# 1.8-V, 600-nA Nanopower, Rail-to-Rail I/O Operational Amplifiers

## Features

- Supply Current: 950 nA per Amplifier (Max)
- Stable 18-kHz GBWP with 10-mV/μs Slew Rate
- Offset Voltage: 1.5 mV (Max)
- Ultra-Low $V_{OS}$TC: 0.5 μV/°C
- Low Input Bias Current: 1 pA (Typ)
- High Open-Loop Voltage Gain: 120 dB
- Unity-Gain Stable for 1,000-nF Capacitive Load
- Rail-to-Rail Input/Output Voltage Range
- Outputs Source and Sink 20 mA of Load Current
- No Phase Reversal for Overdriven Inputs
- Ultra-Low Single-Supply Operation Down to +1.8 V
- Operating Temperature Range: –40°C to 125°C
- Robust 6-kV HBM and 1.5-kV CDM ESD Rating
- Green, Popular Type Package

## Applications

- Handsets and Mobile Accessories
- Current Sensing
- Wireless Remote Sensors, Active RFID Readers
- Environment/Gas/Oxygen Sensors
- Threshold Detectors/Discriminators
- Low-Power Filters
- Battery or Solar-Powered Devices
- Sensor Network Powered by Energy Scavenging

## Description

The TP212x is a series of ultra-low-power, precision CMOS op amps featuring a maximum supply current of 950 nA per amplifier with an ultra-low typical input bias current of 1 pA. Analog trim and calibration routine reduce the input offset voltage to below 1.5 mV, and the precision temperature compensation technique makes offset voltage temperature drift at 0.5 μV/°C, which allows the use of the TP212x in systems with high gain without creating excessively large output offset errors.

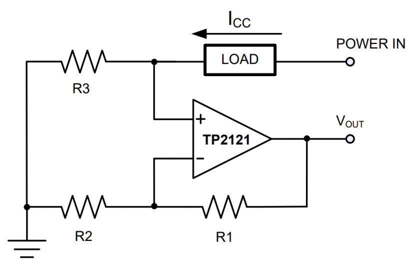
The TP212x series is unity-gain stable with 1,000-nF capacitive load with a constant 18-kHz GBWP, 10-mV/μs slew rate, which makes it suitable for low-frequency applications, such as battery current monitoring and sensor conditioning. The TP212x operates from a single-supply voltage from 1.8 V to 6.0 V or a dual-supply voltage from ±0.9 V to ±3.0 V. Beyond the rails input and rail-to-rail output characteristics allow the full power-supply voltage to be used for signal range.

The combined features make the TP212x ideal choices for battery-powered applications because they minimize errors caused by power supply voltage variations over the lifetime of the battery and maintain high CMRR even for a rail-to-rail input op amp. Mobile accessories, wireless remote sensing, backup battery sensors, and single-Li+ or 2-cell NiCd/Alkaline battery-powered systems can benefit from the features of the TP212x op amps.

**Table 1. Ultra-Low Supply Current Op Amps**

| **Supply Current** | 0.3 μA | 0.6 μA | 4 μA |
|---|---|---|---|
| **GBWP** | 10 kHz | 18 kHz | 150 kHz |
| **Single** | TP2111 | TP2121 | TP1511 |
| **Dual** | TP2112 | TP2122 | TP1512 |
| **Quad** | TP2114 | TP2124 | TP1514 |

## Typical Application Circuit




$$V_{OUT} = I_{CC} \times R_3 \times (\frac{R_1}{R_2} + 1)$$

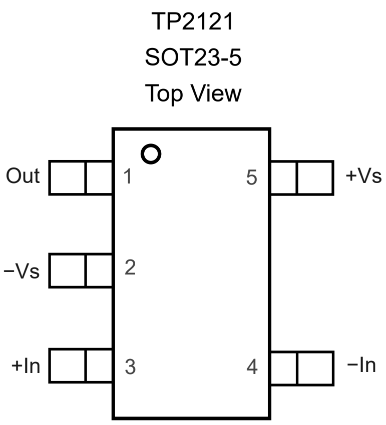
**TP2121 in Low-Side Battery Current Sensor**

# Table of Contents

## Revision History

| Date | Revision | Notes |
|---|---|---|
| 2023-04-07 | Rev.A.1 | The following updates are all about the new datasheet formats or typos, and the actual product remains unchanged.<br>• Updated the format of Package Outline Dimensions.<br>• Updated the specification with test limit.<br>• Added MSL information.<br>• Added Tape and Reel Information. |
| 2024-03-21 | Rev.A.2 | Added Thermal Information. |
| 2024-12-18 | Rev.A.3 | The following updates are all about the new datasheet formats or typos, and the actual product remains unchanged.<br>• Updated to a new datasheet format.<br>• Updated the Tape and Reel Information. |

## Pin Configuration and Functions



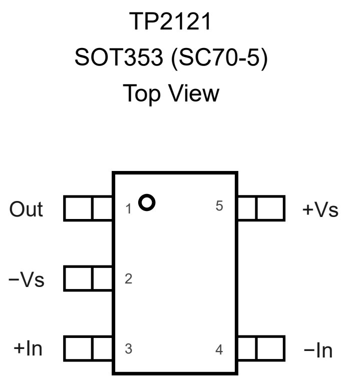
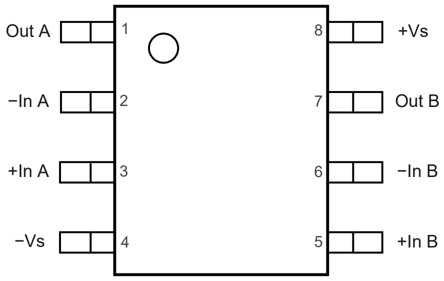




**Table 2. Pin Functions: TP2121**

| Pin No. | Name | I/O | Description |
|---|---|---|---|
| 1 | Out | O | Amplifier output. The voltage range extends to within milli-volts of each supply rail. |
| 2 | $-V_S$ | - | Negative power supply. It is normally tied to GND. It can also be tied to a voltage other than ground when the voltage between $+V_S$ and $–V_S$ is from 1.8 V to 5.5 V. If it is not connected to ground, bypass it with a capacitor of 0.1 μF to the part as close as possible. |
| 3 | +In | I | Non-inverting input of amplifier. This pin has the same voltage range as –IN. |
| 4 | −In | I | Inverting input of the amplifier. Voltage range of this pin can go from $(–V_S) – 0.3$ V to $(+V_S) + 0.3$ V. |
| 5 | $+V_S$ | - | Positive power supply. Typically, the voltage is from 1.8 V to 5.5 V. Split supplies are possible when the voltage between $+V_S$ and $-V_S$ is between 1.8 V and 5.5 V. A bypass capacitor of 0.1 μF to the part as close as possible should be used between power supply pins or between supply pins and ground. |

TP2122
SOP8
Top View




TP2122
MSOP8
Top View

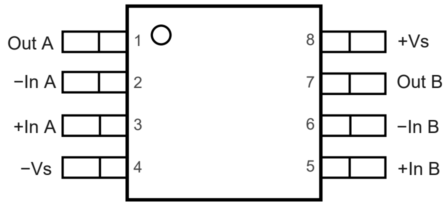
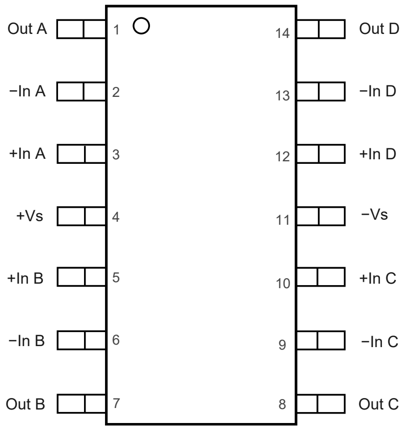



**Table 3. Pin Functions: TP2122**

| Pin No. | Name | I/O | Description |
|---|---|---|---|
| 1 | Out A | O | Output. |
| 2 | −In A | I | Inverting input. |
| 3 | +In A | I | Non-inverting input. |
| 4 | $-V_S$ | - | Negative power supply. It is normally tied to GND. It can also be tied to a voltage other than ground when the voltage between $+V_S$ and $–V_S$ is from 1.8 V to 5.5 V. If it is not connected to ground, bypass it with a capacitor of 0.1 μF to the part as close as possible. |
| 5 | +In B | I | Non-inverting input. |
| 6 | −In B | I | Inverting input. |
| 7 | Out B | O | Output. |
| 8 | $+V_S$ | - | Positive power supply. Typically, the voltage is from 1.8 V to 5.5 V. Split supplies are possible when the voltage between $+V_S$ and $-V_S$ is between 1.8 V and 5.5 V. A bypass capacitor of 0.1 μF to the part as close as possible should be used between power supply pins or between supply pins and ground. |

