# Multifuse® Polymer PTC Resettable Fuses

## INTRODUCTION

A very important consideration in reliability is achieving a good solder bond between a surface mount device (SMD) and it's substrate since the solder provides the thermal path from the chip. A good bond is less prone to thermal fatiguing and will result in improved device reliability. The most economical method of soldering is a process in which all components are soldered simultaneously.

## SOLDERING OF POLYMERIC PTC RESETTABLE FUSES

Multifuse® PPTC Resettable Fuses are made from conductive filled polymer. In normal operation, the conductive particles in the polymer form a continuous path, which allows current to flow through the device without interruption. Typical base resistance of the device may range from a few milliohms to a few ohms. When there is an overload condition, the polymer heats up internally from $I^2R$ heating. When the polymer heats up to approximately 90 °C - 160 °C, its molecular structure changes from semi-crystalline to amorphous. This causes a macroscopic expansion, which breaks the conductive paths. When the conductive paths are broken there is a large increase in resistance - typically several orders of magnitude. At this point, the device is in the “tripped state.”

Upon cooling, the polymer reforms to its semi-crystallized state and the conductive pathways are reestablished. However, when the polymer recrystallizes it does not return immediately to the same base resistance. It does not compact as tightly as when it was pre-tripped, and therefore the post trip resistance in most cases is typically 50 % higher then the initial resistance. Note the post trip resistance increase is not a cumulative effect; additional tripping will not cause increases in resistance in excess of the first trip event. Further resistance recovery is possible if the device is conditioned by actively current cycling the device or passively heating the device below 85 °C. Figure 1 shows the change in resistance under temperature cycling or environmental cycling. This process is similar to an environmental burn in process, which is done by many circuit board manufacturers. Over a short number of cycles, the resistance typically decreases from 1.8 to 1.5 times the initial resistance.

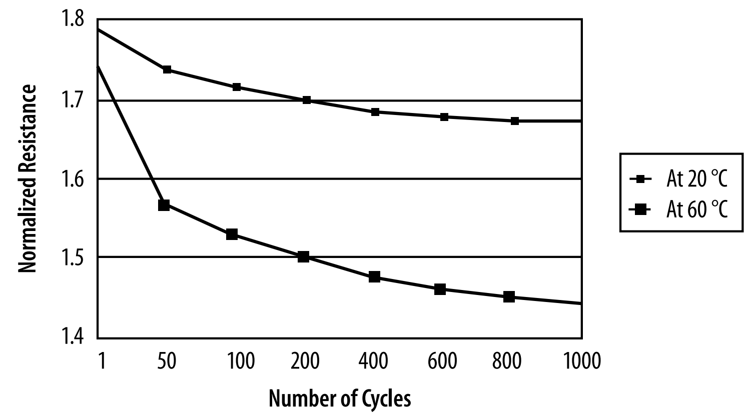



*Figure 1 - Resistance Recovery After Passive Conditioning*

## REFLOW SOLDERING

The preferred technique for mounting surface mount components on substrates is reflow soldering. In a reflow process, the solder paste is printed on the component sites of the printed circuit board. Then the components are placed on the board on top of the solder paste. Often, a separate adhesive is used to hold the device in place until soldering takes place. The board and attached components are then heated to activate the flux, elevate the temperature of the base metals, and melt (or reflow) the solder.

*Recommended substrates: Alumina or FR4 PCB material*

It is best to prepare the substrate by either dipping the substrate in a solder bath or by screenprinting solder paste.

After the substrate is prepared, devices are picked and placed in position with vacuum pencils. Each device may be placed without special alignment procedures due to its self-aligning properties during the solder reflow process and will be held in place by surface tension.

