LM317L 3-Terminal Adjustable Regulator

1 Features
- Output Voltage Range Adjustable 1.25 V to 32 V
- Output Current Capability of 100 mA
- Input Regulation Typically 0.01% Per Input-Voltage Change
- Output Regulation Typically 0.5%
- Ripple Rejection Typically 80 dB
- For Higher Output Current Requirements, See LM317M (500 mA) and LM317 (1.5 A)

2 Applications
- Electronic Points of Sale
- Medical, Health, and Fitness Applications
- Printers
- Appliances and White Goods
- TV Set-Top Boxes

3 Description
The LM317L device is an adjustable, 3-terminal, positive-voltage regulator capable of supplying 100 mA over an output-voltage range of 1.25 V to 32 V. It is exceptionally easy to use and requires only two external resistors to set the output voltage.

Device Information

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>PACKAGE</th>
<th>BODY SIZE (NOM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM317L</td>
<td>SOIC (8)</td>
<td>4.90 mm × 3.91 mm</td>
</tr>
<tr>
<td></td>
<td>TO-92 (3)</td>
<td>4.30 mm × 4.30 mm</td>
</tr>
<tr>
<td></td>
<td>SOT-89 (3)</td>
<td>4.50 mm × 2.50 mm</td>
</tr>
<tr>
<td></td>
<td>TSSOP (8)</td>
<td>3.00 mm × 4.40 mm</td>
</tr>
</tbody>
</table>

4 Simplified Schematic
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5 Revision History

Changes from Revision D (October 2011) to Revision E

- Added Device Information table, Pin Functions table, Handling Ratings table, Thermal Information table, Typical Characteristics, Detailed Description, Application and Implementation, Power Supply Recommendations, Layout, Device and Documentation Support, and Mechanical, Packaging, and Orderable Information sections .................................................. 1
- Deleted Ordering Information table. .......................... 1
6 Pin Configuration and Functions

<table>
<thead>
<tr>
<th>NAME</th>
<th>D, PW</th>
<th>LP, PK</th>
<th>TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADJUSTMENT</td>
<td>4</td>
<td>√</td>
<td>I</td>
<td>Output feedback voltage</td>
</tr>
<tr>
<td>INPUT</td>
<td>1</td>
<td>√</td>
<td>I</td>
<td>Input supply voltage</td>
</tr>
<tr>
<td>NC</td>
<td>5</td>
<td>√</td>
<td>—</td>
<td>No connect</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OUTPUT</td>
<td>2</td>
<td></td>
<td>O</td>
<td>Regulated output voltage</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NC – No internal connection
OUTPUT terminals are all internally connected.
7 Specifications

7.1 Absolute Maximum Ratings\(^{(1)}\)
over operating temperature range (unless otherwise noted)

<table>
<thead>
<tr>
<th></th>
<th>(-40) °C to (125) °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>(V_{i} - V_{o})</td>
<td>35 V</td>
</tr>
<tr>
<td>(T_{J})</td>
<td>150 °C</td>
</tr>
</tbody>
</table>

\(^{(1)}\) 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.

7.2 Handling Ratings

<table>
<thead>
<tr>
<th></th>
<th>(-65) °C to (150) °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>(T_{stg})</td>
<td>0 V</td>
</tr>
<tr>
<td>(V_{(ESD)})</td>
<td>0 V</td>
</tr>
</tbody>
</table>

(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.

