36-V, 4-MHz, RRIO Operational Amplifier

Features

- Supply Voltage: 3 V to 36 V
- Offset Voltage: ±3.5 mV Maximum at 25°C
- Rail-to-Rail Input and Output
- Bandwidth: 4.6 MHz
- Slew Rate: 3.5 V/μs
- Low Noise: 53 nV/$\sqrt{Hz}$ at 1 kHz
- Zero-Crossover Input:
  - Excellent THD+N: 0.0008 %
- AEC-Q100 Qualified for Automotive Applications, Grade 1: −40°C to +125°C T_A

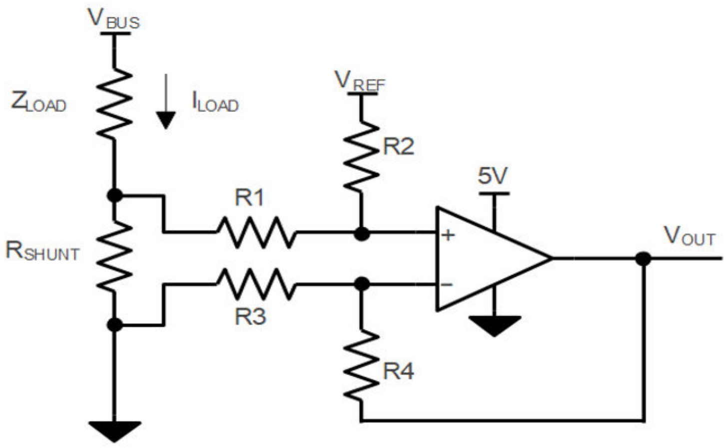
Applications

- On-Board Charger
- Automotive ECU

Description

The TPA277xQ is a series of the newest high-supply-voltage amplifiers with 3.5-mV low-offset voltage, low noise, and stable high-frequency response. The series incorporates proprietary and patented design techniques to achieve excellent AC performance with a 4-MHz bandwidth, a 3.5-V/μs slew rate, and low distortion while drawing a quiescent current of 1 mA per amplifier. The input common-mode voltage extends to $-V_S$ and $+V_S$, and the output swings rail-to-rail. The amplifier can be used as a plug-in replacement for commercially available op amps to improve performance.

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
2025-01-26	Rev.A.0	Initial version.

Pin Configuration and Functions

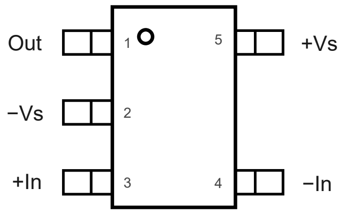
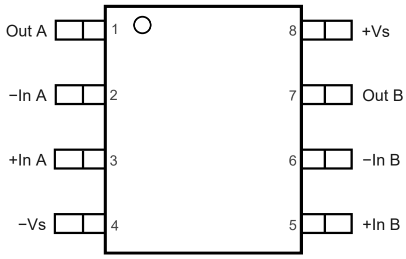


Table 1. Pin Functions: TPA2771

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

TPA2772
SOP8
Top View



TPA2772
MSOP8
Top View

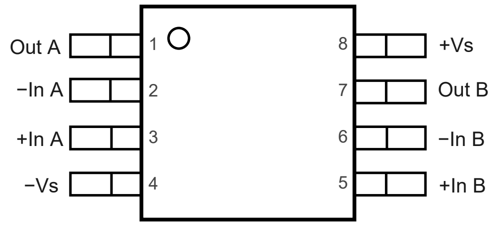


Table 2. Pin Functions: TPA2772

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

Specifications

Absolute Maximum Ratings (1)

Parameter		Min	Max	Unit
	Supply Voltage, $(+V_S) - (-V_S)$		40	V
	Input Voltage	$(-V_S) - 0.3$	$(+V_S) + 0.3$	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 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 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	AEC-Q100-002	2	kV
CDM	Charged Device Model ESD	AEC-Q100-011	1.5	kV
LU	Latch Up	AEC-Q100-004, 25°C	150	mA
		AEC-Q100-004, 125°C	100	mA

