# 2.2-V Input Isolated Amplifier

## Features

- CMTI: 100 kV/μs
- Input Voltage Range: 2.2 V
- Fixed Gain: 1
- Low Offset Error: 1.5 mV maximum at 25°C
- Very Low Gain Error: 0.3% Maximum at 25°C
- Wide Temperature Range: −40°C to +125°C
- TPA800x-SOAR-S is Qualified for Automotive Applications with AEC-Q100 Reliability Test
- Finished Safety-Related Certifications:
  - 5000-$V_{RMS}$ Isolation Rating per UL 1577
  - CQC Certification per GB 4943.1
  - CB Certifications
- Ongoing Safety-Related Certifications:
  - VDE Certification according to DIN VDE V 0884-17(IEC60747-17)
  - CSA, TUV Certifications

## Applications

- Motor Control
- Power Supplies
- Automotive OBC

## Description

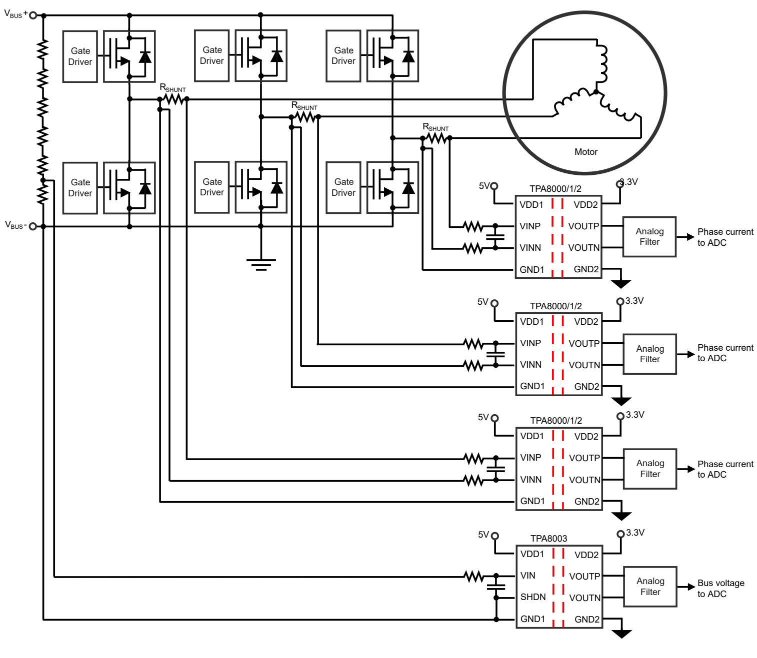
The TPA8003 is a precision, isolated amplifier with an output separated from the input circuitry by capacitive silicon dioxide insulation barrier. This barrier is certified to provide isolation of up to 5000-$V_{RMS}$ according to UL1577.

The common mode transient immunity (CMTI) of the TPA8003 has been significantly enhanced through innovative circuit design and optimized structure.

The input of the TPA8003 is high-impedance which can be connected to high-impedance resistive dividers or any other high-impedance voltage signal source. The excellent performance of the device supports bus voltage in motor control or other applications. The feature of the TPA8003 detecting whether high-side supply voltage is missing or not simplifies system-level diagnostics.

The device is available in the WSOP8 package, and is characterized from −40°C to +125°C.

## Typical Application Circuit



# Table of Contents

## Revision History

| Date | Revision | Notes |
|---|---|---|
| 2023-12-20 | Rev.A.0 | Initial Version |

## Pin Configuration and Functions

TPA8003
WSOP8 Package
Top View


**Table 1. Pin Functions**

| Pin | | I/O | Description |
|---|---|---|---|
| No. | Name | | |
| 1 | VDD1 | | High-side power supply |
| 2 | VIN | Input | Analog input |
| 3 | SHDN | Input | Shutdown input, active high, with internal pullup resistor. Connect to GND1 to enable the device. |
| 4 | GND1 | | High-side analog ground |
| 5 | GND2 | | Low-side analog ground |
| 6 | VOUTN | Output | Negative analog output |
| 7 | VOUTP | Output | Positive analog output |
| 8 | VDD2 | | Low-side power supply |

# Specifications

## Absolute Maximum Ratings (1)

| Parameter | | Min | Max | Unit |
|---|---|---|---|---|
| VDD | Supply Voltage, VDD1 to GND1 or VDD2 to GND2 | −0.3 | 7 | V |
| $V_{INPUT}$ | Analog Input Voltage at VIN | GND1 – 6 | VDD1 + 0.5 | V |
| | Analog Input Voltage at SHDN | GND1 – 0.5 | VDD1 + 0.5 | V |
| | Analog Output Voltage at VOUTP, VOUTN | GND2 – 0.5 | VDD2 + 0.5 | V |
| $I_{IN}$ | Input Current to Any Pin except Supply Pins | −10 | 10 | mA |
| $T_J$ | Operating Virtual Junction Temperature | | 150 | °C |
| $T_{stg}$ | Storage Temperature | −65 | 150 | °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.

## ESD, Electrostatic Discharge Protection - TPA8003-SOAR

| Parameter | | Condition | Value | 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) | 1.5 | 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.

