

## TANDEM 64-TAP DIGITAL POTENTIOMETER

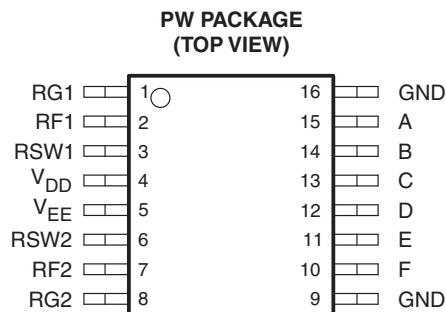
Check for Samples: [TPL8002-25](#)

### FEATURES

- Adjustable Gain From 23.25 dB to –24 dB
- 64-Tap Positions With 0.75 dB Per Step
- Supports 8-MHz Analog Bandwidth
- Operating Range up to  $-4\text{-V } V_{EE}/+4\text{-V } V_{DD}$
- 100- $\mu\text{A}$  Maximum Static Supply Current
- $\pm 30\%$  End-to-End Resistance Tolerance
- Absolute Tolerance of  $\pm 0.3$  dB
- Operating Temperature Range From  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$
- ESD Performance Tested Per JESD 22
  - 2000-V Human-Body Model (A114-B, Class II)

### APPLICATIONS

- Tandem Adjustable Feedback and Gain Resistors for Operational Amplifiers



### DESCRIPTION/ORDERING INFORMATION

The TPL8002-25 is a programmable resistor device implementing two digital potentiometers with 64 wiper positions each that are tandem controlled through a 6-bit parallel interface. The device has fixed wiper resistances at the respective wiper contacts that tap the potentiometer resistors at a point determined by the binary code present at its digital inputs.

The resistive wiper tap terminals, RSW, of the TPL8002-25 are typically connected to the inverting inputs (–) of an external differential path inverting operational amplifier configuration, with the non-inverting inputs (+) connected through to ground. The application's differential input to the configuration is the device's RG terminals. The differential output of the external operational amplifiers is connected to the device's RF terminals, and thus becomes the differential output of the application configuration.

The resistance between the wiper contacts and the end points RG and RF of the TPL8002-25 provides a logarithmic gain/attenuation response of the configuration. With a digital code of decimal 0 (b000000) the configuration has an inverting maximum attenuation of –24 dB. With a digital code of decimal 32 (b100000) the configuration has inverting unity gain of 0.00 dB. With a digital code of decimal 63 (b111111) the configuration has an inverting maximum gain of +23.25 dB. The response of the configuration with respect to the digital code varies in fixed steps of 0.75 dB.

### ORDERING INFORMATION

| T <sub>A</sub> | PACKAGE <sup>(1)</sup> (2)  | ORDERABLE PART NUMBER | TOP-SIDE MARKING |
|----------------|-----------------------------|-----------------------|------------------|
| –40°C to 85°C  | TSSOP – PW<br>Tape and reel | TPL8002-25PWR         | PHY03A           |

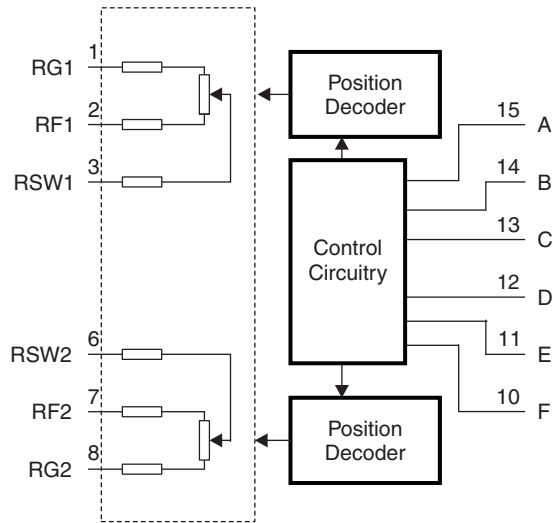
(1) Package drawings, thermal data, and symbolization are available at [www.ti.com/packaging](http://www.ti.com/packaging).

(2) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at [www.ti.com](http://www.ti.com).

