1.5-MHz, 100-µA, RRIO, Operational Amplifiers

Features

- Supply Voltage: 2.5 V to 5.5 V
- Low Supply Current: 100 µA per Channel
- Excellent Capacitive Load Drive Capability
- Offset Voltage: 3.5 mV
- Offset Voltage Temperature Drift: 1µV/°C
- Rail-to-Rail Input and Output
- Bandwidth: 1.5 MHz
- Slew Rate: 0.7 V/µs
- Excellent EMI Suppress Performance
- Low Noise: 22 nV/√Hz at 1 kHz
- Operating Temperature Range: –40°C to 125°C

Applications

- Active Filters, ASIC Input or Output Amplifier
- Sensor Interface
- Smoke/Gas/Environment Sensors
- Portable Instruments and Mobile Devices

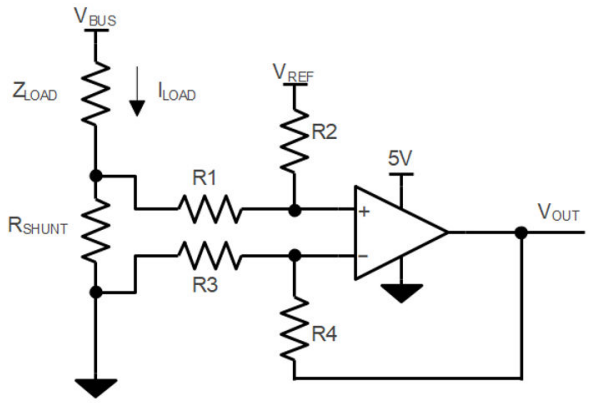
Description

The TPA6031/6032/6034 is a series of CMOS dual, and quad RRIO operational amplifiers with low offset, low power, and stable high-frequency response. The series incorporates 3PEAK's proprietary and patented design techniques to achieve excellent AC performance with 1.5-MHz bandwidth, 0.7-V/µs slew rate, and low distortion while drawing only 100 µA of quiescent current per amplifier. The TPA6031/6032/6031 series can drive capacitive loads up to 10uF to maintain stable output without oscillation.

The input common-mode voltage range extends 100 mV beyond V– and V+, and the outputs swing rail-to-rail. The TPA6031/6032/6034 series can be used as plug-in replacements for commercially available op amps to reduce power and improve input/output range and performance. The combination of features makes the TPA6031/6032/6034 ideal for motor control, portable audio amplification, sound ports, and other consumer audios.

The TPA6031/6032/6034 op amps are very stable and are capable of driving heavy capacitive loads such as those found in LCDs. The ability to swing rail-to-rail at the inputs and outputs enables designers to buffer CMOS DACs, ASICs, or other wide-output swing devices in single-supply systems.

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
2024-11-15	Rev.A.0	Initial version.
2025-02-11	Rev.A.1	Corrected handwriting errors. The physical object has not changed.

Pin Configuration and Functions

TPA6031
SOT23-5
Top View

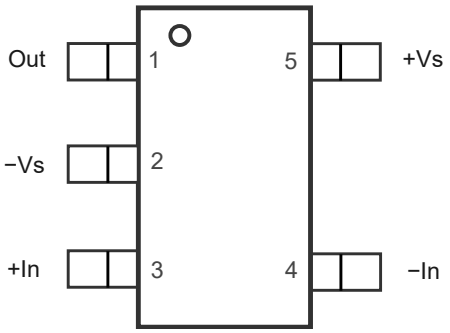
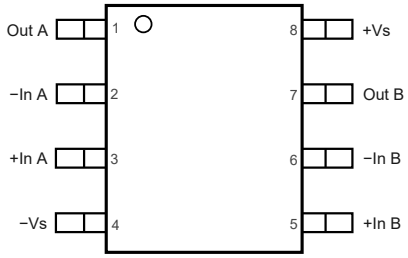


Table 1. Pin Functions: TPA6031

Pin No. SOT23-5	Name	I/O	Description
1	Out	O	Output
2	$-V_S$		Negative power supply
3	+In	I	Non-inverting input
4	−In	I	Inverting input
5	$+V_S$		Positive power supply

TPA6032
SOP8
Top View



TPA6032
MSOP8
Top View

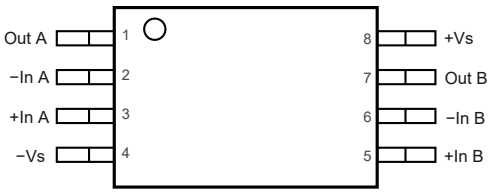
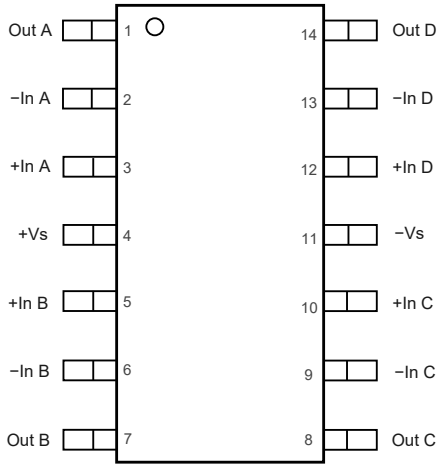