## ESD, Electrostatic Discharge Protection - TPA8003-SOAR-S

| 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 |

## Recommended Operating Conditions

| Parameter | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| VDD1 | High-side Supply Voltage (VDD1 to GND1) | 4.5 | 5.0 | 5.5 | V |
| VDD2 | Low-side Supply Voltage (VDD2 to GND2) | 3.0 | 3.3 | 5.5 | V |
| $T_A$ | Operating Ambient Temperature | −40 | 25 | 125 | °C |

## Thermal Information

| Package Type | $\theta_{JA}$ | $\theta_{JC}$ | Unit |
|---|---|---|---|
| WSOP8 | 85 | 43 | °C/W |

## Insulation Specifications

The value of UL and VDE is provided by lab test, the UL and VDE certifications is ongoing.

| Parameter | | Conditions | Value | Unit |
|---|---|---|---|---|
| | | | WSOP8 | |
| CLR | External Clearance | Shortest terminal-to-terminal distance through air | 8.0 | mm |
| CPG | External Creepage | Shortest terminal-to-terminal distance across the package surface | 8.0 | mm |
| DTI | Distance through the Insulation | Minimum internal gap (internal clearance) | 22 | μm |
| DTC | Distance through the Molding Compound | Minimum internal distance across the conductors inside the package | 0.8 | mm |
| CTI | Comparative Tracking Index | DIN EN 60112 (VDE 0303-11); IEC 60112; UL 746A | > 600 | V |
| | Material Group | According to IEC 60664-1 | I | |
| | Over-voltage Category | For Rated Mains Voltage ≤ 150 $V_{RMS}$ | I-IV | |
| | | For Rated Mains Voltage ≤ 300 $V_{RMS}$ | I-IV | |
| | | For Rated Mains Voltage ≤ 600 $V_{RMS}$ | I-IV | |
| | | For Rated Mains Voltage ≤ 1000 $V_{RMS}$ | I-III | |
| | Climatic Category | | 40/125/21 | |
| | Pollution Degree | | 2 | |
| **DIN V VDE V 0884-17 (1)(2)** | | | | |
| $V_{IORM}$ | Maximum Repetitive Isolation Voltage | AC voltage | 1700 | $V_{PK}$ |
| $V_{IOWM}$ | Maximum Working Isolation Voltage | AC voltage; TDDB Test | 1200 | $V_{RMS}$ |
| | | DC voltage | 1700 | $V_{DC}$ |
| $V_{IOTM}$ | Maximum Transient Isolation Voltage | $V_{TEST}$ = $V_{IOTM}$, t = 60 s (qualification); $V_{TEST}$ = 1.2 x $V_{IOTM}$, t = 1 s (100% production) | 7000 | $V_{PK}$ |
| $V_{IOSM}$ | Maximum Surge Isolation Voltage (3) | Test method per IEC 62368-1, 1.2/50 μs waveform, $V_{TEST}$ = 1.3 × $V_{IOSM}$ (qualification) | 6500 | $V_{PK}$ |
| $q_{pd}$ | Apparent Charge | Method a, After Input/Output safety test subgroup 2/3, $V_{ini}$ = $V_{IOTM}$, $t_{ini}$ = 60 s; $V_{pd(m)}$ = 1.2 × $V_{IORM}$, $t_m$ = 10 s | ≤ 5 | pC |
| | | Method a, After environmental tests subgroup 1, $V_{ini}$ = $V_{IOTM}$, $t_{ini}$ = 60 s; $V_{pd(m)}$ = 1.6 × $V_{IORM}$, $t_m$ = 10 s | ≤ 5 | |
| | | Method b1; At routine test (100% production) and preconditioning (type test), $V_{ini}$ = 1.2 x $V_{IOTM}$, $t_{ini}$ = 1 s; $V_{pd(m)}$ = 1.875 × $V_{IORM}$, $t_m$ = 1 s | ≤ 5 | |

| Parameter | | Conditions | Value (WSOP8) | Unit |
|---|---|---|---|---|
| $C_{IO}$ | Isolation Capacitance | $V_{IO}$ = 0.4 × sin (2πft), f = 1 MHz | ~0.5 | pF |
| $R_{IO}$ | Isolation Resistance | $V_{IO}$ = 500 V, T A= 25°C | > $10^{12}$ | Ω |
| | | $V_{IO}$ = 500 V, 100°C ≤ T A≤ 125°C | > $10^{11}$ | Ω |
| | | $V_{IO}$ = 500 V at T S= 150°C | > $10^{9}$ | Ω |
| **UL 1577** | | | | |
| $V_{ISO}$ | Withstanding Isolation Voltage | $V_{TEST}$= $V_{ISO}$ , t = 60 s(qualification); $V_{TEST}$= 1.2 × $V_{ISO}$, t = 1 s (100% production) | 5000 | $V_{RMS}$ |

(1) All pins on each side of the barrier are tied together creating a two-terminal device.
(2) This coupler is suitable for safe electrical insulation only within the safety operating ratings. Compliance with the safety ratings shall be ensured by means of suitable protective circuits.
(3) Testing must be carried out in oil.