TP2124
SOP14
Top View




TP2124
TSSOP14
Top View

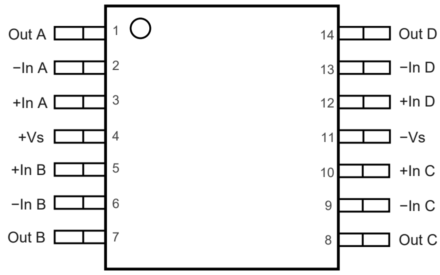



**Table 4. Pin Functions: TPA2124**

| Pin No. | Name | I/O | Description |
|---|---|---|---|
| 1 | Out A | O | Output. |
| 2 | −In A | I | Inverting input. |
| 3 | +In A | I | Non-inverting input. |
| 4 | $+V_S$ | - | Positive power supply. Typically, the voltage is from 1.8 V to 5.5 V. Split supplies are possible when the voltage between $+V_S$ and $-V_S$ is between 1.8 V and 5.5 V. A bypass capacitor of 0.1 μF to the part as close as possible should be used between power supply pins or between supply pins and ground. |
| 5 | +In B | I | Non-inverting 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 | Non-inverting input. |
| 11 | $-V_S$ | - | Negative power supply. It is normally tied to GND. It can also be tied to a voltage other than ground when the voltage between $+V_S$ and $-V_S$ is from 1.8 V to 5.5 V. If it is not connected to ground, bypass it with a capacitor of 0.1 μF to the part as close as possible. |
| 12 | +In D | I | Non-inverting input. |
| 13 | −In D | I | Inverting input. |
| 14 | Out D | O | Output. |

# Specifications

## Absolute Maximum Ratings (1)

| Symbol | Parameters | Min | Max | Unit |
|---|---|---|---|---|
| | Supply Voltage: $(+V_S) – (−V_S)$ | | 6.5 | 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) | | Indefinite | |
| $T_A$ | Operating Temperature Range | −40 | 125 | ℃ |
| $T_{STG}$ | Storage Temperature Range | −65 | 150 | ℃ |
| $T_J$ | Maximum Junction Temperature | | 150 | ℃ |
| $T_L$ | Lead Temperature (Soldering, 10 sec) | | 260 | ℃ |

(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 500 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 (1) | 6 | 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.

## Electrical Characteristics: 5 V

All test conditions: $T_A$ = 27°C, $V_{DD}$ = 5 V, $V_{CM}$ = $V_{OUT}$ = $V_{DD}$ / 2, $R_L$ = 100 kΩ, $C_L$ = 60 pF, unless otherwise specified.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{OS}$ | Input Offset Voltage | $V_{CM}$ = $V_{DD}$ / 2, $V_{CM}$ = GND | −1.5 | ±0.1 | 1.5 | mV |
| $V_{OS}$ TC | Input Offset Voltage Drift | | | 0.5 | | µV/°C |
| $I_B$ | Input Bias Current | $T_A$ = 27°C | | 1 | | pA |
| | | $T_A$ = 85°C | | 20 | | pA |
| | | $T_A$ = 125°C | | 100 | | pA |
| $I_{OS}$ | Input Offset Current | | | 1 | | pA |
| $V_n$ | Input Voltage Noise | f = 0.1 Hz to 10 Hz | | 6.5 | | $µV_{P-P}$ |
| $e_n$ | Input Voltage Noise Density | f = 1 kHz | | 170 | | nV/√Hz |
| $R_{IN}$ | Input Resistance | | | 1 | | TΩ |
| $C_{IN}$ | Input Capacitance | Differential mode | | 2.9 | | pF |
| | | Common mode | | 5 | | pF |
| CMRR | Common-Mode Rejection Ratio | $V_{CM}$ = 0.1 V to 4.9 V | 60 | 100 | | dB |
| $V_{CM}$ | Common-Mode Input Voltage Range | | ($-V_S$) − 0.3 | | ($+V_S$) + 0.3 | V |
| PSRR | Power Supply Rejection Ratio | $V_{DD}$ = 1.8 V to 5.5 V | 70 | 92 | | dB |
| $A_{VOL}$ | Open-Loop Large Signal Gain | $V_{OUT}$ = 0.5 V to 4.5 V, $R_{LOAD}$ = 100 kΩ | 80 | 120 | | dB |
| $V_{OL}$, $V_{OH}$ | Output Swing from Supply Rail | $R_{LOAD}$ = 100 kΩ | | 5 | | mV |
| $R_{OUT}$ | Closed-Loop Output Impedance | G = 1, f = 1 kHz, $I_{OUT}$ = 0 | | 0.4 | | Ω |
| $R_O$ | Open-Loop Output Impedance | f = 1 kHz, $I_{OUT}$ = 0 | | 2.6 | | Ω |
| $I_{SC}$ | Output Short-Circuit Current | Sink or source current | | 20 | | mA |
| $V_{DD}$ | Supply Voltage | | 1.8 | | 6.0 | V |
| $I_Q$ | Quiescent Current per Amplifier | | | 600 | 950 | nA |
| PM | Phase Margin | $R_{Load}$ = 100 kΩ, $C_{LOAD}$ = 60 pF | | 61 | | ° |
| GM | Gain Margin | $R_{Load}$ = 100 kΩ, $C_{Load}$ = 60 pF | | 10 | | dB |
| GBWP | Gain-Bandwidth Product | f = 1 kHz | | 18 | | kHz |
| $t_S$ | Settling Time, 1.5 V to 3.5 V, Unity Gain | 0.1% | | 0.25 | | ms |
| | | 0.01% | | 0.253 | | |
| | Settling Time, 2.45 V to 2.55 V, Unity Gain | 0.1% | | 0.035 | | |
| | | 0.01% | | 0.038 | | |
| SR | Slew Rate | $A_V$ = 1, $V_{Out}$ = 1.5 V to 3.5 V, $C_{LOAD}$ = 60 pF, $R_{LOAD}$ = 100 kΩ | | 10 | | mV/µs |

(1) The full-power banwidth is calculated from the slew rate FPBW = SR/π · $V_{P-P}$.