Table 2. Pin Functions: TPA6032

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

TPA6034
SOP14
Top View



TPA6034
TSSOP14
Top View

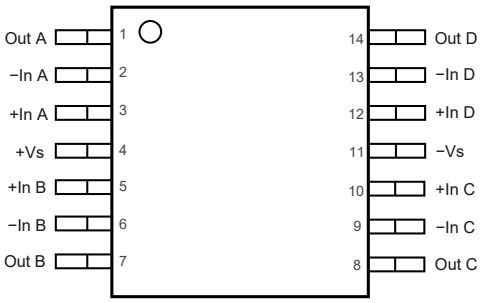


Table 3. Pin Functions: TPA6034

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: $(+V_S) – (-V_S)$		6	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 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 and outputs are protected by ESD protection diodes to each power supply. If the input or output extends more than 300 mV beyond the 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)	7	kV
CDM	Charged Device Model ESD	ANSI/ESDA/JEDEC JS-002 (2)	1.5	kV
LU	Latch Up	JESD 78, 25°C	600	mA
		JESD 78, 125°C	600	mA

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

Thermal Information

Package Type	θ_{JA}	θ_{JC}	Unit
SOT23-5	250	81	°C/W
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 = 5 V, T_A = 25°C, R_L = 10 kΩ, unless otherwise noted.

Symbol	Parameter	Conditions	T_A	Min	Typ	Max	Unit
Power Supply							
V_S	Supply Voltage Range			2.5		5.5	V
I_Q	Quiescent Current per Amplifier	V_S = 5 V			101	125	μA
			−40°C to 125°C			190	μA
PSRR	Power Supply Rejection Ratio	V_S = 2.5 V to 5.5 V, V_{CM} = 1 V		80	95		dB
			−40°C to 125°C	75			dB
Input Characteristics							
V_{OS}	Input Offset Voltage	V_{CM} = 0 V to 3 V		-3	1.5	3	mV
			−40°C to 125°C	−3.5		3.5	mV
		V_{CM} = 3 V to 5 V		-5	1.5	5	mV
			−40°C to 125°C	−5.5		5.5	mV
V_{OS} TC	Input Offset Voltage Drift		−40°C to 125°C		1		μV/°C
I_B	Input Bias Current			−200	50	200	pA
			−40°C to 125°C	−9	0.05	9	nA
I_{OS}	Input Offset Current			−200	50	200	
			−40°C to 125°C	−9	0.03	9	nA
C_{IN}	Input Capacitance	Differential mode			6		pF
		Common mode			8		pF
A_V	Open-Loop Voltage Gain	V_S = 5 V, V_{OUT} = 1 V to 4 V		85	100		dB
			−40°C to 125°C	80			dB
V_{CMR}	Common-Mode Input Voltage Range			(−V_S) − 0.1		(+V_S) + 0.1	V
CMRR	Common-Mode Rejection Ratio	V_{CM} = 0 V to 5 V		60	80		dB
			−40°C to 125°C	55			dB
		V_{CM} = 0 V to 3 V		89	110		dB
			−40°C to 125°C	80			dB

Symbol	Parameter	Conditions	T_A	Min	Typ	Max	Unit
Output Characteristics							
V_{OH},V_{OL}	Output Swing from Positive Rail	R_{LOAD} = 10 kΩ to V_S / 2			10	15	mV
			−40°C to 125°C			20	mV
	Output Swing from Negative Rail	R_{LOAD} = 10 kΩ to V_S / 2			10	15	mV
			−40°C to 125°C			20	mV
I_{SC}	Output Short-Circuit Current	Source current		70	85		mA
			−40°C to 125°C	60			
		Sink current		75	95		mA
			−40°C to 125°C	60			
AC Specifications							
GBW	Gain-Bandwidth Product				1.5		MHz
SR	Slew Rate	G = 1, 2-V step			0.7		V/µs
t_{OR}	Overload Recovery				1.2		us
t_S	Settling Time, 0.1%	G = 1, 2-V step			4.3		µs
	Settling Time, 0.01%				5.4		µs
PM	Phase Margin	V_S = 5 V, R_L = 10 kΩ, C_L = 100 pF			80		°
GM	Gain Margin	V_S = 5 V, R_L = 10 kΩ, C_L = 100 pF			15		dB
Noise Performance							
E_N	Input Voltage Noise	f = 0.1 Hz to 10 Hz			8		μV_{PP}
e_N	Input Voltage Noise Density	f = 1 kHz			22		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_{PP}			0.002		%

Typical Performance Characteristics

All test conditions: V_S = 5 V, V_{CM} = 2.5 V, R_L = 10 kΩ, unless otherwise noted.