## Safety-Related Certifications

| VDE | UL | TUV | CQC | CSA | CB |
|---|---|---|---|---|---|
| Certified according to DIN VDE V 0884-17 | Certified according to UL 1577 and CSA Component Acceptance Notice 5A | Certified according to EN IEC 62368-1 and EN IEC 61010-1 | Certified according to GB 4943.1 | Certified CSA C22.2 No. 62368-1 and CAN/CSA-C22.2 No. 60601-1 | Certified according to EN IEC 62368-1 |
| | (WSOP)Single protection, 5000Vrms | | Reinforced insulation (WSOP) | | Reinforced insulation (WSOP) |
| Certificate No. | Report Reference E524241 | Registration No. | Certificate No. CQC23001393276 | Master contract: | Ref. Certif. No. CN59992 |

## Safety Limiting Values

| Parameter | Conditions (1) | Min | Typ | Max | Unit |
|---|---|---|---|---|---|
| Safety Input, Output or Supply Current | $R_{\theta JA}$ = 85°C/W, VDD1 = VDD2 = 5.5 V, $T_J$ = 150°C, $T_A$ = 25°C, WSOP8 Package | | | 267 | mA |
| | $R_{\theta JA}$ = 85°C/W, VDD1 = VDD2 = 3.6 V, $T_J$ = 150°C, $T_A$ = 25°C, WSOP8 Package | | | 408 | mA |
| Safety Total Power | $R_{\theta JA}$ = 85°C/W, $T_J$ = 150°C, $T_A$ = 25°C, WSOP8 Package | | | 1470 | mW |
| Maximum Safety Temperature | | | | 150 | °C |

(1) The assumed junction-to-air thermal resistance in the Thermal Information is that of a device installed on a high-K test board for leaded surface-mount packages.

## Electrical Characteristics

Minimum and maximum specifications apply from $T_A$= –40°C to +125°C, VDD1 = 4.5 V to 5.5 V, VDD2 = 3.0 V to 5.5 V, VIN = 0.1 V to 2 V(unless otherwise noted); typical specifications are at $T_A$= 25°C, VDD1 = 5 V, and VDD2 = 3.3 V.

| Parameter | | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **Analog Input** | | | | | | |
| $V_{Clipping}$ | Input Voltage before Clipping Output | IN to GND1 | | 2.5 | | V |
| $V_{FSR}$ | Specified Linear Full-scale Voltage (1) | IN to GND1 | 0.1 | | 2.2 | V |
| | Specified Linear Full-scale Voltage | IN to GND1 | 0.1 | | 2 | V |
| $V_{OS}$ | Input Offset Voltage | VDD1 = 5V, VDD2 = 5V, In VFSR, $T_A$= 25°C | –1.5 | 0.4 | 1.5 | mV |
| | | In 0V to 0.1V, $T_A$= 25°C | | 10 | | mV |
| $TCV_{OS}$ | Input Offset Drift (1) | In VFSR | | 10 | 30 | μV/°C |
| $C_{IND}$ | Differential Input Capacitance | | | 7 | | pF |
| $R_{IN}$ | Single-ended Input Resistance | VINN = GND1 | | 1 | | GΩ |
| $I_{IB}$ | Input bias Current | IN = GND1, $T_A$ = 25°C | –15 | 3 | 15 | nA |
| **Analog Output** | | | | | | |
| | Nominal Gain | VIN at VFSR | | 1 | | |
| $E_G$ | Gain Error | VDD1 = 5 V, VIN at VFSR, $T_A$= 25°C | –0.3 | ±0.05 | 0.3 | % |
| $TCE_G$ | Gain Error Drift (1) | VDD1 = 5 V, VIN at VFSR | –100 | ±30 | 100 | ppm/°C |
| | Nonlinearity (1) | | –0.02 | ±0.01 | 0.02 | % |
| | Nonlinearity Drift | | | 1 | | ppm/°C |
| THD | Total Harmonic Distortion | $f_{IN}$= 10 kHz | | –80 | | dB |
| | Output Noise | VIN = GND1, BW = 100 kHz | | 240 | | μVRMS |
| SNR | Signal-to-noise Ratio | $f_{IN}$= 1 kHz, BW = 10 kHz | | 80 | | dB |
| | | $f_{IN}$= 10 kHz, BW = 100 kHz | | 62 | | dB |
| PSRR | Power-supply Rejection Ratio | vs VDD1, at dc | | –70 | | dB |
| | | vs VDD1, 100-mV and 10-kHz ripple | | –70 | | dB |
| | | vs VDD2, at dc | | –65 | | dB |
| | | vs VDD2, 100-mV and 10-kHz ripple | | –65 | | dB |
| CMTI | Common-mode Transient Immunity | \|GND1 – GND2\| = 1 kV | | 100 | | kV/μs |
| $V_{CMout}$ | Common-mode Output Voltage | | | 1.4 | | V |
| | Output Short-circuit Current | | | ±15 | | mA |
| $R_{OUT}$ | Output Resistance | on VOUTP or VOUTN | | < 0.2 | | Ω |

| Parameter | | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| BW | Output Bandwidth | | | 300 | | kHz |
| $V_{CLIPout}$ | Clipping Differential Output Voltage | | | 2.5 | | V |
| $V_{FAILSAFE}$ | Failsafe Differential Output Voltage | SHDN = high, or VDD1 undervoltage, or VDD1 missing | | –2.56 | –2.5 | V |
| **Digital Input** | | | | | | |
| | Input Voltage | SHDN to GND1 | 0 | | VDD1 | V |
| $I_{IN}$ | Input Current | SHDN pin, GND1 ≤ SHDN ≤ VDD1 | –70 | | 1 | µA |
| $C_{IN}$ | Input Capacitance | SHDN pin | | 5 | | pF |
| $V_{IH}$ | High-level Input Voltage | Shutdown | 0.7 × VDD1 | | | V |
| $V_{IL}$ | Low-level Input Voltage | Enable | | | 0.3 × VDD1 | V |
| **Power Supply** | | | | | | |
| | VDD1 Undervoltage Detection Threshold | VDD1 falling | | 2 | | V |
| | VDD2 Undervoltage Detection Threshold | VDD2 falling | | 2 | | V |
| IDD1 | High-side Supply Current | VDD1 = 5.5 V | | 15 | 18 | mA |
| IDD2 | Low-side Supply Current | VDD2 = 3 V | | 8 | 10 | mA |
| | | VDD2 = 5.5 V | | 9 | 11 | mA |
| **Switching Characteristics** | | | | | | |
| $t_r$ | Rise Time | | | 1 | | µs |
| $t_f$ | Fall Time | | | 1 | | µs |
| | $V_{IN}$ to $V_{OUT}$ signal delay (50% – 10%)(1) | | | 0.9 | 1.4 | µs |
| | $V_{IN}$ to $V_{OUT}$ signal delay (50% – 50%)(1) | | | 1.5 | 2.0 | µs |
| | $V_{IN}$ to $V_{OUT}$ signal delay (50% – 90%)(1) | | | 2.0 | 2.7 | µs |
| | Analog Settling Time | VDD1 step to 5.0 V with VDD2 ≥ 3.0 V, to VOUTP, VOUTN valid, 0.1% settling | | 500 | | µs |
| | Enable Time | Set SHDN high to low | | 35 | | µs |
| | Shutdown Time | Set SHDN low to high | | 2 | | µs |