## Typical Performance Characteristics

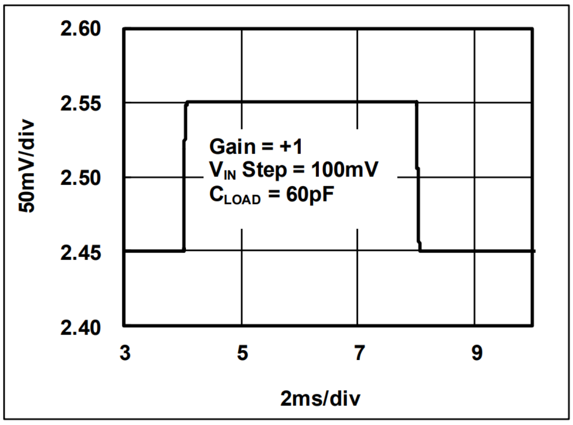



Figure 1. Small-Signal Step Response, 100-mV Step

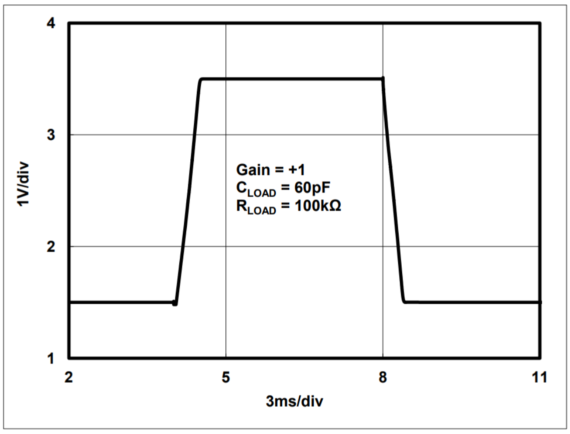



Figure 2. Large-Signal Step Response, 2-V Step

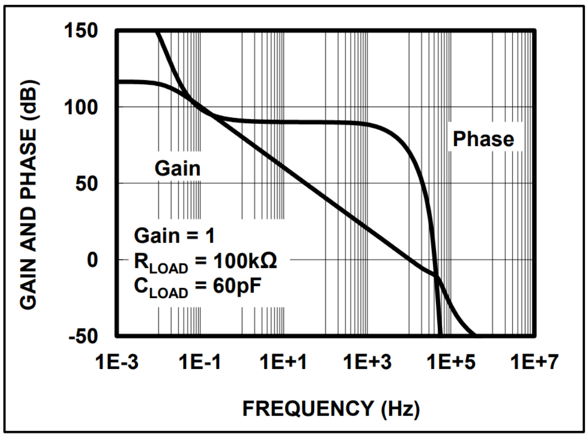



Figure 3. Open-Loop Gain and Phase

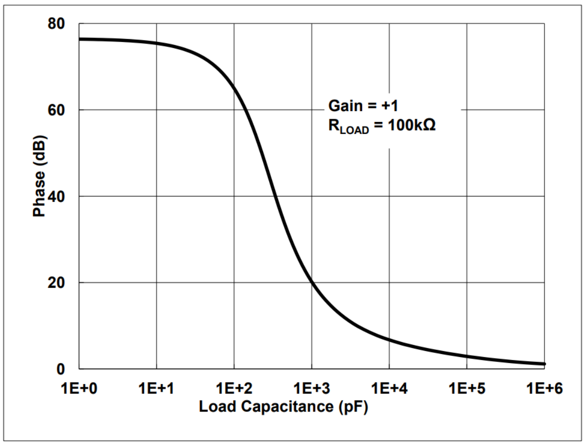



Figure 4. Phase Margin vs. $C_{LOAD}$ (Stable for Any $C_{LOAD}$)