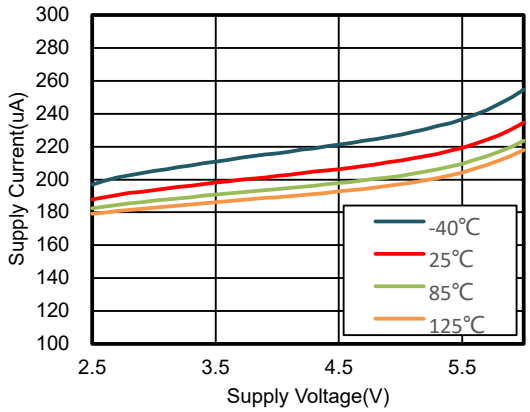


Figure 1. Quiescent Current vs. Supply Voltage, TPA6032

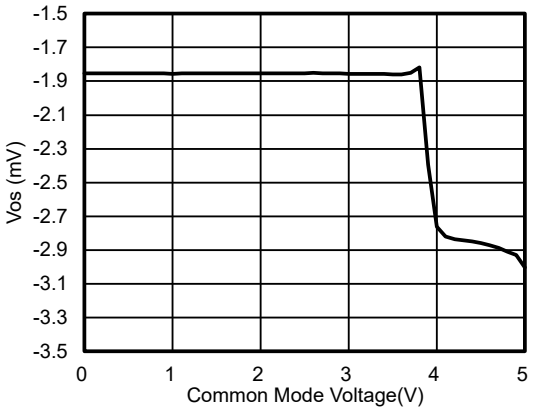


Figure 2. Offset Voltage vs. Common-Mode Voltage

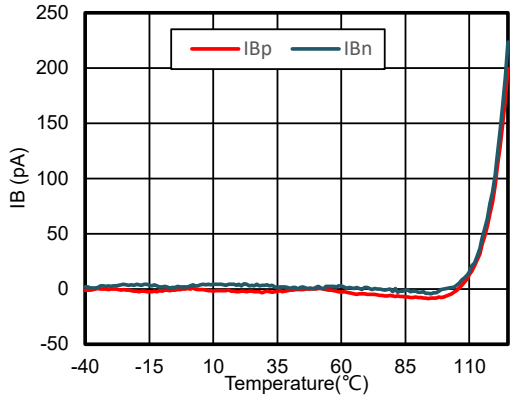


Figure 3. I_B vs. Temperature, −40 to 125°C

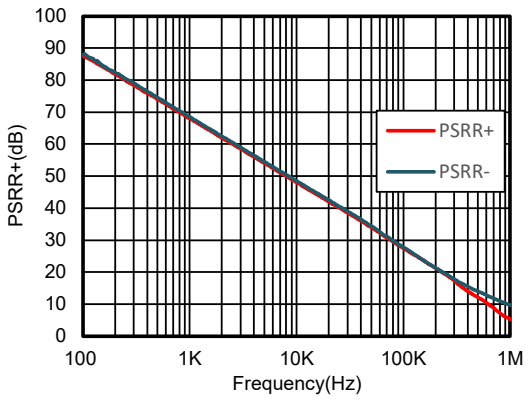


Figure 4. PSRR vs. Frequency

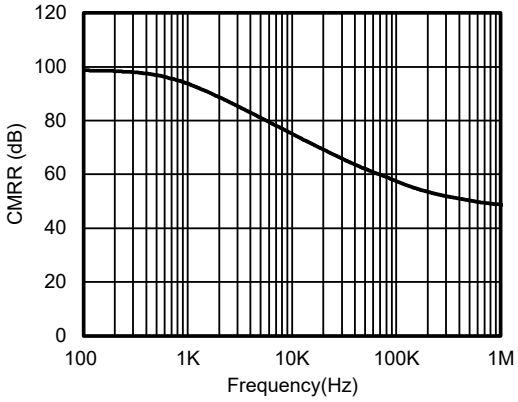


Figure 5. CMRR vs. Frequency

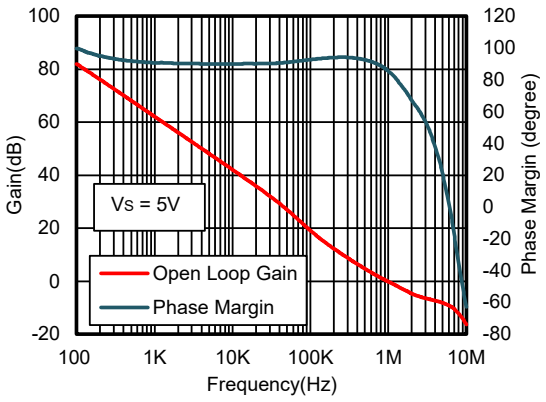


Figure 6. Open-Loop Gain and Phase vs. Frequency

R_{LOAD} = 10 kΩ, C_{LOAD} = 100 pF

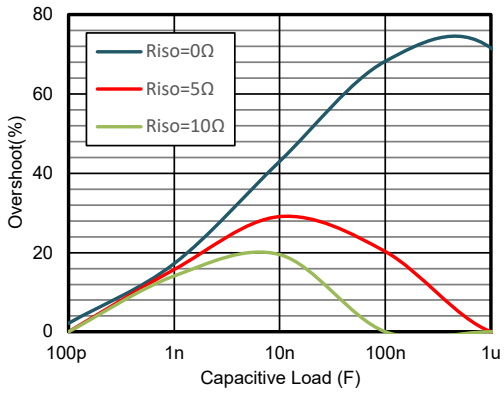


Figure 7. 100-mV Small-Signal Overshoot vs. Capacitive Load

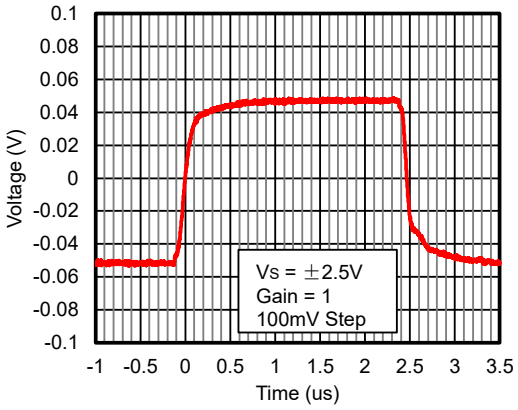


Figure 8. 100-mV Signal Step Response

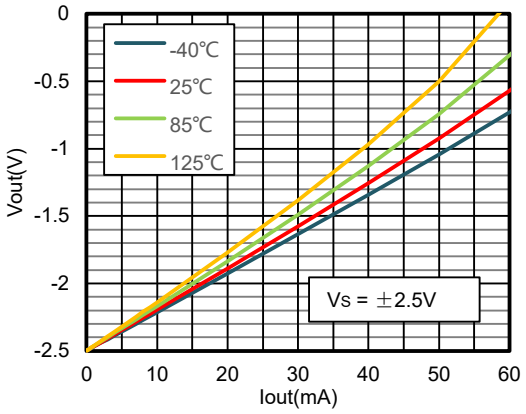


Figure 9. Negative Output Voltage vs. Output Current

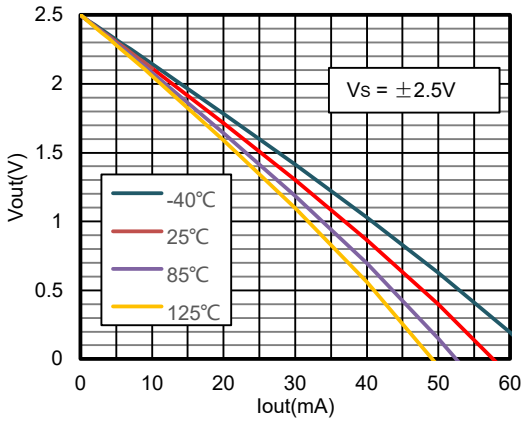


Figure 10. Positive Output Voltage vs. Output Current

