



Another Look - Wave Solder Process for Surface Mount Applications

Complications/
Contradictions/
Excellent Performance

The Key to
Performance is
Understanding and
A Robust Part

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Prologue

This is an update of the earlier KEMET Engineering Bulletin F-2101 regarding the Wave Solder Process for Surface Mount Applications. As with all surface mount processes, the wave solder process has been very dynamic. Many improvements have been made in equipment, in surface mount parts, and in the understanding of effects of the variables on the overall performance of the process itself. In addition, other factors have come into play, such as the recent introduction of “no clean” fluxes, and more information on the effects of repair and rework. This update will attempt to summarize the information and assist you in understanding the ingredients of the wave solder process.

One of the keys to the progress of Surface Mount Technology has been the cooperation of the leading participants in the industry. The manufacturers of wave solder equipment, the manufacturers of the solders and fluxes, the users (our customers), and the surface mount parts suppliers (KEMET and its competitors) have all worked to increase the understanding of this process. Improvements in all the elements have resulted in a much improved process.

If you have read the first Engineering Bulletin, take time to scan this update. Much has been added, and we hope it results in improved knowledge and understanding. If you have not read the first Bulletin, take time to read this revision and think through what is presented. It is important that you stretch your knowledge and test your theories. Don't take this Bulletin as the gospel, but as a thought provoker. Many of our readers have read the contents over and over as their experience level increases. Test and retest are the keys to process improvements. Process improvements are the keys to success.

And Now - Time Out For One Very Small Commercial

Success!! Improvements!! Ceramic Capacitors!!

KEMET is one of the leading manufacturers of ceramic chip capacitors for surface mount applications. As our understanding of the wave solder process grew, it became evident to us that not all solder wave processes could be made ideal. As you read further, this understanding should become clearer to you also.

Ceramic chip capacitors from all manufacturers have had, at some time, problems with thermal shock cracking in the wave solder process. When investigated, the crack may have been introduced due to the lack of robustness of the capacitor or the stress level applied by the wave solder process variables. Most likely the cause was a complex combination of both. Since KEMET manufactures ceramic chip capacitors, it became very important that KEMET produce the most robust chip, a chip that could withstand the variations in wave solder processes in use at the customers.

KEMET Has This Robust Chip Capacitor.

Of course, the availability of this robust chip capacitor does not mean that the process engineer can concentrate less on achieving the closest approximation of the ideal wave solder process. There are many other advantages to doing this. The ideal solder process is one of the items that will result in the best product performance in your customers' application, and of course, this can lead to additional business for you.

Introduction

Surface Mount Technology (SMT) has brought the electronic industry many benefits. Size and cost reduction as well as increased in quality and reliability have been demonstrated in numerous cases. There are many success stories and these are driving the industry in the direction of greater implementation of SMT every day. The major users of SMT have found that SMT is a process which can result in continuous improvements in product performance.

Many of the users have reported that product life in the field is increased as a result of a “no repair” goal in the manufacturing environment. This, of course, does not mean that the product is discarded if it needs repair. What it does mean is that the process engineer has established a very achievable goal of “no repair”. The processes are being fine tuned every day, with much of the feed back coming from the repair station. The repair station is a part of the solder process. In less focused operations, the solder process and repair areas are two separate processes, but unfortunately seen as necessary to making the product.

Yesterday

The benefits of SMT could be negated as a result of harsh processing of the SMT circuit. Two of the processes of greatest concern in this regard are "Wave Solder", the automatic soldering process; and "Hand Soldering", used to repair the result of poor automatic soldering processes. The wave solder process has been around for a long time. During the early days of SMT it was an easy temptation to adapt the wave solder equipment used in the former Leaded thru Hole version of the product. Historically, the wave solder process was a brute force process. When soldering problems occurred they were typically corrected by applying additional heat or slowing the conveyor speed. The option of preheat was only important to accommodate the action of the flux. Control of preheat and multizones, if any were employed, were crude. When defects were found, repair was simply accomplished, and not seen as detrimental to the product.

