# LP6294

High Slew Rate Rail-to-Rail QuadOperational Amplifiers with OTP

## Features

- Wide supply voltage range 4.5V ~ 18V
- Unity-gain stable
- Rail-to-rail output swing
- High slew rate 40V/μs
- GBWP 20MHz
- Over Temperature Protection (OTP)
- ±350mA Output Short Circuit Current
- Pb-Free Package
- PackageTSSOP-14

## Applications

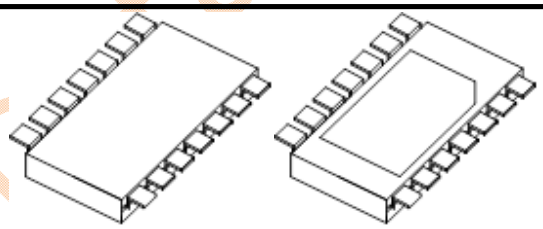
- TFT-LCD Reference Driver
- ADC/DAC Buffer, Active Filter
- Office Automation, Wireless LANs
- Portable Electronics
- Personal Communication Devices
- Direct Access Arrangement
- Portable Electronics
- Personal Digital Assistant (PDA)
- Touch-Screen Display, Sampling ADC Amplifier

## Description

The LP6294 is a rail-to-rail quad channels operational amplifier with wide supply range from 4.5V to 18V. It provides 0.5V beyond the supply rails of common mode input range and capability of rail-to-rail output swing as well. This enables the amplifier to offer maximum dynamic range at any supply voltage among many applications. A 20MHz gain bandwidth product allows LP6294 to perform more stable.

With features of 40V/μs high slew rate, as well as 100mA (sink and source) of high output driving capability, the LP6294 is ideal for the requirements of flat panel Thin Film Transistor Liquid Crystal Displays (TFT-LCD) panel reference buffers application.

With standard operational amplifier pin assignment, the LP6294 is offered in space saving 14-Pin TSSOP package and specified over the -40°C to +85°C temperature range.

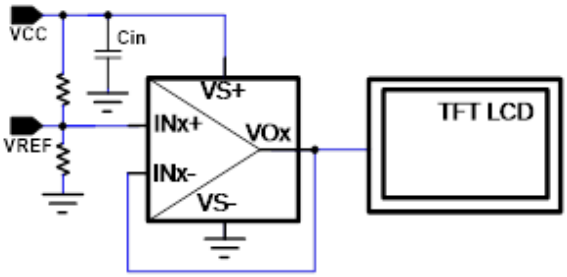


TSSOP14 and ETSSOP14
0.65mm pin pitch

## Ordering Information

LP6294 □□□
- F: Pb-Free
- Package Type
  - SO: TSSOP-14
  - SP: ETSSOP-14

## Typical Application Circuit




## Marking Information

| Device | Marking | Package | Shipping |
|---|---|---|---|
| LP6294SOF | LPS<br>LP6294<br>YWX | TSSOP14 | 5K/REEL |
| LP6294SPF | LPS<br>LP6294<br>YWX | ETSSOP14 | 5K/REEL |
| Marking indication:<br>**Y**: Year code. **W**: Week code. **X**: Series number. | | | |