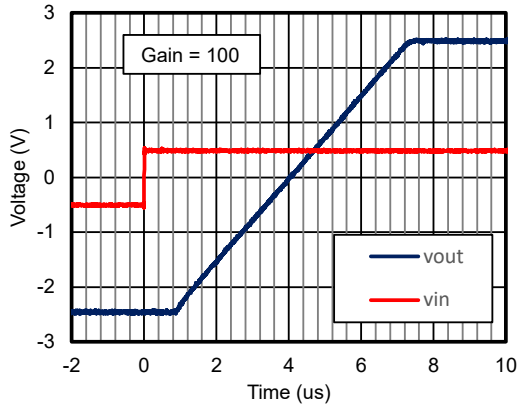


Figure 11. Positive Overload Recovery

Voltage: 1 V/div for output, Time: 2 μs/div, G = 100, V_{IN} = 1 V_{PP}, R = 10 kΩ, C = 100 pF, V_S = 5 V, V_{CM}= 2.5 V

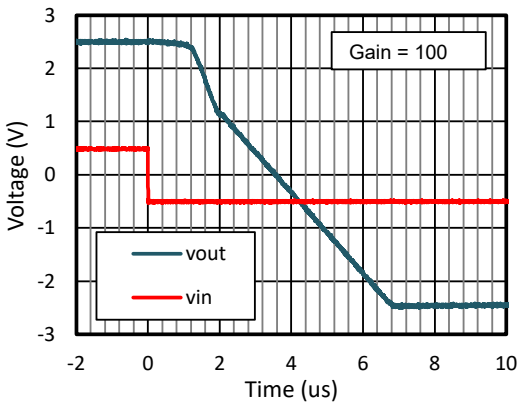


Figure 12. Negative Overload Recovery

Voltage: 1 V/div for output, Time: 2 μs/div, G = 100, V_{IN} = 1 V_{PP}, R = 10 kΩ, C = 100 pF, V_S = 5 V, V_{CM}= 2.5 V

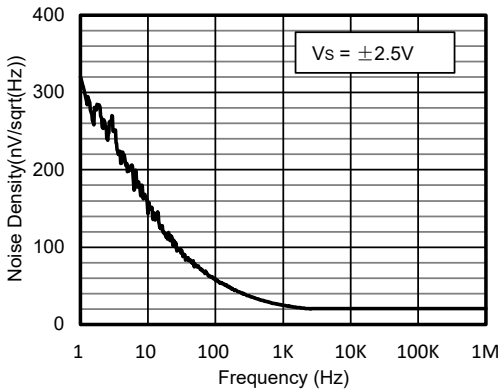


Figure 13. Voltage Noise Spectral Density vs. Frequency

V_S = 5 V, V_{CM} = 2.5 V

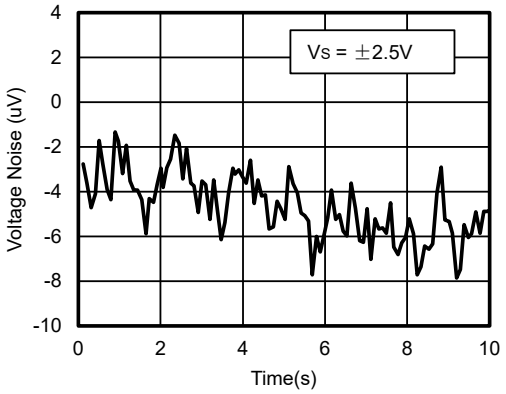


Figure 14. 0.1 to 10-Hz Voltage Noise

V_S = 5 V, V_{CM} = 2.5 V

Detailed Description

Overview

The TPA6031/6032/6034 is a series of low-power, rail-to-rail output operational amplifiers. The series operates from 2.5 V to 5.5 V and is unity-gain stable and designed for a wide range of general-purpose applications.