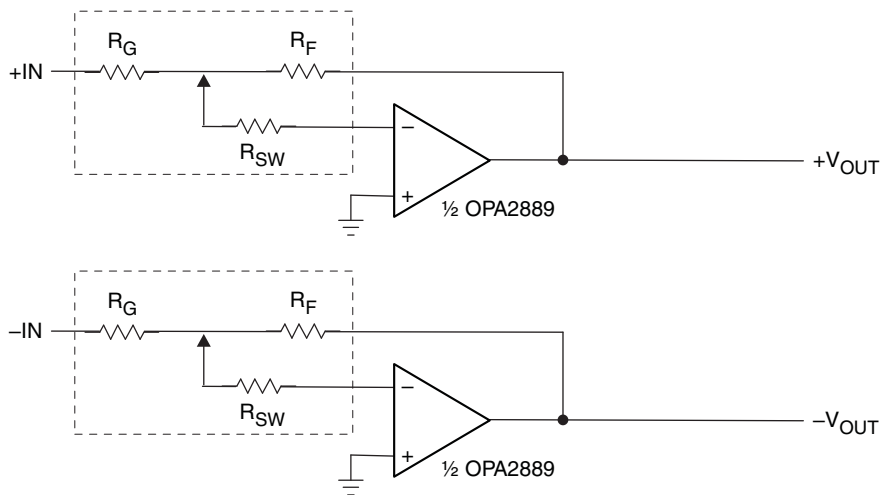


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**FUNCTIONAL BLOCK DIAGRAM**



**TYPICAL APPLICATION CIRCUIT**



## FUNCTION TABLE

**Table 1. Switch Truth Table**

| DECIMAL CONTROL | FEDCBA | GAIN/ATTN (dB) | R <sub>G</sub> (Ω) | R <sub>F</sub> (Ω) |
|-----------------|--------|----------------|--------------------|--------------------|
| 63              | 111111 | 23.25          | 161                | 2339               |
| 62              | 111110 | 22.5           | 174                | 2326               |
| 61              | 111101 | 21.75          | 189                | 2311               |
| 60              | 111100 | 21             | 205                | 2295               |
| 59              | 111011 | 20.25          | 221                | 2279               |
| 58              | 111010 | 19.5           | 239                | 2261               |
| 57              | 111001 | 18.75          | 259                | 2241               |
| 56              | 111000 | 18             | 280                | 2220               |
| 55              | 110111 | 17.25          | 302                | 2198               |
| 54              | 110110 | 16.5           | 325                | 2175               |
| 53              | 110101 | 15.75          | 351                | 2149               |
| 52              | 110100 | 15             | 377                | 2123               |
| 51              | 110011 | 14.25          | 406                | 2094               |
| 50              | 110010 | 13.5           | 436                | 2064               |
| 49              | 110001 | 12.75          | 468                | 2032               |
| 48              | 110000 | 12             | 502                | 1998               |
| 47              | 101111 | 11.25          | 537                | 1963               |
| 46              | 101110 | 10.5           | 575                | 1925               |
| 45              | 101101 | 9.75           | 614                | 1886               |
| 44              | 101100 | 9              | 655                | 1845               |
| 43              | 101011 | 8.25           | 697                | 1803               |
| 42              | 101010 | 7.5            | 742                | 1758               |
| 41              | 101001 | 6.75           | 787                | 1713               |
| 40              | 101000 | 6              | 835                | 1665               |
| 39              | 100111 | 5.25           | 883                | 1617               |
| 38              | 100110 | 4.5            | 933                | 1567               |
| 37              | 100101 | 3.75           | 984                | 1516               |
| 36              | 100100 | 3              | 1036               | 1464               |
| 35              | 100011 | 2.25           | 1089               | 1411               |
| 34              | 100010 | 1.5            | 1142               | 1358               |
| 33              | 100001 | 0.75           | 1196               | 1304               |
| 32              | 100000 | 0              | 1250               | 1250               |
| 31              | 011111 | -0.75          | 1304               | 1196               |
| 30              | 011110 | -1.5           | 1358               | 1142               |
| 29              | 011101 | -2.25          | 1411               | 1089               |
| 28              | 011100 | -3             | 1464               | 1036               |
| 27              | 011011 | -3.75          | 1516               | 984                |
| 26              | 011010 | -4.5           | 1567               | 933                |
| 25              | 011001 | -5.25          | 1617               | 883                |
| 24              | 011000 | -6             | 1665               | 835                |
| 23              | 010111 | -6.75          | 1713               | 787                |
| 22              | 010110 | -7.5           | 1758               | 742                |
| 21              | 010101 | -8.25          | 1803               | 697                |
| 20              | 010100 | -9             | 1845               | 655                |