## Pin Configuration

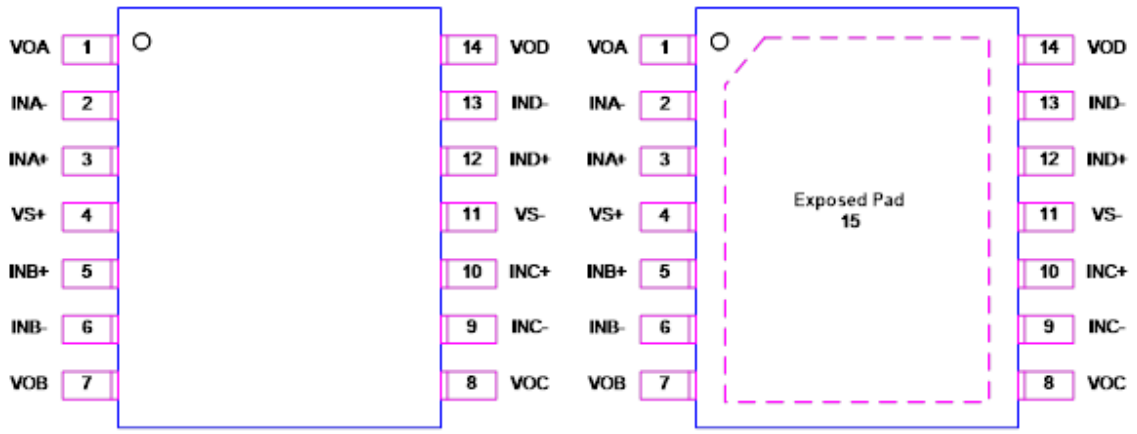



Figure 1.Package Top View

## Pin Description

| Pin No. | Name | Description |
|---|---|---|
| 1,7,8,14 | VOx | Operational Amplifier Output. |
| 2,6,9,13 | INx- | Operational Amplifier Inverting Input. |
| 3,5,10,12 | INx+ | Operational Amplifier Non-Inverting Input. |
| 4 | VS+ | Supply Voltage VCC can range from 4.5V to 18V. |
| 11 | VS- | IC GND or Negative power supply. |
| EP | | Exposed Pad. Connect this pin to VS- pin. |

## Absolute Maximum Ratings(Note 1)

- Supply Voltage VS+ to VS- ---------- -0.3V to 20V
- Input Voltage ---------- VS- -0.5V to VS+ +0.5V
- Maximum Continuous Output Current ---------- 100mA
- Maximum Junction Temperature ($T_J$) ---------- 125°C
- Operating Ambient Temperature Range ($T_A$) ---------- -40℃ to 85°C
- Storage Temperature Range ---------- 65°C to +150°C
- Maximum Soldering Temperature (At leads, 10 sec) ---------- 260°C

*Note 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 in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## Recommended OperatingConditions

- Input Voltage, $V_{IN}$ ---------- 6V to 18V
- Output Current, $I_{OUT}$ ---------- 0.01A to 0.1A

## Electrical Characteristics

**The parameters are measured under conditions VS+=+5V, VS-= -5V, RL=10kΩ, and CL=10pF, TA=25°C, unless otherwise specified.**

| Parameter | Symbol | Test Conditions | Min | Typ. | Max | Units |
|---|---|---|---|---|---|---|
| **Input Characteristics** | | | | | | |
| Input Offset Voltage | $V_{OS}$ | $V_{CM}$= 0V | | 2 | 12 | mV |
| Input Drift Bias Current | $I_B$ | $V_{CM}$= 0V | | 2 | 50 | nA |
| Input Impedance | $R_{IN}$ | | | 1 | | GΩ |
| Input Capacitance | $C_{IN}$ | | | 1.35 | | pF |
| Common-Mode Input | CMIR | | -5.0 | | +5.0 | V |
| Common-Mode Rejection Ratio | CMRR | for VIN from -5.5V to 5.5V | 50 | 70 | | dB |
| Open-Loop Gain | $A_{VOL}$ | -4.5V≦VOx≦4.5V | 75 | 90 | | dB |
| **Output Characteristics** | | | | | | |
| Output Swing Low | $V_{OL}$ | $I_L$=-5mA | | -4.92 | -4.85 | V |
| Output Swing High | $V_{OH}$ | $I_L$=5mA | 4.85 | 4.92 | | V |
| Short Circuit Current | $I_{SC}$ | (Note 2) | | ±350 | | mA |
| Output Current | $I_{OUT}$ | | | ±100 | | mA |
| Output Peak Current(Note 3) | $R_{DIS}$ | Iload VOx to GND | | ±450 | | mA |
| | | I loadVOx to VCC | | | | |
| **Power Supply Performance** | | | | | | |
| Power Supply RejectionRatio | PSRR | VS is moved from±3V to ±7.75V | 60 | 80 | | dB |
| Supply Current | $I_S$ | No Load | | 3 | | mA |
| **Dynamic Performance** | | | | | | |
| Slew Rate | SR | $V_{S+}$=8V,$V_{S-}$=-8V, -4V≦VOx≦4V, 20% to 80% | 30 | 40 | | V/μs |
| -3dB Bandwidth | BW | $R_L$=10kΩ, $C_L$=10pF | | 30 | | MHz |
| Gain-Bandwidth Product | GBWP | $R_L$=10kΩ, $C_L$=10pF | | 20 | | MHz |
| Phase Margin | PM | $R_L$=10kΩ, $C_L$=10pF | | 50 | | Degree |
| **Temperature Performance** | | | | | | |
| Thermal Shutdown | Temp | | | 150 | | °C |

*Note 2: Short circuit current is tested with one output at a time.

