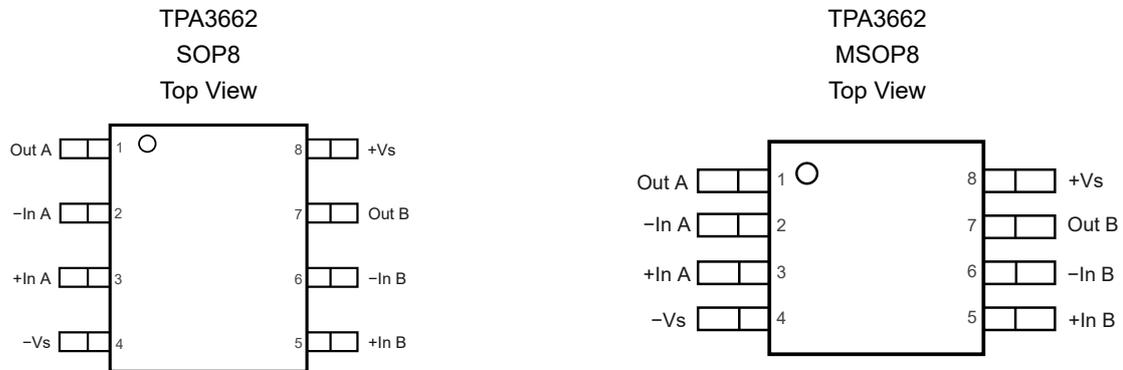
Date	Revision	Notes
2024-01-15	Rev.A.0	Initial version.
2024-12-18	Rev.A.1	Changed the status of the TPA3662-SO1R, TPA3664-SO2R to production in the Order Information. Corrected handwriting errors. The physical object has not changed.

## Pin Configuration and Functions

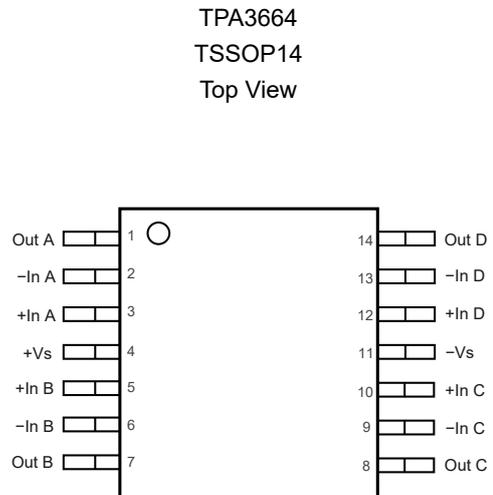
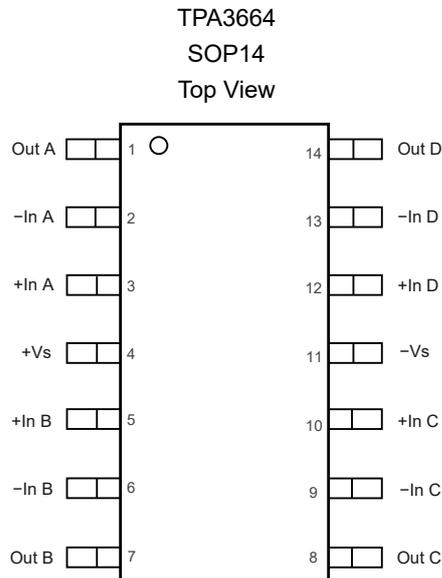


**Table 1. Pin Functions: TPA6531, TPA6531U**

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

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

**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	-Vs	-	Negative power supply
5	+In B	I	Noninverting input
6	-In B	I	Inverting input
7	Out B	O	Output
8	+Vs	-	Positive power supply


**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	+Vs	-	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	-Vs	-	Negative power supply
12	+In D	I	Noninverting input
13	-In D	I	Inverting input
14	Out D	O	Output

## Specifications

### Absolute Maximum Ratings <sup>(1)</sup>

Parameter		Min	Max	Unit
	Supply Voltage, (+V <sub>S</sub> ) – (–V <sub>S</sub> )		18	V
	Input Voltage	(–V <sub>S</sub> ) – 0.3	(+V <sub>S</sub> ) + 0.3	V
	Differential Input Voltage	(–V <sub>S</sub> ) – (+V <sub>S</sub> )	(+V <sub>S</sub> ) – (–V <sub>S</sub> )	V
	Input Current: +IN, –IN <sup>(2)</sup>	–10	+10	mA
	Output Voltage	(–V <sub>S</sub> ) – 0.3	(+V <sub>S</sub> ) + 0.3	V
	Output Short-Circuit Duration <sup>(3)</sup>		Infinite	
T <sub>J</sub>	Maximum Junction Temperature		150	°C
T <sub>A</sub>	Operating Temperature Range	–40	125	°C
T <sub>STG</sub>	Storage Temperature Range	–65	150	°C
T <sub>L</sub>	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 <sup>(1)</sup>	3	kV
CDM	Charged Device Model ESD	ANSI/ESDA/JEDEC JS-002 <sup>(2)</sup>	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 <sub>S</sub>	Supply Voltage	Single Supply	2.7	16	V
		Dual Supply	±1.35	±8	V
T <sub>A</sub>	Operating Temperature Range	–40		125	°C

**Thermal Information**

Package Type	$\theta_{JA}$	$\theta_{JC}$	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

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

 All test conditions:  $V_S = 15\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$ ,  $C_L = 100\text{ pF}$ , unless otherwise noted.