(1) Provided by bench test and design simulation.

## Typical Performance Characteristics

All test conditions: VDD1 = 5 V, VDD2 = 3.3 V, SHDN = 0 V,, unless otherwise noted.

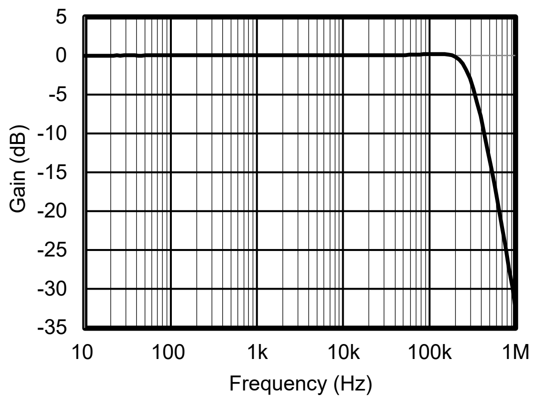



**Figure 1. Normalized Gain vs Input Frequency**

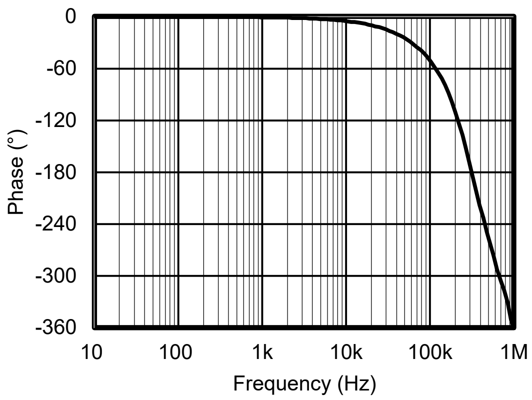



**Figure 2. Phase vs Input Frequency**

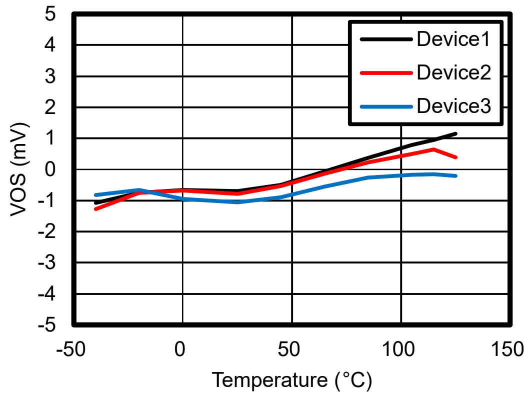



**Figure 3. VOS vs Temperature**

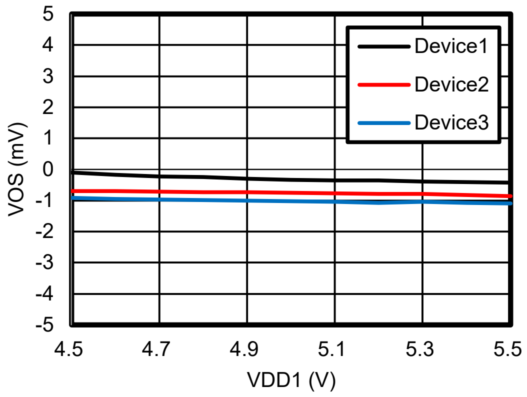



**Figure 4. VOS vs VDD1**

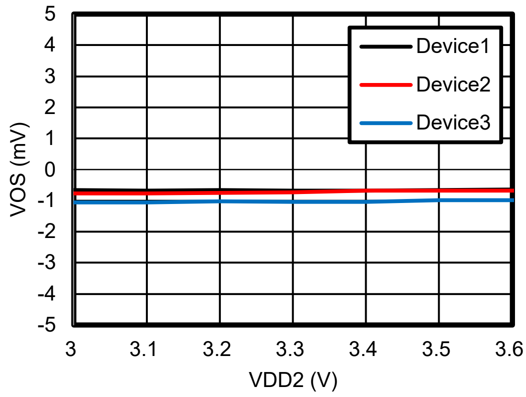



**Figure 5. VOS vs VDD2**

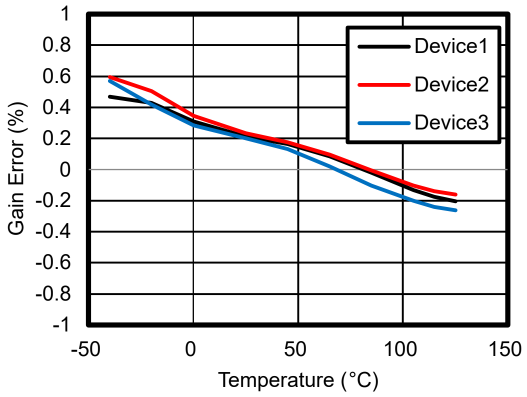



**Figure 6. Gain Error vs Temperature**

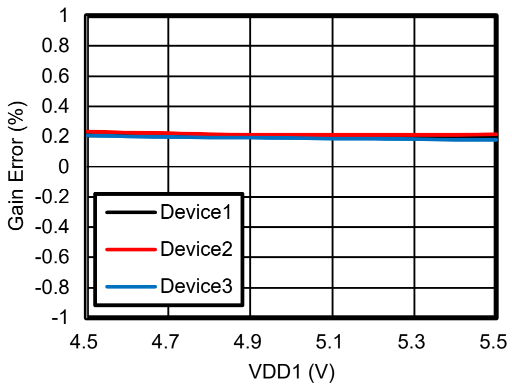



Figure 7. Gain Error vs VDD1

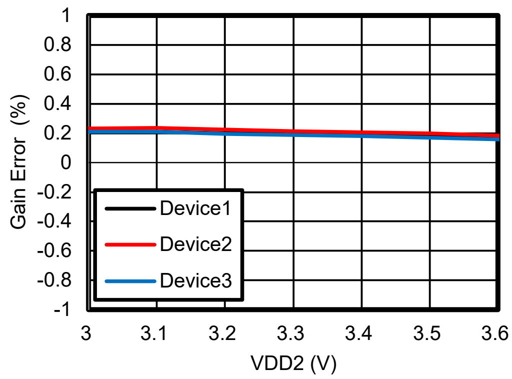



Figure 8. Gain Error vs VDD2

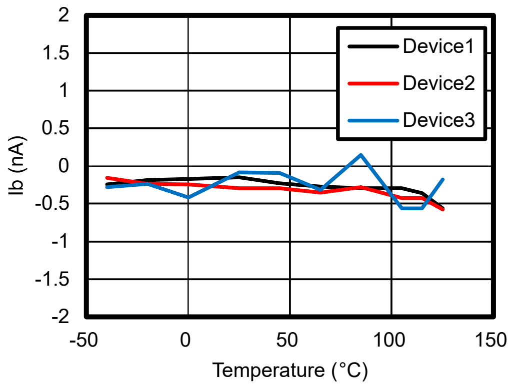



Figure 9. IB vs Temperature