Today

These excuses no longer prevail. With the continued implementation of SMT, and a greater understanding and concentration being placed on the elimination of repairs as a means of improving product quality and life, the wave solder process has been a lucrative target for improvement. Much has been written on improving the process. Many studies have shown the benefits of controlling the wave solder process. One study has shown the results of maintaining an ideal solder wave profile tuned to minimizing repairs in SMT processes (3 times fewer repairs than a similar process without all the adjustments) also minimized the number of repairs on the conventional leaded thru hole products (a minimum of 14 times fewer repairs than the conventional process). The benefits of a good solder wave process are well known, and are becoming easier to accomplish.

Goals

What is the ideal wave solder process? We think it is the process that results in the optimum solder joint, results in nearly zero repair actions, and does not damage the assembly or its parts in any way. Stated in a little more detail we can break these goals into two categories. The first (and more traditional) set of goals includes:

- uniform solder joints
- minimum repairs and replacements of parts
- minimum solder skips, solder balls and bridges
- maximum cleanliness of the completed assembly

These goals are in line with the reduction of labor cost benefits of SMT manufacturing. Adding labor to repair solder joints and replace parts placed with high degrees of automation adds cost and negates some of the major benefits of SMT.

The second goal category has only recently been a focus of the process engineer. These include:

- zero repairs
- achieving an optimum solder fillet
- minimizing stress and damage to the PCB
- minimizing stress and damage to the SMT parts
- minimizing reflow of "top side" solder joints
- minimizing "leaching" of part terminations
- minimizing the need for cleaning the product

These goals are in line with increased quality, performance, and environmental focus of the process engineer. Many of the benefits are not noticed immediately, as many of the results of poor solder process are not detected until the product has been in the field for a while, or are detected in expensive environmental tests late in the product developmental cycle. It has been shown that if the wave solder process is optimized, the costs involved in unnecessary test programs, product return catastrophes, and extensive repair cycles will be greatly reduced.

Optimum Solder Fillet

What is the optimum solder fillet? We have already discussed achieving an optimum solder fillet, and will be adjusting the process to obtain one. What is it?

Experience has shown that the best solder fillet for all SMT applications is one which makes a reliable connection and which best withstands the environmental exposures of the products with minimum degradation. This fillet is difficult to describe quantitatively for all parts. For the parts on the wave solder side, especially the resistor and capacitor chips, the fillet is easier to describe. See Figure 1. the optimum fillet ranges in height from about 1/3 to 2/3 of the part termination height. This does not mean that all solder joints outside of this range should be repaired. It does mean that this is the target for the process engineer to reach for in his process. As many as possible of the solder fillets on the board should be in this range. (See KEMET's Engineering Bulletin entitled "Repair - Touch-up - Hand Solder - Can These Be Controlled - F2103 for the additional discussion of the optimum solder fillet and when to repair).

Achievement

The goals of an optimum automatic process can be achieved. There is no key, no great technological breakthrough that is needed. *The primary focus is to treat the product as valuable, as something that brings us profit.* With this focus we can see that it is necessary to treat the product with great care. If you asked the process engineers, they would all say they are going all they can to protect the product from excessive stress during the manufacturing process. Many safeguards are in place to protect the electronics from the dangers of Electro Static Dissipation (ESD). Focus on protecting the product from mechanical stresses demands a good deal of effort and tooling. In addition to the manufacturing tooling and fixturing, much time is spent on using the ideal shipping packages. Protecting the product has become recognized as very important to the product's performance and acceptance by the customer.

Today's compact designs are somewhat sensitive to mechanical stress, and even more sensitive to thermal stresses. Excessive thermal stresses can be very hazardous and its effects difficult to detect in normal product testing. The largest potential for excessive thermal stresses are found in the wave solder and hand solder processes. Minimizing these stresses is very important to protecting the product, and increasing its productive life.

Let's Look into the Process Further

As we do, you will be presented at various times with decisions that will cause you to think about changes in your process. Will you decide to evaluate them? Will you take the easy way out, after all things seem to be working well as they are? What is your goal, improvement, or status quo? We also suggest that you evaluate changes prior to introducing them in your day to day process. Many of the variables are dependent on other variables and on product and equipment types and performance. We also request your feedback. If you have experiences or thoughts which could improve the knowledge of others, we welcome this.