For reliable connections, the following guidelines should be adhered to:

1) *The maximum temperature of the leads or tab during the soldering cycle should not exceed 260 °C.*
2) *The flux must affect neither components nor connectors.*
3) *The residue of the flux must be easily removable.*

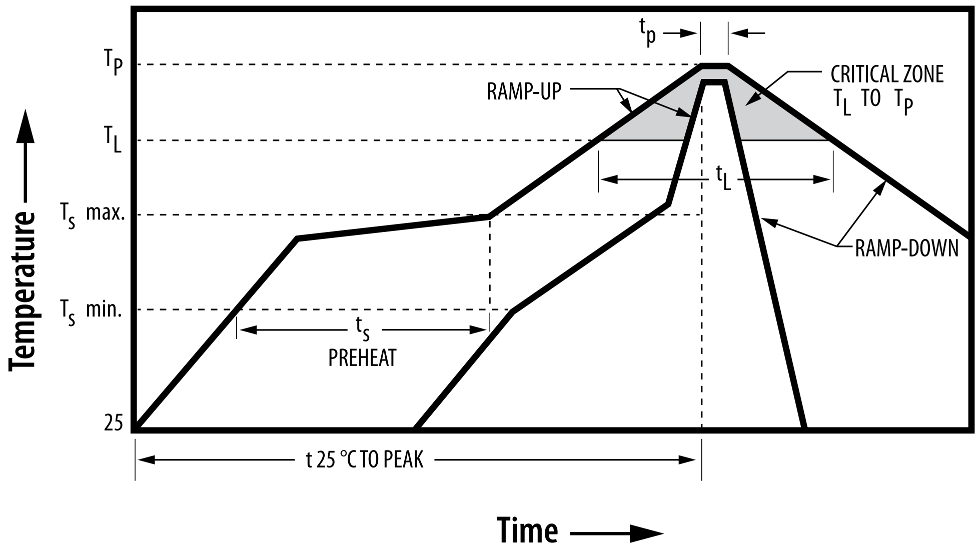
Having first been fluxed, all components are positioned on the substrate. The slight adhesive force of the flux is sufficient to keep the components in place.

Solder pastes contain a flux and therefore have good inherent adhesive properties, which eases positioning of the components. Flux should be allowed to dry at room temperature or in a 70 °C oven until dry to the touch.

With the components in position, the substrate is heated to a point where the solder begins to turn to an amorphous state. This can be done on a heating plate, on a conveyor belt running through an infrared tunnel, or by using vapor phase soldering.

No matter which method of heating is used, the maximum allowed temperature must not exceed 260 °C during the soldering process. For further temperature behavior during the soldering process, see Figure 2, Recommended Reflow Profile.

# Multifuse® Polymer PTC Resettable Fuses




| Profile Feature | Pb-Free Assembly |
|---|---|
| Average Ramp-Up Rate ($Ts_{max}$ to $T_p$) | 3 °C / second max |
| PREHEAT: | |
| Temperature Min. ($Ts_{min}$) | 150 °C |
| Temperature Max. ($Ts_{max}$) | 200 °C |
| Time ($Ts_{min}$ to $Ts_{max}$) (ts) | 60 ~ 180 seconds |
| TIME MAINTAINED ABOVE: | |
| Temperature ($T_L$) | 217 °C |
| Time ($t_L$) | 60 ~ 150 seconds |
| Peak Temperature ($T_p$) | 260 °C |
| Time within °C of Actual Peak Temperature ($t_p$) | 20 ~ 40 seconds |
| Ramp-Down Rate | 6 °C / second max. |
| Time 25 °C to Peak Temperature | 8 minutes max. |

*Figure 2 - Recommended Reflow Profile*

## REFLOW SOLDERING (CONTINUED)

The surface tension of the liquid solder tends to draw the leads of the device toward the center of the soldering area and has a correcting effect on slight misalignments. However, if the layout leaves something to be desired, the same effect can result in undesirable shifts, particularly if the soldering areas on the substrate and the components are not concentrically arranged. This problem can be solved using a standard contact pattern, which leaves sufficient scope for the self-positioning effect.