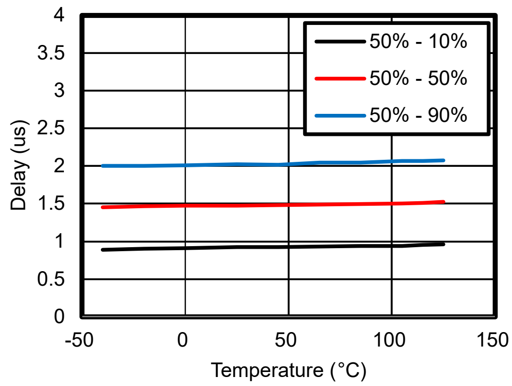



Figure 10. Signal Delay vs Temperature

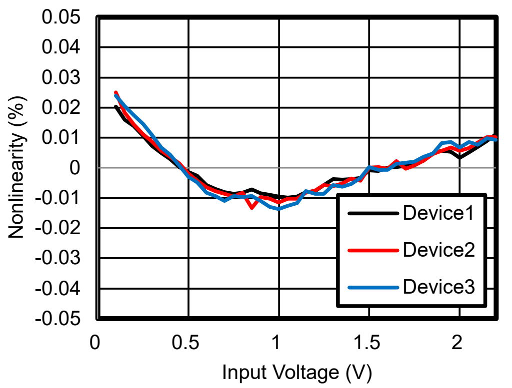



Figure 11. Nonlinearity vs Input Voltage

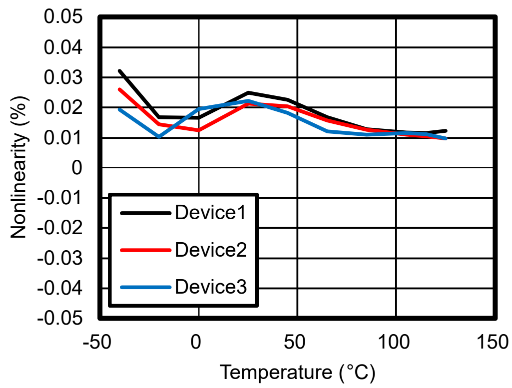



Figure 12. Nonlinearity vs Temperature

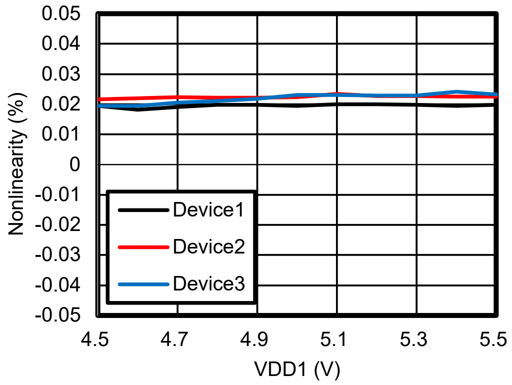



**Figure 13. Nonlinearity vs VDD1**

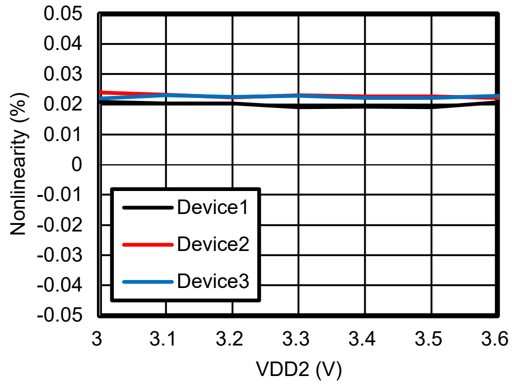



**Figure 14. Nonlinearity vs VDD2**

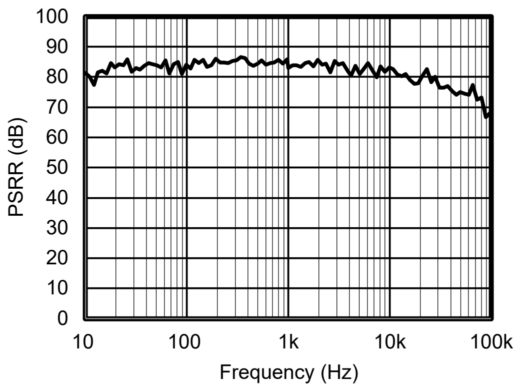



**Figure 15. VDD1 PSRR vs Frequency**

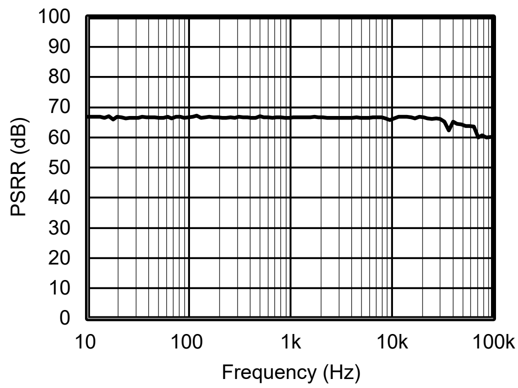



**Figure 16. VDD2 PSRR vs Frequency**

# Detailed Description

## Overview

The device is a single-end input isolated amplifier with differential output. The input stage of the device drives a delta-sigma (ΔΣ) modulator. The modulator utilizes an internal voltage reference source and clock generator to convert the analog input signal into a digital