Functional Block Diagram

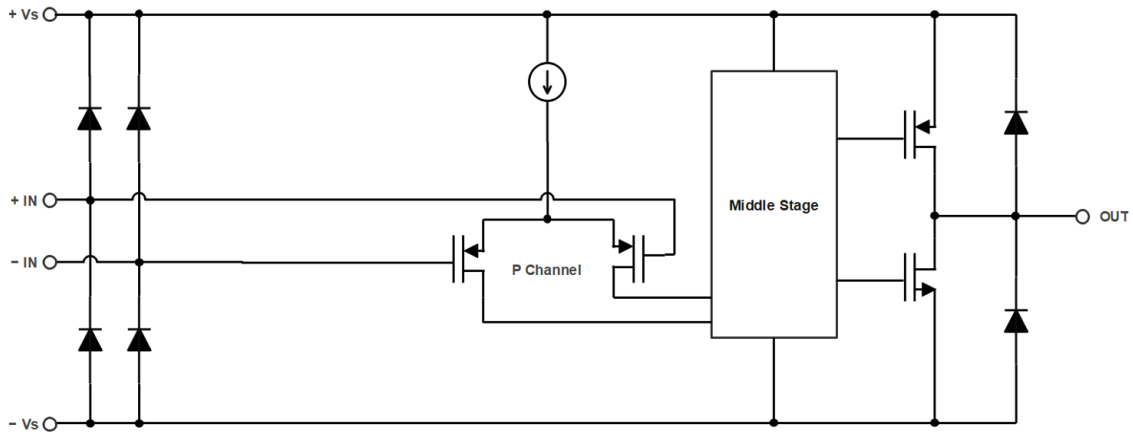


Figure 15. Functional Block Diagram

Feature Description

Capacitive Load and Stability

For amplifiers, driving capacitive loads often causes loop instability, which can be manifested as persistent oscillation of the output or output voltage reaching the maximum voltage range. The TPA6031/TPA6032/TPA6034 series has a specially designed structure that improves the ability to drive capacitive loads, so that the amplifier outputs can be driven with capacitive loads up to 10uF and remain stable without persistent oscillation.

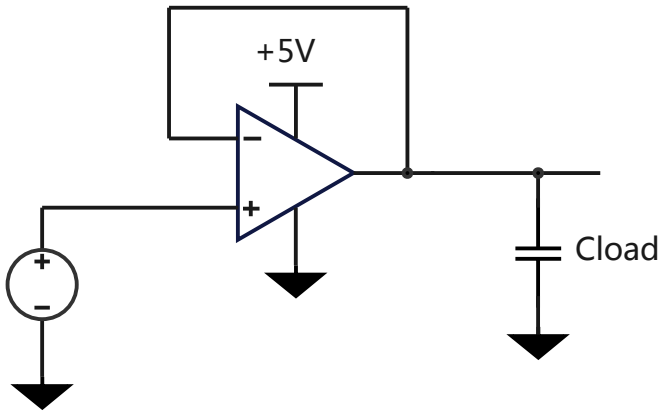


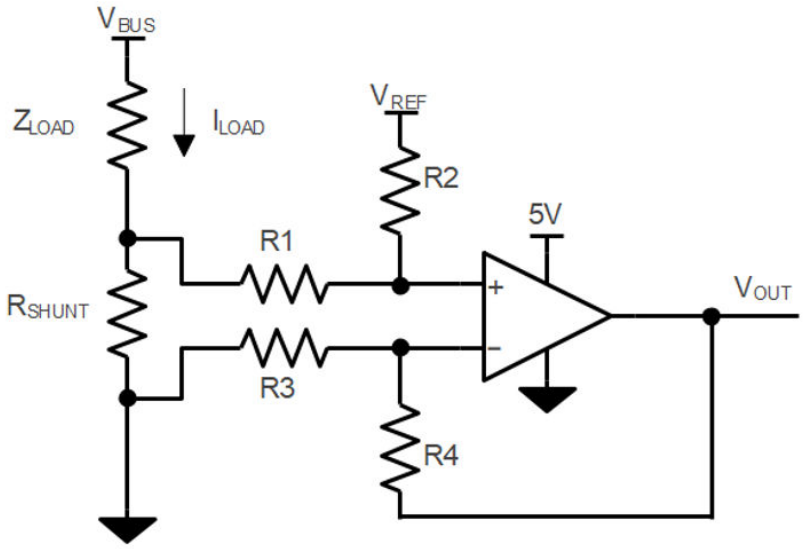
Figure 16. Extending Capacitive Load Drive with the TPA603x

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.

Typical Application

Figure 17 shows the typical application schematic.