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

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

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

(1) Provided by design simulation.

Typical Performance Characteristics

All test conditions:  $V_S = 5\text{ V}$ ,  $T_A = +25^\circ\text{C}$ , unless otherwise noted.

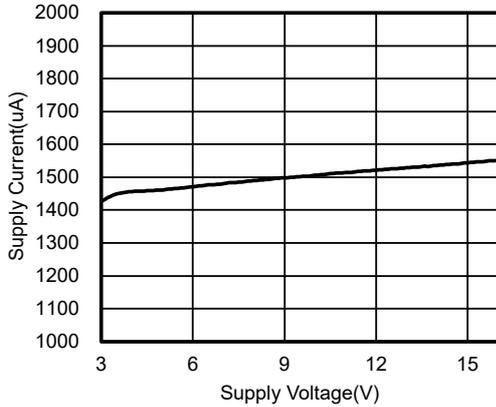


Figure 1. Supply Current vs. Supply Voltage, TPA3662

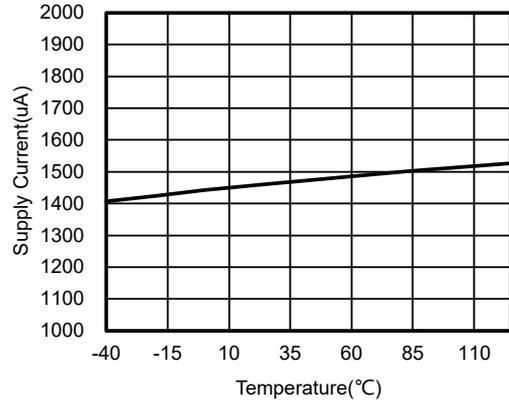


Figure 2. Supply Current vs. Temperature, TPA3662

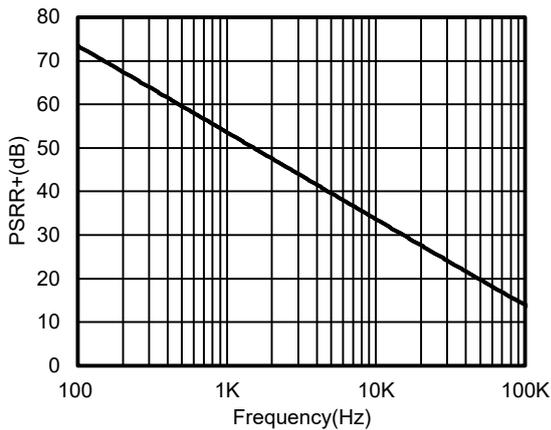


Figure 3. PSRR+ vs. Frequency

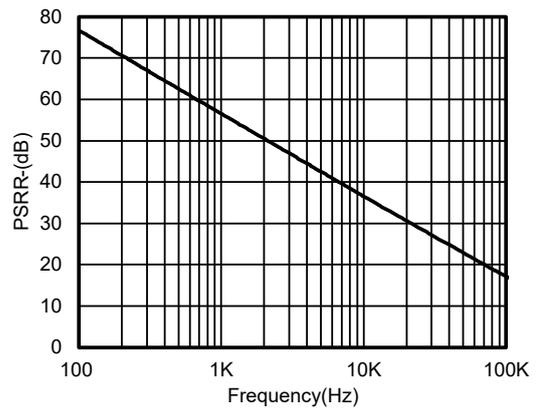


Figure 4. PSRR- vs. Frequency

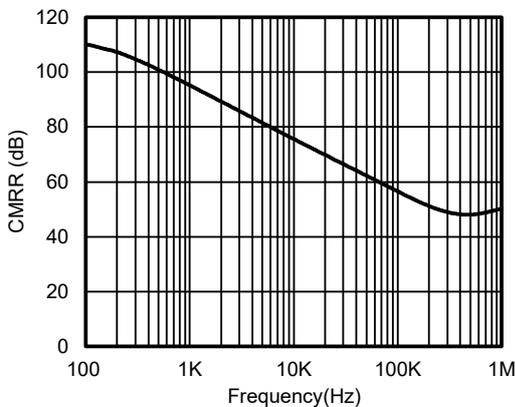


Figure 5. CMRR vs. Frequency,  $V_S = 16\text{ V}$

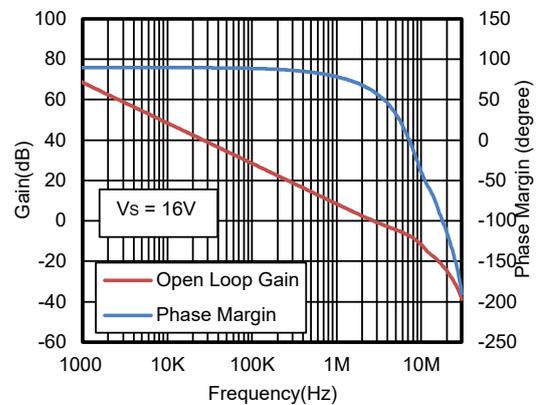


Figure 6. Open-Loop Gain and Phase Margin vs. Frequency,  $R_L = 10\text{ k}\Omega$ ,  $C_L = 100\text{ pF}$