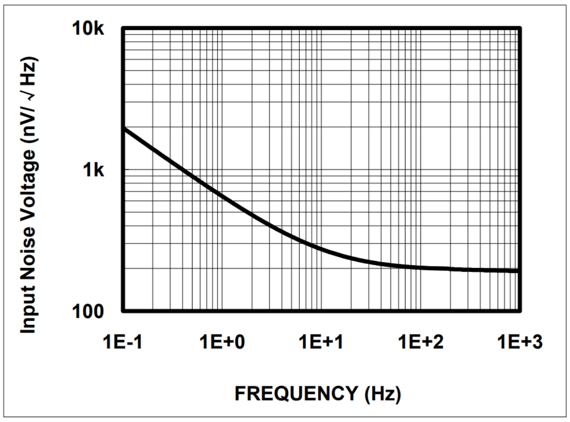



Figure 5. Input Voltage Noise Spectral Density

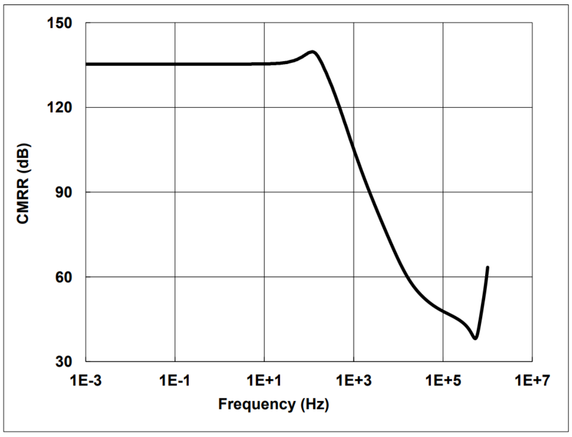



Figure 6. Common-Mode Rejection Ratio

## Typical Performance Characteristics (Continued)

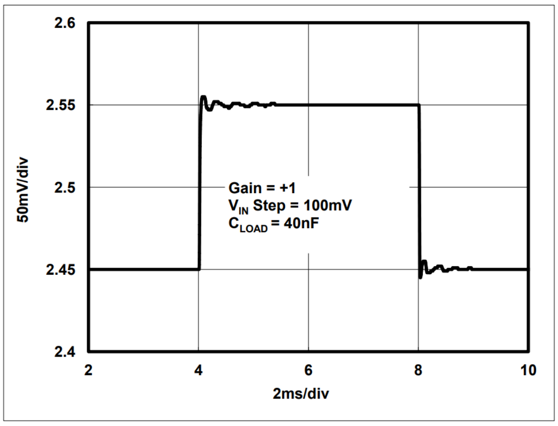



Figure 7. Over-Shoot Voltage, $C_{LOAD}$ = 40 nF, Gain = +1, $R_{FB}$ = 100 kΩ

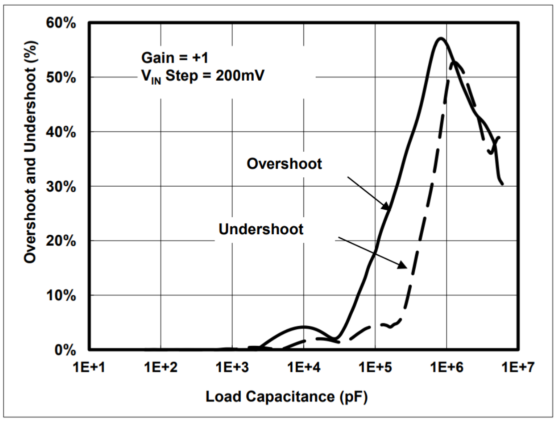



Figure 8. Over-Shoot % vs. $C_{LOAD}$, Gain = +1, $R_{FB}$ = 1 MΩ

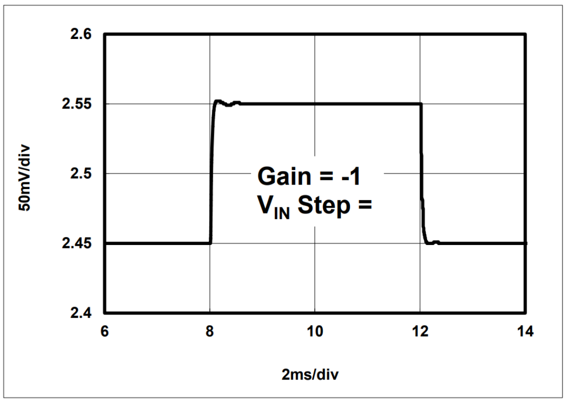



Figure 9. Over-Shoot Voltage, $C_{LOAD}$ = 40 nF, Gain = −1, $R_{FB}$ = 100 kΩ

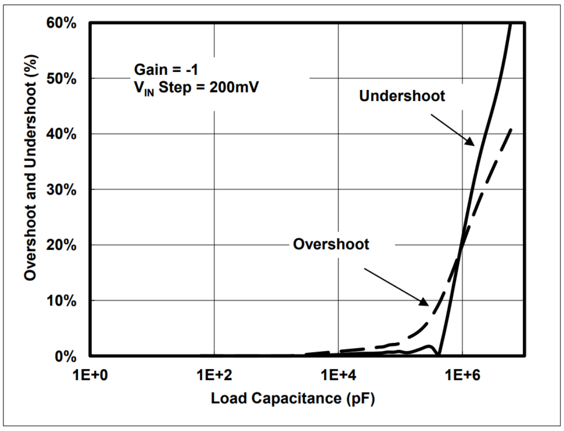



Figure 10. Over-Shoot % vs. $C_{LOAD}$, Gain = −1, $R_{FB}$ = 1 MΩ

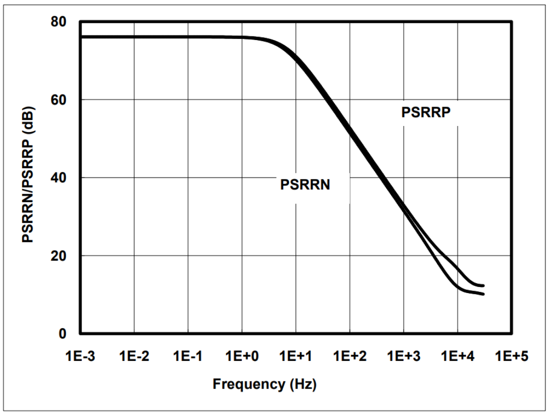



Figure 11. Power-Supply Rejection Ratio

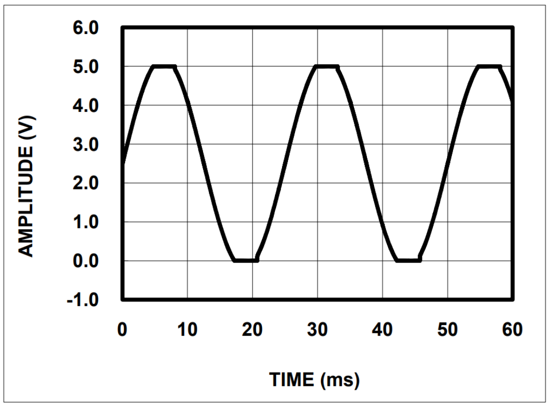



Figure 12. $V_{IN}$ = −0.2 V to 5.7 V, No Phase Reversal

## Typical Performance Characteristics (Continued)

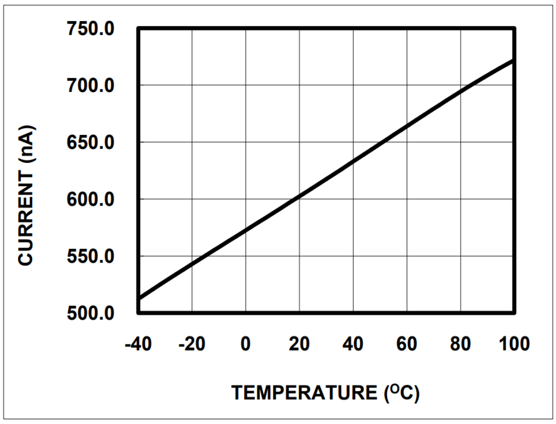



Figure 13. Quiescent Supply Current vs. Temperature

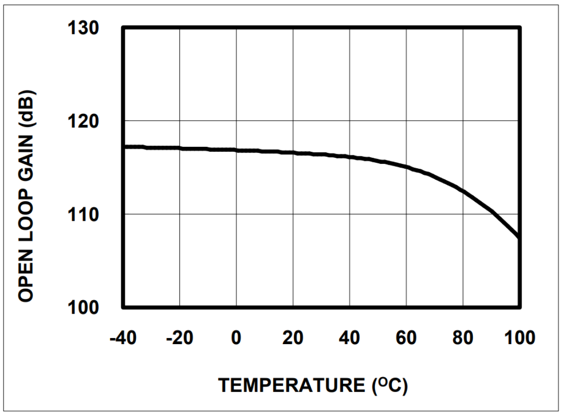



Figure 14. Open-Loop Gain vs. Temperature

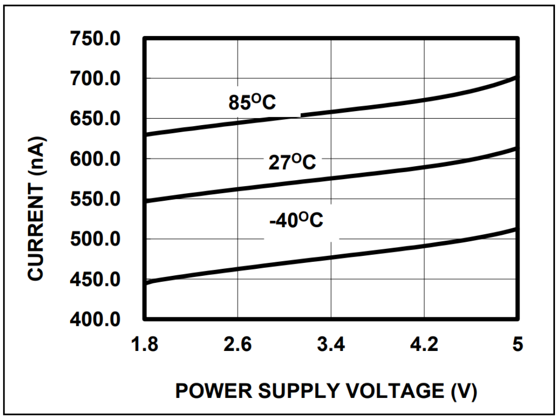



Figure 15. Quiescent Supply Current vs. Supply Voltage

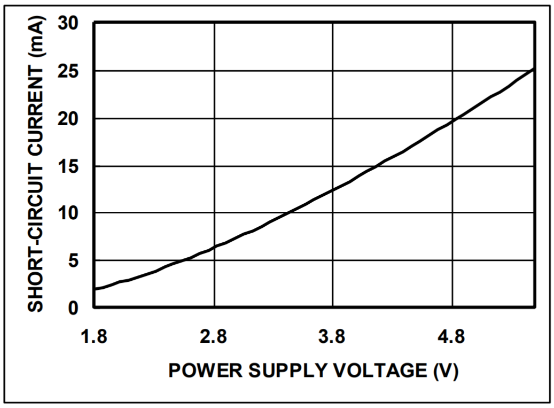



Figure 16. Short-Circuit Current vs. Supply Voltage

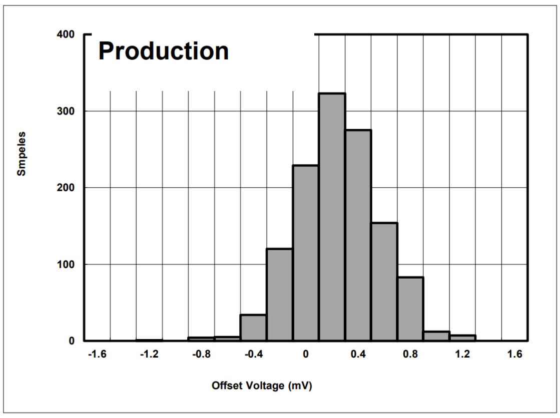



Figure 17. Input Offset Voltage Distribution

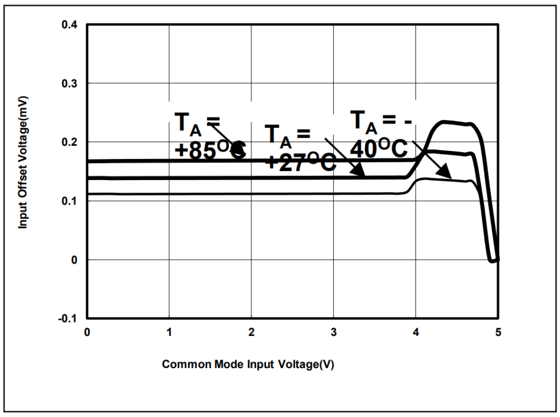



Figure 18. Input Offset Voltage vs. Common-Mode Input Voltage

## Typical Performance Characteristics (Continued)

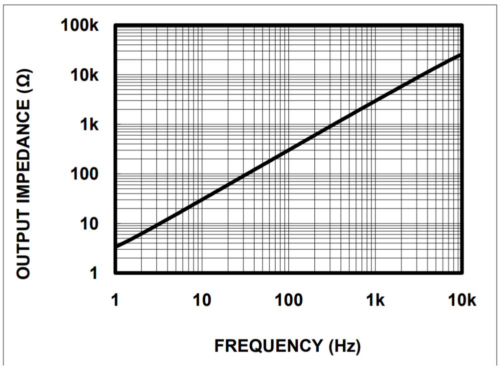



**Figure 19. Closed-Loop Output Impedance vs. Frequency**

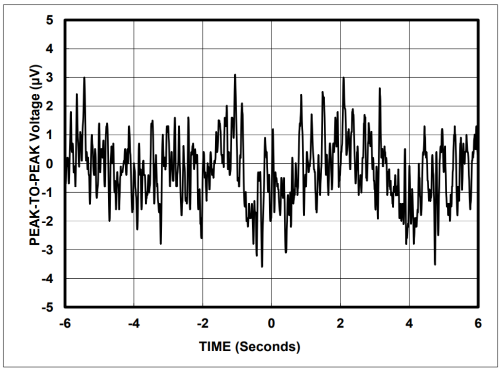



**Figure 20. 0.1-Hz to 10-Hz Time Domain Output Voltage Noise**

# Detailed Description

## Overview

The TP212x is a series of ultra-low-power, precision CMOS op amps featuring a maximum supply current of 950 nA per amplifier with an ultra-low typical input bias current of 1 pA. Analog trim and calibration routine reduce input offset voltage to below 1.5 mV, and the precision temperature compensation technique makes offset voltage temperature drift at 0.5 μV/°C, which allows the use of the TP212x in systems with high gain without creating excessively large output offset errors.

The TP212x series is unity-gain stable with 1,000-nF capacitive load with a constant 18-kHz GBWP, 10-mV/μs slew rate, which makes it suitable for low-frequency applications, such as battery current monitoring and sensor conditioning. The TP212x operates from a single-supply voltage from 1.8 V to 6.0 V or a dual-supply voltage from ±0.9 V to ±3.0 V. Beyond the rails input and rail-to-rail output characteristics allow the full power-supply voltage to be used for signal range.

The combined features make the TP212x ideal choices for battery-powered applications because they minimize errors caused by power supply voltage variations over the lifetime of the battery and maintain high CMRR even for a rail-to-rail input op amp. Mobile accessories, wireless remote sensing, backup battery sensors, and single-Li+ or 2-cell NiCd/Alkaline battery-powered systems can benefit from the features of the TP212x op amps.

## Detailed Description

The TP212x family input signal range extends beyond the negative and positive power supplies. The output can even extend to the negative supply. The input stage is comprised of two CMOS differential amplifiers, a PMOS stage and NMOS stage that are active over different ranges of common-mode input voltage. The Class-AB control buffer and output bias stage uses a proprietary compensation technique to take full advantage of the process technology to drive very high capacitive loads. This is evident from the transient over-shoot measurement plots in the Typical Performance Characteristics (Continued).