1. Product Design

Not all of the variables are under the control of the process engineer. The product designer and the layout designer can do much to influence the end process. Some of the items under their control are:

A. Parts Location: The most traditional parts placed on the wave soldered side of the board are the resistor chips, ceramic capacitor chips, and SOT transistor packages. Traditionally, the sizes of the resistor chips and ceramic capacitor chips have been restricted to sizes of 0805, 1206, and 1210. Larger sizes are not recommended for wave soldering. The most adventurous designers have sometimes placed SO package ICs, tantalum chip capacitors, and larger size (1812) resistor chip and ceramic chip capacitors on the wave solder side of the board. Some success in these adventures has been achieved, but only when the process and the process controls are near ideal and the process has included all of the safe guards possible. It is certainly not recommended for a new or early SMT program, or for processes and equipment which have few of the necessary controls in place. The number of "disasters" far exceed the number of successes. Choosing to put these parts on the "top" or reflow solder side of the board is much preferred for all applications. Larger size (1825, 2225) resistor chips and ceramic capacitor chips should not be wave soldered. Thermal differentials across these larger chips are cause for concern, and they are much more susceptible to variations in the process. The much preferred location is on the reflow solder side of the circuit board.

B. Circuit Pad Design: Circuit pad designs for wave solder processes are not the same as for reflow solder processes. It has been shown that more ideal solder fillets can be obtained, if the wave solder circuit pad width is about 2/3 the width of the component. This helps minimize the amount of solder and results in a more flexible solder joint. This is very important in applications with many expected temperature excursions, and in cases where the designer insists on placing 1812 size chips on the wave solder side of the board. These can also help minimize the effects of minor board bending and other normal mechanical stresses applied to the board. For more design details on pad designs refer to KEMET Engineering Bulletin entitled "Surface Mount - Mounting Pad Dimensions and Considerations" F2100.

C. Circuit Pad Orientation: For the maximum opportunity to achieve the ideal solder fillet, the parts should be oriented parallel to the solder wave. When the layout efficiency demands that the part be perpendicular to the wave, and that to do other side would greatly reduce the design density, then all is not lost. One decision needs to be made. Which direction will the board travel through the wave? This will entail a decision by the process engineer during the early design stages of the product. Once this is known, then the trailing circuit pad length should be increased by about twice its dimension. This will allow the pad to act as a drain and reduce the size of the fillet and prevent large fillets. It will also minimize the solder skips and bridges. When parts are oriented in this direction, care should also be taken to increase the spacing between parts in the length dimension to minimize bridging. (See Figure 2).

2. Product

The product is a printed circuit board (PCB) assembly. The wave solder process is typically the second solder process. Typically the reflow soldering side is completed earlier by mounting larger SMT parts in solder paste and then reflow soldering and cleaning the board. The circuit board itself typically takes advantage of SMT miniaturization and is multilayer and plated through hole, and in many cases, has numerous unevenly distributed ground planes. It typically is not well thermally balanced by design. Later on we will be discussing evenness of heating in preheat and soldering sections. The designer can help the evenness of heating, and minimize the need for excessive temperature, by paying close attention to thermal balancing during layout. Ground plane balancing in the artwork and large part placement balancing are very important. The circuit board coefficient of thermal expansion (CTE) does not match the CTE of other parts, nor of the solder itself. Excessive temperature gradients can result in delamination of the circuit board, peel back of copper, and introduction of twist and warp stresses. The glass transition temperature of epoxy used in the circuit board is below that of the preheat and wave solder temperatures. FR4 material has a glass transition temperature (approximately 125°C) nearer the preheat and wave solder temperatures than some other commercial board materials, however, excessive times in the preheat and wave sections can result in excessive delamination of the board. Sometimes to increase manufacturing productivity, the board is a panel consisting of numerous boards. These are sometimes pre-routed or otherwise separated to ease separation after processing. These can increase the twist and warp during the wave solder process if they are not well balanced. For all of these reasons, it is desirable to apply even preheat conditions, minimize the time in preheat and wave solder zones, and minimize the thermal shocks seen by the board as it proceeds from the preheat to the wave solder zones and out to the environment.

