# 36-V Dual Operational Amplifiers with Internal 2.5-V Reference

## Features

- Operational Amplifier
  - Supply Voltage: 3 V to 36 V
  - Low Supply Current: 220 μA (Max)
  - Input Rail to $-V_S$, Rail-to-Rail Output
  - Excellent High-Frequency PSRR+: 65 dB at 100 kHz
  - Offset Voltage of TPA7252/7252A: ±4 mV at 25°C (Max)
  - Offset Voltage of TPA7253/7253A: ±2 mV at 25°C (Max)
- Voltage Reference
  - 2.5-V Output, Stable with No Load to 1-μF Load
  - TPA7252/7253: 1% Initial Accuracy
  - TPA7252A/7253A: 0.4% Initial Accuracy
- Operating Temperature Range: −40°C to 125°C

## Applications

- Power Module
- Adapter
- Led Lighting

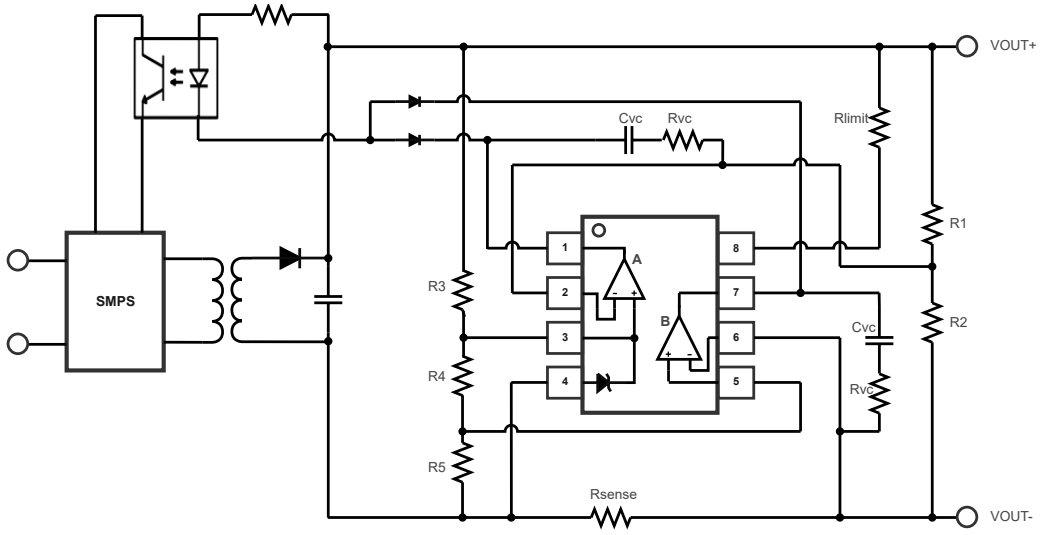
## Description

The device combines a dual operational amplifier and a fixed 2.5-V shunt voltage reference, which are often used in the control circuitry of power supplies.

The operational amplifier A has the non-inverting input internally tied to the shunt reference which is used for the voltage control loop. The operational amplifier B is independent of the current control loop.

The device has a 220-μA power supply excluding the current in the reference, and the minimum working current for the reference is 50 μA, which can be used in low-power applications.

## Typical Application Circuit




**TPA7252 in a Constant-Current and Constant-Voltage Battery Charger**

# Table of Contents

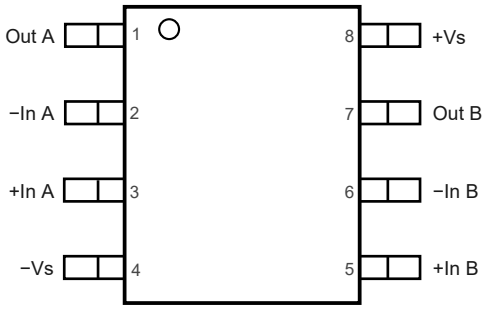
**Features** ..... 1
**Applications** ..... 1
**Description** ..... 1
**Typical Application Circuit** ..... 1
**Revision History** ..... 3
**Pin Configuration and Functions** ..... 4
**Specifications** ..... 5
Absolute Maximum Ratings (1) ..... 5
ESD, Electrostatic Discharge Protection ..... 5
Recommended Operating Conditions ..... 5
Thermal Information ..... 6
Electrical Characteristics ..... 7
Typical Performance Characteristics ..... 9
**Detailed Description** ..... 11
Overview ..... 11
Functional Block Diagram ..... 11
Feature Description ..... 11
**Application and Implementation** ..... 13
Application Information ..... 13
Typical Application ..... 13
**Tape and Reel Information** ..... 15
**Package Outline Dimensions** ..... 16
SOP8 ..... 16
**Order Information** ..... 17
**IMPORTANT NOTICE AND DISCLAIMER** ..... 18