# 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 Supply Voltage and Low Power Consumption

The TP212x operational amplifiers operate with power supply voltages from 1.8 V to 6.0 V. Each amplifier draws only 600 nA quiescent current. The low supply voltage capability and low supply current are ideal for portable applications demanding high capacitive load driving capability and constant wide bandwidth. The TP212x family is optimized for wide bandwidth low power applications. It has an industry-leading high GBWP to power ratio and is unity-gain stable for a 1,000-nF capacitive load. When the load capacitance increases, the increased capacitance at the output pushes the non-dominant pole to a lower frequency in the open-loop frequency response, lowering the phase and gain margin. Higher gain configurations tend to have better capacitive drive capability than lower gain configurations due to lower closed-loop bandwidth and hence higher phase margin.

### Low Input Referred Noise

The TP212x family provides a low input referred noise density of 170 nV/√Hz at 1 kHz. The voltage noise grows slowly with the frequency in the wideband range, and the input voltage noise is typically 6.5 $\mu V_{P-P}$ at the frequency of 0.1 Hz to 10 Hz.

### Low Input Offset Voltage

The TP212x family has a low offset voltage of 1.5 mV maximum which is essential for precision applications. The offset voltage is trimmed with a proprietary trim algorithm to ensure low offset voltage for precision signal processing requirements.

### Ground Sensing and Rail-to-Rail Output

The TP212x family has excellent output drive capability, delivering over 10 mA of output drive current. The output stage is a rail-to-rail topology that is capable of swinging to within 5 mV of either rail. Since the inputs can go 300 mV beyond either rail, the op amp can easily perform 'true ground' sensing.

The maximum output current is a function of the total supply voltage. As the supply voltage to the amplifier increases, the output current capability also increases. Attention must be paid to keeping the junction temperature of the IC below 150°C when the output is in continuous short-circuit. The output of the amplifier has reverse-biased ESD diodes connected to each supply. The output should not be forced more than 0.5 V beyond either supply, otherwise current flows through these diodes.

### ESD

The TP212x family has reverse-biased ESD protection diodes on all inputs and outputs. Input and output pins cannot be biased more than 300 mV beyond either supply rail.

### Driving Large Capacitive Load

The TP212x op amps are designed to drive large capacitive loads. Refer to Figure 4. As always, larger load capacitance decreases overall phase margin in a feedback system where internal frequency compensation is utilized. As the load capacitance increases, the phase margin of the feedback loop decreases, and the closed-loop bandwidth is reduced. This produces gain peaking in the frequency response, with overshoot and ringing in the output step response. The unity-gain buffer (G = +1V/V) is most sensitive to large capacitive loads.

When driving large capacitive loads with the TP212x op amps (e.g., > 200 pF when G = +1V/V), a small series resistor at the output ($R_{ISO}$ in Figure 21) improves the phase margin and stability of the feedback loop by making the output load resistive at higher frequencies.

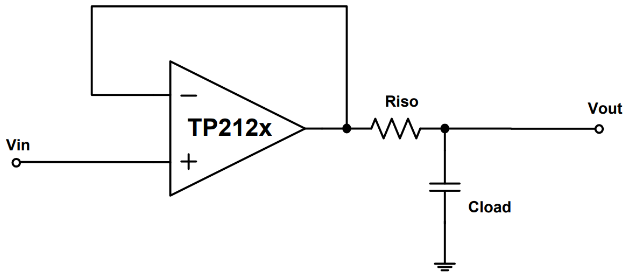



**Figure 21.**

**Power Supply Layout and Bypass**

The power supply pins ($V_{DD}$ for single supply) of the TP212x op amps should have a local bypass capacitor (i.e., 0.01 μF to 0.1 μF) within 2 mm for high-frequency performance. It can also use a bulk capacitor (i.e., 1 μF or larger) within 100 mm to provide large, slow currents. This bulk capacitor can be shared with other analog parts.

A ground layout improves performance by decreasing the amount of stray capacitance and noise at the inputs and outputs of the op amps. To decrease the stray capacitance, minimize PC board lengths and resistor leads, and place external components to the pins of the op amps as close as possible.

**Proper Board Layout**

To ensure optimum performance at the PCB level, care must be taken in the design of the board layout. To avoid leakage currents, the surface of the board should be kept clean and free of moisture. Coating the surface creates a barrier to moisture accumulation and helps reduce parasitic resistance on the board.

Keeping supply traces short and properly bypassing the power supplies minimizes power supply disturbances due to output current variation, such as when driving an AC signal into a heavy load. Bypass capacitors should be connected as close as possible to the device supply pins. Stray capacitances are a concern at the outputs and inputs of the amplifier. It is recommended that signal traces be kept at least 5 mm from supply lines to minimize coupling.

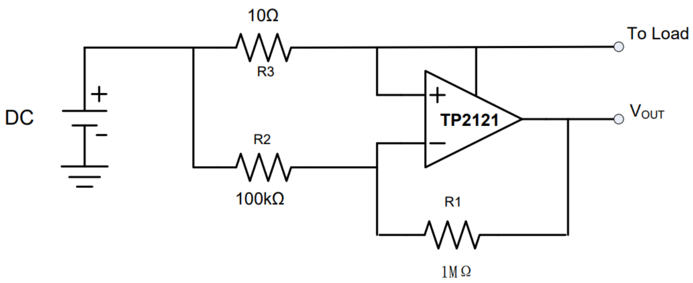
A variation in temperature across the PCB can cause a mismatch in the Seebeck voltages at solder joints and other points where dissimilar metals are in contact, resulting in thermal voltage errors. To minimize these thermocouple effects, orient the resistors so heat sources warm both ends equally. The input signal paths should contain matching numbers and types of components, where possible to match the number and type of thermocouple junctions. For example, dummy components such as zero-value resistors can be used to match real resistors in the opposite input path. Matching components should be located in close proximity and should be oriented in the same manner. Ensure that leads are of equal length so that thermal conduction is in equilibrium. Keep heat sources on the PCB as far away from amplifier input circuitry as is practical.

A ground plane is highly recommended. The ground plane reduces EMI noise and also helps maintain a constant temperature across the circuit board.

**Battery Current Sensing**

The common-mode input voltage range of TP212x op amps, which goes 0.3 V beyond both supply rails, supports their use in high-side and low-side battery current sensing applications. The low quiescent current (600 nA, typical) helps prolong battery life, and the rail-to-rail output supports the detection of low currents.

The battery current ($I_{DD}$) through the 10-Ω resistor causes its top terminal to be more negative than the bottom terminal. This keeps the Common-Mode Input voltage below $V_{DD}$, which is within its allowed range. The output of the op amp is also below $V_{DD}$, within its Maximum Output Voltage Swing specification.



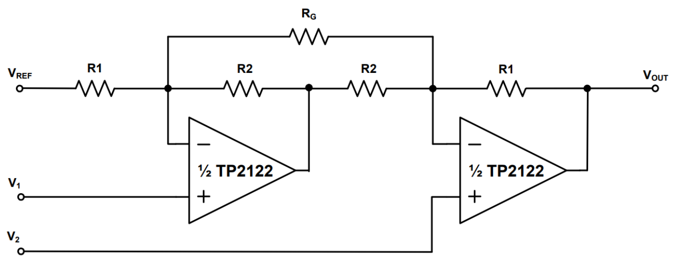

$$I_{DD} = \frac{V_{DD} - V_{OUT}}{\frac{R1}{R2} \cdot R3}$$

**Figure 22.**

### Instrumentation Amplifier

The TP212x op amps are well-suited for conditioning sensor signals in battery-powered applications. Figure 23 shows a two-op-amp instrumentation amplifier, using the TP212x op amp.

The circuit works well for applications requiring rejection of Common-Mode noise at higher gains. The reference voltage ($V_{REF}$) is supplied by a low-impedance source. In single voltage supply applications, $V_{REF}$ is typically $V_{DD}$ / 2.




$$V_{OUT} = (V_1 - V_2)(1 + \frac{R_1}{R_2} + \frac{2R_1}{R_G}) + V_{REF}$$

**Figure 23.**

### Buffered Chemical Sensor (pH) Probe

The TP212x op amps have an input bias current in the pA range. This is ideal for buffering high-impedance chemical sensors such as pH probes. As an example, the circuit in Figure 24 eliminates expansive low-leakage cables required to connect pH probes to metering ICs, such as ADC, AFE and/or MCU. A TP212x op amp and a lithium battery are housed in the probe assembly. A conventional low-cost coaxial cable can be used to carry the output signal of the op amp to subsequent ICs for pH reading.