3. Materials

The materials associated with the wave soldering process have gone through an optimization process. Higher temperature fluxes were developed to allow higher preheat temperatures. The fluxes were also optimized to increase the effectiveness of the cleaning process, and now the cleaning process is being challenged to improve the environment. This means much work needs to be done with the soldering materials.

A. Fluxes/No Clean: The greatest goal, of course, is to eliminate the cleaning process. Development of no clean fluxes is ongoing. These fluxes are referred to as no clean or low solids fluxes. They are typically "RMA" with 90% alcohol, 2 to 5% resin solids content, and less than 2% acidic activators.

These classes of fluxes leave the process engineer in an interesting box. Since the amount of activators is greatly reduced and the amount of volatiles are increased, the need to control the preheat conditions is greatly increased as compared to the preheat needs for the previous classes of flux. Preheat temperatures may need to be increased. Two reasons for increased preheat are the need to drive off the increased volatiles, and because some new fluxes are not fully activated until they reach a higher temperature. Failure to completely drive off the volatiles can result in excessive outgassing at the point of solder which will lead to excessive solder skips and solder spatter. Not reaching optimum temperature for the activator may result in less than optimum wetting conditions and poor solderability. On the other side, excess preheat temperatures may oxidize the no clean fluxes, causing severe loss of activity in wetting action.

Precision monitoring of this new class of fluxes is very important. The low solids fluxes are not as forgiving in the process as are the conventional fluxes. Monitoring specific gravity, the conventional process parameter measured, will not be sensitive enough to act as a process control variable. The acid number must also be determined a number of times during each shift, as this control variable is more precise in controlling the flux parameters for low solids fluxes.

When low solids fluxes are used, it is also very important to monitor and control the wave solder conveyor speed. If the speed is high, the flux will not be displaced in the wave leaving excessive flux on the board. If the speed is too slow, it can cause a depletion of fluxing agents needed for reducing the surface tension at the solder wave exit, and increase the number of solder bridges, icicles, and shorts. One manufacturer reports that a 10 to 20% reduction in conveyor speed was necessary from the speed used with conventional fluxes.

The higher amounts of alcohol in the no clean fluxes also place greater importance on the solder mask process on the circuit board. The solder mask is not always fully cured. The noncured solder mask materials are very volatile, and when reacting with the higher amounts of solvents in the low solids fluxes, can increase the amount of outgassing dramatically. Of course, this can lead to excessive solder skips and solder splatter.

B. Fluxes/Conventional: In the interest of decreasing the thermal shock between the preheat and wave solder zones, some users have increased the preheat to excess levels. This may cause the flux to decompose on the substrate, and be very inefficient in the cleansing of surfaces to be soldered. In addition, the flux residues will have very low solubility in the cleaning solutions, making removal very difficult.

C. Cleaning methods and materials: A recent trend in the industry has been seen as the search for the optimum cleaning process goes on. Increased use of ultrasonic cleaning stages is appearing. This process should be fully evaluated prior to introduction in the day to day process. Excessive levels of energy have been shown to damage Integrated Circuits, lead frames on various components such as inductors, tantalum capacitors, and other similar parts. The amount of energy applied by ultrasonic cleaning is very difficult to qualify, and also very dependent on the amount of boards in the cleaner, the amount and type of fluid used, and the time of cleaning. Ultrasonics can be used successfully. Care and process control are very important.

4. Preheat and Flux Zones

The purpose of the preheat and flux zones is to prepare the PCB assembly for soldering. To maximize reaching the established goals, the flux should prepare the terminations and PCB solder pads for the solder. RMA type fluxes are adequate. If the PCB or the parts do not demonstrate good solder wetting characteristics, the supplier of these need to improve the solderability. Concentrated efforts with the suppliers in improving solderability can pay large dividends.

The solder wave equipment manufacturers have recognized the importance of preheat and have included individually controlled bottom side and top side preheat zones with individually controlled heaters to reduce the gradual nature of the heating zones.

The goals of the process profile in the preheat zone are numerous.