## Revision History

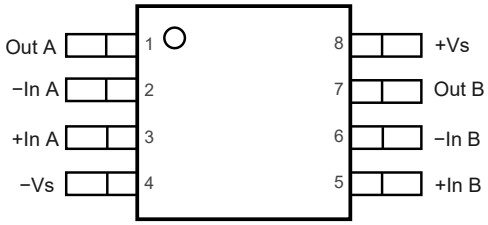
| Date | Revision | Notes |
|---|---|---|
| 2021-12-20 | Rev.A.0 | Initial version. |
| 2022-03-28 | Rev.A.1 | Corrected typo on page 7: from "Reference Voltage, TPA7252, 0.4%" to "Reference Voltage, TPA7252A, 0.4%". |
| 2023-05-10 | Rev.A.2 | Updated the document format. |
| 2023-08-17 | Rev.A.3 | Added Input Voltage Noise Density in Electrical Characteristics.<br>Updated Figure 2. |
| 2023-11-08 | Rev.A.4 | Added products: TPA7253 and TPA7253A. |
| 2024-01-25 | Rev.A.5 | Added typical value of $V_{OS}$ in Electrical Characteristics. |
| 2024-03-18 | Rev.A.6 | The following updates are all about the new datasheet formats or typos, and the actual product remains unchanged.<br>Updated the pin configuration of the SOP8 package. |
| 2024-12-18 | Rev.A.7 | The following updates are all about the new datasheet formats or typos, and the actual product remains unchanged.<br>• Updated the Tape and Reel Information. |

## Pin Configuration and Functions

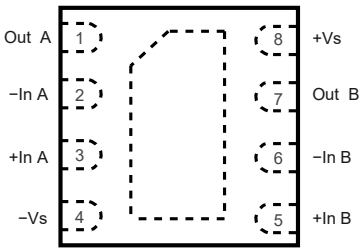
TPA725x
SOP8
Top View




TPA725x
MSOP8
Top View




TPA725x
DFN2X2-8
Top View




The thermal pad of DFN2X2-8 is recommended to be left or connected to $-V_S$.

**Table 1. Pin Functions: TPA725x**

| Pin No. | Name | I/O | Description |
|---|---|---|---|
| 1 | Out A | O | Output of the channel A. |
| 2 | −In A | I | Inverting input of the channel A. |
| 3 | +In A | I | Non-inverting input of the channel A. |
| 4 | $-V_S$ | I | Negative power supply. |
| 5 | +In B | I | Non-inverting input of the channel B. |
| 6 | −In B | I | Inverting input of the channel B. |
| 7 | Out B | O | Output of the channel B. |
| 8 | $+V_S$ | I | 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 |
| | 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 each 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

| Symbol | Parameter | Condition | Minimum Level | Unit |
|---|---|---|---|---|
| HBM | Human Body Model ESD | ANSI/ESDA/JEDEC JS-001 (1) | 2 | kV |
| CDM | Charged Device Model ESD | ANSI/ESDA/JEDEC JS-002 (2) | 1 | kV |

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

## Recommended Operating Conditions

| Parameter | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| $V_S$ | Supply Voltage, $(+V_S) - (-V_S)$ | 3 | | 36 | V |
| | Cathode Current of Reference | 0.08 | | 100 | mA |
| $T_A$ | Operating Temperature Range | −40 | | 125 | °C |

## Thermal Information

| Package Type | $\theta_{JA}$ | $\theta_{JC}$ | Unit |
|---|---|---|---|
| SOP8 | 158 | 43 | °C/W |
| MSOP8 | 210 | 45 | °C/W |
| DFN2X2-8 | 100 | 60 | °C/W |