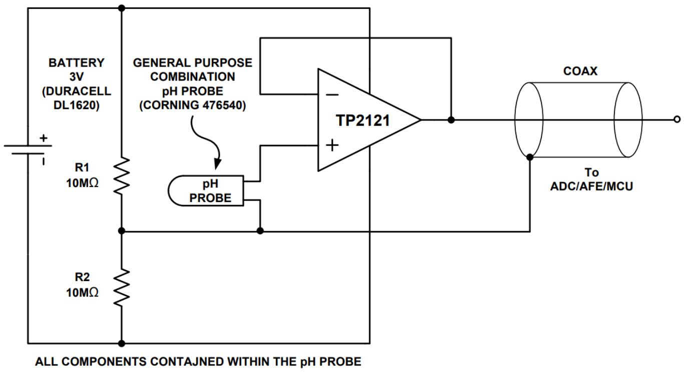



**Figure 24. Buffer pH Probe**

**Portable Gas Sensor Amplifier**

Gas sensors are used in different industrial and medical applications. Gas sensors generate a current that is proportional to the percentage of a particular gas concentration sensed in an air sample. This output current flows through a load resistor, and the resultant voltage drop is amplified. According to the sensed gas and sensitivity of the sensor, the output current can be in the range of tens of microamperes to a few milli-amperes. Gas sensor datasheets often specify a recommended load resistor value or a range of load resistors from which to choose.

There are two main applications for oxygen sensors – applications that sense oxygen when it is abundantly present (that is, in the air or near an oxygen tank) and those that detect traces of oxygen in parts-per-million concentration. In medical applications, oxygen sensors are used when air quality or oxygen delivered to a patient needs to be monitored. In fresh air, the concentration of oxygen is 20.9%, and air samples containing less than 18% oxygen are considered dangerous. In industrial applications, oxygen sensors are used to detect the absence of oxygen; for example, vacuum-packaging of food products.

The circuit in Figure 25 illustrates a typical implementation used to amplify the output of an oxygen detector. With the components shown in the figure, the circuit consumes less than 600 nA of supply current ensuring that small form-factor single- or button-cell batteries (exhibiting low mAh charge ratings) can last the operating life of the oxygen sensor. The precision specifications of these amplifiers, such as their low offset voltage, low $V_{OS}$TC, low input bias current, high CMRR, high PSRR, and other factors make these amplifiers excellent choices for this application.

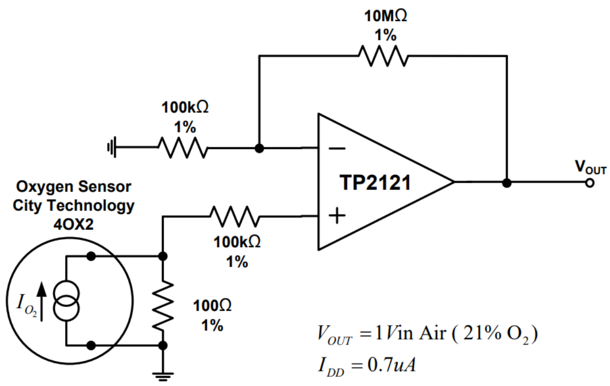
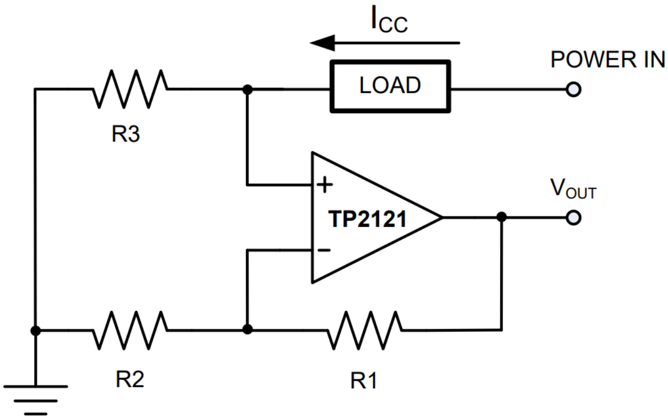



**Figure 25.**

## Typical Application

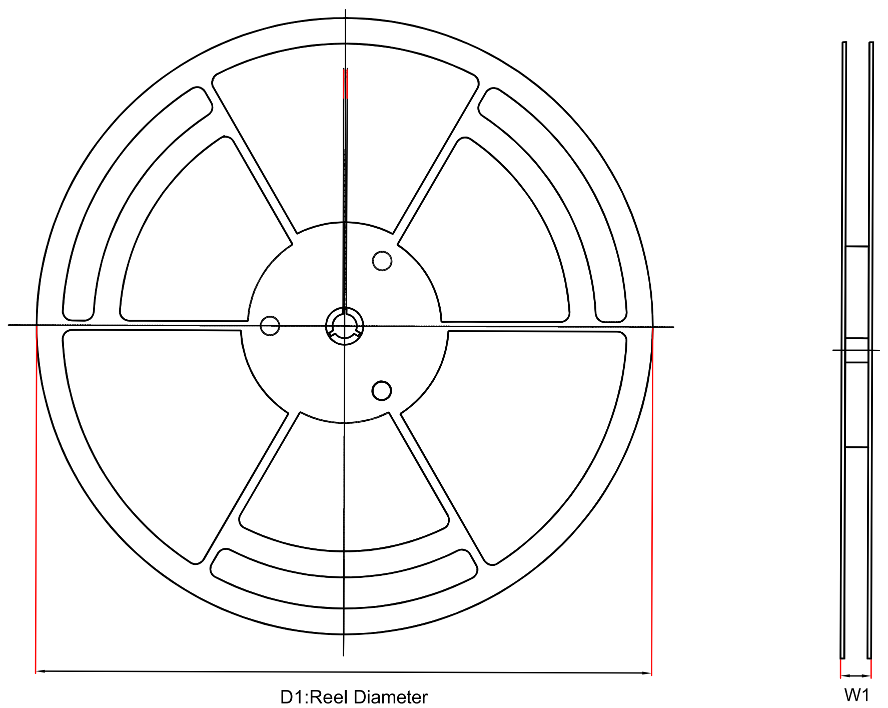
Figure 26 shows the typical application schematic.