*Note 3: Ipeak current is for a 1μs pulsed current only , not to exceed thermal characteristics of package.

## Typical Waveforms and Curves

$T_A$=+25°C,$V_{S+}$ = 10V, $V_{S-}$ = GND,$R_L$=10kΩ, $C_L$=10pF (Unless Otherwise Specified)

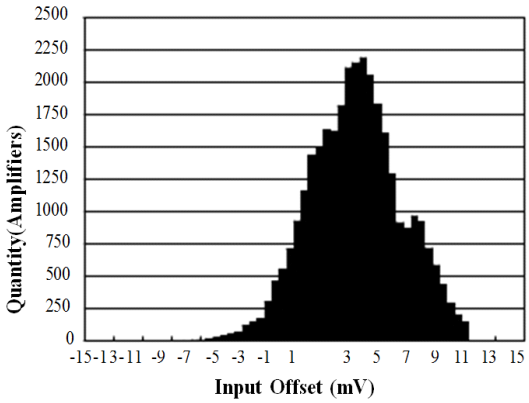



Figure 2. Input Offset Voltage Distribution

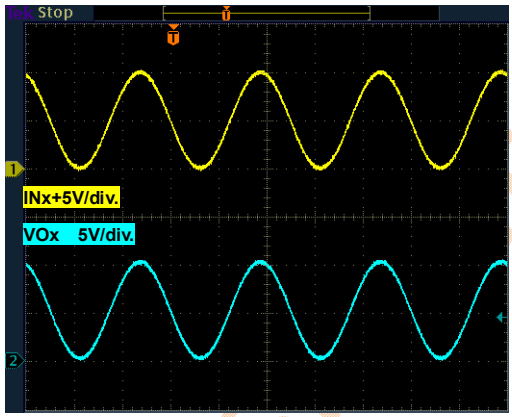



Figure 3.Rail to Rail Capability

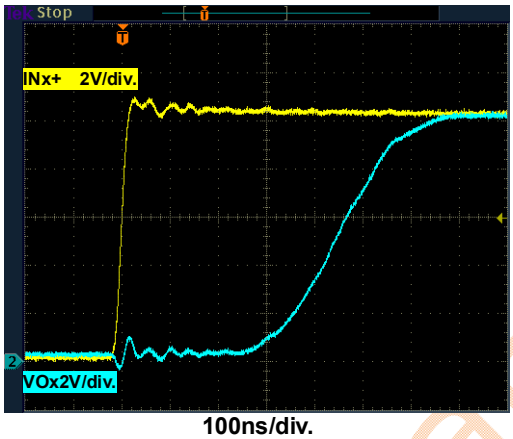



Figure 4.Large Signal Transient Response

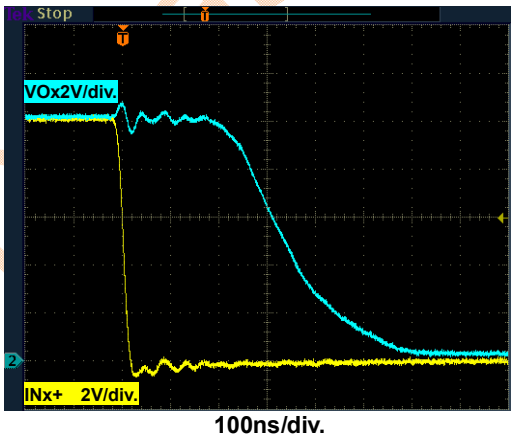



Figure 5.Large Signal Transient Response

# ApplicationInformation

## Supply Voltage, Input Range and Output Swing

The LP6294 can be operated with a single nominal wide supply voltage ranging from 4.5V to 18V with stable performance over operating temperatures of -40 °C to +85 °C. With 500mV greater than rail-to-rail input common mode voltage range and 80dB of Common Mode Rejection Ratio, the LP6294 allows a wide range sensing among many applications without having any concerns over exceeding the range and no compromise in accuracy. The output swings of the LP6294 typically extend to within 80mV of positive and negative supply rails with load currents of 5mA. The output voltage swing can be even closer to the supply rails by merely decreasing the load current. Figure 1 show the input and output waveforms for the device in the unity-gain configuration. The amplifier is operated under ±5V supply with a 10k load connected to GND. The input is a 10Vp-p sinusoid. An approximately 9.985 Vp-p of output voltage swing can be easily achieved.