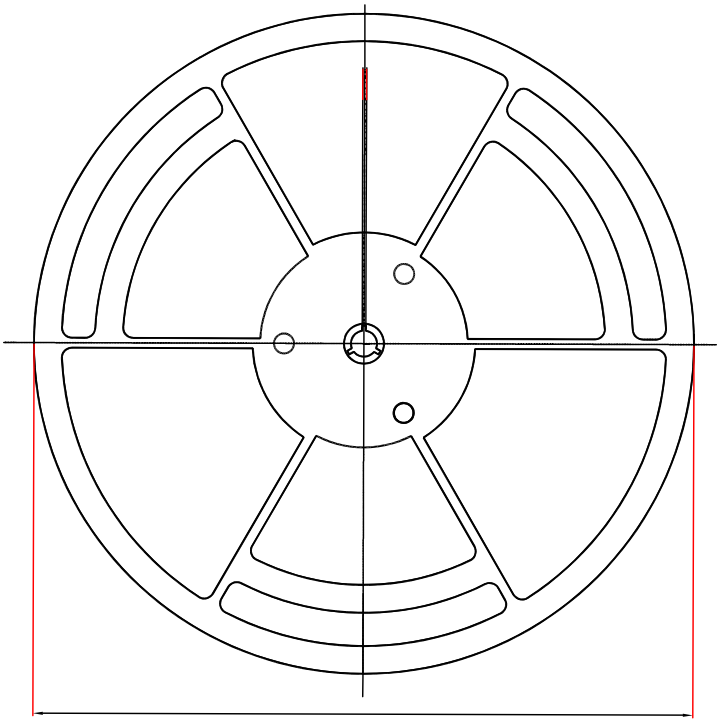


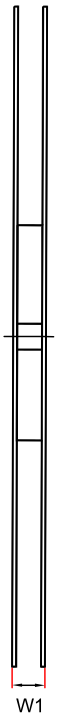
$$V_{OUT} = (I_{LOAD} \times R_{SHUNT}) \times (R2 / R1) + V_{REF}$$

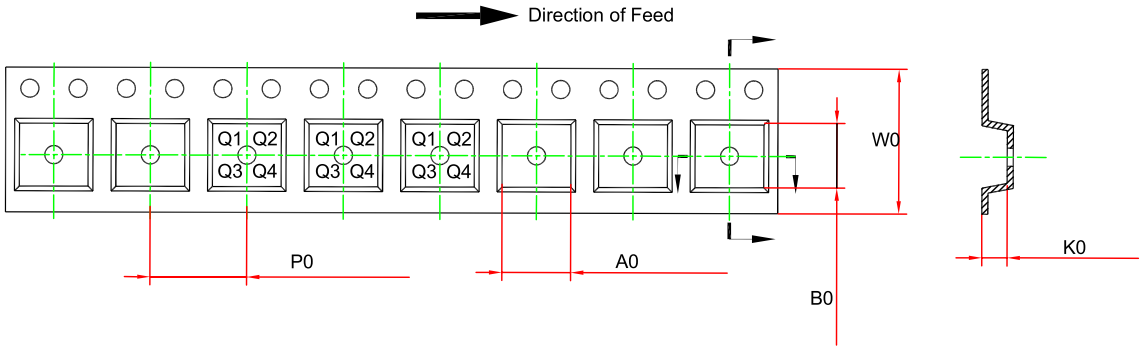
When R3 = R1, R2 = R4, $R_{SHUNT} << R1$

Figure 17. Typical Application Circuit

Tape and Reel Information







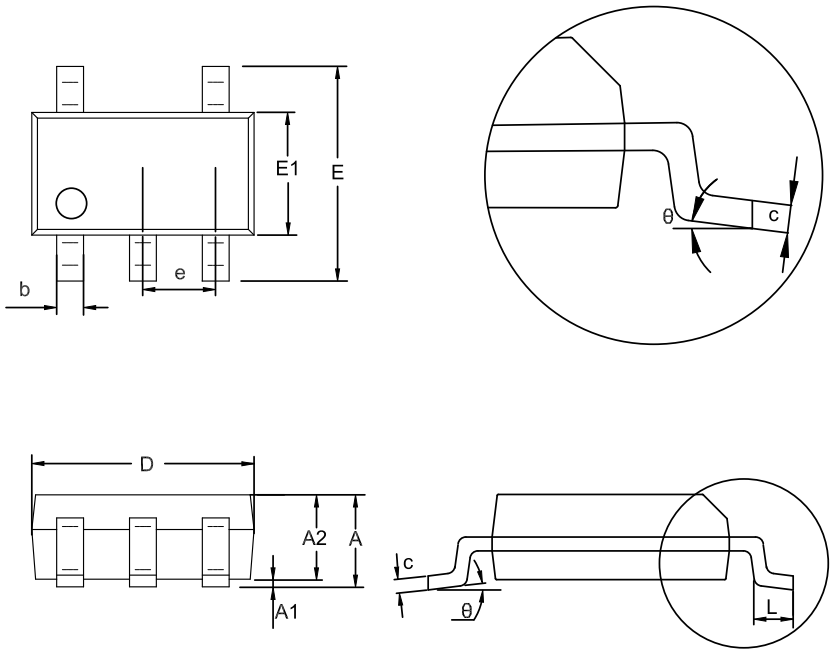
Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm) (1)	B0 (mm) (1)	K0 (mm) (1)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPA6031-S5TR	SOT23-5	180.0	13.1	3.2	3.2	1.4	4.0	8.0	Q3
TPA6032-SO1R	SOP8	330.0	17.6	6.4	5.4	2.1	8.0	12.0	Q1
TPA6032-VS1R	MSOP8	330.0	17.6	5.2	3.3	1.5	8.0	12.0	Q1
TPA6034-SO2R	SOP14	330.0	21.6	6.5	9.0	2.1	8.0	16.0	Q1
TPA6034-TS2R	TSSOP14	330.0	17.6	6.8	5.4	1.2	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)