Recommended Operating Conditions

Parameter		Min	Typ	Max	Unit
V_S	Supply Voltage, $(+V_S) - (-V_S)$	3		36	V

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

Electrical Characteristics

All test conditions: V_S = 36 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	$(+V_S) - (-V_S)$	3		36	V
I_Q	Quiescent Current per Amplifier			1.25	1.7	mA
		T_A = −40°C to 125°C			2	mA
		V_S = 5 V		1	1.4	mA
		V_S = 5 V, T_A = −40°C to 125°C			1.7	mA
PSRR	Power Supply Rejection Ratio	V_S = 3 V to 36 V	82	105		dB
		V_S = 3 V to 36 V, T_A = −40°C to 125°C	78			dB
Input Characteristics						
V_{OS}	Input Offset Voltage	V_{CM} = 0 V to 36.1 V	−3.5	±0.8	3.5	mV
		V_{CM} = 0 V to 36.1 V, T_A = −40°C to 125°C	−5		5	mV
		V_S = 5 V, V_{CM} = 0 V to 5.1 V	−2.5	±0.5	2.5	mV
		V_S = 5 V, V_{CM} = 0 V to 5.1 V, T_A = −40°C to 125°C	−3.5		3.5	mV
V_{OS} TC	Input Offset Voltage Drift	T_A = −40°C to 125°C		1		μV/°C
I_B	Input Bias Current	V_{CM} = 18 V	−40	−20	40	nA
		V_{CM} = 18 V, T_A = −40°C to 125°C	−100		100	nA
I_{OS}	Input Offset Current	V_{CM} = 18 V	−10	1	10	nA
		V_{CM} = 18 V, T_A = −40°C to 125°C	−30		30	nA
R_{IN}	Input Resistance	Differential mode		3.5		MΩ
		Common mode		30		GΩ
C_{IN}	Input Capacitance	Differential mode		3		pF
		Common mode		2		pF
A_V	Open-Loop Voltage Gain	V_{OUT} = 0.5 V to 35.5 V	105	115		dB
		V_{OUT} = 0.5 V to 35.5 V, T_A = −40°C to 125°C	100			dB
V_{CMR}	Common-Mode Input Voltage Range		$-V_S$		$(+V_S)$ + 0.1	V
CMRR	Common-Mode Rejection Ratio	V_{CM} = 0 V to 36.1 V	90	110		dB
		V_{CM} = 0 V to 36.1 V, T_A = −40°C to 125°C	85			dB

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
	Differential-Mode Input Voltage Range		$(-V_S) - (+V_S)$		$(+V_S) - (-V_S)$	
Output Characteristics						
	Output Swing from Rail	No load		5	20	mV
		No load, $T_A = -40°C$ to 125°C			25	mV
		R_L = 10 kΩ to V_S / 2		60	100	mV
		R_L = 10 kΩ to V_S / 2, $T_A = -40°C$ to 125°C			150	mV
		R_L = 2 kΩ to V_S / 2		300	500	mV
		R_L = 2 kΩ to V_S / 2, $T_A = -40°C$ to 125°C			800	mV
	Output Swing from Negative Rail	V_S = 5 V, no load		3	10	mV
		V_S = 5 V, no load, $T_A = -40°C$ to 125°C			15	mV
		V_S = 5 V, R_L = 10 kΩ to V_S / 2		10	30	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		50	100	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	V_S = 36 V		100		mA
		V_S = 5 V		50		mA
AC Specifications						
GBW	Gain-Bandwidth Product			4.6		MHz
SR	Slew Rate	G = 1, 10-V step	2.5	3.5		V/μs
		G = 1, 10-V step, $T_A = -40°C$ to 125°C	1.7			V/μs
t_{OR}	Overload Recovery			1.5		μs
t_S	Settling Time, 0.1%	V_S = 36 V, 9-V step, R_L = 10 kΩ, C_L = 100 pF, G = 1		5.8		μs
	Capacitive Load Drive			0.1		nF
PM	Phase Margin	R_L= 10 kΩ, C_L= 50 pF		50		°
GM	Gain Margin	R_L= 10 kΩ, C_L= 50 pF		7.5		dB
	Crosstalk	V_{OUT} = 5 Vpp, f = 10 kHz, G = +11, R_L = 10 kΩ		115		dB
Noise Performance						
E_N	Input Voltage Noise	f = 0.1 Hz to 10 Hz		5.5		μV_{PP}
e_N	Input Voltage Noise Density	f = 10 Hz		274		$nV/\sqrt{Hz}$

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
		f = 1 kHz		53		nV/√Hz
i_N	Input Current Noise	f = 1 kHz		0.2		pA/√Hz
THD+N	Total Harmonic Distortion and Noise	V_S = 36 V, V_{IN} = 1 Vrms, R_L = 10 kΩ, A_V = +1, f = 1 kHz, BW = 22 kHz		0.0008		%

