NE5532x, SA5532x Dual Low-Noise Operational Amplifiers

1 Features

- Equivalent Input Noise Voltage: 5 nV/√Hz Typ at 1 kHz
- Unity-Gain Bandwidth: 10 MHz Typ
- Common-Mode Rejection Ratio: 100 dB Typ
- High DC Voltage Gain: 100 V/mV Typ
- Peak-to-Peak Output Voltage Swing 26 V Typ
- With $V_{CC} = \pm 15 \text{V}$ and $R_L = 600 \Omega$
- High Slew Rate: 9 V/μs Typ

2 Applications

- AV Receivers
- Embedded PCs
- Netbooks
- Video Broadcasting and Infrastructure: Scalable Platforms
- DVD Recorders and Players
- Multichannel Video Transcoders
- Pro Audio Mixers

3 Description

The NE5532, NE5532A, SA5532, and SA5532A devices are high-performance operational amplifiers combining excellent DC and AC characteristics. They feature very low noise, high output-drive capability, high unity-gain and maximum-output-swing bandwidths, low distortion, high slew rate, input-protection diodes, and output short-circuit protection. These operational amplifiers are compensated internally for unity-gain operation. These devices have specified maximum limits for equivalent input noise voltage.

4 Simplified Schematic

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VOUT
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5 Revision History

Changes from Revision I (April 2009) to Revision J Page

- Added Applications, Device Information table, Pin Functions table, ESD Ratings table, Thermal Information table, Typical Characteristics, Feature Description section, Device Functional Modes, Application and Implementation section, Power Supply Recommendations section, Layout section, Device and Documentation Support section, and Mechanical, Packaging, and Orderable Information section. ................................................................................................. 1
- Deleted Ordering Information table. ................................................................................................................. 1
6 Pin Configuration and Functions

<table>
<thead>
<tr>
<th>PIN</th>
<th>TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1IN+</td>
<td>I</td>
<td>Noninverting input</td>
</tr>
<tr>
<td>1IN-</td>
<td>I</td>
<td>Inverting Input</td>
</tr>
<tr>
<td>OUT1</td>
<td>O</td>
<td>Output</td>
</tr>
<tr>
<td>2IN+</td>
<td>I</td>
<td>Noninverting input</td>
</tr>
<tr>
<td>2IN-</td>
<td>I</td>
<td>Inverting Input</td>
</tr>
<tr>
<td>2OUT</td>
<td>O</td>
<td>Output</td>
</tr>
<tr>
<td>VCC+</td>
<td>—</td>
<td>Positive Supply</td>
</tr>
<tr>
<td>VCC-</td>
<td>—</td>
<td>Negative Supply</td>
</tr>
</tbody>
</table>

NE5532, NE5532A . . . D, P, OR PS PACKAGE
SA5532, SA5532A . . . D OR P PACKAGE
(TOP VIEW)

1OUT □ 1  8 □ Vcc.
1IN– □ 2  7 □ 2OUT
1IN+ □ 3  6 □ 2IN–
Vcc □ 4  5 □ 2IN+
7 Specifications

7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)\(^{(1)}\)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(V_{CC}) Supply voltage(^{(2)})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(V_{CC+})</td>
<td>0</td>
<td>22</td>
<td>V</td>
</tr>
<tr>
<td>(V_{CC-})</td>
<td>–22</td>
<td>0</td>
<td>V</td>
</tr>
<tr>
<td>Input voltage, either input(^{(2)(3)})</td>
<td>(V_{CC-})</td>
<td>(V_{CC+})</td>
<td>V</td>
</tr>
<tr>
<td>Input current(^{(4)})</td>
<td>–10</td>
<td>10</td>
<td>mA</td>
</tr>
<tr>
<td>Duration of output short circuit(^{(5)})</td>
<td>Unlimited</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(T_J) Operating virtual-junction temperature</td>
<td>150</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>(T_{stg}) Storage temperature range</td>
<td>–65</td>
<td>150</td>
<td>°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.

\(^{(2)}\) All voltage values, except differential voltages, are with respect to the midpoint between \(V_{CC+}\) and \(V_{CC-}\).