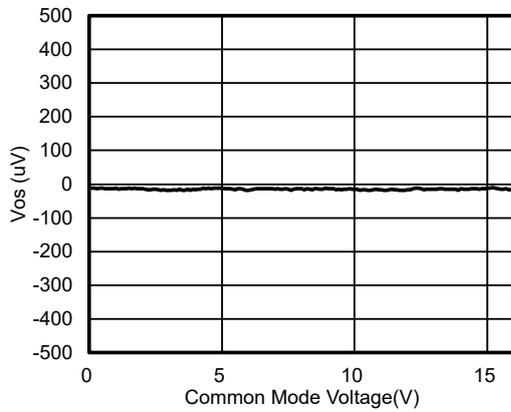


Figure 7.  $V_{OS}$  vs.  $V_{CM}$ ,  $V_S = 16\text{ V}$

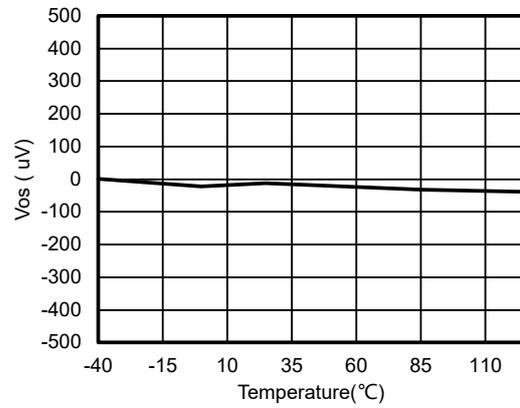


Figure 8.  $V_{OS}$  vs. Temperature

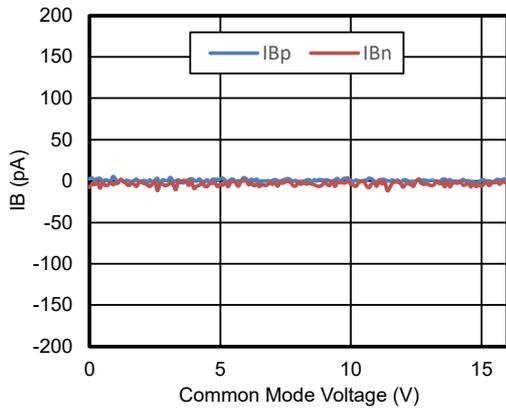


Figure 9.  $I_B$  vs. Common Voltage,  $V_S = 16\text{ V}$

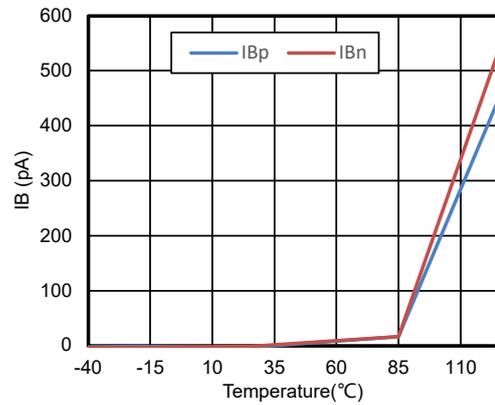


Figure 10.  $I_B$  vs. Temperature,  $V_S = 16\text{ V}$ ,  $V_{CM} = 8\text{ V}$

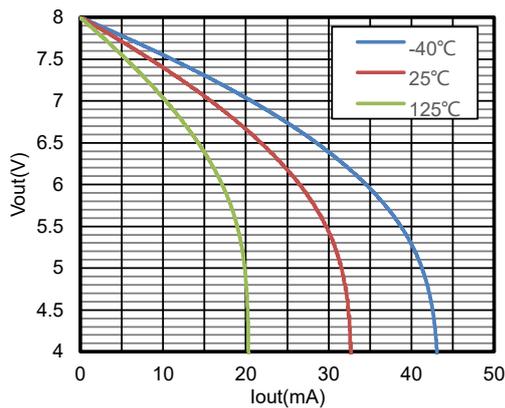


Figure 11. Output Voltage vs. Output Current, Source,  $(-V_S) = -8\text{ V}$ ,  $(+V_S) = 8\text{ V}$

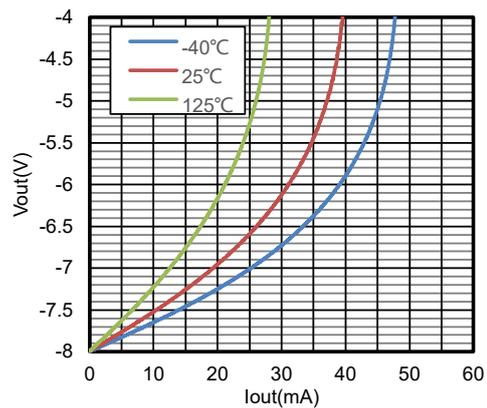


Figure 12. Output Voltage vs. Output Current, Sink,  $(-V_S) = -8\text{ V}$ ,  $(+V_S) = 8\text{ V}$