After the solder has set and cooled, the connections are visually inspected. Finally, the remnants of the flux must be carefully removed.

Use a vapor degreasing process with an azeotrope solvent or equivalent to remove flux. The substrate should then be allowed to dry.

After the drying procedure is complete, the assembly will be ready for testing and/or further processing.

After consecutive reflows, Multifuse® Polymer PTC devices will still be functional although post-trip resistance may drift beyond the $R1_{max}$ specification.

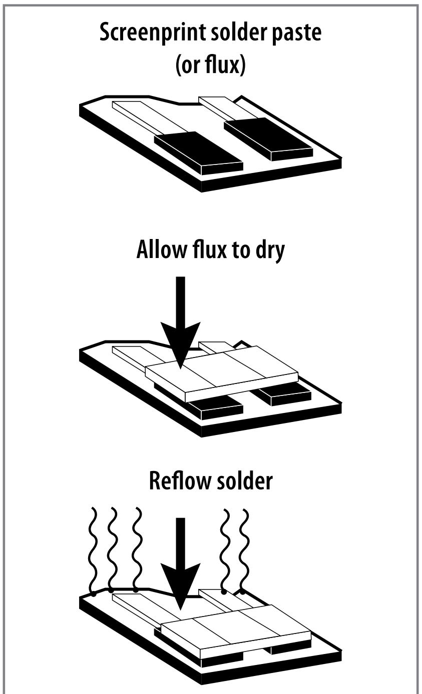



*Figure 3 - Reflow Soldering PTC Devices*

## VAPOR PHASE SOLDERING

In the vapor phase soldering process, the entire PC board is uniformly heated within a vapor phase zone at a temperature of approximately 200 °C. The saturated vapor phase zone is obtained by heating an inert (inactive) fluid to the boiling point. The vapor phase is locked in place by a secondary vapor (see Figure 4). Vapor phase soldering provides uniform heating and prevents overheating.

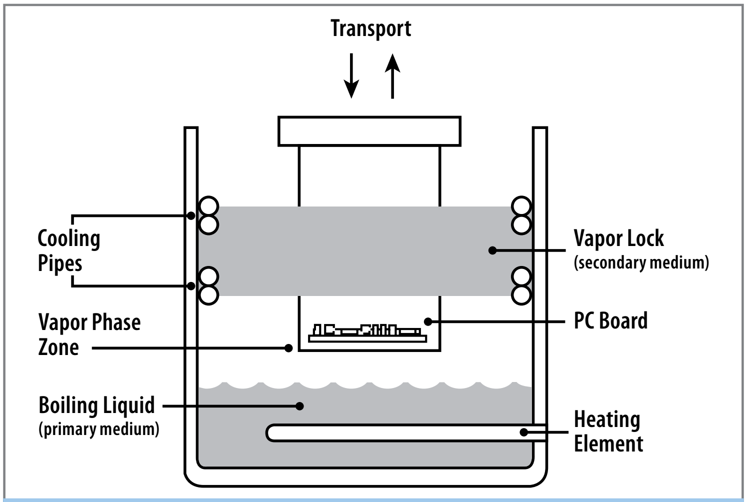



*Figure 4 - Principle of Vapor Phase Soldering*

## WAVE SOLDERING[1]

One of the benefits of surface mount technology is that devices can be mounted to both the top and bottom sides of the printed circuit board. During wave soldering, components on the underneath side are actually immersed into the hot molten solder. The plastic-metal interface can be affected if it is left on the molten solder for more than 5 seconds. Most wave soldering operations occur at temperatures between 240 °C to 260 °C. Epoxies used for semiconductor encapsulation have glass transition temperatures between 140 °C to 170 °C. If integrated circuit is exposed to these temperatures, it may effect its long term functionality and reliability. However, with topside mounting (as used for dual in-line packages or DIPs) there are some factors that reduce the risk.