\(^{(3)}\) The magnitude of the input voltage must never exceed the magnitude of the supply voltage.

\(^{(4)}\) Excessive input current will flow if a differential input voltage in excess of approximately 0.6 V is applied between the inputs, unless some limiting resistance is used.

\(^{(5)}\) The output may be shorted to ground or either power supply. Temperature and/or supply voltages must be limited to ensure the maximum dissipation rating is not exceeded.

7.2 ESD Ratings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>VALUE</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(V_{(ESD)}) Electrostatic discharge</td>
<td>Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins(^{(1)})</td>
<td>2000</td>
</tr>
<tr>
<td></td>
<td>Charged device model (CDM), per JEDEC specification JESD22-C101, all pins(^{(2)})</td>
<td>1000</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>Parameter</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(V_{CC+}) Supply voltage</td>
<td>5</td>
<td>15</td>
<td>V</td>
</tr>
<tr>
<td>(V_{CC-}) Supply voltage</td>
<td>–5</td>
<td>–15</td>
<td>V</td>
</tr>
<tr>
<td>(T_A) Operating free-air temperature</td>
<td>NE5532, NE5532A</td>
<td>0</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td>SA5532, SA5532A</td>
<td>–40</td>
<td>85</td>
</tr>
</tbody>
</table>

7.4 Thermal Information

<table>
<thead>
<tr>
<th>THERMAL METRIC(^{(1)})</th>
<th>NE5532, NE5532A, SA5532, and SA5532A</th>
</tr>
</thead>
<tbody>
<tr>
<td>(R_{NJ/A}) Junction-to-ambient thermal resistance (^{(2)(3)})</td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>97</td>
</tr>
</tbody>
</table>

\(^{(1)}\) For more information about traditional and new thermal metrics, see the IC Package Thermal Metrics application report, SPR953.

\(^{(2)}\) The package thermal impedance is calculated in accordance with JEDEC 51-7.

\(^{(3)}\) Maximum power dissipation is a function of \(T_j(max)\), \(\theta_{JA}\), and \(T_A\). The maximum allowable power dissipation at any allowable ambient temperature is \(P_D = (T_j(max) – T_A) / \theta_{JA}\). Operating at the absolute maximum \(T_j\) of 150°C can affect reliability.
### 7.5 Electrical Characteristics

$V_{CC} = \pm 15 \, V$, $T_A = 25^\circ C$ (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>$V_{IO}$ Input offset voltage</td>
<td>$V_O = 0$ $T_A = 25^\circ C$</td>
<td>0.5</td>
<td>4</td>
<td>5</td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td>$T_A = $ Full range (2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{IO}$ Input offset current</td>
<td>$T_A = 25^\circ C$</td>
<td>10</td>
<td>150</td>
<td>nA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$T_A = $ Full range (2)</td>
<td></td>
<td>200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{IB}$ Input bias current</td>
<td>$T_A = 25^\circ C$</td>
<td>200</td>
<td>800</td>
<td>nA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$T_A = $ Full range (2)</td>
<td></td>
<td>1000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{ICR}$ Common-mode input-voltage range</td>
<td></td>
<td>±12</td>
<td>±13</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$V_{OPP}$ Maximum peak-to-peak output-voltage swing</td>
<td>$R_L \geq 600 , \Omega, V_{CC} = \pm 15 , V$</td>
<td>24</td>
<td>26</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$A_{VD}$ Large-signal differential-voltage amplification</td>
<td>$R_L \geq 600 , \Omega, V_O = \pm 10 , V$</td>
<td>15</td>
<td>50</td>
<td>V/mV</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$T_A = $ Full range (2)</td>
<td></td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$R_L \geq 2 , k\Omega, V_O \pm 10 , V$</td>
<td>25</td>
<td>100</td>
<td>V/mV</td>
<td></td>
</tr>
<tr>
<td>$A_{sd}$ Small-signal differential-voltage amplification</td>
<td>$f = 10 , kHz$</td>
<td>2.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B_{OM}$ Maximum output-swing bandwidth</td>
<td>$R_L = 600 , \Omega, V_O = \pm 10 , V$</td>
<td>140</td>
<td>kHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B_1$ Unity-gain bandwidth</td>
<td>$R_L = 600 , \Omega, C_L = 100 , pF$</td>
<td>10</td>
<td>MHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$r_i$ Input resistance</td>
<td></td>
<td>30</td>
<td>300</td>
<td>kΩ</td>
<td></td>
</tr>
<tr>
<td>$z_o$ Output impedance</td>
<td>$A_{VD} = 30 , dB, R_L = 600 , \Omega, f = 10 , kHz$</td>
<td>0.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$k_{SVR}$ Supply-voltage rejection ratio ($\Delta V_{CC}/\Delta V_O$)</td>
<td>$V_{CC} = \pm 9 , V$ to $\pm 15 , V, V_O = 0$</td>
<td>80</td>
<td>100</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td>$I_{OS}$ Total supply current</td>
<td></td>
<td>10</td>
<td>38</td>
<td>60</td>
<td>mA</td>
</tr>
<tr>
<td>Crosstalk attenuation ($V_{O1}/V_{O2}$)</td>
<td>$V_{O1} = 10 , V$ peak, $f = 1 , kHz$</td>
<td>8</td>
<td>16</td>
<td>dB</td>
<td></td>
</tr>
</tbody>
</table>