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

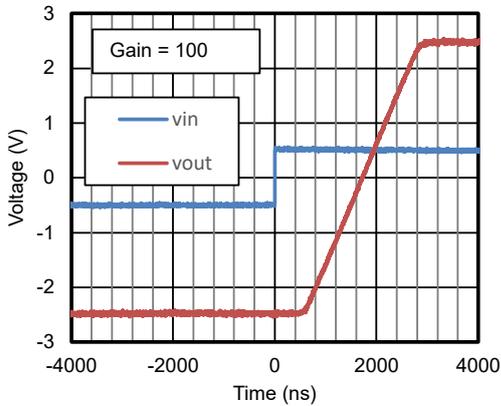


Figure 13. Overload Recovery at Negative Rail

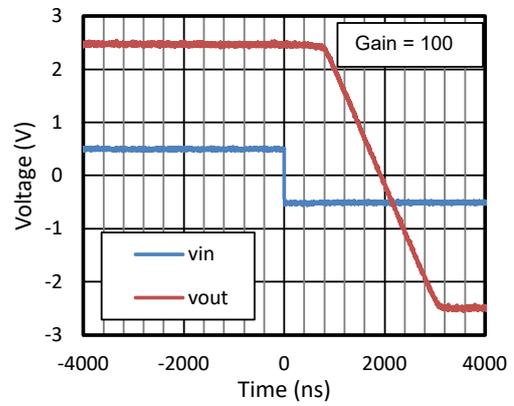


Figure 14. Overload Recovery at Positive Rail

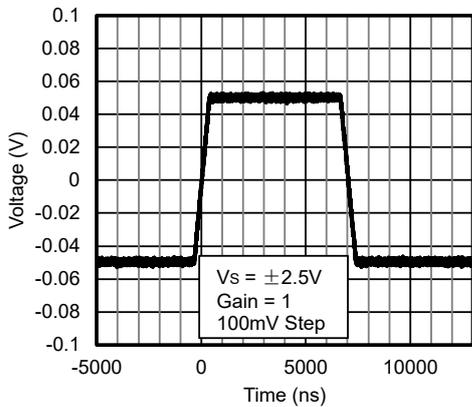


Figure 15. 100-mV Small-Signal Step Response

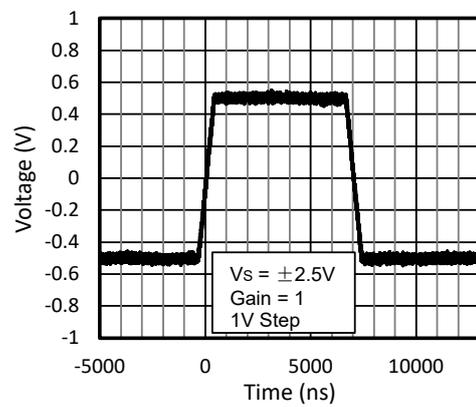


Figure 16. 1-V Large-Signal Step Response

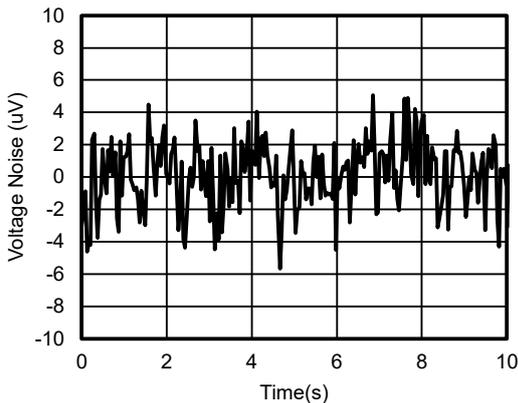


Figure 17. 0.1-Hz to 10-Hz Voltage Noise

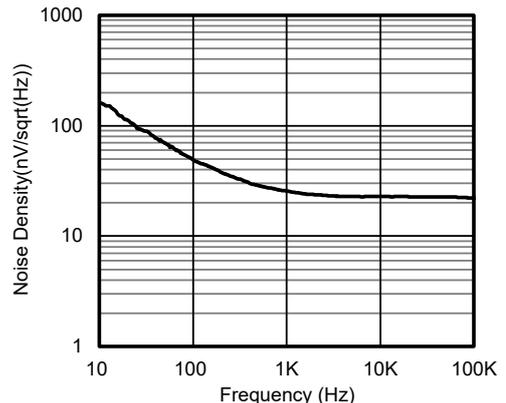
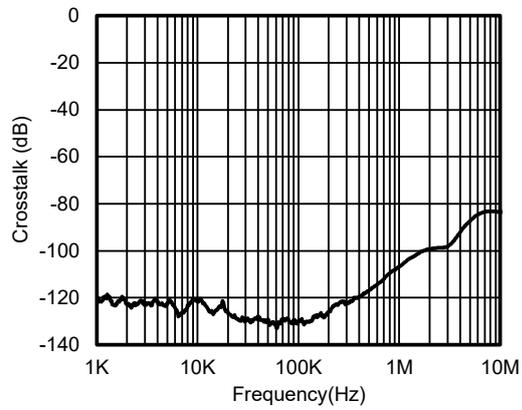


Figure 18. Voltage Noise Spectral Density vs. Frequency



**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 ( $\pm 1.35$  V to  $\pm 8$  V), making them highly versatile and easy to use. The power-supply pins should have local bypass ceramic capacitors (typically 0.01  $\mu$ F to 0.1  $\mu$ F). These devices are specified from 2.7 V to 16 V and over the extended temperature range from  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ . Parameters that exhibit variance with regard to operating voltage or temperature are presented in the [Typical Performance Characteristics](#).