## Electrical Characteristics

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

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **Power Supply** | | | | | | |
| $V_S$ | Supply Voltage Range | | 3 | | 36 | V |
| $I_Q$ | Quiescent Current excluding Current in Voltage Reference, No Load | $V_S$ = 30 V | | 110 | 220 | µA |
| | | $V_S$ = 30 V, $T_A$ = −40°C to 125°C | | | 300 | µA |
| | | $V_S$ = 5 V | | 100 | 200 | µA |
| | | $V_S$ = 5 V, $T_A$ = −40°C to 125°C | | | 270 | µA |
| **Voltage Reference** | | | | | | |
| | Reference Voltage, TPA7252, TPA7253, 1% | $I_K$ = 10 mA, | 2.475 | 2.50 | 2.525 | V |
| | | $I_K$ = 10 mA, $T_A$ = −40°C to 125°C | 2.45 | | 2.55 | V |
| | Reference Voltage, TPA7252A, TPA7253A, 0.4% | $I_K$ = 10 mA, | 2.49 | 2.50 | 2.51 | V |
| | | $I_K$ = 10 mA, $T_A$ = −40°C to 125°C | 2.48 | | 2.52 | V |
| | Reference Voltage Deviation | $I_K$ = 10 mA, $T_A$ = −40°C to 105°C | | 1 | 15 | mV |
| | Minimum Cathode Current for Regulation | | | 0.01 | 0.05 | mA |
| | | $T_A$ = −40°C to 125°C | | | 0.08 | mA |
| | Dynamic Impedance | $I_K$ = 1 mA to 100 mA, f < 1 kHz | | 0.2 | | Ω |
| | Capacitive Load | $T_A$ = −40 to 125°C | | | 1 | µF |
| **OPA - Input Characteristics** | | | | | | |
| $V_{OS}$ | Input Offset Voltage, TPA7252, TPA7252A | $V_S$ = 36 V, $V_{CM}$ = 0 V to 34.5 V | −4 | ±1 | 4 | mV |
| | | $V_S$ = 36 V, $V_{CM}$ = 0 V to 34.5 V, $T_A$ = −40°C to 125°C | −5 | | 5 | mV |
| | | $V_S$ = 5 V, $V_{CM}$ = 0 V to 3.5 V | −4 | ±1 | 4 | mV |
| | | $V_S$ = 5 V, $V_{CM}$ = 0 V to 3.5 V, $T_A$ = −40°C to 125°C | −5 | | 5 | mV |
| $V_{OS}$ | Input Offset Voltage, TPA7253, TPA7253A | $V_S$ = 36 V, $V_{CM}$ = 0 V to 34.5 V | −2 | ±1 | 2 | mV |
| | | $V_S$ = 36 V, $V_{CM}$ = 0 V to 34.5 V, $T_A$ = −40°C to 125°C | −3 | | 3 | mV |
| | | $V_S$ = 5 V, $V_{CM}$ = 0 V to 3.5 V | −2 | ±1 | 2 | mV |
| | | $V_S$ = 5 V, $V_{CM}$ = 0 V to 3.5 V, $T_A$ = −40°C to 125°C | −3 | | 3 | mV |
| $V_{OS}$ TC | Input Offset Voltage Drift | $V_{CM}$ = 0 V to 2.5 V, $T_A$ = −40°C to 125°C | | 3 | | µV/°C |
| $I_B$ | Input Bias Current | $V_{CM}$ = 0 V | | 10 | | pA |
| | | $V_{CM}$ = 0 V, $T_A$ = −40°C to 125°C | | 1 | | nA |
| $I_{OS}$ | Input Offset Current | $V_{CM}$ = 0 V | | 10 | | pA |
| | | $V_{CM}$ = 0 V, $T_A$ = −40°C to 125°C | | 1 | | nA |

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $A_V$ | Open−Loop Voltage Gain | $V_S$ = 30 V, $V_O$ = 2 V to 26 V | 95 | 110 | | dB |
| | | $V_S$ = 30 V, $V_O$ = 2 V to 26 V, $T_A$ = −40°C to 125°C | 90 | | | dB |
| $V_{CMR}$ | Common-Mode Input Voltage Range | $T_A$ = −40°C to 125°C | (−$V_S$) | | (+$V_S$) – 1.5 | V |
| **OPA - Input Characteristics** | | | | | | |
| CMRR | Common-Mode Rejection Ratio, Channel B only | $V_S$ = 36 V, $V_{CM}$ = 0 V to 34.5 V | 80 | 100 | | dB |
| | | $V_S$ = 36 V, $V_{CM}$ = 0 V to 34.5 V, $T_A$ = −40°C to 125°C | 70 | | | dB |
| PSRR | Power Supply Rejection Ratio | $V_S$ = 5 V to 36 V | 85 | 120 | | dB |
| | | $V_S$ = 5 to 36 V, $T_A$ = −40°C to 125°C | 80 | | | dB |
| **OPA - Output Characteristics** | | | | | | |
| $V_{OH}$ | Output Voltage High | $V_S$ = 30 V, $R_L$ = 2 kΩ to (−$V_S$) | 26 | 27 | | V |
| | | $V_S$ = 30 V, $R_L$ = 2 kΩ to (−$V_S$), $T_A$ = −40°C to 125°C | 26 | | | V |
| | | $V_S$ = 30 V, $R_L$ = 10 kΩ to (−$V_S$) | 27 | 28 | | V |
| | | $V_S$ = 30 V, $R_L$ = 10 kΩ to (−$V_S$), $T_A$ = −40°C to 125°C | 27 | | | V |
| $V_{OL}$ | Output Voltage Low | $V_S$ = 30 V, $R_L$ = 10 kΩ to (−$V_S$) | | 1 | 15 | mV |
| | | $V_S$ = 30 V, $R_L$ = 10 kΩ to (−$V_S$), $T_A$ = −40°C to 125°C | | | 20 | mV |
| $I_{OUT}$ | Output Current, Source | $V_S$ = 15 V, $V_{ID}$ = 1 V, $V_O$ = 2 V | 20 | 40 | | mA |
| | | $V_S$ = 15 V, $V_{ID}$ = 1 V, $V_O$ = 2 V, $T_A$ = −40°C to 125°C | 10 | | | mA |
| | Output Current, Sink | $V_S$ = 15 V, $V_{ID}$ = −1 V, $V_O$ = 2 V | 10 | 20 | | mA |
| | | $V_S$ = 15 V, $V_{ID}$ = −1 V, $V_O$ = 2 V, $T_A$ = −40°C to 125°C | 5 | | | mA |
| | | $V_S$ = 15 V, $V_{ID}$ = −1 V, $V_O$ = 0.2 V | 12 | 50 | | µA |
| | | $V_S$ = 15 V, $V_{ID}$ = −1 V, $V_O$ = 0.2 V, $T_A$ = −40°C to 125°C | 5 | | | µA |
| $I_{SC}$ | Output Short-Circuit Current | $V_S$ = 15 V | | 50 | | mA |
| **OPA - AC Characteristics** | | | | | | |
| GBW | Gain-Bandwidth Product | | | 1 | | MHz |
| SR | Slew Rate | G = 1, 2-V step | | 0.9 | | V/µs |
| PM | Phase Margin | $R_L$ = 10 kΩ, $C_L$ = 100 pF | | 50 | | ° |
| GM | Gain Margin | $R_L$ = 10 kΩ, $C_L$ = 100 pF | | 6 | | dB |
| **OPA - Noise Performance** | | | | | | |
| $E_N$ | Input Voltage Noise | f = 0.1 Hz to 10 Hz | | 1 | | $\mu V_{RMS}$ |
| $e_N$ | Input Voltage Noise Density | f = 1 kHz | | 65 | | nV/√Hz |