## Output Short Circuit Current Limit

A +/-350mA short circuit current will be limited by the LP6294 if the output is directly shorted to the positive or the negative supply. For an indefinitely output short circuit, the power dissipation could easily increase such that the device may be damaged. The internal metal interconnections are well designed to prevent the output continuous current from exceeding +/-100mA such that the maximum reliability can be well maintained.

## Output Phase Reversal

The LP6294 is designed to prevent its output from being phase reversal as long as the input voltage is limited from VS--0.5V to VS++0.5V. Although the phase of the device's output will not be reversed, the input's over-voltage should be avoided. An improper input voltage exceeds supply range by more than 0.6V may result in an over stress damage.

## Power Dissipation

The LP6294 is designed for maximum output current capability. Even though momentary output shorted to ground causes little damage to the device.
For the high drive amplifier LP6294, it is possible to exceed the 'absolute-maximum junction temperature' under certain load current conditions. Therefore, it is important to calculate the maximum junction temperature for the application to determine if load conditions need to be modified for the amplifier to remain in the safe operating area. The maximum power dissipation allowed in a package is determined according to:

$$T_{JMAX} = PDmax \times \theta_{JA} + T_{AMAX}$$

Where:
$T_{Jmax}$ = Maximum Junction Temperature
$T_{Amax}$= Maximum Ambient Temperature
$\Theta_{JA}$ = Thermal Resistance of the Package
PDmax= Maximum Power Dissipation in the Package.
The maximum power dissipation actually produced by an IC is the total quiescent supply current times he total power supply voltage, plus the power in the IC due to the loads, or

$$PDmax = \sum i[V_S * I_{SMAX} + (V_{S+} - V_O) * I_L]$$

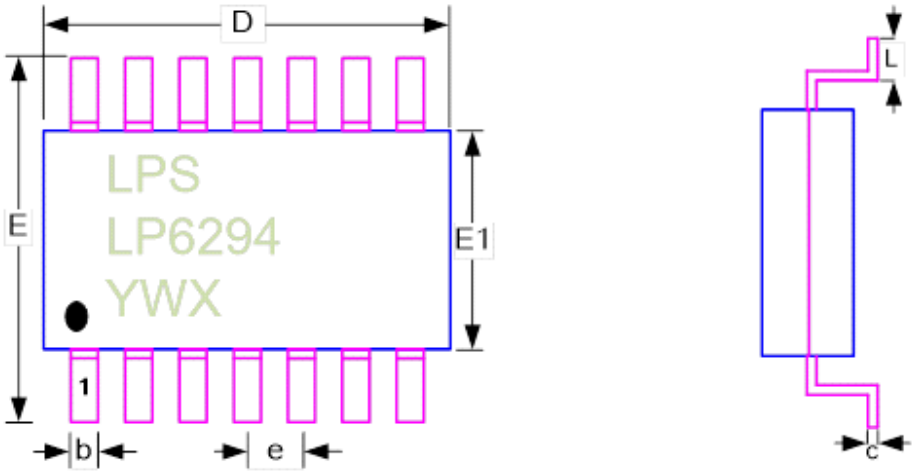
When sourcing, and

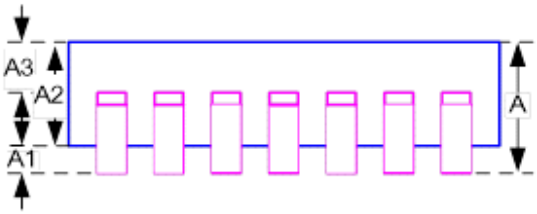
$$PDmax = \sum i[V_S * I_{SMAX} + (V_O - V_{S-}) * I_L]$$

When sinking.
Where:
i = 1 to 4
$V_S$ = Total Supply Voltage
$I_{SMAX}$ = Maximum Supply Current Per Amplifier
$V_O$ = Maximum Output Voltage of the Application
$I_L$= Load current
$R_L$= Load Resistance = $(V_{S+} - V_O)/I_L = (V_O - V_{S-})/ I_L$
A calculation for $R_L$ to prevent device from over heat can be easily solved by setting the two PDmax equations equal to each other.