- A. The heating should be gradual and not exceed 2°C per second.** Higher heating rates have the potential of increasing the temperature differential across the board, which can increase the amount of warp and twist (and possibly local delaminations) in the board as it exceeds the glass transition temperature.
- B. The heating should be somewhat uniform on the top and bottom side of the board.** During the preheat, the reflow solder side of the board must by necessity be kept a little lower than the wave solder side, however, top side preheat will increase the uniformity of wave solder preheat, and will decrease the temperature gradients the PCB is subjected to.
- C. The heating should be in line with the needs of the fluxes.** No clean fluxes may demand a little more preheat. Excessive preheat should not be used.
- D. The preheat should be uniform across the boards, and not be subject to board loading and environmental conditions.** The preheat zones of most wave solder machines are infrared heating zones. Uniformity of heating is improving as more and more zones are being added to the wave solder. However, most users have not applied the same care to the preheat zones of wave solder equipment as they have to the reflow solder equipment themselves.

Typical problems seen with wave solder equipment preheat zones are usually as a result of the openness of the throat and the equipment itself, and the environment the machine has been placed in. The profile is typically established under ideal one board conditions. Then in production numerous board loading configurations are run, resulting in excessive and different load conditions on the preheaters. Profiling under all conditions is suggested.

A considerably worse situation can be encountered. The environment around the wave solder equipment is normally very warm and uncomfortable. Venting is added, air conditioning is sometimes made available, and doors to the room are opened to make the environment more tolerable. All this variable cooling air is typically drawn into the preheat zone through the bottom of the machine or the throat of the machine. Vents for fumes accelerate this cooling tunnel. These have very large effects on the control and variability of the profile, and can result in very large thermal stresses as the part leaves the solder wave.

Shadowing of the preheaters also can result in differentials of preheat across the board. It is suggested that profiles be run with thermocouples in numerous locations across the board. Shadowing can result from large components being placed near smaller components, tooling and fixturing proximity, etc.

- E. The temperature differential between the preheat and the wave solder peak should not exceed 120°C.** Of course, less is better. Some of the largest benefits in reduction of thermal stresses can be achieved in the preheat zone. This recommendation is higher than that normally given by ceramic chip capacitor suppliers. See notes under "Conclusions". Some of the results seen with higher thermal stresses are:
 - increased solder fillet sizes
 - increased solder bridging
 - increased amounts of solder balls
 - increased amounts of solder peaking
 - increased failures of thermal stress sensitive parts such as ceramic chip capacitors

Traps to be Avoided

- Preheating from one side only
- Counting on controllers which measure heater temperature
- Establishing the profile under ideal conditions
- Using the same profile for all assemblies
- Using solder wave equipment which was designed for through hole soldering, and not having adequate preheat zones.
- Large gaps between preheat and solder wave which result in large temperature drops.

Attention to the profiles as seen in the preheat zone, and then monitoring the important parameters on a regular basis, can pay very high dividends in reduction of thermal stress on the product.

5. Solder Wave Zone

Most SMT solder wave equipment now have dual zones. The first zone is more agitated to increase the wetting action of the solder, and the second zone is usually a smoothing zone to optimize the shape of the fillet and reduce bridging. Some of the waves are separated and some are adjoining each other in the equipment.

As the PCB leaves the preheat zone and enters the solder wave zone, large temperature gradients are established across the board. The differences in expansion establish twist, bow, bend, and numerous other stresses across the assembly. These stresses are magnified for thinner boards, and for large panels of multiple boards which have been pre-routed for separation. Adequate fixturing and tooling is necessary to keep these stresses to a minimum.

The goals for the wave zone are:

- A. The peak temperature of the wave solder should be kept to a minimum.** Some tests have shown that reduction of thermal stress between preheat and the wave solder is better accomplished by reduction of the peak wave temperature (as opposed to increasing the preheat temperature). A good goal is a peak wave solder temperature of 235°C. With this a peak preheat temperature of 115°C is allowable, and the temperature does not exceed the glass transition temperature of the board material. Wave solder peak temperatures of 250°C are common, however, this requires larger preheat temperatures, and typically results in more stress to the PCB.
- B. Time in the wave should be kept to a minimum.** Typical times in the total solder wave are 5 to 8 seconds. Time in the wave exceeding 10 seconds can begin to have detrimental effects on the solder ability of the parts and the board, result in breakdown of the fluxes making cleaning more difficult, and greatly magnify the stresses applied to the board.
- C. Temperature between the waves should be maintained above the liquidus points.** Some equipment have gaps between the two waves, and with improper venting and room environments, the solder temperature can go below the solidus temperature, and then be subjected to another thermal stress in the second wave. This also will defeat the purpose of the second wave, and greatly diminish the effect of "air knives" if they are used.
- D. Temperature of the reflow solder on the opposite side should not exceed 150°C.** If the temperature of the top side solder exceeds 150°C, then excessive grain growth in the solder can occur and weaken the fatigue strength of the solder joint.

Traps to be Avoided

- Increasing wave temperature to improve solderability
- Increasing time in wave to improve solderability
- Increasing temperatures to reduce solder balls, bridges, skips, etc.
- Establishing wave profiles once, and not monitoring frequently
- Adding forced air cooling directly after wave solder
- Using fixturing which adds stress to the boards
- Conveyor transfer systems which drop boards or introduce the possibility of twisting boards by mechanical jamming in the conveyor

6. Hot Air Debridging

The concept of using hot air blowing on the solder joints immediately after the wave to minimize bridging and solder fillet size, is an excellent idea. The air temperature immediately at the exit of the orifice is typically set near 275°C, and the impinging air on the part/board assembly is typically less than 230°C. This concept was developed with SMT assemblies in mind, and has been shown to be an excellent improvement.

7. Cooling Zone

After the board assembly leaves the solder wave and the hot air debridging area, it enters a very critical area. It is very important to let the stresses applied by the large heat and mechanical warp, twist, and expansion differences relieve themselves in a natural slow manner. Some very recent data indicates that thermal shock stresses applied by cooling after the wave can be more detrimental than that applied by the heat stress of the wave itself.

The process engineer might have a tendency to supply forced air cooling directly after the wave solder and hot air debridging areas. Some wave solder equipment is being supplied with fans and some even have "CHILLER" zones. There are multiple reasons given for this attempt at cooling. One is that the board needs to be cooled for people to handle it. Another is that the fans are there and are turned on without reason. Both of these are not valid technically and need further consideration. Another reason is that the solder needs to be cooled rapidly to establish fine grain solder fillets (represented by nice "shiny" solder joints). While cooling can help this, it has been shown that the fine grain structure achieved this way is only temporary. The stresses set up in the solder fillet and the board are relieved in less than 24 hours at room temperature and the solder structure begins to coarsen. Fatigue testing of various solder joints have shown that the perceived advantage of shiny joints is not proven out.

Other sources of excessive thermal stresses can be found to be applied by:

- large heatsinks on the top side of the board which have not reached high temperatures during the process
- excessive venting of the wave solder machine directly after or above the wave zone.
- room air inlets under the wave solder machine or through the exit and input throats of the machine. Air conditioned or winter air rushing through the machine can cause very stressful profiles.

Wave Solder Process & Parts

Parts mounted on the circuit board are subjected to very large stresses. These stresses can be minimized when an ideal or optimum wave solder temperature profile is used, and the parts can be soldered successfully. Examples of parts which can be successfully wave soldered, and some failure types which can occur if stresses are excessive, are as follows.

- A. Parts with precious metal terminations (i.e. ceramic capacitors, resistors, inductors, etc.) are targets for "leaching" of the precious metal.** The scrubbing action of the wave in addition to the excessive time/temperatures accelerates this leaching action. The resultant solder connection has the potential of being brittle and weaken during additional thermal cycling. In addition, the leaching of precious metal from the termination weakens the connection to the part itself.
- B. Parts with epoxy bodies are very capable of being mounted and wave soldered with the most robust ceramic body parts.** Examples of these are tantalum capacitors, inductors, SOT transistors/diodes, and even some integrated circuits. In these cases it is very important that the wave solder temperature maximums not be exceeded. The largest cause of concern is the large difference in the coefficient of thermal expansion of the epoxy cases, lead frames, and the internal part itself. Typical failure modes that can occur when the temperature extremes have been exceeded are increased leakage currents and equivalent series resistance (ESR) for tantalum capacitors, fine wire breakage or decrease of Q for inductors, and fine wire breakage or parametric changes in semiconductor parts.
- C. When the PCB assembly has parts mounted and reflow soldered on one side prior to wave solder, these solder joints are susceptible to being reheated and reflowed again as the assembly passes over the wave.** This is especially likely in areas of thru hole connections, or over internal copper ground planes in multilayer boards. This uneven reflow can result in weakened solder joints, open joints, or in the extreme cases can result in parts moving and have to be totally replaced.
- D. Ceramic capacitors are placed under great stress as the metal terminations and electrodes heat up much faster than the ceramic dielectric body.** Parts may crack and fail at a localized site weakness under extreme shock conditions. The failure mode can be manifested in the form of a short circuit either immediately or at a later date.