## Typical Performance Characteristics

All test conditions: $V_{IN}$ = 5 V, $T_A$ = 25°C, unless otherwise noted.

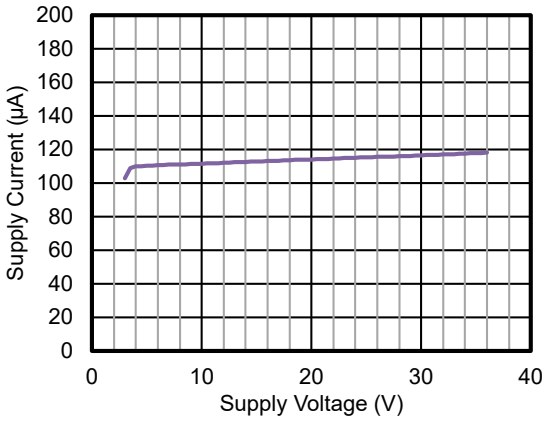



**Figure 1. Supply Current vs. Supply Voltage**

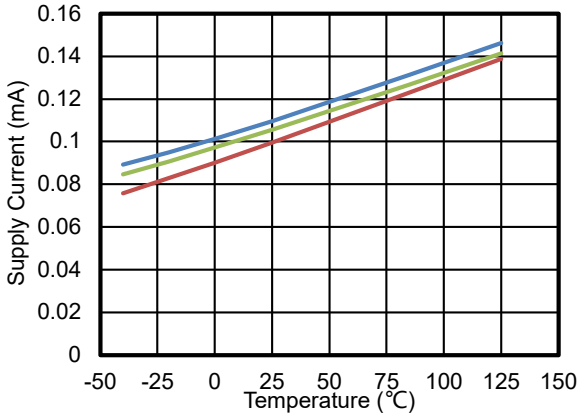



**Figure 2. Supply Current vs. Temperature, $V_S$ = 15 V**

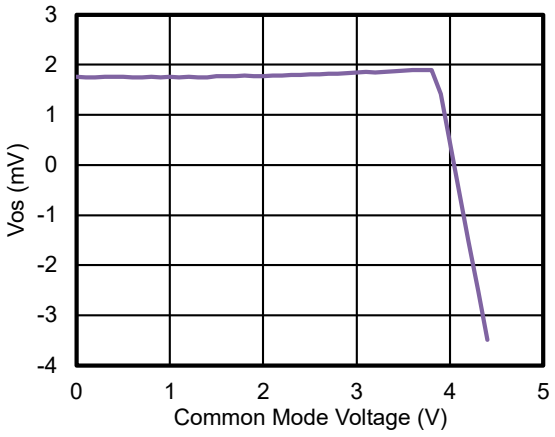



**Figure 3. $V_{OS}$ vs. $V_{CM}$, $V_S$ = 5 V**

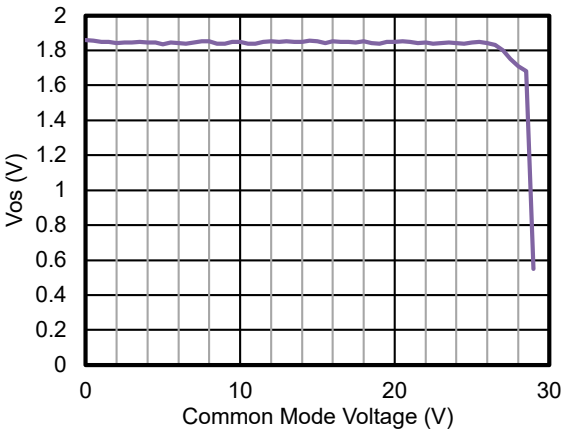



**Figure 4. $V_{OS}$ vs. $V_{CM}$, $V_S$ = 30 V**

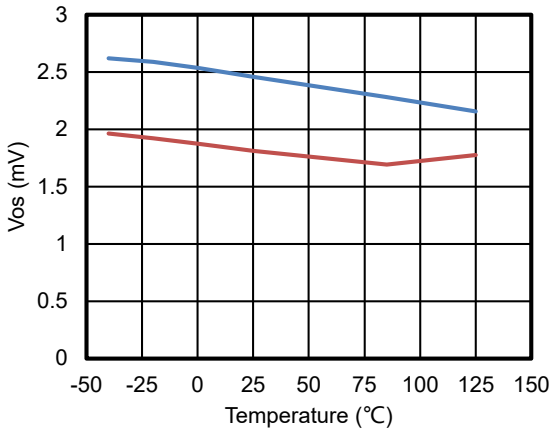



**Figure 5. $V_{OS}$ vs. Temperature, $V_S$ = 5 V, $V_{CM}$ = 2.5 V**

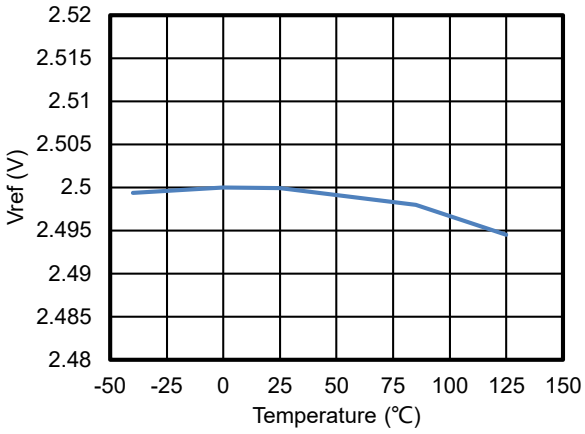



**Figure 6. Reference Output vs. Temperature**

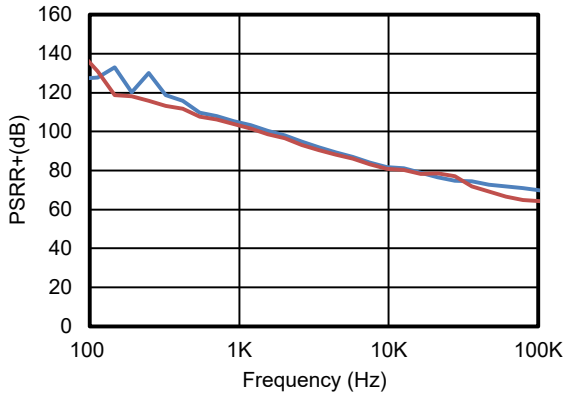



**Figure 7. PSRR+ vs. Frequency**

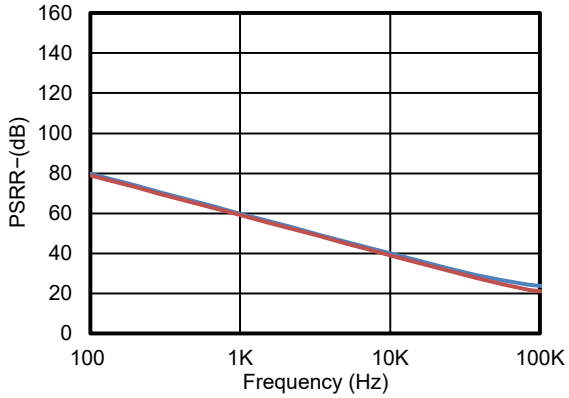