### Functional Block Diagram

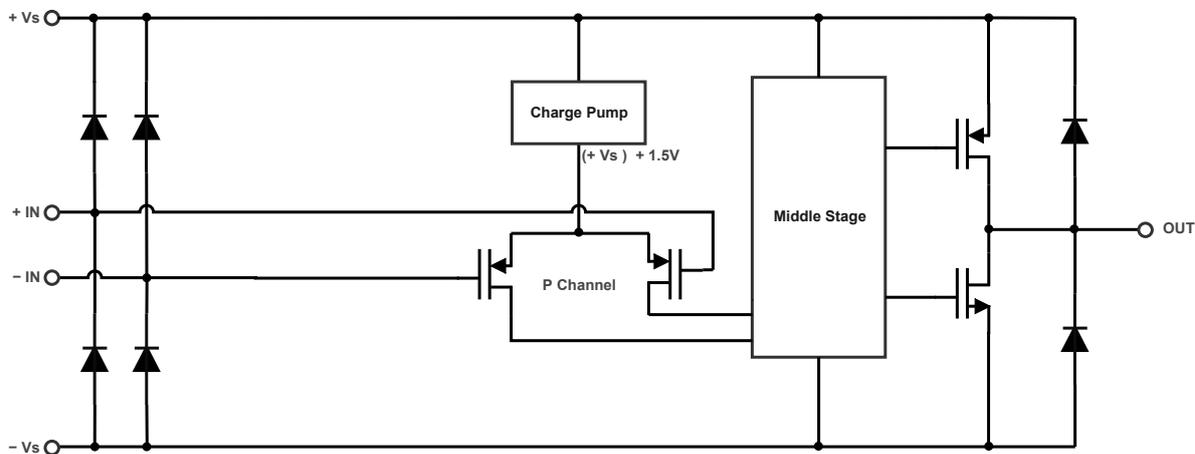


Figure 20. Functional Block Diagram

## 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  $\pm 1.35$  V to  $\pm 8$  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  $\pm 1.35$  V and the maximum voltage is  $\pm 8$  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.

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

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

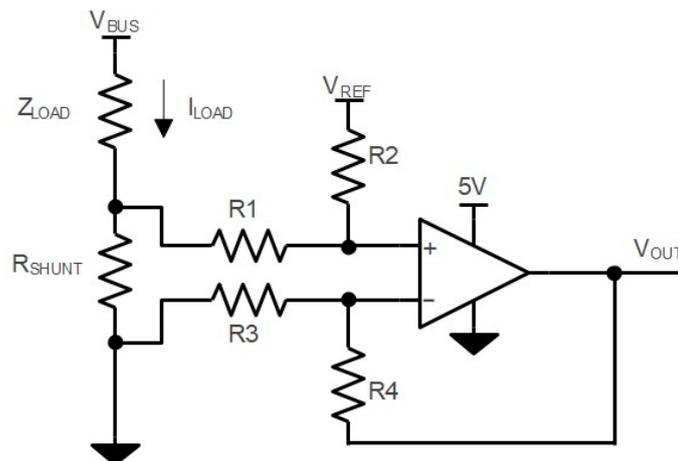
### Note

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.



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

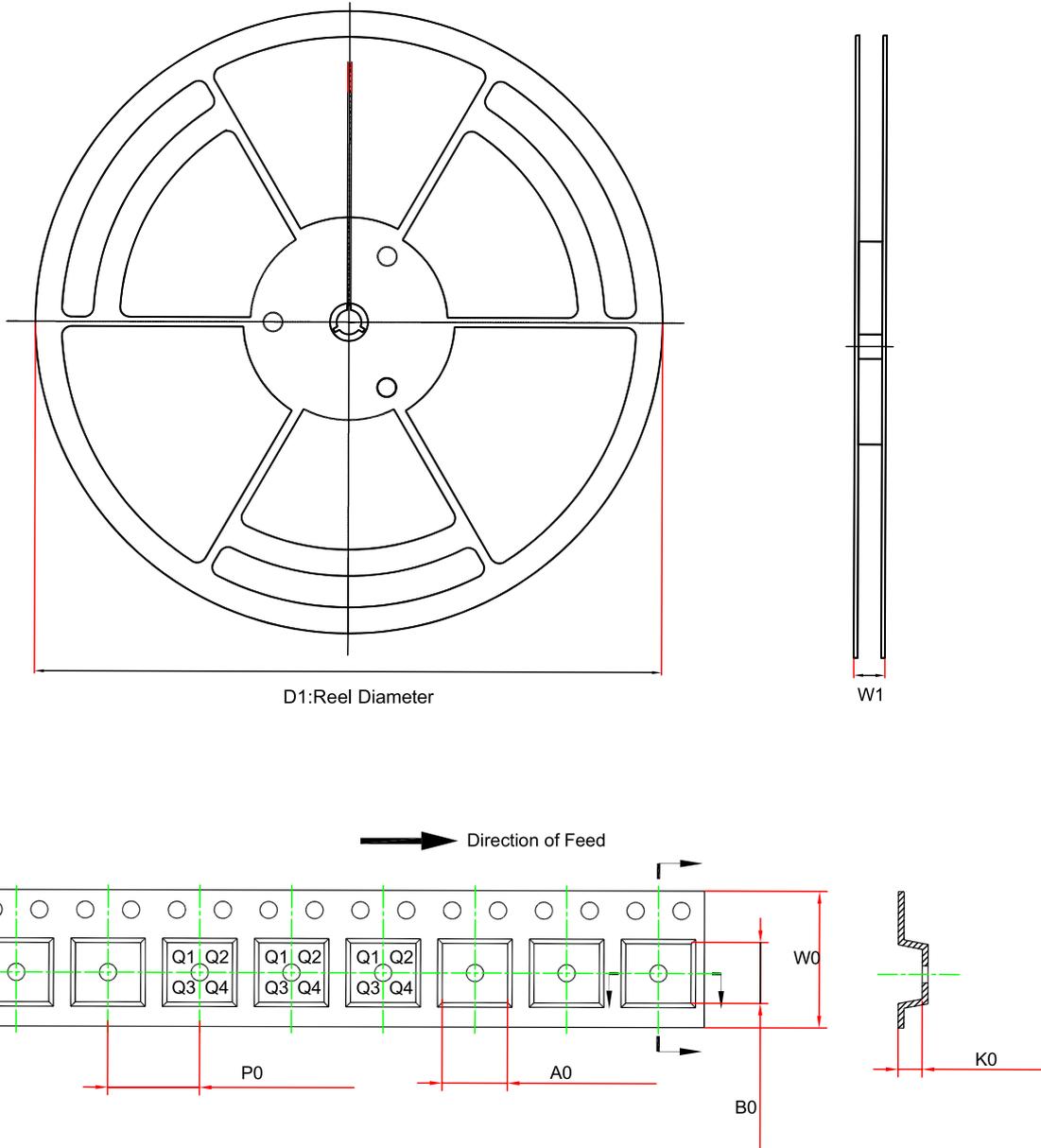
$$\text{When } R3 = R1, R2 = R4, R_{SHUNT} \ll R1$$