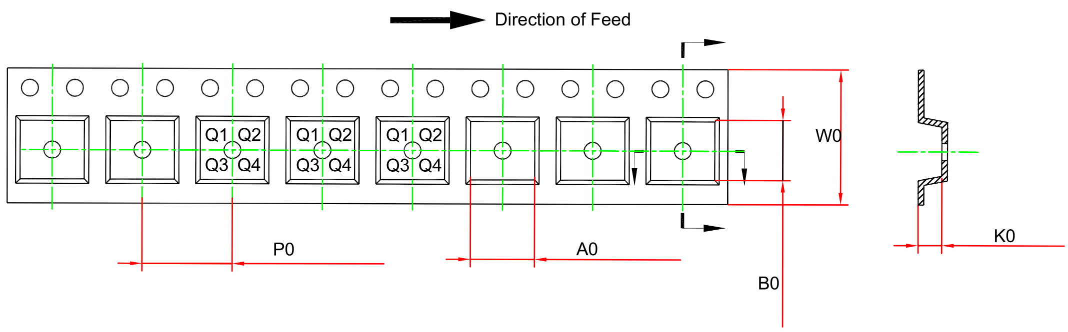



$$V_{OUT} = I_{CC} \times R_3 \times (\frac{R_1}{R_2} + 1)$$

**Figure 26. Typical Application Circuit**

## Tape and Reel Information



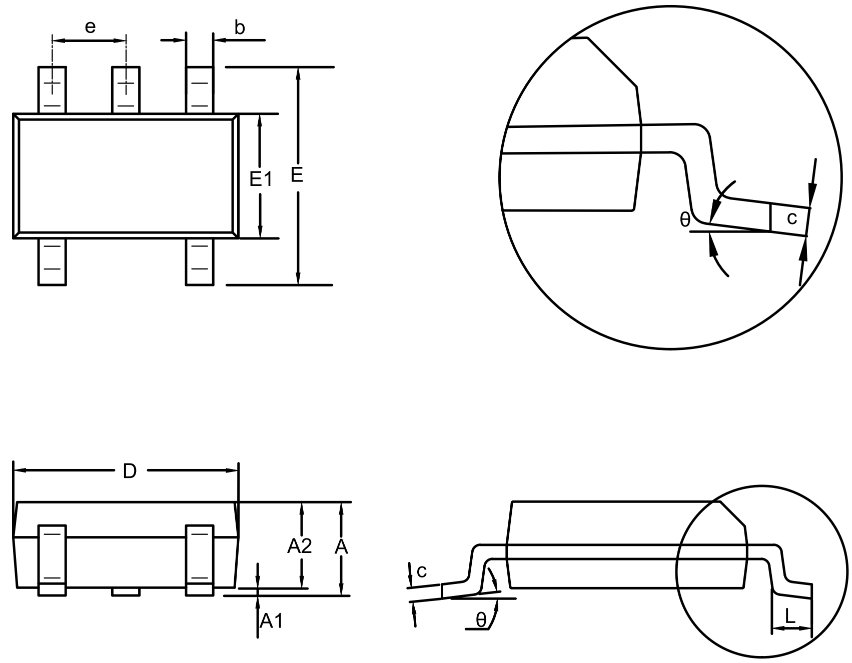

| Order Number | Package | D1 (mm) | W1 (mm) | A0 (mm) (1) | B0 (mm) (1) | K0 (mm) (1) | P0 (mm) | W0 (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|
| TP2121-CR | SOT353 | 178 | 12.1 | 2.4 | 2.5 | 1.2 | 4 | 8 | Q3 |
| TP2121-TR | SOT23-5 | 180 | 12 | 3.3 | 3.25 | 1.4 | 4 | 8 | Q3 |
| TP2122-SR | SOP8 | 330 | 17.6 | 6.5 | 5.4 | 2 | 8 | 12 | Q1 |
| TP2122-VR | MSOP8 | 330 | 17.6 | 5.3 | 3.4 | 1.3 | 8 | 12 | Q1 |
| TP2124-SR | SOP14 | 330 | 21.6 | 6.5 | 9.15 | 1.8 | 8 | 16 | Q1 |
| TP2124-TR | TSSOP14 | 330 | 17.6 | 6.8 | 5.5 | 1.3 | 8 | 12 | Q1 |

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

## Package Outline Dimensions

### SOT353 (SC70-5)

Package Outline Dimensions SC5(SOT353-5-A)



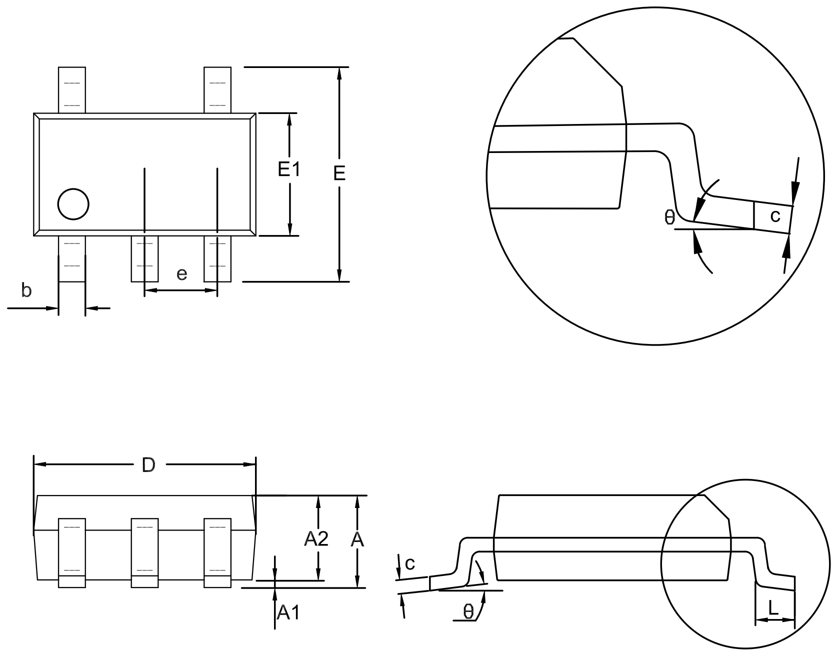

| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | MIN | MAX | MIN | MAX |
| A | 0.850 | 1.100 | 0.033 | 0.043 |
| A1 | 0.000 | 0.100 | 0.000 | 0.004 |
| A2 | 0.800 | 1.000 | 0.031 | 0.039 |
| b | 0.150 | 0.350 | 0.006 | 0.014 |
| c | 0.110 | 0.230 | 0.004 | 0.009 |
| D | 2.000 | 2.200 | 0.079 | 0.087 |
| E | 2.150 | 2.450 | 0.085 | 0.096 |
| E1 | 1.150 | 1.350 | 0.045 | 0.053 |
| e | 0.650 BSC | | 0.026 BSC | |
| L | 0.260 | 0.460 | 0.010 | 0.018 |
| θ | 0 | 8° | 0 | 8° |

NOTES

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

## SOT23-5

Package Outline Dimensions S5T(SOT23-5-A)



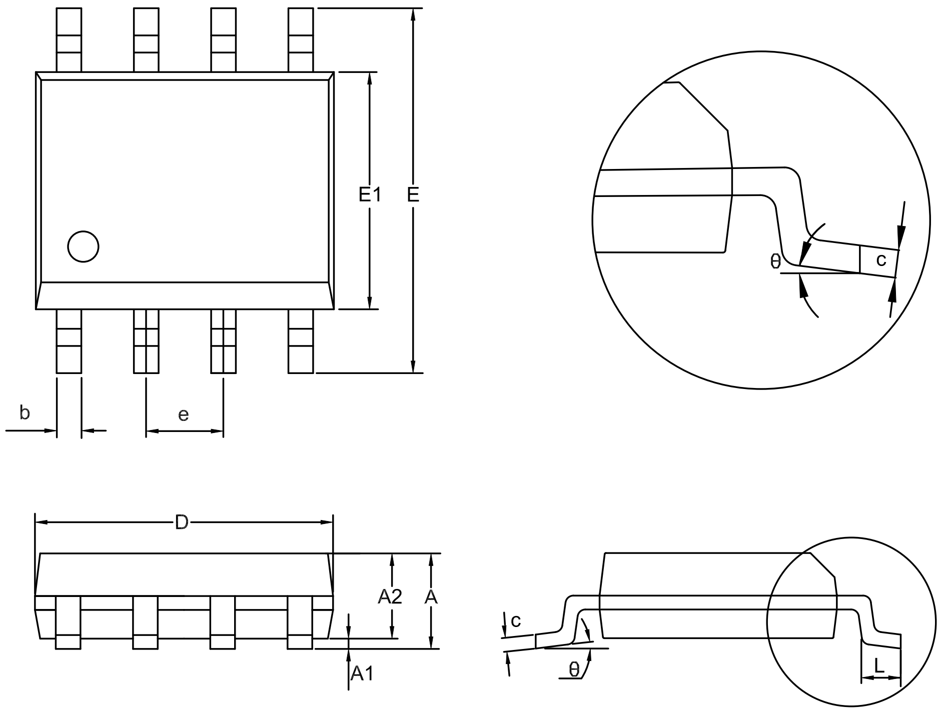

| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | MIN | MAX | MIN | MAX |
| A | 1.050 | 1.250 | 0.041 | 0.049 |
| A1 | 0.000 | 0.150 | 0.000 | 0.006 |
| A2 | 1.000 | 1.200 | 0.039 | 0.047 |
| b | 0.280 | 0.500 | 0.011 | 0.020 |
| c | 0.100 | 0.230 | 0.004 | 0.009 |
| 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)