bit stream. A driver (referred to as TX in the functional block diagram) transmits the output of the modulator to the isolation barrier, which isolates the high-side and low-side voltage domains. The received bitstream and clock are synchronized and processed by an analog filter on the low-side and presented as a differential output of the device.

Based on $SiO_2$-based, double-capacitive isolation barrier, the digital modulation and isolation barrier characteristics provide the device high reliability and common-mode transient immunity.

## Functional Block Diagram

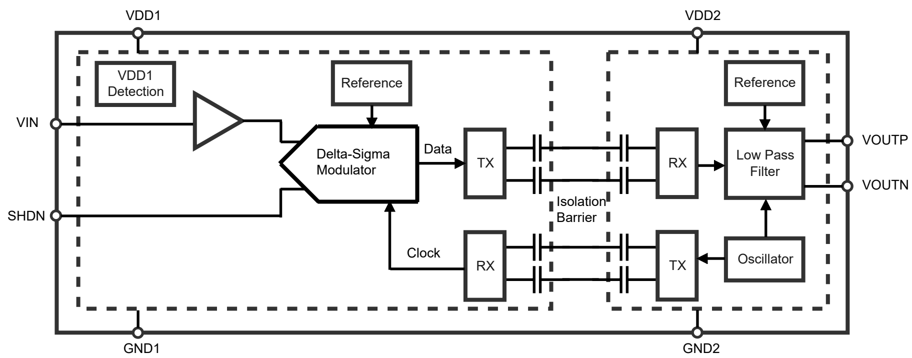



**Figure 17. Functional Block Diagram**

## Feature Description

### Fail-Safe Output

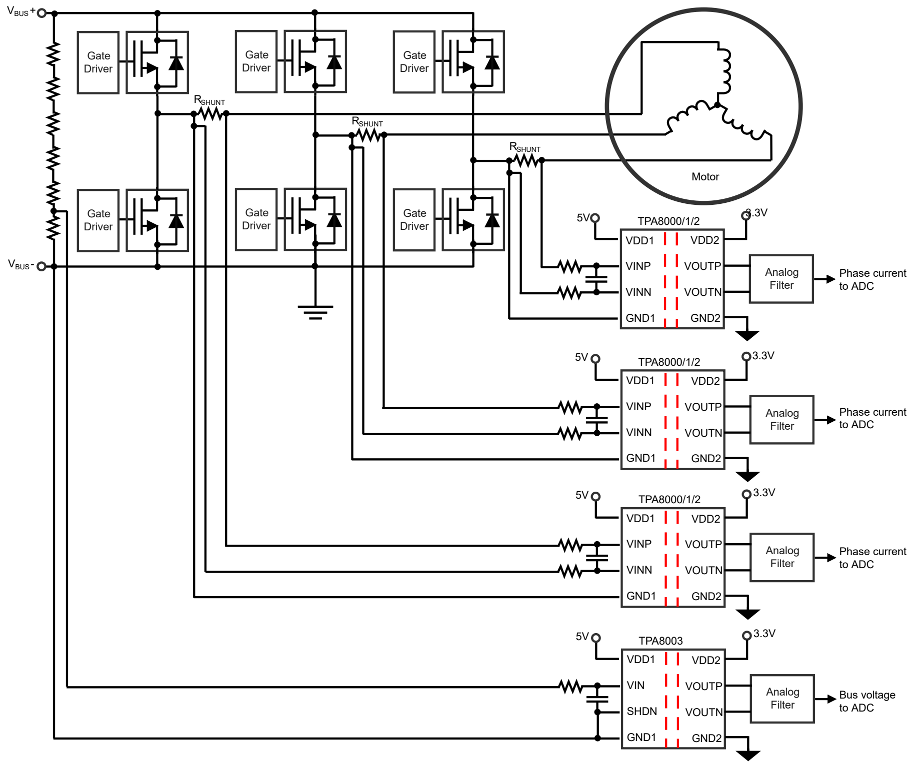
The device provides a fail-safe output that simplifies diagnostics on a system level. The fail-safe output is active in the following case:

• When the VDD1 is missing, or the voltage at VDD1 is lower than $VDD1_{UV}$ (the undervoltage detection threshold voltage of VDD1 ).

A negative differential output voltage exists when the fail-safe output is active. Use the $V_{FAILSAFE}$ voltage specified in the Electrical Characteristics table as a reference value for system diagnostics.

# Application and Implementation

## Typical Application




### Motor Drive Application

Isolated amplifiers are widely used in frequency inverters, which are critical parts of industrial motor drives, photovoltaic inverters, power supplies, and other industrial applications.

The TPA8000/1/2 are optimized for current sensing applications with shunt resistors. The figure in typical application section shows a typical operation of the TPA8000/1/2 for current sensing in a motor drive application. Phase current is measured by the shunt resistors, $R_{SHUNT}$. The differential input and the high common-mode transient immunity of the TPA8000/1/2 ensure reliable and accurate operation in high-noise environments.

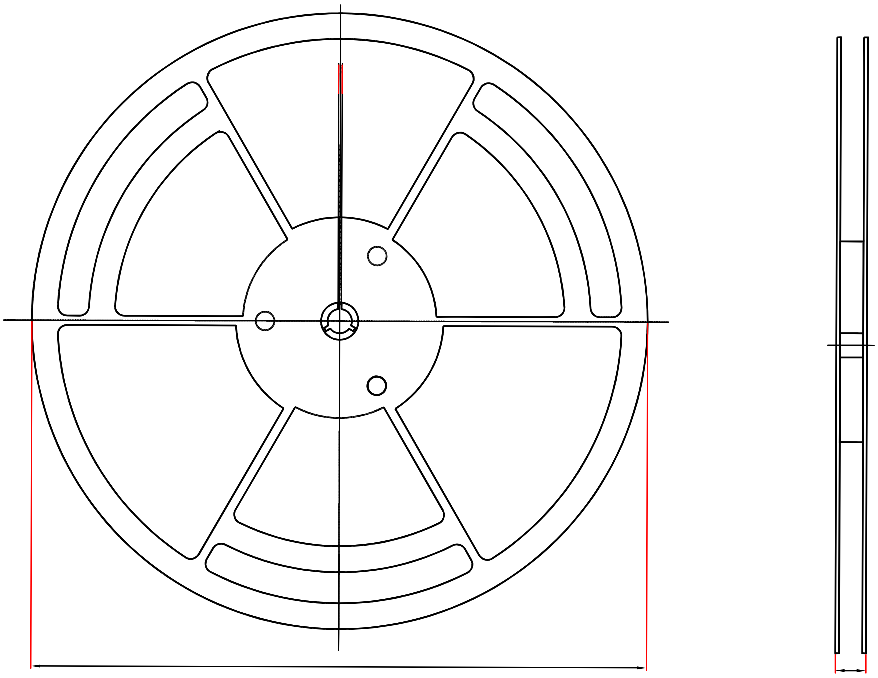
The DC bus voltage is measured by TPA8003 with high-impedance input and wide input voltage range.

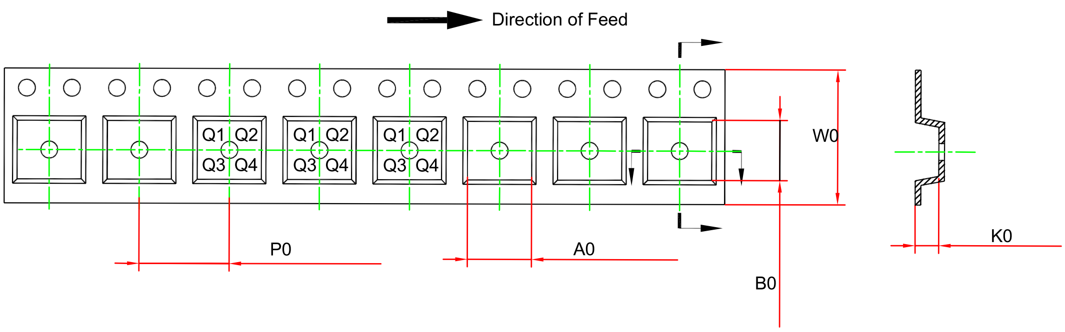
### Power Supply Recommendation

In a typical frequency inverter application, the high-side power supply (VDD1) of the device is derived by the floating power supply of the upper gate driver. A Zener diode with shunt resistor can be used to provide the high-side power supply of the device, or a low-cost low-dropout regulator (LDO) may be used to reduce the noise on the power supply. Place a 0.1-μF bypass capacitors as close as possible to the VDD1 pin of the device for best performance, an additional 1-μF to 10-μF capacitor may be used for better filtering.