Typical Performance Characteristics

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

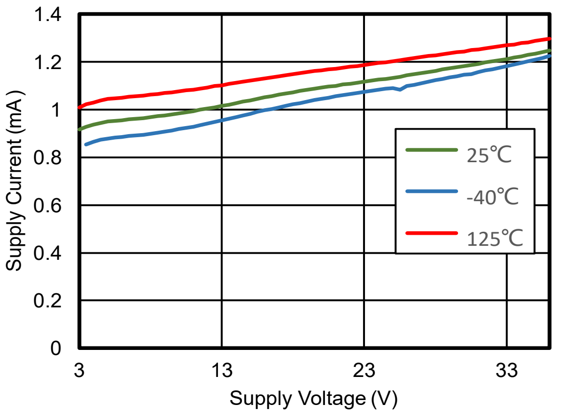


Figure 1. Supply Current vs. Supply Voltage, 1ch

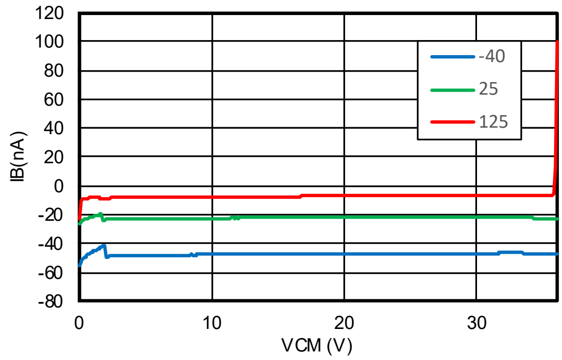


Figure 2. I_B vs. Common-Mode Voltage

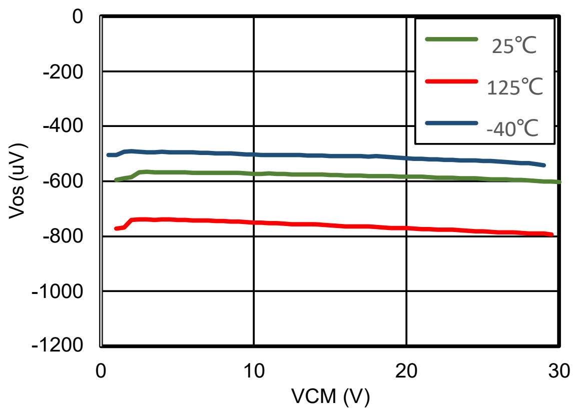


Figure 3. V_{OS} vs. Common-Mode Voltage

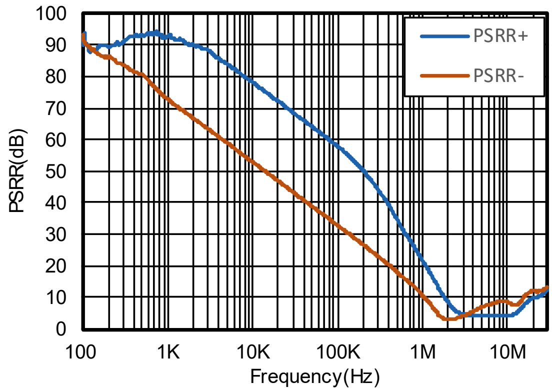


Figure 4. PSRR vs. Frequency

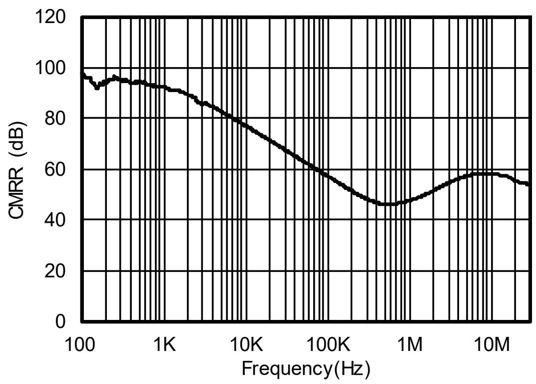


Figure 5. CMRR vs. Frequency

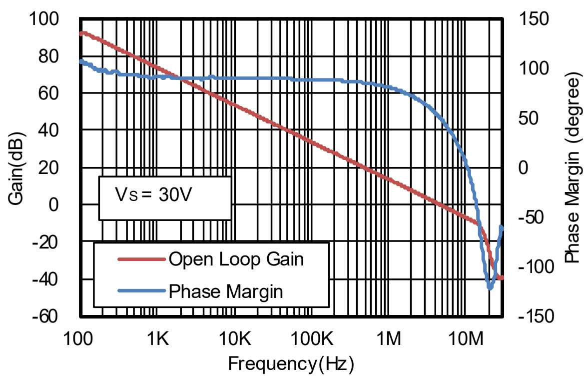


Figure 6. Open-Loop Gain and Phase vs. Frequency

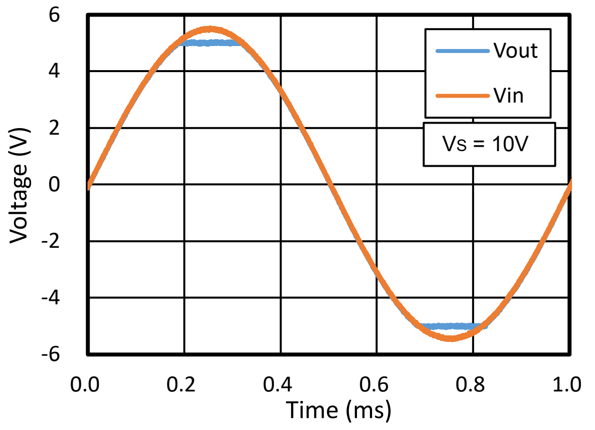


Figure 7. No Phase Reversal