**Figure 8. PSRR− vs. Frequency**

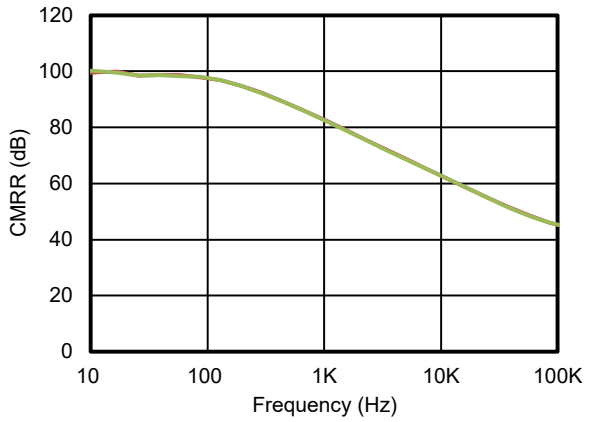



**Figure 9. CMRR vs. Frequency**

G = 1, $V_{IN}$ = 1/2 $V_S$ during Power-on and Power-off,

Yellow: +$V_S$; Green: Output

**Figure 10. Power-on and Power-off Behavior, 2 ms**

G = 1, $V_{IN}$ = 4 V during Power-on and Power-off,

Yellow: +$V_S$; Green: Output

**Figure 11. Power-on and Power-off Behavior, 10 ms**

G = 1, $V_{IN}$ = 4 V during Power-on and Power-off,

Yellow: +$V_S$; Green: Output

**Figure 12. Power-on and Power-off Behavior, 100 ms**

# Detailed Description

## Overview

The device combines a dual operational amplifier and a fixed 2.5-V shunt voltage reference. The operational amplifier A has the non-inverting input internally tied to the shunt reference which is used for the voltage control loop. The operational amplifier B is independent of the current control loop.