## Package Dimensions

**TSSOP14 Package (Unit: mm)**

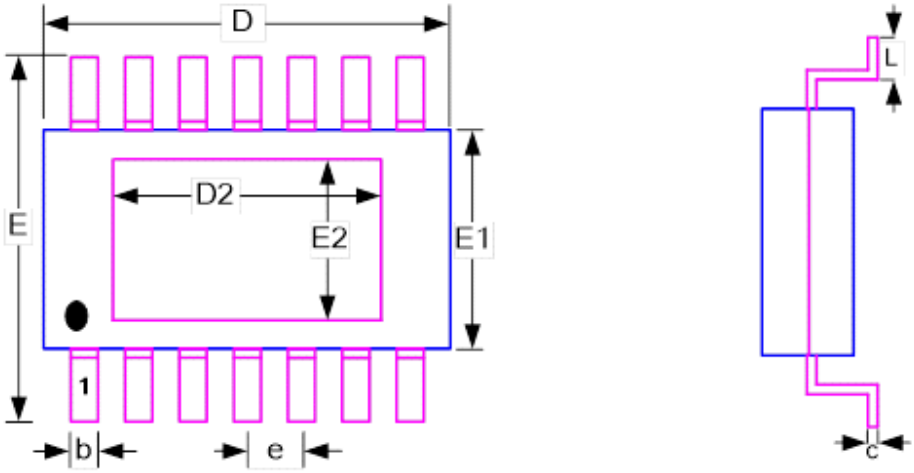


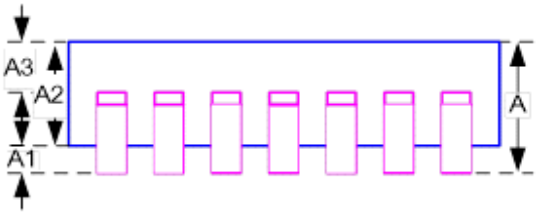




| SYMBOLSUNIT | DIMENSION IN MILLIMETER | | |
|---|---|---|---|
| | MIN | NOM | MAX |
| A | -- | -- | 1.200 |
| A1 | 0.050 | -- | 0.150 |
| A2 | 0.800 | 1.000 | 1.050 |
| A3 | 0.390 | 0.440 | 0.490 |
| b | 0.190 | -- | 0.300 |
| c | 0.130 | -- | 0.170 |
| D | 4.900 | 5.000 | 5.100 |
| E | 6.200 | 6.400 | 6.600 |
| E1 | 4.300 | 4.400 | 4.500 |
| e | 0.65BSC | | |
| L | 0.450 | 0.600 | 0.750 |