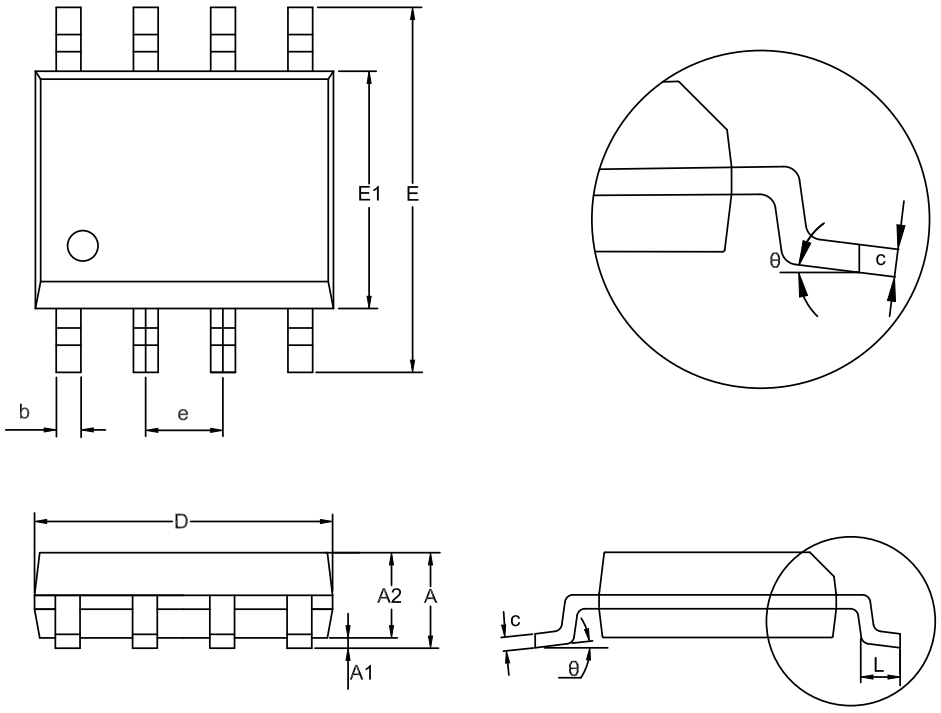
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.150	0.000	0.006
A2	1.000	1.200	0.039	0.047
b	0.280	0.500	0.011	0.020
c	0.100	0.230	0.004	0.009
D	2.820	3.020	0.111	0.119
E	2.600	3.000	0.102	0.118
E1	1.500	1.720	0.059	0.068
e	0.950 BSC		0.037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



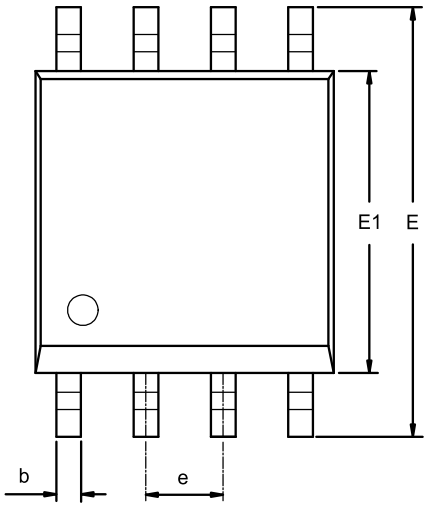
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.550	0.049	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050 BSC	
L	0.400	1.000	0.016	0.039
θ	0	8°	0	8°

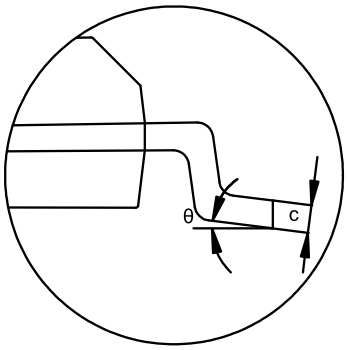
NOTES

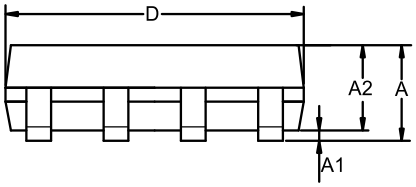
1. Do not include mold flash or protrusion.
2. This drawing is subject to change without notice.

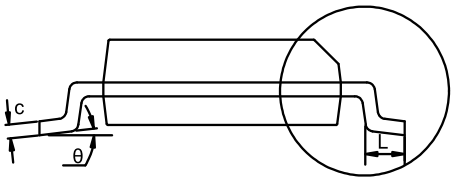
MSOP8

Package Outline Dimensions VS1(MSOP-8-A)