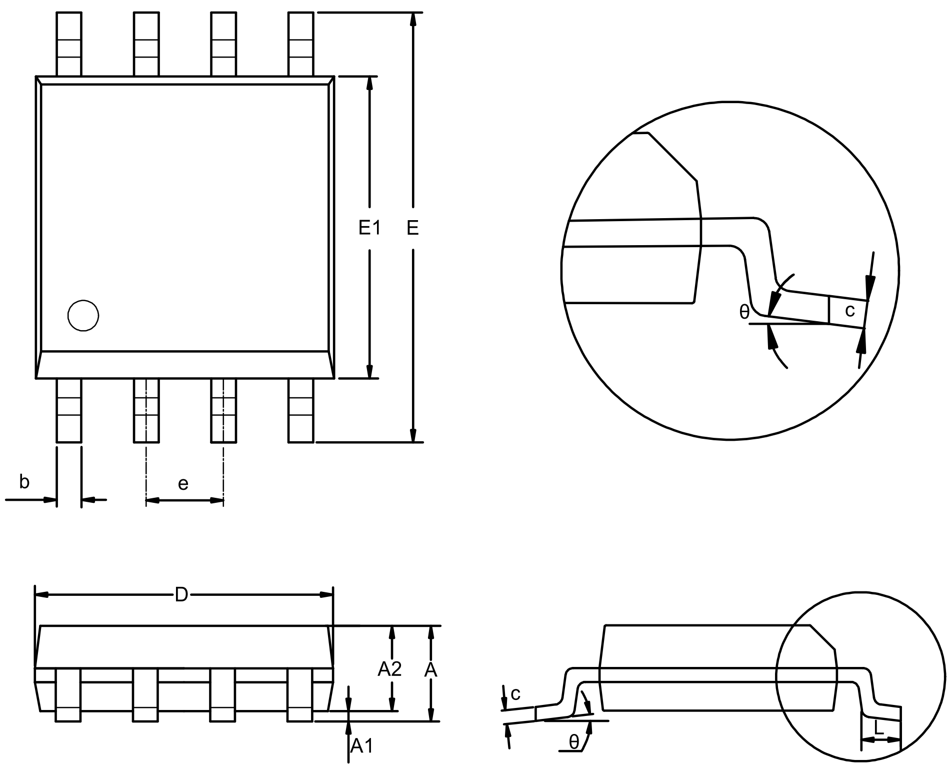

| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | MIN | MAX | MIN | MAX |
| A | 1.350 | 1.750 | 0.053 | 0.069 |
| A1 | 0.050 | 0.250 | 0.002 | 0.010 |
| A2 | 1.250 | 1.550 | 0.049 | 0.061 |
| b | 0.330 | 0.510 | 0.013 | 0.020 |
| c | 0.170 | 0.250 | 0.007 | 0.010 |
| 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)



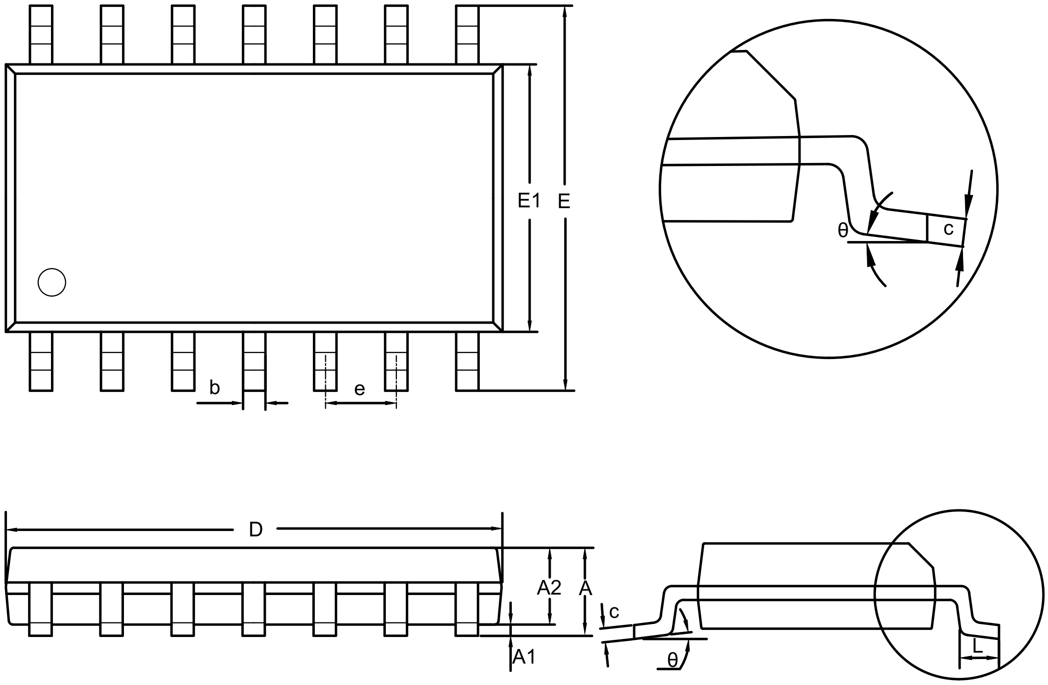

| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | MIN | MAX | MIN | MAX |
| A | 0.800 | 1.100 | 0.031 | 0.043 |
| A1 | 0.020 | 0.150 | 0.001 | 0.006 |
| A2 | 0.750 | 0.950 | 0.030 | 0.037 |
| b | 0.250 | 0.380 | 0.010 | 0.015 |
| c | 0.090 | 0.230 | 0.004 | 0.009 |
| 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)



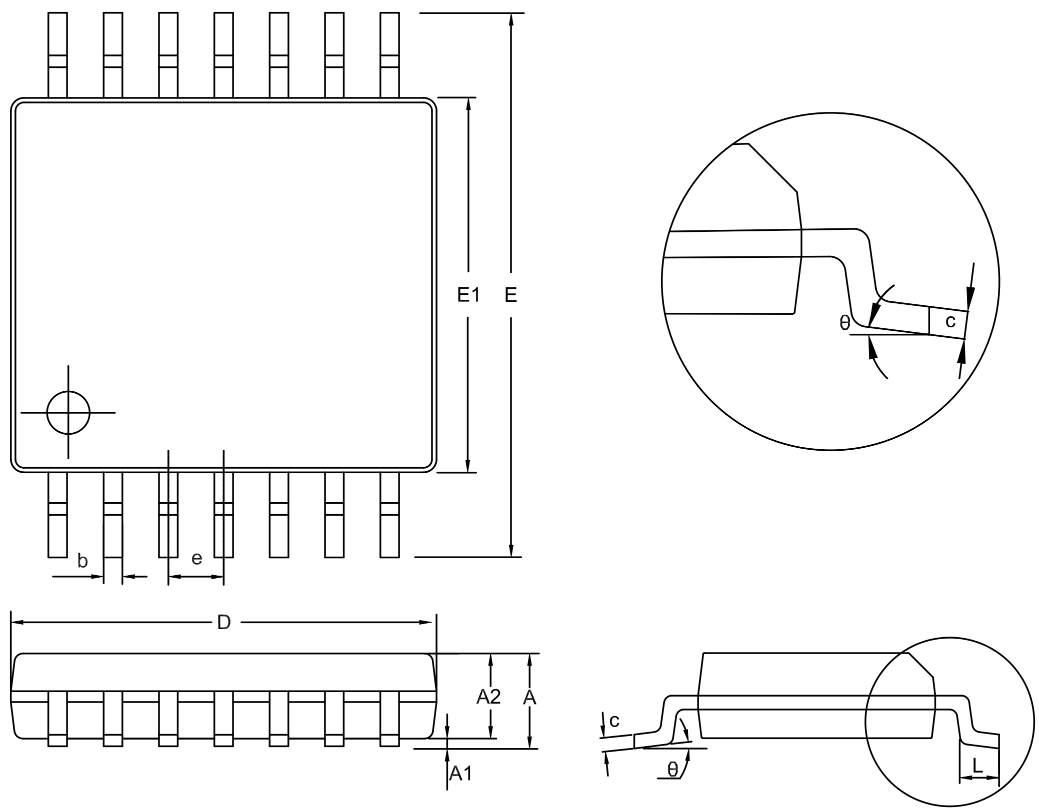

| Symbol | Dimensions In Millimeters | | Dimensions In Inches | |
|---|---|---|---|---|
| | MIN | MAX | MIN | MAX |
| A | 1.350 | 1.750 | 0.053 | 0.069 |
| A1 | 0.050 | 0.250 | 0.002 | 0.010 |
| A2 | 1.250 | 1.650 | 0.049 | 0.065 |
| b | 0.310 | 0.510 | 0.012 | 0.020 |
| c | 0.100 | 0.250 | 0.004 | 0.010 |
| 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 |
|---|---|---|---|---|---|---|
| TP2121-TR | –40°C to 125°C | SOT23-5 | B2T | 3 | Tape and Reel, 3,000 | Green |
| TP2121-CR | –40°C to 125°C | SOT353 (SC70-5) | B2C | 3 | Tape and Reel, 3,000 | Green |
| TP2122-SR | –40°C to 125°C | SOP8 | B22S | 3 | Tape and Reel, 4,000 | Green |
| TP2122-VR | –40°C to 125°C | MSOP8 | B22V | 3 | Tape and Reel, 3,000 | Green |
| TP2124-SR | –40°C to 125°C | SOP14 | B24S | 3 | Tape and Reel, 2,500 | Green |
| TP2124-TR | –40°C to 125°C | TSSOP14 | B24T | 3 | Tape and Reel, 3,000 | Green |

**Green**: 3PEAK defines "Green" to mean RoHS compatible and free of halogen substances.

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