7.3 Recommended Operating Conditions

<table>
<thead>
<tr>
<th></th>
<th>(-40) °C to (125) °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>(V_{o})</td>
<td>1.25 V</td>
</tr>
<tr>
<td>(V_{i} - V_{o})</td>
<td>2.5 V</td>
</tr>
<tr>
<td>(I_{O})</td>
<td>2.5 mA</td>
</tr>
<tr>
<td>(T_{J})</td>
<td>LM317LC 0 °C to 125 °C</td>
</tr>
<tr>
<td></td>
<td>LM317LI -40 °C to 125 °C</td>
</tr>
</tbody>
</table>

7.4 Thermal Information

<table>
<thead>
<tr>
<th></th>
<th>(D) (8) PINS</th>
<th>(LP) (3) PINS</th>
<th>(PK) (3) PINS</th>
<th>(PW) (8) PINS</th>
</tr>
</thead>
<tbody>
<tr>
<td>(R_{BAJ})</td>
<td>97.1</td>
<td>139.5</td>
<td>51.5</td>
<td>149.4</td>
</tr>
</tbody>
</table>

\(^{(1)}\) For more information about traditional and new thermal metrics, see the IC Package Thermal Metrics application report (SPRA953).
7.5 Electrical Characteristics

over recommended operating virtual-junction temperature range (unless otherwise noted)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS (1)</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage regulation (2)</td>
<td>( V_i - V_o = 5 ) V to 35 V, ( T_J = 25^\circ C )</td>
<td>0.01</td>
<td>0.02</td>
<td>0.02</td>
<td>% V</td>
</tr>
<tr>
<td></td>
<td>( I_O = 2.5 ) mA to 100 mA</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ripple regulation</td>
<td>( V_O = 10 ) V, ( f = 120 ) Hz</td>
<td>65</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td></td>
<td>( V_O = 10 ) V, ( 10 ) μF capacitor between ADJUSTMENT and ground</td>
<td>65</td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Output voltage regulation</td>
<td>( V_i = 5 ) V to 35 V, ( T_J = 25^\circ C ), ( I_O = 2.5 ) mA to 100 mA, ( V_O \leq 5 ) V</td>
<td>25</td>
<td></td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td>( V_O \geq 5 ) V</td>
<td>5</td>
<td></td>
<td></td>
<td>mV/V</td>
</tr>
<tr>
<td></td>
<td>( V_i = 5 ) V to 35 V, ( I_O = 2.5 ) mA to 100 mA, ( V_O \leq 5 ) V</td>
<td>50</td>
<td></td>
<td></td>
<td>mV/V</td>
</tr>
<tr>
<td></td>
<td>( V_O \geq 5 ) V</td>
<td>10</td>
<td></td>
<td></td>
<td>mV/V</td>
</tr>
<tr>
<td>Output voltage change with temperature</td>
<td>( T_J = 0^\circ C ) to 125°C</td>
<td>10</td>
<td></td>
<td></td>
<td>mV/V</td>
</tr>
<tr>
<td>Output voltage long-term drift</td>
<td>After 1000 hours at ( T_J = 125^\circ C ) and ( V_i - V_O = 35 ) V</td>
<td>3</td>
<td>10</td>
<td></td>
<td>mV/V</td>
</tr>
<tr>
<td>Output noise voltage</td>
<td>( f = 10 ) Hz to 10 kHz, ( T_J = 25^\circ C )</td>
<td>30</td>
<td></td>
<td></td>
<td>μV/V</td>
</tr>
<tr>
<td>Minimum output current to maintain regulation</td>
<td>( V_i - V_O = 35 ) V</td>
<td>1.5</td>
<td>2.5</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>Peak output current</td>
<td>( V_i - V_O = 35 ) V</td>
<td>100</td>
<td>200</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>ADJUSTMENT current</td>
<td>( V_i - V_O = 35 ) V</td>
<td>50</td>
<td>100</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>Change in ADJUSTMENT current</td>
<td>( V_i - V_O = 2.5 ) V to 35 V, ( I_O = 2.5 ) mA to 100 mA</td>
<td>0.2</td>
<td>1.3</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Reference voltage (output to ADJUSTMENT)</td>
<td>( V_i - V_O = 5 ) V to 35 V, ( P \leq ) rated dissipation</td>
<td>1.2</td>
<td>1.3</td>
<td></td>
<td>V</td>
</tr>
</tbody>
</table>

(1) Unless otherwise noted, these specifications apply for the following test conditions: \( V_i - V_O = 5 \) V and \( I_O = 40 \) mA. Pulse-testing techniques must be used that maintain the junction temperature as close to the ambient temperature as possible. All characteristics are measured with a 0.1-μF capacitor across the input and a 1-μF capacitor across the output.