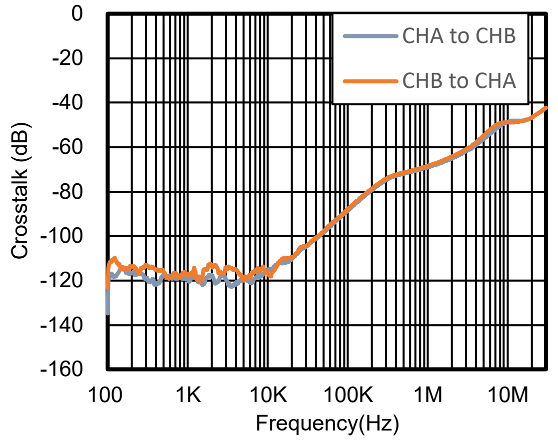


Figure 8. Channel Crosstalk vs. Frequency

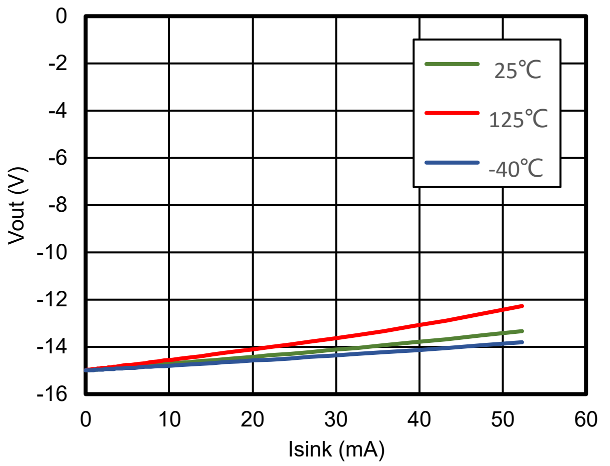


Figure 9. I_{sink} vs. V_{OUT}

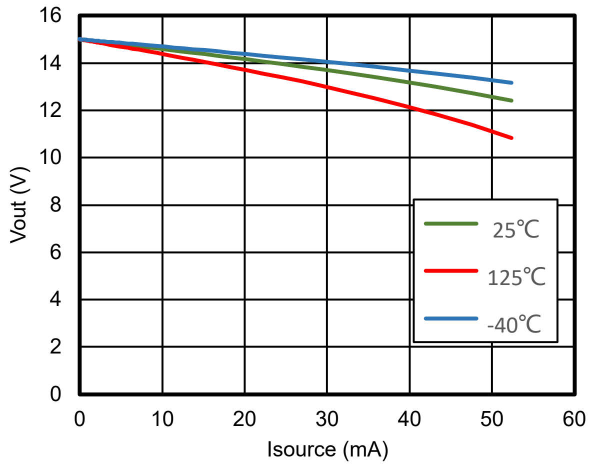


Figure 10. I_{source} vs. V_{OUT}

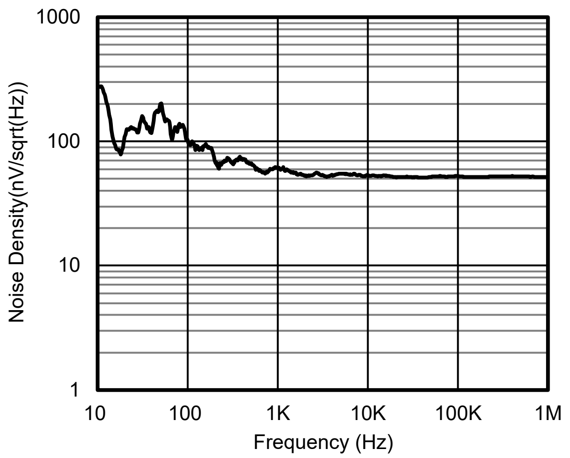


Figure 11. Input Voltage Noise Spectral Density vs. Frequency

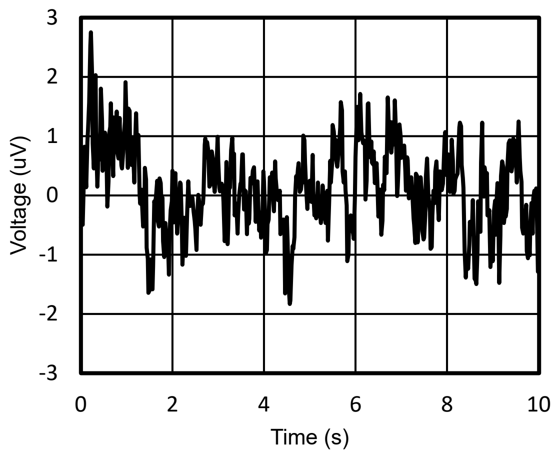


Figure 12. 0.1-Hz to 10-Hz Voltage Noise

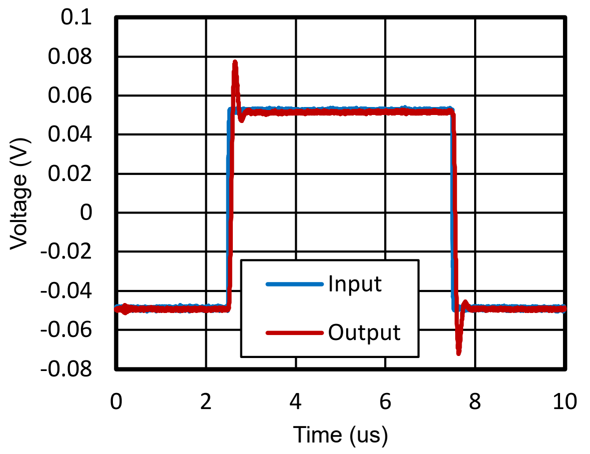


Figure 13. 100-mV Small-Signal Step Response

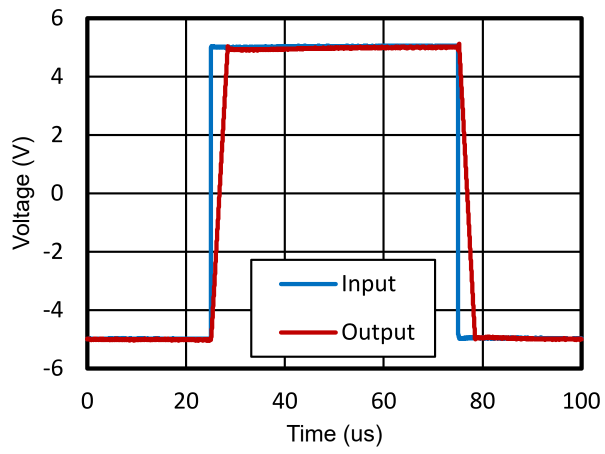


Figure 14. 10-V Large-Signal Step Response

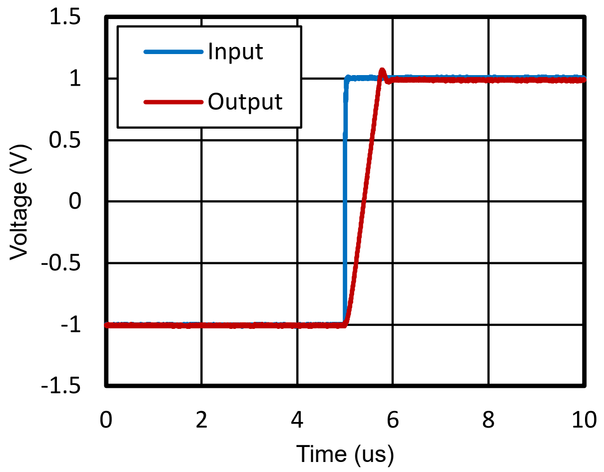


Figure 15. Positive Slew Rate