## Package Dimensions (Continued)

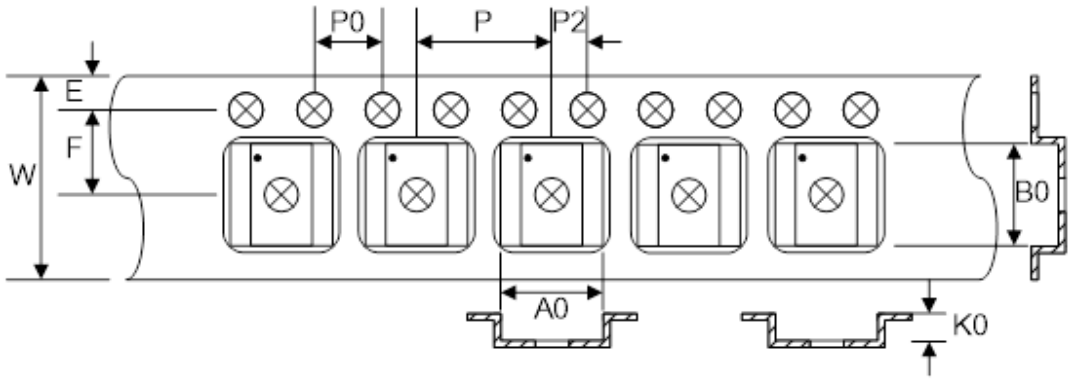
**ETSSOP14 Package(Unit: mm)**



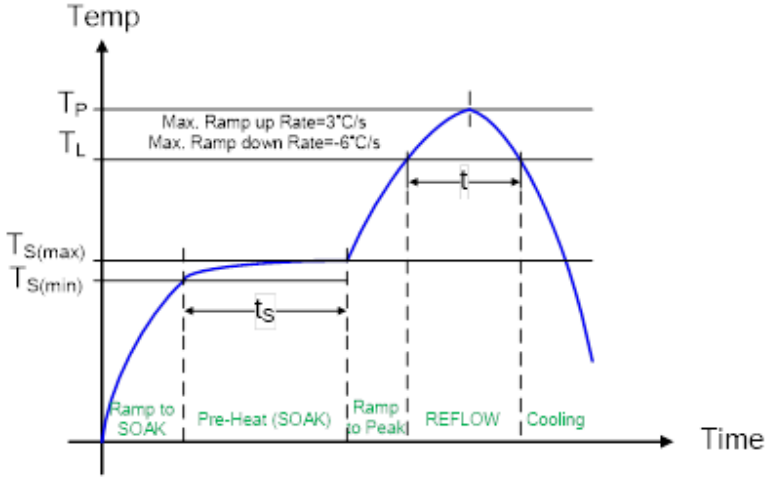

| SYMBOLSUNIT | DIMENSION IN MILLIMETER | | |
|---|---|---|---|
| | MIN | NOM | MAX |
| A | -- | -- | 1.200 |
| A1 | 0.050 | -- | 0.150 |
| A2 | 0.800 | 1.000 | 1.050 |
| A3 | 0.390 | 0.440 | 0.490 |
| b | 0.190 | -- | 0.300 |
| c | 0.130 | -- | 0.170 |
| D | 4.900 | 5.000 | 5.100 |
| D2 | 2.95REF | | |
| E | 6.200 | 6.400 | 6.600 |
| E1 | 4.300 | 4.400 | 4.500 |
| E2 | 2.90REF | | |
| e | 0.65BSC | | |
| L | 0.450 | 0.600 | 0.750 |

## Carrier Dimensions




| Device | Package Type | | Pins | A0 (mm) | B0 (mm) | K0 (mm) |
|---|---|---|---|---|---|---|
| LP6294 | TSSOP<br>ETSSOP | | 14 | 6.8±0.1 | 5.4±0.1 | 1.3±0.1 |
| | W (mm) | E (mm) | F (mm) | P (mm) | P0 (mm) | P2 (mm) |
| | 12±0.1 | 1.75±0.1 | 5.5±0.1 | 8±0.1 | 4±0.1 | 2±0.05 |

## Classification Profile




| Profile Feature | Sn-Pb Eutectic Assembly | Pb-Free Assembly |
|---|---|---|
| Temperature min ($T_{S(min)}$)<br>Temperature max ($T_{S(max)}$)<br>Time ($T_{S(min)}$to $T_{S(max)}$) ($t_S$) | 100 °C<br>150 °C<br>60-120 seconds | 150 °C<br>200 °C<br>60-120 seconds |
| Average ramp-up rate ($T_{S(max)}$to $T_P$) | 3 °C/second max. | 3°C/second max. |
| Liquidous temperature ($T_L$)<br>Time at liquidous ($T_L$) | 183 °C<br>60-150 seconds | 217 °C<br>60-150 seconds |
| Peak package body Temp. ($T_P$) | See Classification Temp in table 1 | See Classification Temp in table 2 |
| Time ($T_P$) within 5°C of the specified classification temperature | 20 seconds | 30 seconds |
| Average ramp-down rate ($T_P$ to $T_{S(max)}$) | 6 °C/second max. | 6 °C/second max. |
| Time 25°C to peak temperature | 6 minutes max. | 8 minutes max. |

Table 1. SnPb Eutectic Process – Classification Temperatures

| Package Thickness | Volume $mm^3$< 350 | Volume $mm^3$≥350 |
|---|---|---|
| <2.5 mm | 235 °C | 220 °C |
| ≥2.5 mm | 220 °C | 220 °C |

Table 2. Pb-free Process – Classification Temperatures

| Package Thickness | Volume $mm^3$< 350 | Volume $mm^3$<350 - 2000 | Volume $mm^3$≥ 2000 |
|---|---|---|---|
| <1.6 mm | 260 °C | 260 °C | 260 °C |
| 1.6 mm ~ 2.5 mm | 260 °C | 250 °C | 245 °C |
| ≥ 2.5 mm | 250 °C | 245 °C | 245 °C |