(2) Input voltage regulation is expressed here as the percentage change in output voltage per 1-V change at the input.

7.6 Typical Characteristics

![Figure 1. Change in Adjustment Current Over Temperature](image-url)
8 Detailed Description

8.1 Overview

The LM317L device is a 100-mA linear regulator with high voltage tolerance up to 35 V. The device has a feedback voltage that is relative to the output instead of ground. This ungrounded design allows the LM317L device to have superior line and load regulation. This design also allows the LM317L device to be used as a current source or current sink using a single resistor. Any output voltage from 1.25 to 32 V can be obtained by using two resistors. The bias current of the device, up to 2.5 mA, flows to the output; this current must be used by the load or the feedback resistors. The power dissipation is the product of pass-element voltage and current, which is calculated as shown in Equation 1.

\[ P_D = (V_{IN} - V_{OUT}) \times I_{OUT} \quad (1) \]

The application heat sink must be able to absorb the power calculated in Equation 1.

In addition to higher performance than fixed regulators, this regulator offers full overload protection, available only in integrated circuits. Included on the chip are current-limiting and thermal-overload protection. All overload-protection circuitry remains fully functional even when ADJUSTMENT is disconnected. Normally, no capacitors are needed unless the device is situated far from the input filter capacitors, in which case an input bypass is needed. An optional output capacitor can be added to improve transient response. ADJUSTMENT can be bypassed to achieve very high ripple rejection, which is difficult to achieve with standard three-terminal regulators.

In addition to replacing fixed regulators, the LM317L regulator is useful in a wide variety of other applications. Since the regulator is floating and sees only the input-to-output differential voltage, supplies of several hundred volts can be regulated as long as the maximum input-to-output differential is not exceeded. Its primary application is that of a programmable output regulator, but by connecting a fixed resistor between ADJUSTMENT and OUTPUT, this device can be used as a precision current regulator. Supplies with electronic shutdown can be achieved by clamping ADJUSTMENT to ground, programming the output to 1.25 V, where most loads draw little current.

The LM317LC device is characterized for operation over the virtual junction temperature range of 0°C to 125°C. The LM317LI device is characterized for operation over the virtual junction temperature range of –40°C to 125°C.

8.2 Functional Block Diagram
8.3 Feature Description

8.3.1 NPN Darlington Output Drive
NPN Darlington output topology provides naturally low output impedance and an output capacitor is optional. To support maximum current and lowest temperature, 2.5-V headroom is recommended ($V_I - V_O$).

8.3.2 Overload Block
Over-current and over-temperature shutdown protects the device against overload or damage from operating in excessive heat.

8.3.3 Programmable Feedback
Op amp with 1.25-V offset input at the ADJUST pin provides easy output voltage or current (not both) programming. For current regulation applications, a single resistor whose resistance value is $1.25 \, \text{V} / I_{\text{OUT}}$ and power rating is greater than $(1.25 \, \text{V})^2 / R$ should be used. For voltage regulation applications, two resistors set the output voltage. See Typical Application for a schematic and the resistor formula.

8.4 Device Functional Modes

8.4.1 Normal operation
The device OUTPUT pin will source current necessary to make OUTPUT pin 1.25 V greater than ADJUST terminal to provide output regulation.

8.4.2 Operation With Low Input Voltage
The device requires up to 2.5-V headroom ($V_I - V_O$) to operate in regulation. With less headroom, the device may drop out and OUTPUT voltage will be INPUT voltage minus drop out voltage.

8.4.3 Operation at Light Loads
The device passes its bias current to the OUTPUT pin. The load or feedback must consume this minimum current for regulation or the output may be too high.