**Figure 21. Low-Side Current-Sensing Application**

### Power Supply Recommendations

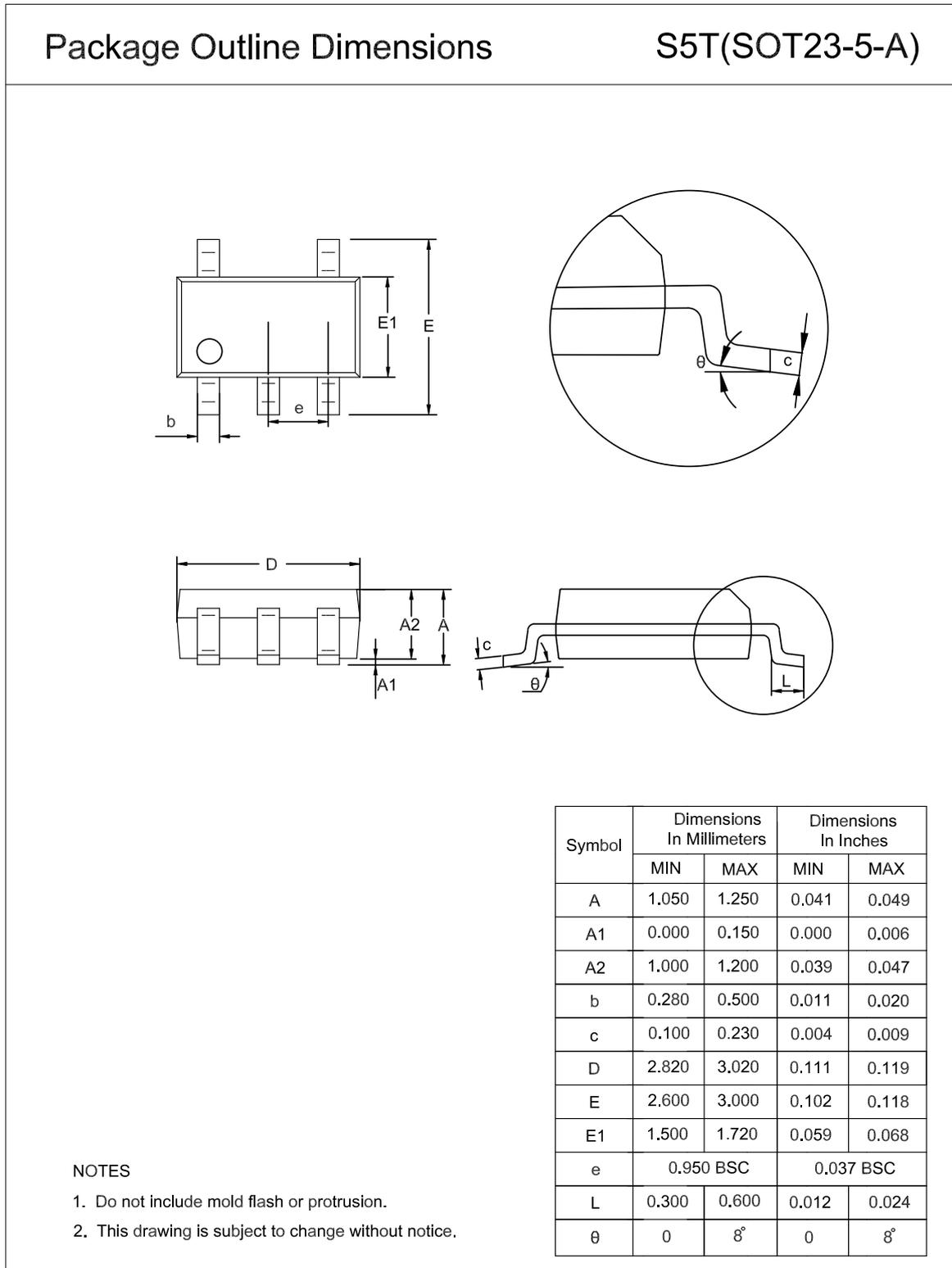
Place 0.1- $\mu$ F bypass capacitors close to the power supply pins to reduce coupling errors from the noise or high-impedance power supplies.