To decouple the low-side power supply, place a 0.1-μF capacitor placed as close to the VDD2 pin of the device as possible, an additional 1-μF to 10-μF capacitor may be used for better filtering.

## Tape and Reel Information



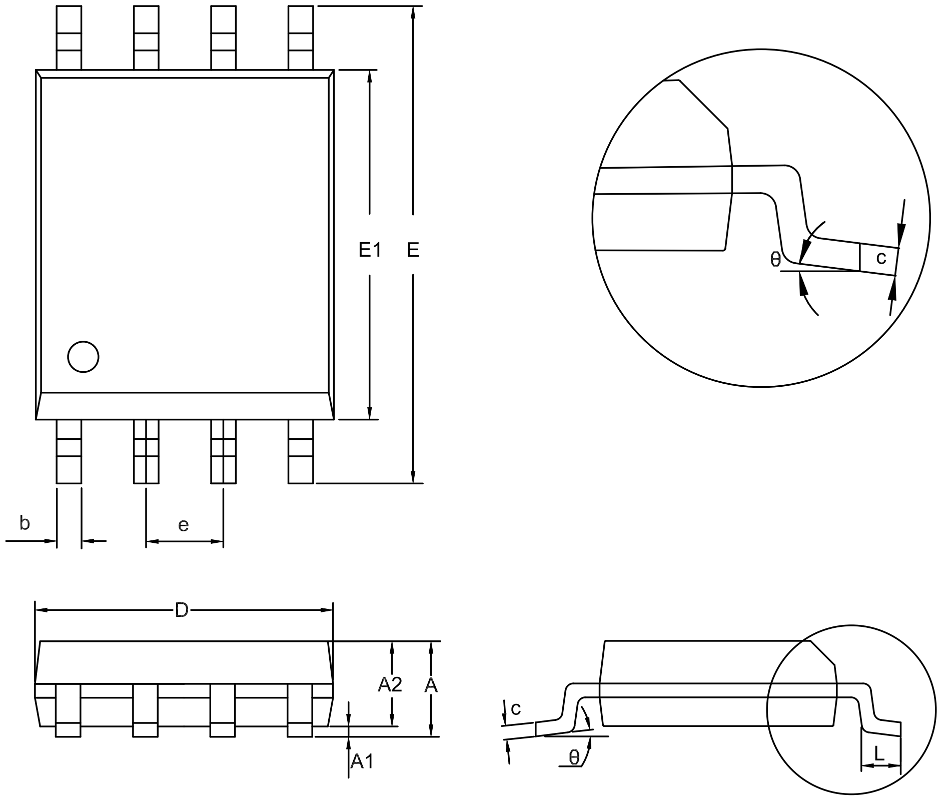




| Order Number | Package | D1 (mm) | W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P0 (mm) | W0 (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|
| TPA8003-SOAR | WSOP8 | 330 | 21.6 | 11.95 | 6.2 | 3.1 | 16.0 | 16.0 | Q1 |
| TPA8003-SOAR-S | WSOP8 | 330 | 21.6 | 11.95 | 6.2 | 3.1 | 16.0 | 16.0 | Q1 |

## Package Outline Dimensions

### WSOP8-B

Package Outline Dimensions SOA(WSOP-8-B)




| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | MIN | MAX | MIN | MAX |
| A | 2.350 | 2.650 | 0.093 | 0.104 |
| A1 | 0.100 | 0.300 | 0.004 | 0.012 |
| A2 | 2.250 | 2.350 | 0.089 | 0.093 |
| b | 0.310 | 0.510 | 0.012 | 0.020 |
| c | 0.150 | 0.300 | 0.006 | 0.012 |
| D | 5.750 | 5.950 | 0.226 | 0.234 |
| E | 11.250 | 11.750 | 0.443 | 0.463 |
| E1 | 7.400 | 7.600 | 0.291 | 0.299 |
| e | 1.270 BSC | | 0.050 BSC | |
| L | 0.500 | 1.000 | 0.020 | 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 |
|---|---|---|---|---|---|---|
| TPA8003-SOAR | −40 to 125°C | WSOP8 | A8003 | MSL3 | Tape and Reel, 1000 | Green |
| TPA8003-SOAR-S (1) | −40 to 125°C | WSOP8 | A8003 | MSL3 | Tape and Reel, 1000 | Green |

(1) Passed AEC-Q100 Reliability Test.

**Green**: Defines "Green" to mean RoHS compatible and free of halogen substances.

# IMPORTANT NOTICE AND DISCLAIMER



**Performance Information.** Performance tests or performance range contained in this document/material are either results of design simulation or actual tests conducted under designated testing environment. Any variation in testing environment or simulation environment, including but not limited to testing method, testing process or testing temperature, may affect actual performance of the product.

**Disclaimer.** 3PEAK provides technical and reliability data (including data sheets), design resources (including reference designs), application or other design recommendations, networking tools, security information and other resources "As Is". 3PEAK makes no warranty as to the absence of defects, and makes no warranties of any kind, express or implied, including without limitation, implied warranties as to merchantability, fitness for a particular purpose or non-infringement of any third-party's intellectual property rights. Unless otherwise specified in writing, products supplied by 3PEAK are not designed to be used in any life-threatening scenarios, including critical medical applications, automotive safety-critical systems, aviation, aerospace, or any situations where failure could result in bodily harm, loss of life, or significant property damage. 3PEAK disclaims all liability for any such unauthorized use.