8.4.4 Operation In Self Protection
When an overload occurs the device will shut down Darlington NPN output stage or reduce the output current to prevent device damage. The device will automatically reset from the overload. The output may be reduced or alternate between on and off until the overload is removed.
9 Application and Implementation

NOTE
Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI’s customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

9.1 Application Information
The two output resistors are the only components required to adjust $V_{OUT}$.

9.2 Typical Application

9.2.1 Design Requirements
1. Use of an input bypass capacitor is recommended if regulator is far from the filter capacitors.
2. For this design example, use the parameters listed in Table 1.
3. Use of an output capacitor improves transient response, but is optional.

Table 1. Design Parameters

<table>
<thead>
<tr>
<th>DESIGN PARAMETER</th>
<th>EXAMPLE VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input voltage range</td>
<td>(Output Voltage + 2.5 V) to 32 V</td>
</tr>
<tr>
<td>Output voltage</td>
<td>$V_{REF} \times \left(1 + \frac{R_2}{R_1}\right) + I_{ADJ} \times R_2$</td>
</tr>
</tbody>
</table>

9.2.2 Detailed Design Procedure

9.2.2.1 Input Capacitor
An input capacitor is not required, but it is recommended, particularly if the regulator is not in close proximity to the power-supply filter capacitors. A 0.1-µF ceramic or 1-µF tantalum provides sufficient bypassing for most applications, especially when adjustment and output capacitors are used.

9.2.2.2 Output Capacitor
An output capacitor improves transient response, but it not needed for stability.

9.2.2.3 Feedback Resistors
The feedback resistor set the output voltage using Equation 2.

$$V_{REF} \times \left(1 + \frac{R_2}{R_1}\right) + I_{ADJ} \times R_2$$ (2)
9.2.2.4 Adjustment Terminal Capacitor

The optional adjustment pin capacitor will improve ripple rejection by preventing the amplification of the ripple. When capacitor is used and $V_{\text{OUT}} > 6\,\text{V}$, a protection diode from adjust to output is recommended.

9.2.2.5 Design Options and Parameters

Common Linear Regulator designs are concerned with the following parameters:

- Input voltage range
- Input capacitor range
- Output voltage
- Output current rating
- Output capacitor range
- Input short protection
- Stability
- Ripple rejection

9.2.2.6 Output Voltage

$V_O$ is calculated as shown in Equation 3.

\[
V_{\text{OUT}} = V_{\text{REF}} \times \left( 1 + \frac{R_2}{R_1} \right) + (I_{\text{ADJ}} \times R_2)
\]

(3)

Because $I_{\text{ADJ}}$ typically is 50 $\mu\text{A}$, it is negligible in most applications.

9.2.2.7 Ripple Rejection

$C_{\text{ADJ}}$ is used to improve ripple rejection; it prevents amplification of the ripple as the output voltage is adjusted higher. If $C_{\text{ADJ}}$ is used, it is best to include protection diodes.

9.2.2.8 Input Short Protection

If the input is shorted to ground during a fault condition, protection diodes provide measures to prevent the possibility of external capacitors discharging through low-impedance paths in the IC. By providing low-impedance discharge paths for $C_O$ and $C_{\text{ADJ}}$, respectively, D1 and D2 prevent the capacitors from discharging into the output of the regulator.

9.2.3 Application Curves

![Figure 2. Adjustment Voltage Relative to Output Over Temperature](image)
9.3 General Configurations

9.3.1 Regulator Circuit With Improved Ripple Rejection
C2 helps to stabilize the voltage at the adjustment pin, which will help reject noise. Diode D1 exists to discharge C2 in case the output is shorted to ground.

![Figure 3. Regulator Circuit With Improved Ripple Rejection](image)

\[ V_{OUT} = V_{REF} \left( 1 + \frac{R_2 + R_3}{R_1} \right) - 10 \text{V} \]  

(4)

9.3.2 0-V to 30-V Regulator Circuit
In the 0-V to 30-V regulator circuit application, the output voltage is determined by Equation 4.