**Table 1. Switch Truth Table (continued)**

| DECIMAL CONTROL | FEDCBA | GAIN/ATTN (dB) | R <sub>G</sub> (Ω) | R <sub>F</sub> (Ω) |
|-----------------|--------|----------------|--------------------|--------------------|
| 19              | 010011 | -9.75          | 1886               | 614                |
| 18              | 010010 | -10.5          | 1925               | 575                |
| 17              | 010001 | -11.25         | 1963               | 537                |
| 16              | 010000 | -12            | 1998               | 502                |
| 15              | 001111 | -12.75         | 2032               | 468                |
| 14              | 001110 | -13.5          | 2064               | 436                |
| 13              | 001101 | -14.25         | 2094               | 406                |
| 12              | 001100 | -15            | 2123               | 377                |
| 11              | 001011 | -15.75         | 2149               | 351                |
| 10              | 001010 | -16.5          | 2175               | 325                |
| 9               | 001001 | -17.25         | 2198               | 302                |
| 8               | 001000 | -18            | 2220               | 280                |
| 7               | 000111 | -18.75         | 2241               | 259                |
| 6               | 000110 | -19.5          | 2261               | 239                |
| 5               | 000101 | -20.25         | 2279               | 221                |
| 4               | 000100 | -21            | 2295               | 205                |
| 3               | 000011 | -21.75         | 2311               | 189                |
| 2               | 000010 | -22.5          | 2326               | 174                |
| 1               | 000001 | -23.25         | 2339               | 161                |
| 0               | 000000 | -24            | 2352               | 148                |

## ABSOLUTE MAXIMUM RATINGS<sup>(1) (2)</sup>

over operating free-air temperature range (unless otherwise noted)

|                   |   |                                | MIN            | MAX            | UNIT |
|-------------------|---|--------------------------------|----------------|----------------|------|
| $V_{DD} - V_{EE}$ | Power supply delta voltage <sup>(3)</sup>         |                                |                | 10             | V    |
| $V_{DD}$          | Positive supply voltage range <sup>(3)</sup>      |                                | -0.3           | 5              | V    |
| $V_{EE}$          | Negative supply voltage range <sup>(3)</sup>      |                                | 0.3            | -5             | V    |
| $V_{IN}$          | Control input voltage range <sup>(2) (3)</sup>    |                                | -0.3           | $V_{DD} + 0.3$ | V    |
| $V_{I/O}$         | Resistor I/O voltage range <sup>(2) (3) (4)</sup> |                                | $V_{EE} - 0.3$ | $V_{DD} + 0.3$ | V    |
| $I_{IK}$          | Control input clamp current                       | $V_{IN} < 0$ and $V_{I/O} < 0$ |                | -18            | mA   |
| $I_{I/OK}$        | I/O port clamp current                            | $V_{IN} < 0$ and $V_{I/O} < 0$ |                | -18            | mA   |
| $T_{stg}$         | Storage temperature range                         |                                | -40            | 85             | °C   |

- (1) Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltages are with respect to ground, unless otherwise specified.
- (3) The input and output voltage ratings may be exceeded if the input and output clamp-current ratings are observed.
- (4)  $V_I$  and  $V_O$  are used to denote specific conditions for  $V_{I/O}$ .

## RECOMMENDED OPERATING CONDITIONS

over operating free-air temperature range (unless otherwise noted)

|                   |                                  | MIN                  | TYP  | MAX                  | UNIT |
|-------------------|----------------------------------|----------------------|------|----------------------|------|
| $V_{DD} - V_{EE}$ | Power supply delta voltage       |                      |      | 8                    | V    |
| $V_{DD}$          | Positive supply voltage          | 2.5                  | 3.6  | 4                    | V    |
| $V_{EE}$          | Negative supply voltage          | -2.5                 | -3.6 | -4                   | V    |
| $V_{IH}$          | High-level control input voltage | $V_{DD} \times 0.65$ |      |                      | V    |
| $V_{IL}$          | Low-level control input voltage  |                      |      | $V_{DD} \times 0.35$ | V    |
| $V_I$             | Control input voltage            | GND                  |      | $V_{DD}$             | V    |
| $V_{I/O}$         | Resistor inputs/outputs          | $V_{EE}$             |      | $V_{DD}$             | V    |
| $T_A$             | Operating free-air temperature   | -40                  |      | 85                   | °C   |