1) *Only the tips of the leads are exposed to the solder temperature.*
2) *The printed circuit board acts as a heat sink and also shields the components from the temperature of solder. DIPs are typically exposed to a temperature between 120 °C to 150 °C in a five second pass through the solder wave. This accounts for the fact that packages mounted in the conventional manner (topside only) are very reliable.*

Wave soldering requires the use of fluxes to facilitate the solderability of the components to the circuit board. In some instances, the boards and components are processed via acid cleaning prior to passing through the wave. If epoxy-metal separation has occurred, the flux and acid residues (which may be present due to inadequate cleaning) will be forced into the separation mainly by capillary action as they move away from the solder heat source. Once the package is cooled, these contaminants are now trapped inside the package and are able to diffuse with available moisture over time. It should be stressed that electrical tests performed immediately after soldering generally will give no indication of this potential problem. As time passes, however, the end result will be corrosion of the chip metallization and premature failure of the device in the field. Procedures for wave soldering PCBs containing (a) surface mount devices only, and (b) leaded components are shown in Figures 5 and 6. Not every Multifuse® Polymer PTC device can be wave soldered. The following table outlines the models that can and cannot be wave soldered.

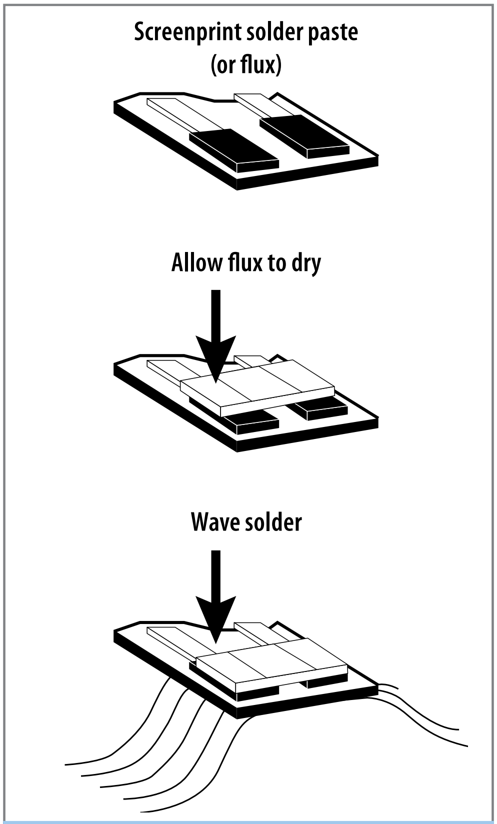



*Figure 5 - Wave Soldering Surface Mount PTC devices*

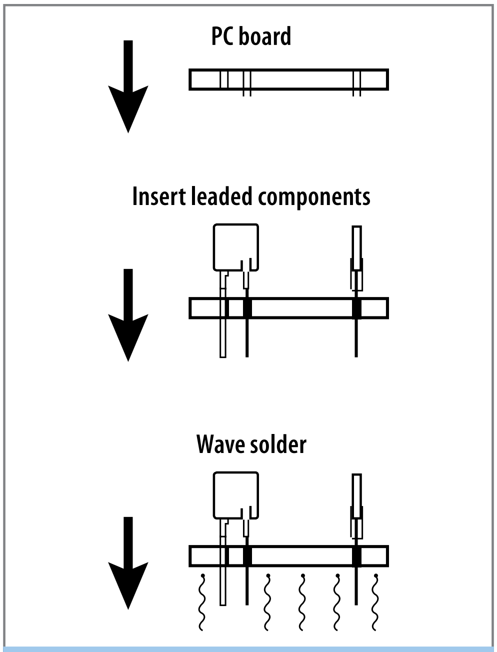



*Figure 6 - Wave Soldering Radial PTC Devices*

[1] *Do not wave solder the body of the PPTC device.*

## WAVE SOLDERING (CONTINUED)

Multifuse® PPTC product families that can be reflow soldered and/or wave soldered:

| Mounting Configuration | Product Family | Reflow Solder | Wave Solder |
|---|---|---|---|
| Radial Leaded Through-Hole | MF-R | Yes* | Yes |
| | MF-R/90 | Yes* | Yes |
| | MF-R/600 | Yes* | Yes |
| | MF-RG | Yes* | Yes |
| | MF-RHT | Yes* | Yes |
| | MF-RM | Yes* | Yes |
| | MF-RX | Yes* | Yes |
| | MF-RX/72 | Yes* | Yes |
| | MF-RX/250 | Yes* | Yes |
| Surface Mount | MF-ASML/X | Yes | Yes*** |
| | MF-FSMF | Yes | Yes*** |
| | MF-FSML | Yes | Yes*** |
| | MF-FSML/X | Yes | Yes*** |
| | MF-PSMF | Yes | Yes*** |
| | MF-PSML | Yes | Yes*** |
| | MF-PSML/X | Yes | Yes*** |
| | MF-PSHT | Yes | Yes*** |
| | MF-NSMF | Yes | Yes*** |
| | MF-NSML | Yes | Yes*** |
| | MF-NSML/X | Yes | Yes*** |
| | MF-NSHT | Yes | Yes*** |
| | MF-USMF | Yes | Yes*** |
| | MF-USML | Yes | Yes*** |
| | MF-USML/X | Yes | Yes*** |
| | MF-USHT | Yes | Yes*** |
| | MF-MSMF | Yes | Yes*** |
| | MF-SMDF | Yes | Yes*** |
| | MF-LSMF | Yes | Yes*** |
| | MF-GSMF | Yes | Yes*** |
| | MF-SM | Yes | Yes*** |
| | MF-SMHT | Yes | Yes*** |
| | MF-SM/250 | Yes | Yes*** |
| | MF-SM/250V | Yes | Yes*** |
| | MF-SD/250 | Yes | Yes*** |
| Axial Leaded Battery Strap | MF-LR | Yes** | Yes*** |
| | MF-LS | Yes** | Yes*** |
| | MF-S | Yes** | Yes*** |
| | MF-SVS | Yes** | Yes*** |
| | MF-VS | Yes** | Yes*** |
| | MF-VS Narrow Body | Yes** | Yes*** |

** Can be reflow soldered if methods such as intrusive reflow are used.*
*** Can be reflow soldered but not common. Spot welding is a more common method.*
**** Can be wave soldered only when solder wave is beneath the PCB and PPTC is placed on topside of the PCB.*

## HAND SOLDERING

It is possible to solder the surface mount Multifuse® Polymer PTC models with a miniature handheld soldering iron, but this method has particular drawbacks and therefore, should be restricted to laboratory use and/or incidental repairs on production circuits. It is difficult to control the amount of heat generated and transferred to the PTC device when using hand soldering.

The following outlines the recommended hand soldering procedure:

*1) Properly orient the part and place it on the PCB pads. Use tweezers to hold the part from the sides and do not press down on the top surface of the PTC device.*
*2) When soldering, the actual placement of the solder iron tip should be at the joint in the center of the pad on the PCB and the PTC device terminal.*
*3) Maintain a clean tip at all times.*
*4) Sometimes it is necessary to apply a small amount of flux to the terminals.*
*5) Use a very slight amount of solder on both PCB pads using a syringe. Too much solder will cause the part to sit at an angle. Solder paste is recommended instead of solder wire for surface mount product families.*
*6) Keep the temperature as low as possible in the region below 350 °C.*
*7) Hold the tip on the joint to heat the joint while holding the solder in the joint as well (for as little time as possible).*
*8) Do not place the solder directly on the tip, but rather into the joint of the two surfaces being joined.*
*9) Hold the tip in place and once the solder wicking begins feed solder until the joint is full.*

| Hand Soldering Parameter for Multifuse® Components | Max. Solder Iron Tip Temperature | Max. Contact Time with Component Lead |
|---|---|---|
| Sn-Pb Soldering | 350 °C | 3 – 4 seconds |
| Pb-Free Soldering | 350 °C | 3 – 4 seconds |

For surface mount devices hand solder rework should be confined to the removal of the installed product and replacement with a fresh device.