![Figure 4. 0-V to 30-V Regulator Circuit](image)

9.3.3 Precision Current-Limiter Circuit
This application will limit the output current to the \( I_{LIMIT} \) shown in Figure 5.

![Figure 5. Precision Current-Limiter Circuit](image)
General Configurations (continued)

9.3.4 Tracking Preregulator Circuit

The tracking preregulator circuit application keeps a constant voltage across the second LM317L in the circuit.

![Tracking Preregulator Circuit Diagram](image)

**Figure 6. Tracking Preregulator Circuit**

9.3.5 Slow-Turn On 15-V Regulator Circuit

The capacitor C1, in combination with the PNP transistor, helps the circuit to slowly start supplying voltage. In the beginning, the capacitor is not charged. Therefore, output voltage will start at 1.9 V, as determined by Equation 5. As the capacitor voltage rises, \( V_{\text{OUT}} \) will rise at the same rate. When the output voltage reaches the value determined by R1 and R2, the PNP will be turned off.

\[
V_{C1} + V_{\text{BE}} + 1.25 \, \text{V} = 0 \, \text{V} + 0.65 \, \text{V} + 1.25 \, \text{V} = 1.9 \, \text{V}
\]  

(5)

![Slow-Turn On 15-V Regulator Circuit Diagram](image)

**Figure 7. Slow-Turn On 15-V Regulator Circuit**
General Configurations (continued)

9.3.6 50-mA Constant-Current Battery-Charger Circuit

The current-limit operation mode can be used to trickle charge a battery at a fixed current as determined by Equation 6. $V_I$ should be greater than $V_{BAT} + 3.75\, V$.

$$I_{CHG} = \frac{1.25\, V}{24\, \Omega}$$  
(6)

$$(1.25\, V \left[V_{REF}\right] + 2.5\, V \left[headroom\right])$$  
(7)

**Figure 8. 50-mA Constant-Current Battery-Charger Circuit**

9.3.7 Current-Limited 6-V Charger

As the charge current increases, the voltage at the bottom resistor increases until the NPN starts sinking current from the adjustment pin. The voltage at the adjustment pin will drop, and consequently the output voltage will decrease until the NPN stops conducting.

**Figure 9. Current-Limited 6-V Charger**
General Configurations (continued)

9.3.8 High-Current Adjustable Regulator

This application allows higher currents at $V_{OUT}$ than the LM317L device can provide, while still keeping the output voltage at levels determined by the adjustment-pin resistor divider of the LM317L.

![Diagram of High-Current Adjustable Regulator](image)

Figure 10. High-Current Adjustable Regulator
10 Power Supply Recommendations

The LM317L device is designed to operate from an input voltage supply range between 2.5 V to 32 V greater than the output voltage. If the device is more than six inches from the input filter capacitors, an input bypass capacitor, 0.1 µF or greater, of any type is needed for stability.

11 Layout

11.1 Layout Guidelines

- It is recommended that the input pin be bypassed to ground with a bypass-capacitor.
- The optimum placement is closest to the VIN of the device and GND of the system. Care must be taken to minimize the loop area formed by the bypass-capacitor connection, the VIN pin, and the GND pin of the system.
- For operation at full-rated load, it is recommended to use wide trace lengths to eliminate IR drop and heat dissipation.

11.2 Layout Example

![Layout Diagram](image-url)

Figure 11. Layout Diagram
12 Device and Documentation Support

12.1 Trademarks
All trademarks are the property of their respective owners.

12.2 Electrostatic Discharge Caution

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

12.3 Glossary

SLYZ022 — *Ti Glossary.*
This glossary lists and explains terms, acronyms, and definitions.