## ELECTRICAL CHARACTERISTICS

### Dual $\pm 4$ -V Supply

over operating free-air temperature range (unless otherwise noted)

| PARAMETER           |                                    | TEST CONDITIONS   | MIN  | TYP | MAX     | UNIT          |
|---------------------|------------------------------------|---|------|-----|---------|---------------|
| $V_{IK}$            | Control inputs                     | $V_{DD} = 4\text{ V}$ , $I_{IN} = -18\text{ mA}$  |      |     | -1.8    | V             |
| $I_{IN}$            |                                    | $V_{DD} = 4\text{ V}$ , $V_{IN} = V_{DD}$ or GND  |      |     | $\pm 1$ | $\mu\text{A}$ |
| $I_{DD} +  I_{EE} $ |                                    | $V_{DD} = 4\text{ V}$ , $V_{EE} = -4\text{ V}$ , $V_{IN} = V_{DD}$ or GND, $I_{IO} = 0$ |      |     | 100     | $\mu\text{A}$ |
| $C_{IN}$            | Control capacitance <sup>(1)</sup> | $V_{DD} = 4\text{ V}$ , $V_{IN} = V_{DD}$ or GND  |      | 3.2 |         | pF            |
| $C_{RG}$            | RG capacitance <sup>(1)</sup>      | $V_{IN} = 0\text{ V}$ , frequency = 10 MHz  |      | 45  |         | pF            |
| $C_{RF}$            | RF capacitance <sup>(1)</sup>      | $V_{IN} = 0\text{ V}$ , frequency = 10 MHz  |      | 45  |         | pF            |
| $C_W$               | Wiper capacitance <sup>(1)</sup>   | $V_{IN} = 0\text{ V}$ , frequency = 10 MHz  |      | 45  |         | pF            |
| R                   | End-to-end resistance              |   | 1.75 | 2.5 | 3.25    | k $\Omega$    |
| $R_W$               | Wiper resistance                   |   |      |     | 420     | $\Omega$      |
| INL                 | Integral nonlinearity              |   | -0.3 |     | 0.3     | dB            |
| DNL                 | Differential nonlinearity          |   | -0.3 |     | 0.3     | dB            |

- (1) The AC method is a frequency domain measurement. A 10-MHz ac voltage signal of known dc offset and amplitude of 82.5 mV are applied to the pin under test. The imaginary component of the complex current is measured and used in the equation:  
 $C = I_{im} / (2 \times \pi \times F \times V_{IN})$  where  $I_{im}$  = imaginary component of input current,  $V_{IN}$  = magnitude of input voltage, and  $F$  = frequency.

## SWITCHING CHARACTERISTICS<sup>(1)</sup>

over operating free-air temperature range (unless otherwise noted)

| PARAMETER |                              | TEST CONDITIONS                                     | MIN | TYP | MAX | UNIT |
|-----------|------------------------------|---|-----|-----|-----|------|
| $t_{PS}$  | Control to output step delay |   |     | 100 |     | ns   |
| BW        | Analog signal bandwidth      | For a typical example, see <a href="#">Figure 2</a> | 8   |     |     | MHz  |

- (1) Typical bandwidth shown in [Figure 2](#) supports 6 MHz minimum.