## Functional Block Diagram

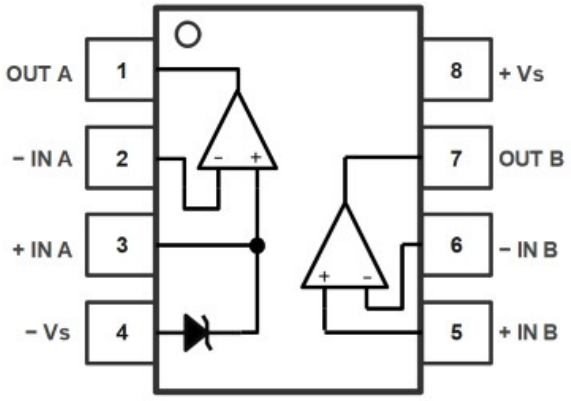



**Figure 13. Functional Block Diagram**

## Feature Description

### Operating Voltage

The device is designed for single-supply operation from 3 V to 36 V, or dual-supply operation from ±1.5 V to ±18 V. The high-power supply voltage helps the device survive on the noisy power supply.

### Low Power Operation

The device has a 220-μA power supply excluding the current in the reference, and the minimum working current for the reference is 50 μA, which is very useful in low-power applications.

### PSRR+ of the Operational Amplifier

The operation amplifier in the device has 65-dB PSRR+ at 100-kHz frequency. This feature reduces the output noise of the operational amplifier produced by the noisy power supply.

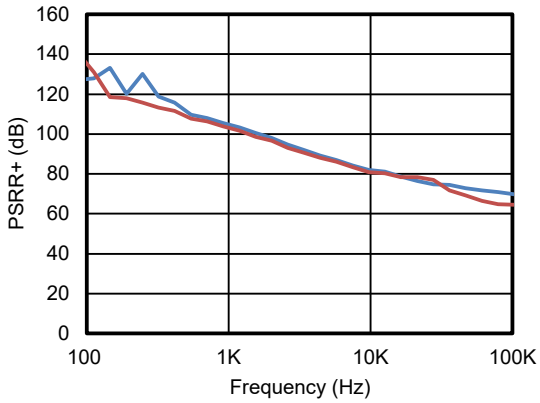



**Figure 14. PSRR+ vs. Frequency**

### Region of Reference Stability

The reference of the device can work stably with a large range of capacitive loads. Figure 15 shows the stability of reference output with 10-ms power-on time:

- "s" means the output is stable.
- "R1" means the output has a ring (< 100 mV) in the power-on time and is stable when the output reaches the final value.
- "R2" means the output has a ring (< 100 mV) and is stable in 1 ms.

| Ik (mA) | 0 | 0.1 | 0.47 | 1 | 4.7 | 47 | 100 | 200 | 300 | 1000 |
|---|---|---|---|---|---|---|---|---|---|---|
| 100 | s | s | s | s | s | s | R2 | R2 | R2 | R2 |
| 50 | s | s | s | s | s | s | R2 | R2 | R2 | R2 |
| 40 | s | s | s | s | s | s | R2 | R2 | R2 | R2 |
| 30 | s | s | s | s | s | s | R2 | R2 | R2 | R2 |
| 25 | s | s | s | s | s | s | R2 | R2 | R2 | R2 |
| 20 | s | s | s | s | s | s | R2 | R2 | R2 | R2 |
| 15 | s | s | s | s | s | s | R2 | R2 | R2 | R2 |
| 10 | s | s | s | s | s | s | R2 | R2 | R2 | R2 |
| 7.5 | s | s | s | s | s | s | R2 | R2 | R2 | R2 |
| 5 | s | s | s | s | s | s | s | s | s | s |
| 2.5 | s | s | s | s | s | s | s | s | s | s |
| 1 | R1 | R1 | s | s | s | s | s | s | s | s |
| 0.5 | R1 | R1 | s | s | s | s | s | s | s | s |
| 0.25 | R1 | R1 | s | s | s | s | s | s | s | s |
| 0.1 | R1 | R1 | R1 | s | s | s | s | s | s | s |
| 0.05 | R1 | R1 | R1 | R1 | s | s | s | s | s | s |

Capacitor (nF) on Vref

**Figure 15. Region of Reference Stability vs. Capacitive Load**

# 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

### 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.

## Typical Application

Figure 16 shows the typical application schematic.

### Constant-Current and Constant-Voltage Battery Charger

Figure 16 shows the device configured in a constant-current and constant-voltage battery charger.