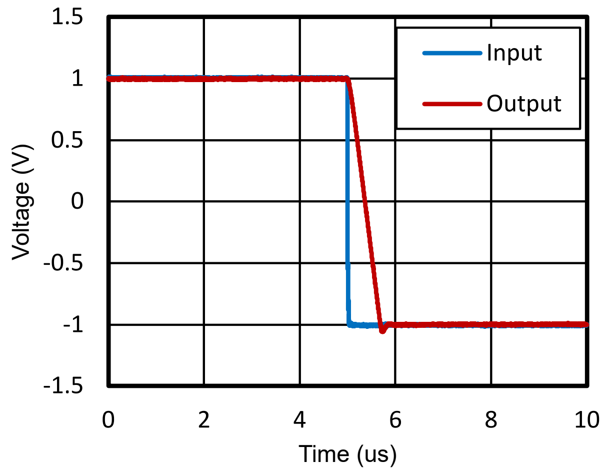


Figure 16. Negative Slew Rate

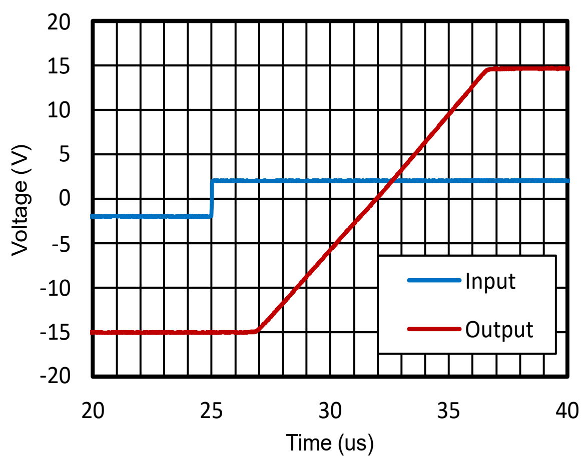


Figure 17. Overload Recovery

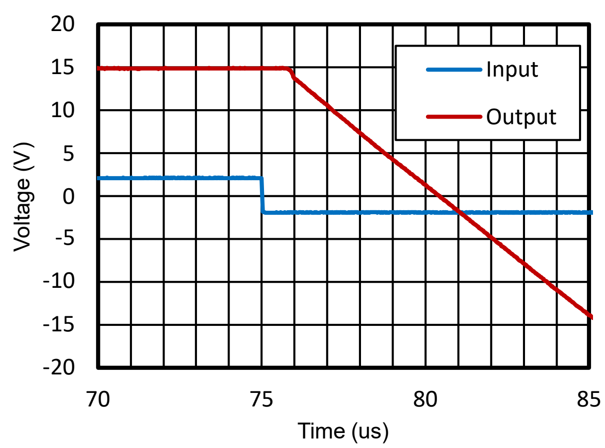


Figure 18. Overload Recovery

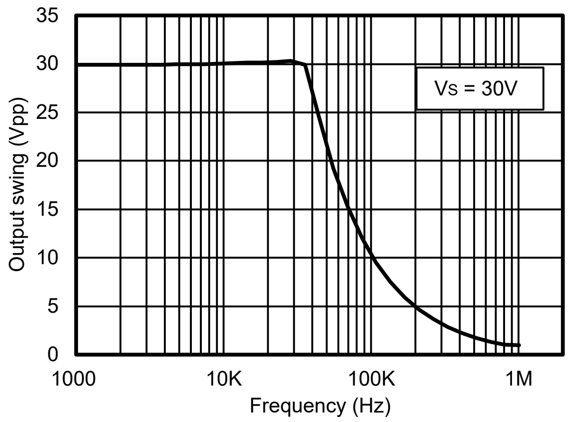


Figure 19. Maximum Output Voltage vs. Frequency

Detailed Description

Overview

The TPA277xQ is a series of op amps that operate on a single-supply voltage (3 V to 36 V), or a split-supply voltage (±1.5 V to ±18 V), making the series 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 amplifiers are fully specified from 3 V to 36 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 Typical Performance Characteristics.