### Tape and Reel Information



Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm) <sup>(1)</sup>	B0 (mm) <sup>(1)</sup>	K0 (mm) <sup>(1)</sup>	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

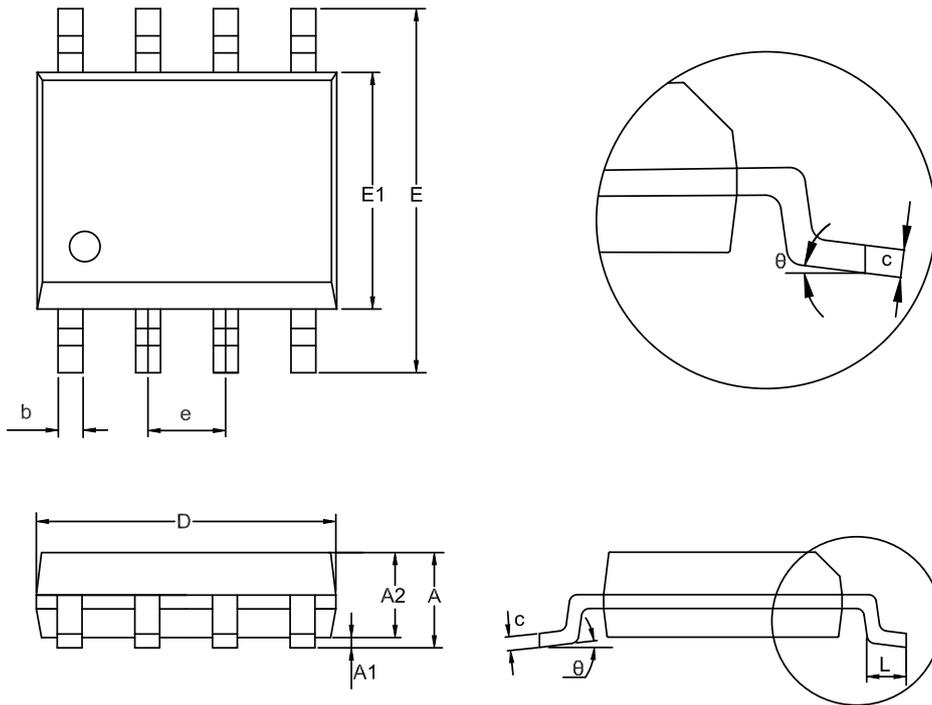
(1) The value is for reference only. Contact the 3PEAK factory for more information.

**Package Outline Dimensions**
**SOT23-5**


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
theta	0	8°	0	8°

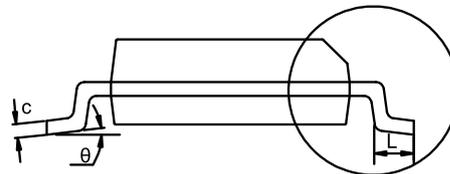
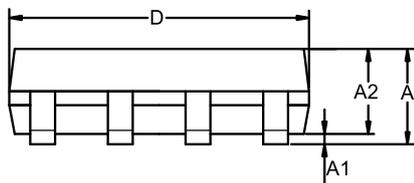
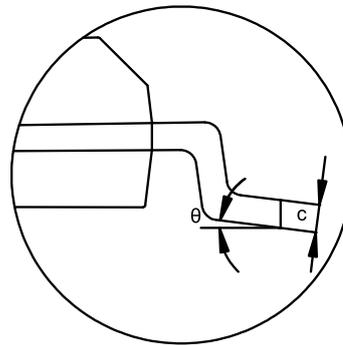
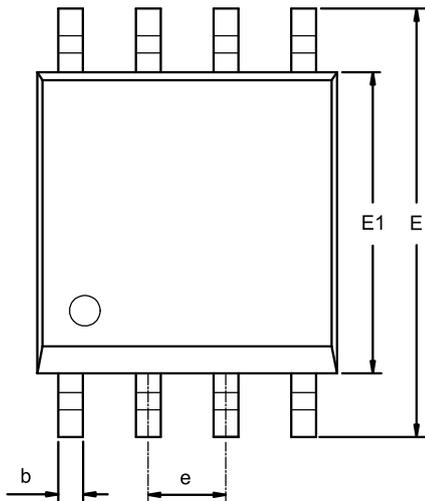
NOTES