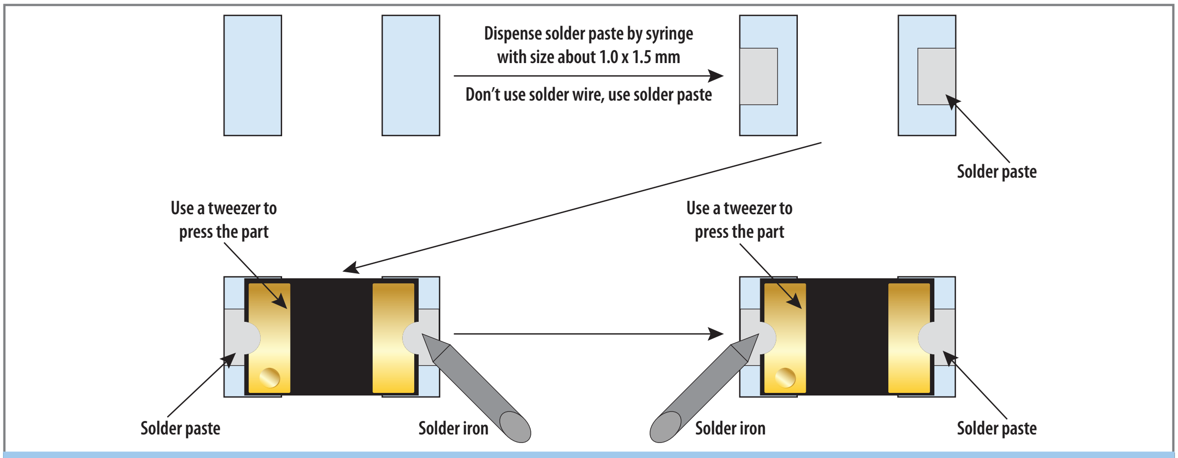



*Figure 7 - Guide for Hand Soldering SMD PTC Devices*

# Multifuse® Polymer PTC Resettable Fuses

## PRE-HEATING

Pre-heating is recommended for good soldering results and avoiding damage to the devices, other components and the substrate. The maximum pre-heating temperature is 160 °C while the maximum preheating duration is 10 seconds. However, atmospheric pre-heating is permissible for several minutes provided the temperature does not exceed 125 °C.

There are three different ways to preheat the printed circuit board: electric heaters, a convection heating process or an infrared heating process. Cost, space and personal preference are some of the parameters used when deciding which pre-heating method works best in your situation.

## GLUING RECOMMENDATIONS

Prior to wave soldering, surface mount devices (SMDs) must be fixed to the PCB or substrate by means of an appropriate adhesive. The adhesive (in most cases, a multicomponent adhesive) has to fulfill the following demands:

*1) Uniform viscosity to ensure easy coating.*
*2) No chemical reactions upon hardening, in order not to cause deterioration to the component and PC board.*
*3) Straightforward exchange of components in case of repair.*

## CLEANING RECOMMENDATIONS

PC board or substrate cleaning in solvents is permitted at approximately 70 °C to 80 °C.

The soldered parts should be cleaned with an azeotrope solvent followed by a solvent such as methyl or isopropyl alcohol.

Cleaning of the parts is best accomplished using an ultrasonic cleaner, which has approximately 20 watts of output per one liter of solvent. The solvent should be replaced on a regular basis.

## DIP SOLDERING

This is very similar to wave soldering, but is a hand operation. The same considerations as above should be followed, particularly the time-temperature cycle, which may become operator dependent. Due to the wide process variations that may occur, this method is not recommended.



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