(1) All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified.

(2) Full temperature ranges are: –40°C to 85°C for the SA5532 and SA5532A devices, and 0°C to 70°C for the NE5532 and NE5532A devices.

### 7.6 Operating Characteristics

$V_{CC} = \pm 15 \, V$, $T_A = 25^\circ C$ (unless otherwise noted)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>NE5532, SA5532</th>
<th>NE5532A, SA5532A</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MIN</td>
<td>TYP</td>
<td>MAX</td>
</tr>
<tr>
<td>SR Slew rate at unity gain</td>
<td>$V_I = 100 , mV, R_L = 600 , \Omega, A_{VD} = 1, C_L = 100 , pF$</td>
<td>9</td>
<td>9</td>
<td>V/μs</td>
</tr>
<tr>
<td>Overshoot factor</td>
<td></td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>$V_n$ Equivalent input noise voltage</td>
<td>$f = 30 , Hz$</td>
<td>8</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>$f = 1 , kHz$</td>
<td>5</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>$I_n$ Equivalent input noise current</td>
<td>$f = 30 , Hz$</td>
<td>2.7</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$f = 1 , kHz$</td>
<td>0.7</td>
<td>0.7</td>
<td></td>
</tr>
</tbody>
</table>
7.7 Typical Characteristics

Figure 1. Equivalent Input Noise Voltage vs Frequency

Figure 2. Equivalent Input Noise Current vs Frequency

Figure 3. Output Swing Bandwidth vs Temperature at $V_{CC} = \pm10$ V
8 Detailed Description

8.1 Overview
The NE5532, NE5532A, SA5532, and SA5532A devices are high-performance operational amplifiers combining excellent dc and ac characteristics. They feature very low noise, high output-drive capability, high unity-gain and maximum-output-swing bandwidths, low distortion, high slew rate, input-protection diodes, and output short-circuit protection. These operational amplifiers are compensated internally for unity-gain operation. These devices have specified maximum limits for equivalent input noise voltage.

8.2 Functional Block Diagram

8.3 Feature Description
8.3.1 Unity-Gain Bandwidth
The unity-gain bandwidth is the frequency up to which an amplifier with a unity gain may be operated without greatly distorting the signal. The NE5532, NE5532A, SA5532, and SA5532A devices have a 10-MHz unity-gain bandwidth.

8.3.2 Common-Mode Rejection Ratio
The common-mode rejection ratio (CMRR) of an amplifier is a measure of how well the device rejects unwanted input signals common to both input leads. It is found by taking the ratio of the change in input offset voltage to the change in the input voltage and converting to decibels. Ideally the CMRR would be infinite, but in practice, amplifiers are designed to have it as high as possible. The CMRR of the NE5532, NE5532A, SA5532, and SA5532A devices is 100 dB.