Functional Block Diagram

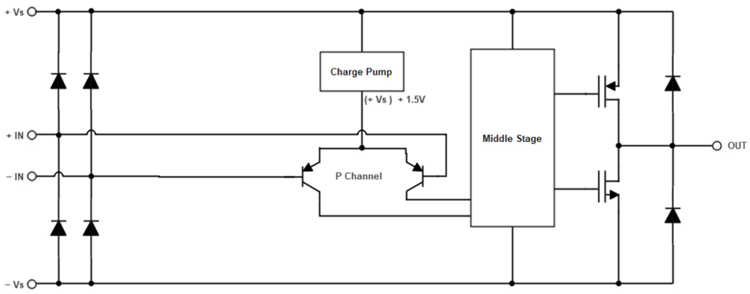


Figure 20. Functional Block Diagram

Feature Description

Operating Voltage

The series is designed for single supply operation from 3 V to 36 V or dual supply operation from ±1.5 V to ±18 V.

The recommended operating voltage conditions are as follows:

Power supply voltage ($+V_S$) − ($-V_S$): 3 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 3 V to 36 V.

For example, if operating with a single supply, ($-V_S$) = 0 V, ($+V_S$) can support 3 V to 36 V. If using dual supplies with equal absolute values, the minimum voltage is ±1.5 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.

Rail-to-Rail Input

The series has 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 negative and positive supplies. CMRR is excellent in all common-mode range and no input stage crossover distortion. When driving ADCs, the highly linear common-mode range of the series assures that the signal conditional system linearity performance is not compromised.

Rail-to-Rail Output

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

Application and Implementation

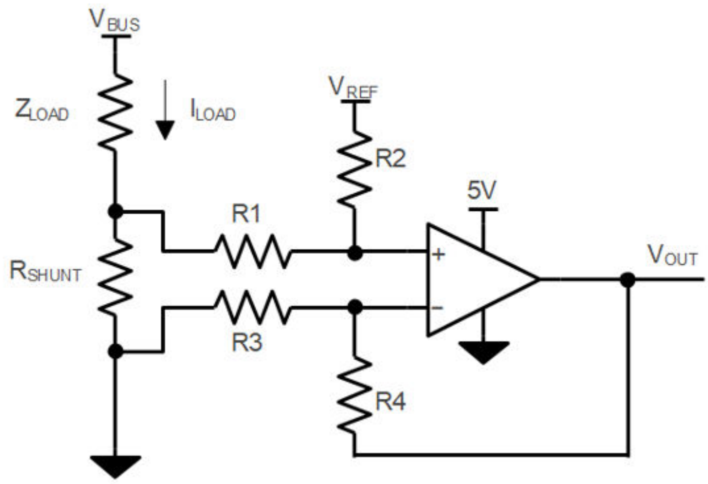
Note

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 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.



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

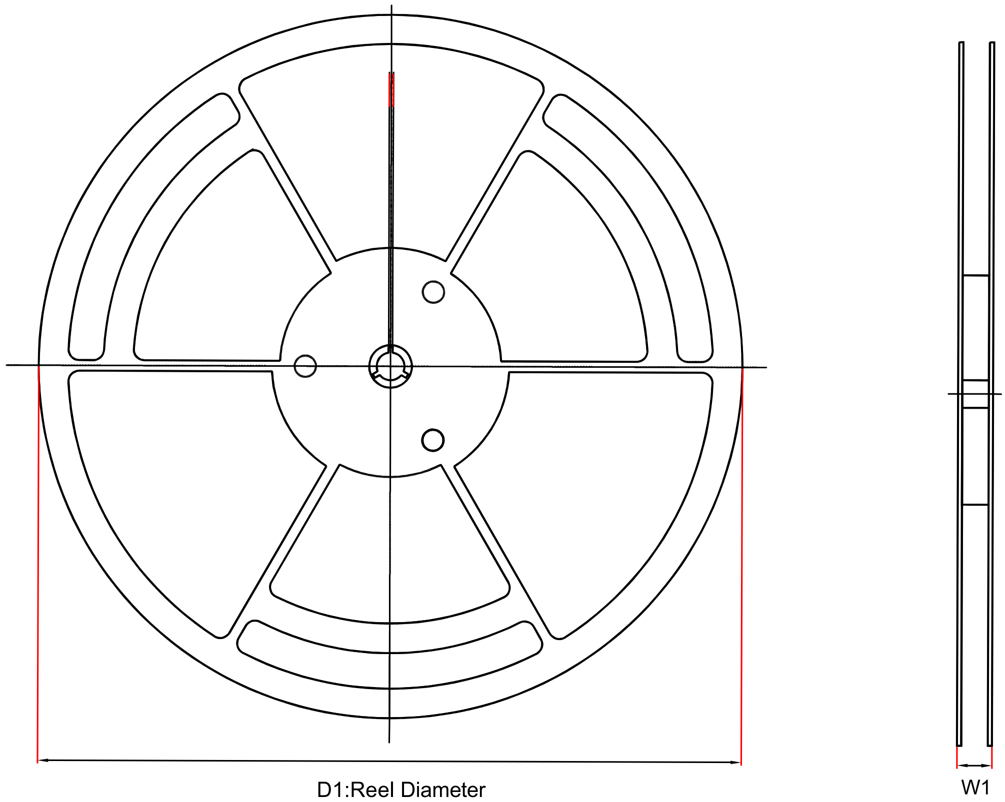
When $R3 = R1$, $R2 = R4$, $R_{SHUNT} << R1$