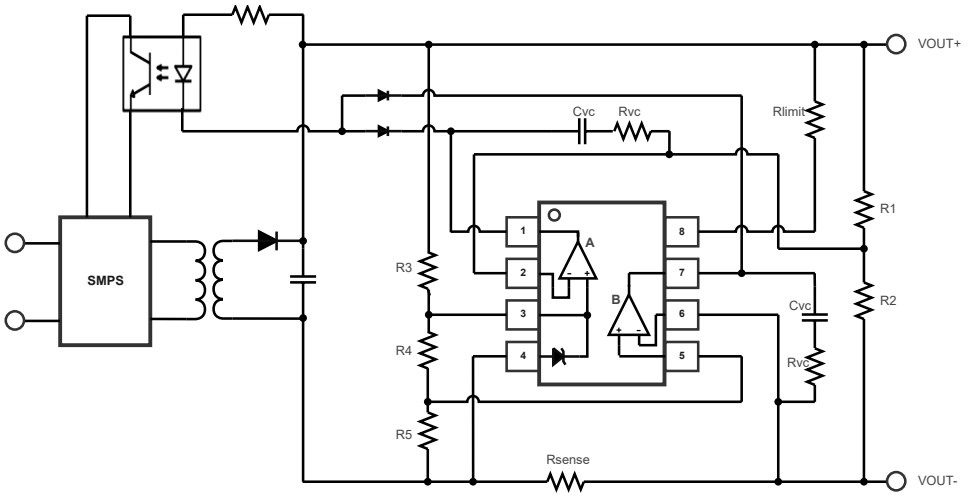



**Figure 16. TPA725x in a Constant-Current and Constant-Voltage Battery Charger**

The voltage control loop is controlled by the operational amplifier A and the resistor divider (R1, R2), and the output voltage is given in Equation 1.

$$V_{OUT} = V_{REF}\frac{R1 + R2}{R2} \quad (1)$$

Where $V_{OUT}$ is the desired maximum output voltage, and $V_{REF}$ is the output voltage of internal reference.

The current control loop is controlled by the operational amplifier B and the resistor divider (R4, R5) tied to the voltage reference. The voltage on $R_{SENSE}$ is given in Equation 2.

$$V_{SENSE} = V_{REF}\frac{R5}{R4 + R5} \quad (2)$$

Where $V_{SENSE}$ is the voltage on $R_{SENSE}$.

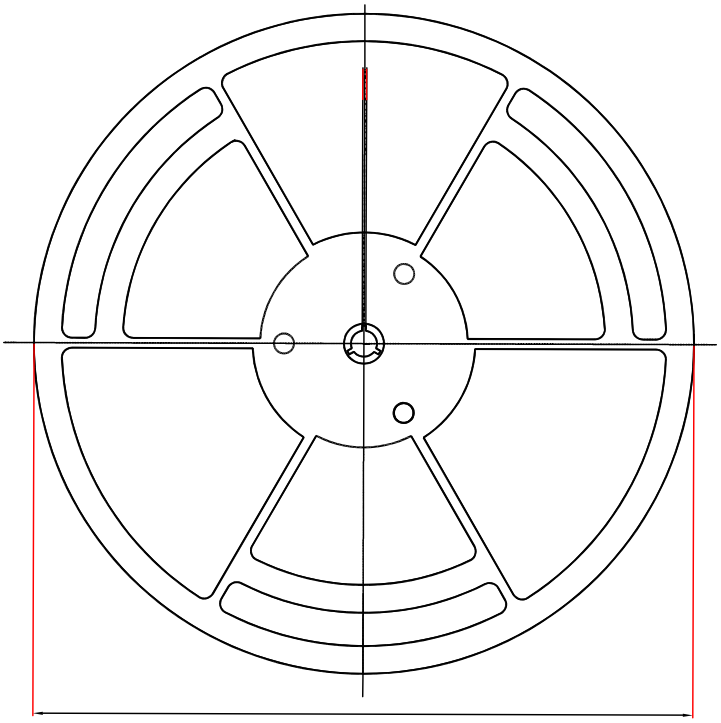
Then the maximum output current is given in Equation 3.

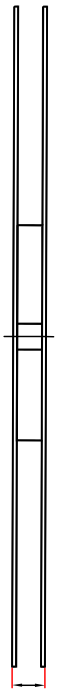
$$I_{OUT} = \frac{V_{SENSE}}{R_{SENSE}} \quad (3)$$

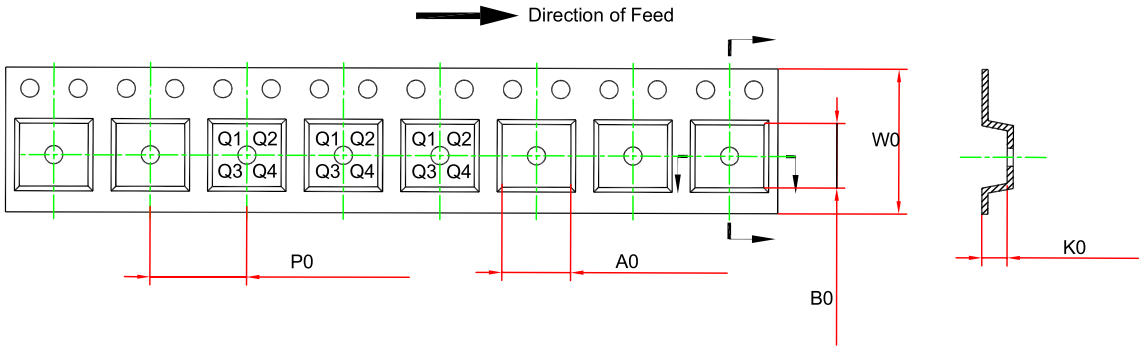
Where $I_{OUT}$ is the desired maximum output current.