8.3.3 Slew Rate
The slew rate is the rate at which an operational amplifier can change its output when there is a change on the input. The NE5532, NE5532A, SA5532, and SA5532A devices have a 9-V/ms slew rate.

8.4 Device Functional Modes
The NE5532, NE5532A, SA5532, and SA5532A devices are powered on when the supply is connected. Each of these devices can be operated as a single supply operational amplifier or dual supply amplifier depending on the application.
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 Typical Application
Some applications require differential signals. Figure 4 shows a simple circuit to convert a single-ended input of 2 V to 10 V into differential output of ±8 V on a single 15-V supply. The output range is intentionally limited to maximize linearity. The circuit is composed of two amplifiers. One amplifier acts as a buffer and creates a voltage, \( V_{OUT+} \). The second amplifier inverts the input and adds a reference voltage to generate \( V_{OUT–} \). Both \( V_{OUT+} \) and \( V_{OUT–} \) range from 2 V to 10 V. The difference, \( V_{DIFF} \), is the difference between \( V_{OUT+} \) and \( V_{OUT–} \).

Figure 4. Schematic for Single-Ended Input to Differential Output Conversion

9.1.1 Design Requirements
The design requirements are as follows:
- Supply voltage: 15 V
- Reference voltage: 12 V
- Input: 2 V to 10 V
- Output differential: ±8 V
9.1.2 Detailed Design Procedure

The circuit in Figure 4 takes a single-ended input signal, $V_{IN}$, and generates two output signals, $V_{OUT+}$ and $V_{OUT-}$ using two amplifiers and a reference voltage, $V_{REF}$. $V_{OUT+}$ is the output of the first amplifier and is a buffered version of the input signal, $V_{IN}$. Equation 1. $V_{OUT-}$ is the output of the second amplifier which uses $V_{REF}$ to add an offset voltage to $V_{IN}$ and feedback to add inverting gain. The transfer function for $V_{OUT-}$ is Equation 2.

\[
V_{OUT+} = V_{IN} \tag{1}
\]

\[
V_{OUT-} = V_{REF} - V_{IN} \tag{5}
\]

\[
V_{DIFF} = 2V_{IN} - V_{REF} \tag{6}
\]

\[
V_{cm} = \left( \frac{V_{OUT+} + V_{OUT-}}{2} \right) = \frac{1}{2} V_{REF} \tag{7}
\]

The differential output signal, $V_{DIFF}$, is the difference between the two single-ended output signals, $V_{OUT+}$ and $V_{OUT-}$. Equation 3 shows the transfer function for $V_{DIFF}$. By applying the conditions that $R_1 = R_2$ and $R_3 = R_4$, the transfer function is simplified into Equation 6. Using this configuration, the maximum input signal is equal to the reference voltage and the maximum output of each amplifier is equal to the $V_{REF}$. The differential output range is $2 \times V_{REF}$. Furthermore, the common mode voltage will be one half of $V_{REF}$ (see Equation 7).

\[
V_{DIFF} = V_{OUT+} - V_{OUT-} = V_{IN} \left( 1 + \frac{R_2}{R_1} \right) - V_{REF} \left( \frac{R_4}{R_3 + R_4} \right) \left( 1 + \frac{R_2}{R_1} \right) \tag{3}
\]

9.1.2.1 Amplifier Selection

Linearity over the input range is key for good dc accuracy. The common mode input range and the output swing limitations determine the linearity. In general, an amplifier with rail-to-rail input and output swing is required. Bandwidth is a key concern for this design. Since the NE5532 has a bandwidth of 10 MHz, this circuit will only be able to process signals with frequencies of less than 10 MHz.

9.1.2.2 Passive Component Selection

Because the transfer function of $V_{OUT-}$ is heavily reliant on resistors ($R_1$, $R_2$, $R_3$, and $R_4$), use resistors with low tolerances to maximize performance and minimize error. This design used resistors with resistance values of 36 kΩ with tolerances measured to be within 2%. But, if the noise of the system is a key parameter, the user can select smaller resistance values (6 kΩ or lower) to keep the overall system noise low. This ensures that the noise from the resistors is lower than the amplifier noise.