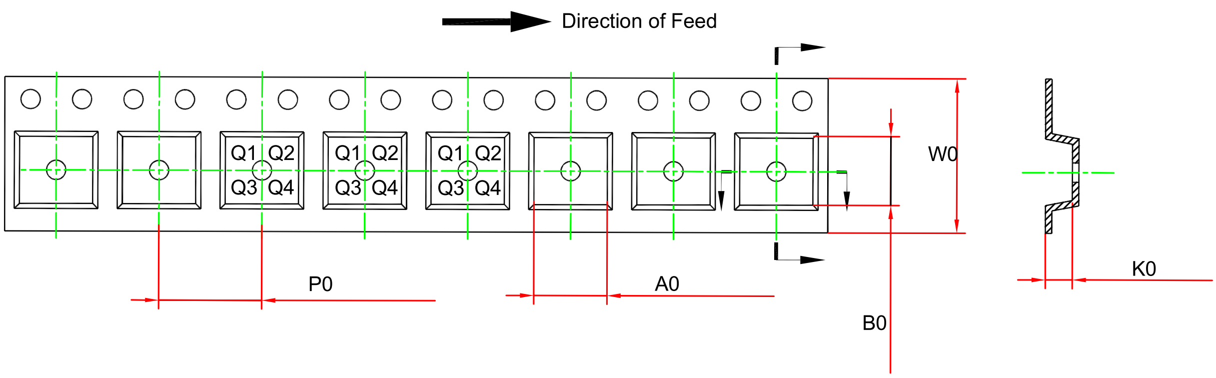
Figure 21. Low-Side Current-Sensing Application

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





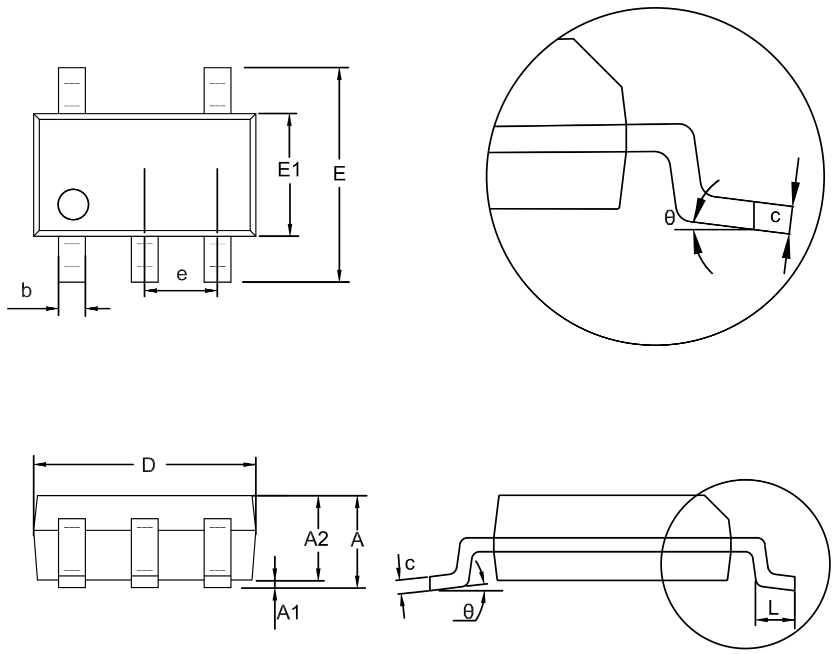
Order Number	Package	D1 (mm)	W1 (mm)	A0 (mm) (1)	B0 (mm) (1)	K0 (mm) (1)	P0 (mm)	W0 (mm)	Pin1 Quadrant
TPA2771Q-S5TR-S	SOT23-5								Q3
TPA2772Q-SO1R-S	SOP8	330.0	17.6	6.5	5.4	2.0	8.0	12.0	Q1
TPA2772Q-VS1R-S	MSOP8								Q1

(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)