13 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.
## Packaging Information

<table>
<thead>
<tr>
<th>Orderable Device</th>
<th>Status</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>Package Qty</th>
<th>Eco Plan</th>
<th>Lead/Ball Finish</th>
<th>MSL Peak Temp</th>
<th>Op Temp (°C)</th>
<th>Device Marking</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM317LCD</td>
<td>ACTIVE</td>
<td>SOIC</td>
<td>D</td>
<td>8</td>
<td>75</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-1-260C-UNLIM</td>
<td>0 to 125</td>
<td>L317LC</td>
<td></td>
</tr>
<tr>
<td>LM317LCDR</td>
<td>ACTIVE</td>
<td>SOIC</td>
<td>D</td>
<td>8</td>
<td>2500</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-1-260C-UNLIM</td>
<td>0 to 125</td>
<td>L317LC</td>
<td></td>
</tr>
<tr>
<td>LM317LCDRG4</td>
<td>ACTIVE</td>
<td>SOIC</td>
<td>D</td>
<td>8</td>
<td>2500</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-1-260C-UNLIM</td>
<td>0 to 125</td>
<td>L317LC</td>
<td></td>
</tr>
<tr>
<td>LM317LCLP</td>
<td>ACTIVE</td>
<td>TO-92</td>
<td>LP</td>
<td>3</td>
<td>1000</td>
<td>Pb-Free (RoHS)</td>
<td>CU SN</td>
<td>N / A for Pkg Type</td>
<td>0 to 125</td>
<td>L317LC</td>
<td></td>
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<tr>
<td>LM317LCLPR</td>
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<td>TO-92</td>
<td>LP</td>
<td>3</td>
<td>2000</td>
<td>Pb-Free (RoHS)</td>
<td>CU SN</td>
<td>N / A for Pkg Type</td>
<td>0 to 125</td>
<td>L317LC</td>
<td></td>
</tr>
<tr>
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<td>Lead/Ball Finish</td>
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<td>Op Temp (°C)</td>
<td>Device Marking (4/5)</td>
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<td>L317LI</td>
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</table>

(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.
OBsolete: 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

![Reel Dimensions Diagram]

### TAPE DIMENSIONS

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<tr>
<th>A0</th>
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<th>K0</th>
<th>W</th>
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- **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

### PACKAGE MATERIALS INFORMATION

*All dimensions are nominal.*

<table>
<thead>
<tr>
<th>Device</th>
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<th>Package Drawing</th>
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<th>SPQ</th>
<th>Reel Diameter (mm)</th>
<th>Reel Width W1 (mm)</th>
<th>A0 (mm)</th>
<th>B0 (mm)</th>
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Pack Materials-Page 1
### TAPE AND REEL BOX DIMENSIONS

*All dimensions are nominal*

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NOTES:  A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
B. This drawing is subject to change without notice.
C. The center lead is in electrical contact with the tab.
D. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion not to exceed 0.15 per side.
E. Thermal pad contour optional within these dimensions.
F. Falls within JEDEC TO-243 variation AA, except minimum lead length, pin 2 minimum lead width, minimum tab width.
NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
   ▲ Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0.15) each side.
   ▲ Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0.43) each side.
E. Reference JEDEC MS-012 variation AA.

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NOTES:

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. 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 .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.
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.
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.
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, variation AA.
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.
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.
Images above are just a representation of the package family, actual package may vary. Refer to the product data sheet for package details.
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. Lead dimensions are not controlled within this area.
4. Reference JEDEC TO-226, variation AA.
5. Shipping method:
   a. Straight lead option available in bulk pack only.
   b. Formed lead option available in tape and reel or ammo pack.
   c. Specific products can be offered in limited combinations of shipping medium and lead options.
   d. Consult product folder for more information on available options.
EXAMPLE BOARD LAYOUT

TO-92 - 5.34 mm max height

LAND PATTERN EXAMPLE
STRAIGHT LEAD OPTION
NON-SOLDER MASK DEFINED
SCALE: 15X

LAND PATTERN EXAMPLE
FORMED LEAD OPTION
NON-SOLDER MASK DEFINED
SCALE: 15X
TAPE SPECIFICATIONS

LP0003A
TO-92 - 5.34 mm max height

FOR FORMED LEAD OPTION PACKAGE
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