PARAMETER MEASUREMENT INFORMATION

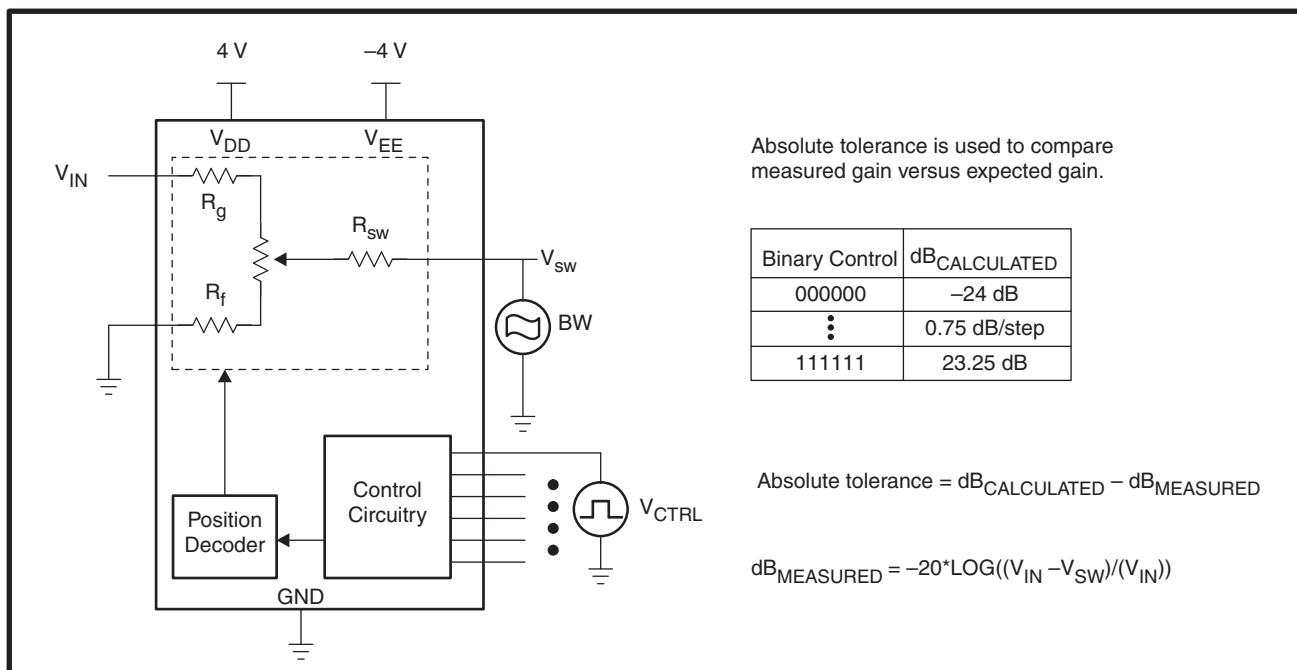


Figure 1. Analog Signal Bandwidth and Absolute Tolerance

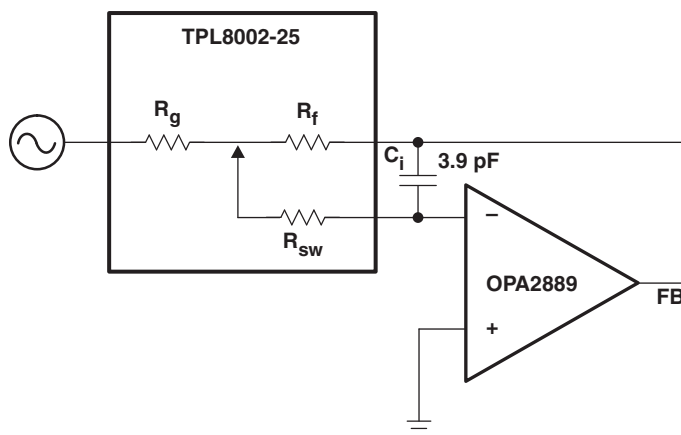


Figure 2. Bandwidth Setup

**PACKAGING INFORMATION**

| Orderable Device | Status<br>(1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan<br>(2)         | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|-----------------|------|-------------|-------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| TPL8002-25PWR    | ACTIVE        | TSSOP        | PW              | 16   | 2000        | Green (RoHS & no Sb/Br) | NIPDAU                  | Level-1-260C-UNLIM   | -40 to 85    | PHY03A                  | <a href="#">Samples</a> |

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSELETE:** TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

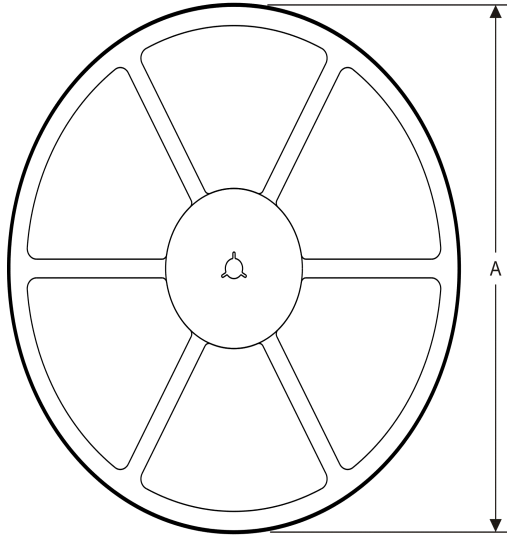
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**TAPE AND REEL INFORMATION**

**REEL DIMENSIONS**



**TAPE DIMENSIONS**



|    |   |
|----|---|
| A0 | Dimension designed to accommodate the component width     |
| B0 | Dimension designed to accommodate the component length    |
| K0 | Dimension designed to accommodate the component thickness |
| W  | Overall width of the carrier tape                         |
| P1 | Pitch between successive cavity centers                   |

**TAPE AND REEL INFORMATION**

\*All dimensions are nominal

| Device        | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TPL8002-25PWR | TSSOP        | PW              | 16   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |

TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device        | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|---------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TPL8002-25PWR | TSSOP        | PW              | 16   | 2000 | 367.0       | 367.0      | 35.0        |



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NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153.

# EXAMPLE BOARD LAYOUT

PW0016A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 10X



SOLDER MASK DETAILS

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NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

PW0016A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE: 10X

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NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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