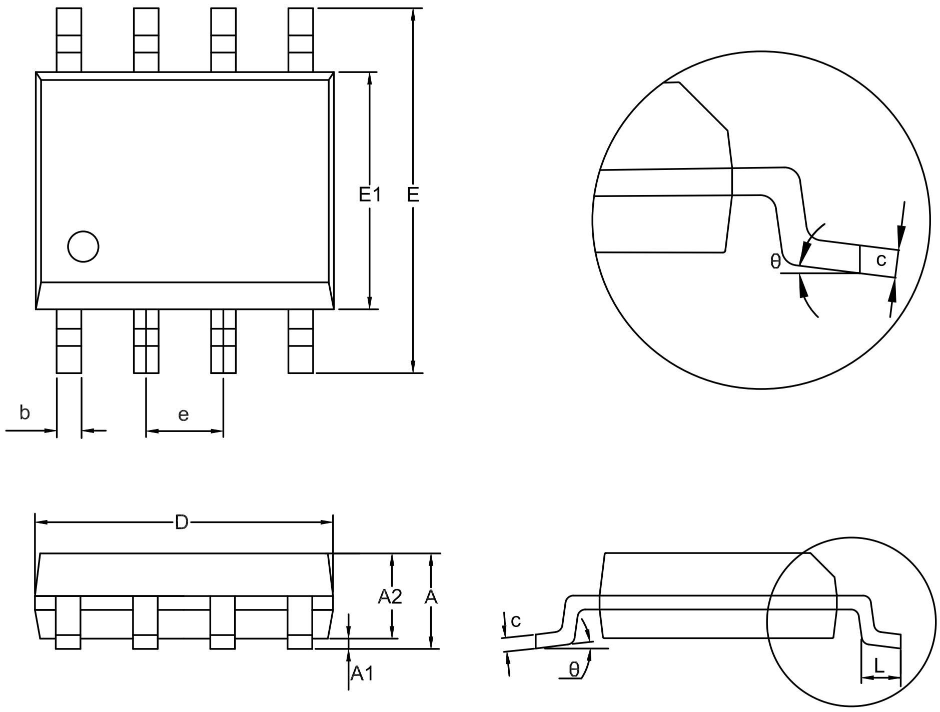
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.050	1.250	0.041	0.049
A1	0.000	0.150	0.000	0.006
A2	1.000	1.200	0.039	0.047
b	0.280	0.500	0.011	0.020
c	0.100	0.230	0.004	0.009
D	2.820	3.020	0.111	0.119
E	2.600	3.000	0.102	0.118
E1	1.500	1.720	0.059	0.068
e	0.950 BSC		0.037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



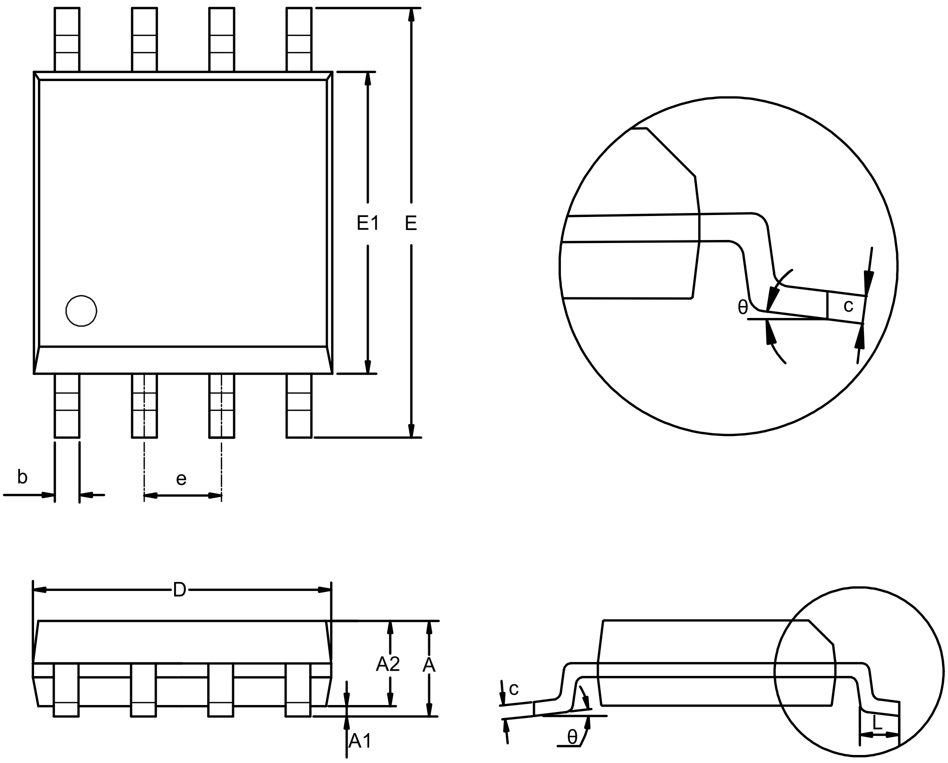
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.050	0.250	0.002	0.010
A2	1.250	1.550	0.049	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.201
E	5.800	6.200	0.228	0.244
E1	3.800	4.000	0.150	0.157
e	1.270 BSC		0.050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

Order Information

Order Number	Operating Temperature Range	Package	Marking Information	MSL	Transport Media, Quantity	Eco Plan
TPA2771Q-S5TR-S (1)	−40 to 125°C	SOT23-5	A34	1	Tape and Reel, 3000	Green
TPA2772Q-SO1R-S	−40 to 125°C	SOP8	2772Q	1	Tape and Reel, 4000	Green
TPA2772Q-VS1R-S (1)	−40 to 125°C	MSOP8	2772Q	1	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.

IMPORTANT NOTICE AND DISCLAIMER