9.1.3 Application Curves

The measured transfer functions in Figure 5, Figure 6, and Figure 7 were generated by sweeping the input voltage from 0 V to 12 V. However, this design should only be used between 2 V and 10 V for optimum linearity.
Typical Application (continued)

Figure 5. Differential Output Voltage vs Input Voltage

Figure 6. Positive Output Voltage Node vs Input Voltage

Figure 7. Positive Output Voltage Node vs Input Voltage
10 Power Supply Recommendations

The NE5532x and SA5532x devices are specified for operation over the range of ±5 to ±15 V; many specifications apply from 0°C to 70°C (NE5532x) and -40°C to 85°C (SA5532x). The Typical Characteristics section presents parameters that can exhibit significant variance with regard to operating voltage or temperature.

CAUTION

Supply voltages outside of the ±22 V range can permanently damage the device (see the Absolute Maximum Ratings).

Place 0.1-μF bypass capacitors close to the power-supply pins to reduce errors coupling in from noisy or high impedance power supplies. For more detailed information on bypass capacitor placement, refer to the Layout Guidelines.

11 Layout

11.1 Layout Guidelines

For best operational performance of the device, use good PCB layout practices, including:

- Noise can propagate into analog circuitry through the power pins of the circuit as a whole and the operational amplifier. Bypass capacitors are used to reduce the coupled noise by providing low impedance power sources local to the analog circuitry.
  - Connect low-ESR, 0.1-μF ceramic bypass capacitors between each supply pin and ground, placed as close to the device as possible. A single bypass capacitor from V+ to ground is applicable for single supply applications.

- Separate grounding for analog and digital portions of circuitry is one of the simplest and most-effective methods of noise suppression. One or more layers on multilayer PCBs are usually devoted to ground planes. A ground plane helps distribute heat and reduces EMI noise pickup. Make sure to physically separate digital and analog grounds, paying attention to the flow of the ground current. For more detailed information, refer to Circuit Board Layout Techniques, SLOA089.

- To reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If it is not possible to keep them separate, it is much better to cross the sensitive trace perpendicular as opposed to in parallel with the noisy trace.

- Place the external components as close to the device as possible. Keeping RF and RG close to the inverting input minimizes parasitic capacitance, as shown in Layout Example.

- Keep the length of input traces as short as possible. Always remember that the input traces are the most sensitive part of the circuit.

- Consider a driven, low-impedance guard ring around the critical traces. A guard ring can significantly reduce leakage currents from nearby traces that are at different potentials.

11.2 Layout Example

![Operational Amplifier Schematic for Noninverting Configuration](image)

Figure 8. Operational Amplifier Schematic for Noninverting Configuration
Run the input traces as far away from the supply lines as possible.

Place components close to device and to each other to reduce parasitic errors.

Only needed for dual-supply operation (or GND for single supply).

Use low-ESR, ceramic bypass capacitor.

Ground (GND) plane on another layer.

Figure 9. Operational Amplifier Board Layout for Noninverting Configuration.
12 Device and Documentation Support

12.1 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

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</table>

12.2 Trademarks

All trademarks are the property of their respective owners.

12.3 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

12.4 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.
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(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 substances 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 finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material 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 Diameter**
- **Reel Width (W1)**

#### 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

#### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE

- **Pocket Quadrants**
- **Sprocket Holes**
- **User Direction of Feed**

*All dimensions are nominal*

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*All dimensions are nominal*
TUBE

T - Tube height
W - Tube width
L - Tube length
B - Alignment groove width

*All dimensions are nominal

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<th>L (mm)</th>
<th>W (mm)</th>
<th>T (µm)</th>
<th>B (mm)</th>
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</tbody>
</table>
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.
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.
MECHANICAL DATA

PS (R-PDSO-G8)  PLASTIC SMALL-OUTLINE PACKAGE

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0.15.

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P (R-PDIP-T8)  PLASTIC DUAL-IN-LINE PACKAGE

NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-001 variation BA.
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