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
$\theta$	0	8°	0	8°

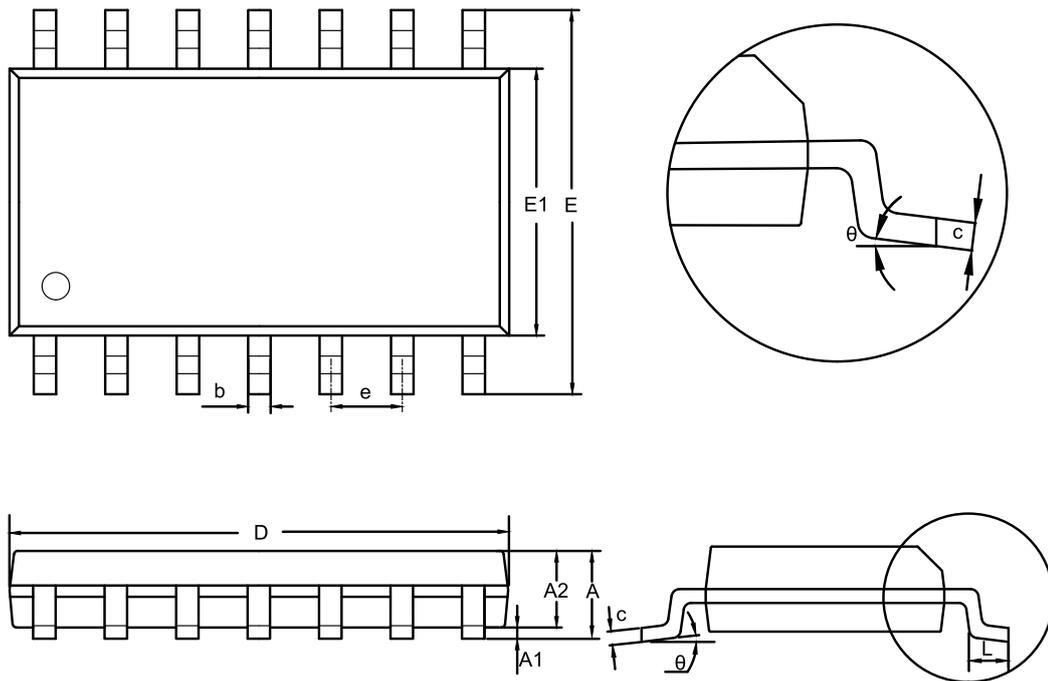
NOTES

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)

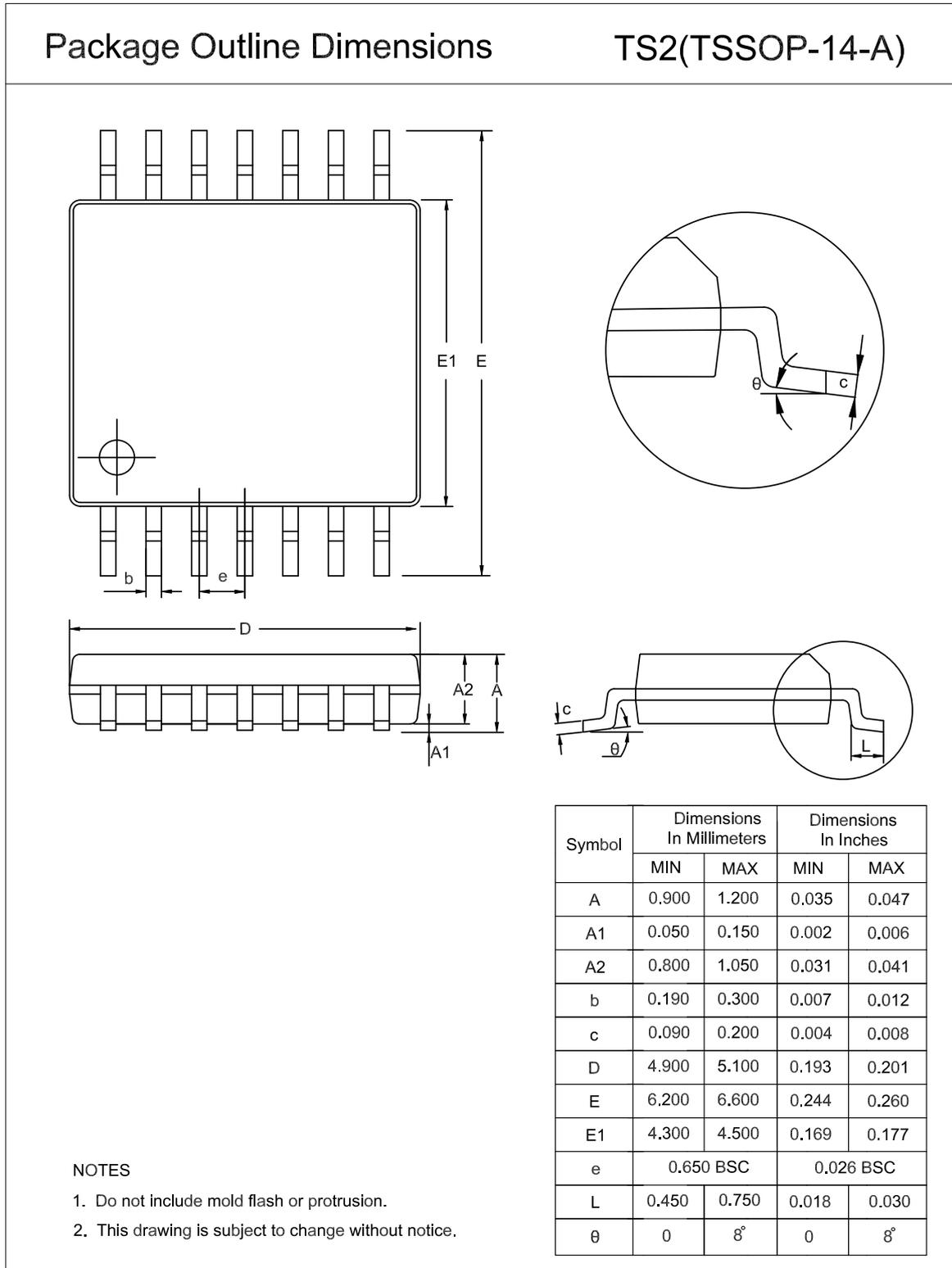


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.650	0.049	0.065
b	0.310	0.510	0.012	0.020
c	0.100	0.250	0.004	0.010
D	8.450	8.850	0.333	0.348
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050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

NOTES

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

TSSOP14



**Order Information**

Order Number	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TPA3661-S5TR <sup>(1)</sup>	-40 to 125°C	SOT23-5	361	3	Tape and Reel, 3000	Green
TPA3661U-S5TR <sup>(1)</sup>	-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 <sup>(1)</sup>	-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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