The outputs of the two operational amplifiers are connected to the opto-coupler through the diode, which makes an ORing function that ensures whenever the values of the current or the voltage reach too high, the opto-coupler is activated.

## Tape and Reel Information



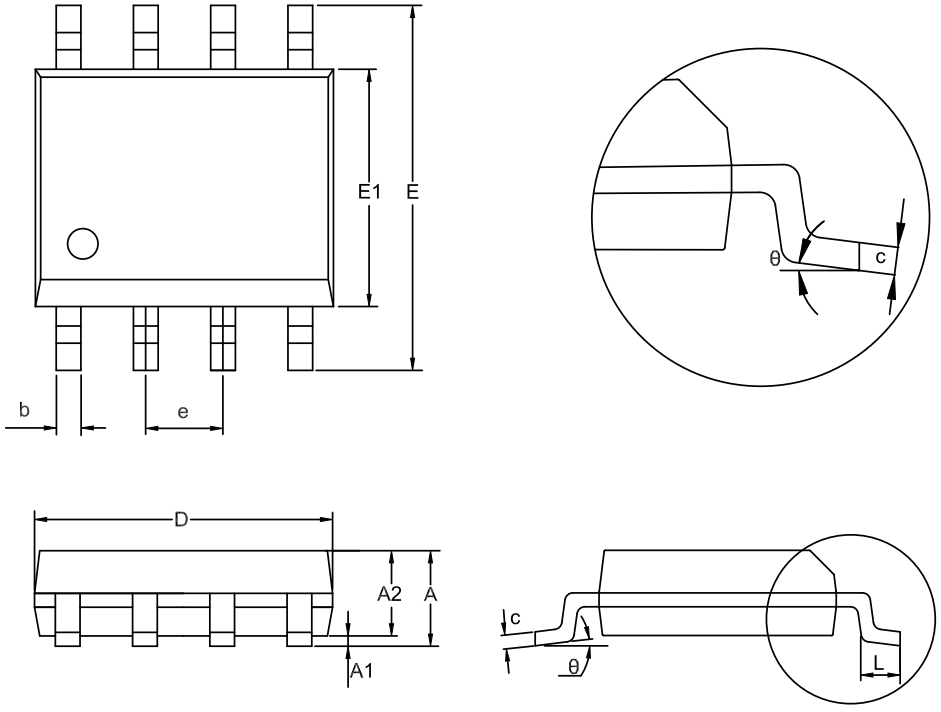

| Order Number | Package | D1 (mm) | W1 (mm) | A0 (mm) (1) | B0 (mm) (1) | K0 (mm) (1) | P0 (mm) | W0 (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|
| TPA725x-SO1R | SOP8 | 330.0 | 17.6 | 6.4 | 5.4 | 2.1 | 8.0 | 12.0 | Q1 |
| TPA725xA-SO1R | SOP8 | 330.0 | 17.6 | 6.4 | 5.4 | 2.1 | 8.0 | 12.0 | Q1 |
| TPA725x-DF4R | DFN2X2-8 | 180.0 | 13.1 | 2.3 | 2.3 | 1.1 | 4.0 | 8.0 | Pending |
| TPA725x-VS1R | MSOP8 | 330.0 | 17.6 | 5.2 | 3.3 | 1.5 | 8.0 | 12.0 | Q1 |

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

## Package Outline Dimensions

### 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.

## Order Information

| Order Number | Operating Temperature Range | Package | Marking Information | MSL | Transport Media, Quantity | Eco Plan |
|---|---|---|---|---|---|---|
| TPA7252-SO1R | −40 to 125°C | SOP8 | A7252 | 3 | Tape and Reel, 4000 | Green |
| TPA7252A-SO1R | −40 to 125°C | SOP8 | A7252 | 3 | Tape and Reel, 4000 | Green |
| TPA7253-SO1R | −40 to 125°C | SOP8 | A7252 | 3 | Tape and Reel, 4000 | Green |
| TPA7253A-SO1R | −40 to 125°C | SOP8 | A7252 | 3 | Tape and Reel, 4000 | Green |
| TPA7252-DF4R (1) | −40 to 125°C | DFN2X2-8 | 752 | 3 | Tape and Reel, 3000 | Green |
| TPA7252-VS1R (1) | −40 to 125°C | MSOP8 | A7252 | 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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