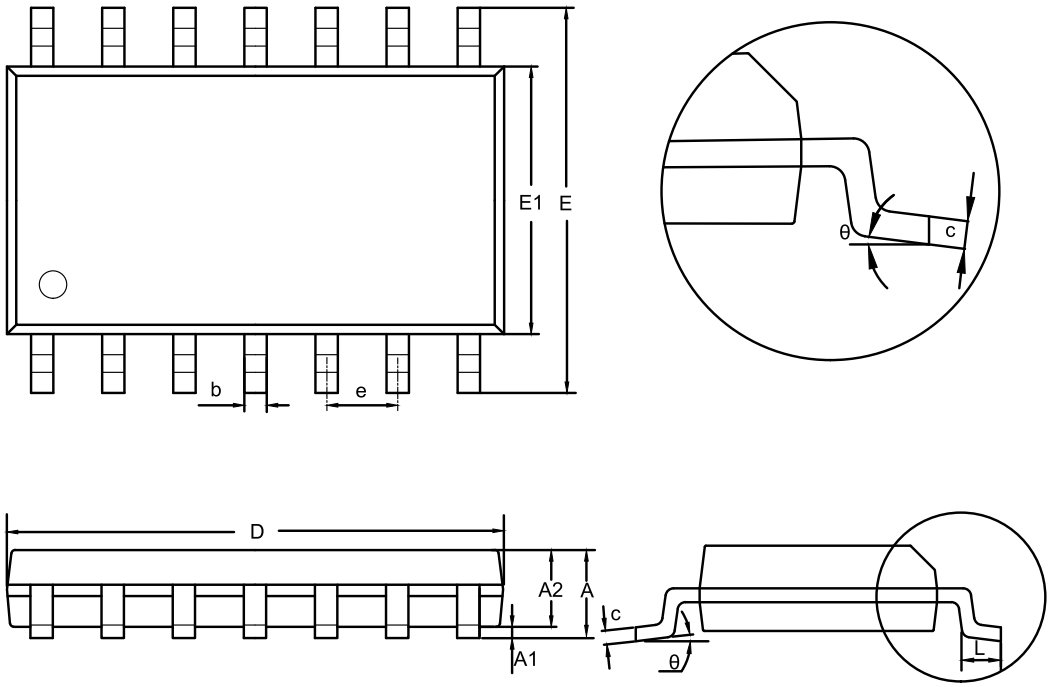
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.800	1.100	0.031	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.250	0.380	0.010	0.015
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
E	4.700	5.100	0.185	0.201
E1	2.900	3.100	0.114	0.122
e	0.650 BSC		0.026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



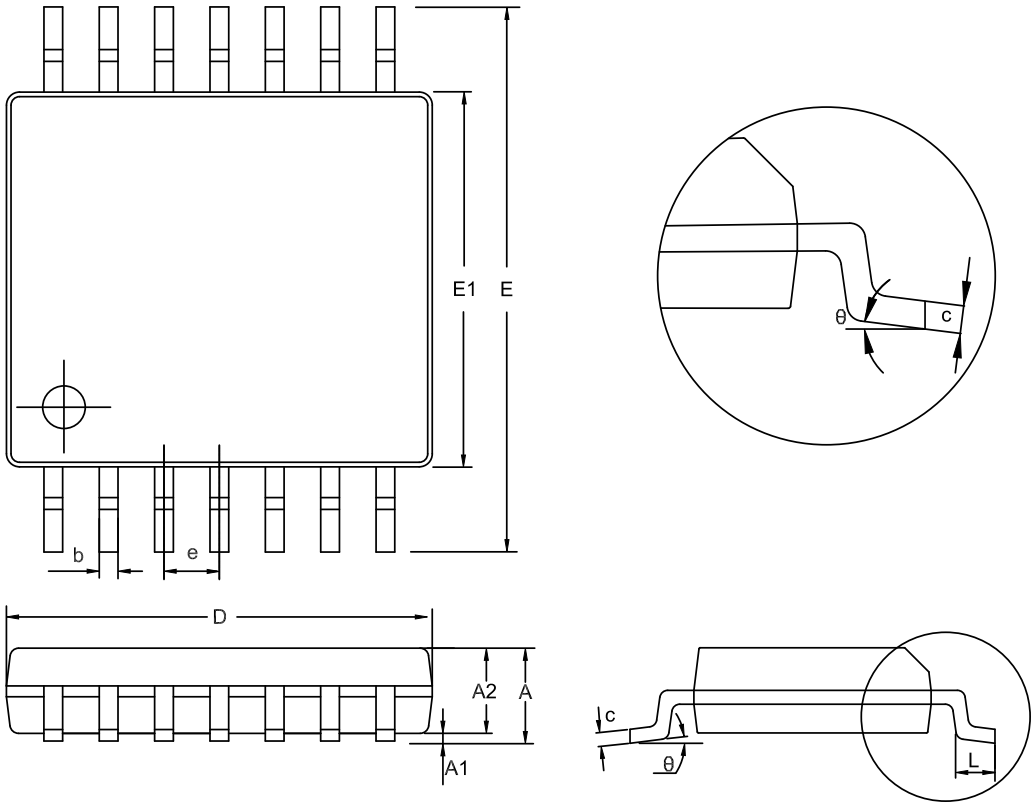
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.650	0.049	0.065
b	0.310	0.510	0.012	0.020
c	0.100	0.250	0.004	0.010
D	8.450	8.850	0.333	0.348
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050 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
TPA6031-S5TR (1)	−40 to 125°C	SOT23-5	AA0	1	Tape and Reel, 3000	Green
TPA6032-SO1R	−40 to 125°C	SOP8	A6032	3	Tape and Reel, 4000	Green
TPA6032-VS1R (1)	−40 to 125°C	MSOP8	A6032	2	Tape and Reel, 3000	Green
TPA6034-SO2R	−40 to 125°C	SOP14	A6034	3	Tape and Reel, 2500	Green
TPA6034-TS2R (1)	−40 to 125°C	TSSOP14	A6034	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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