KEMET has conducted a very in-depth analysis of the effects of thermal stresses on ceramic chip capacitors. A brief summary of this program is presented to whet your appetite.

1. Thermal cracking of ceramic chip capacitors, as seen in the wave solder process, can be created as a result of two factors. The greater the magnitude of these two factors, the greater the probability of thermally cracking the ceramic chip capacitor. The first factor is the thermal stress. This thermal stress is created as a result of the difference in temperature between the preheat stage and the wave solder itself. (The lower this stress, the lower the probability of creating a failure.) The second factor relates to

the thermal robustness of the capacitor. KEMET has greatly improved the thermal robustness of the part by reducing the thickness of some parts (a primary factor), and by greatly reducing internal stress sites in the capacitor.

2. Detection of capacitors which have been thermally cracked is not an easy task. Early methods of detection such as, visual inspection, Insulation Resistance test after soaking in a fluid such as Isopropyl Alcohol, etc. have all proven to be relatively insensitive to detecting all cracks. KEMET has developed the load humidity test (with current limiting) as a very sensitive method of detection of thermal cracks. Testing under very severe conditions has helped KEMET determine the cause of thermal cracking. More importantly this has helped KEMET verify important improvements.
3. KEMET's Recommended Wave Solder Profile remains conservative. We recommend that the user target a nominal preheat temperature such that a difference between the preheat and the wave temperature is maintained at 120°C or less. (See notes under "Conclusions"). The reason for this recommendation is based on the variability available in the wave solder process.
 - a. Preheat zones in wave solder machines are basically infrared heating of some type. These zones are not very sophisticated, certainly not as sophisticated as that seen in reflow solder equipment. Resulting temperature swings from board to board can be large.
 - b. Control of these preheat zones is also not very sophisticated. Generally they are not controlled as a function of the load. The front end of wave solder equipment, where preheat zones are located, are also relatively open to the room environment, and air conditioning/door opening/etc. variations greatly affect the temperature seen by the parts on the board.
 - c. Differences in temperature from location to location on the board are significant. Shadowing of the capacitor from preheating can occur by location near other parts, highly dense areas, large thermal sinks such as ground planes, and location near the side of the board in the vicinity of the wave solder carrier plate.

With all these process variations, KEMET feels a profile with a nominal setting of 120°C delta or less, could result in some capacitors on the board seeing higher deltas. Some data seen indicates deltas of 150°C are seen on the board, even when the nominal is established at 120°C.

For additional information about this ongoing program, contact your KEMET salesperson.

Conclusions

1. A well designed solder wave process can help achieve the benefits of SMT manufacturing. An optimized solder profile is shown in Figure 3. Characteristics of an optimum wave include:
 - Smooth and uniform preheat ramps of less than 2°C/sec.
 - Bottom side preheat to solder wave temperature differences of less than 120°C*
 - Solder wave temperatures near 235°C
 - Free air cooling prior to cleaning
 - Smooth and uniform cooling ramps
 - Continuous monitoring and feedback of heating
 - Periodic test board runs to insure profile is correct
 - Monitoring of repair rates and relating to profile adjustmentsIt has been demonstrated that repair rates of less than 1 PPM can be obtained when care is taken in establishing and monitoring an optimum solder wave process.
2. Not all solder wave profiles can be optimum. For these situations, the profile should be as close as possible to the optimum and fine tuned with experience.
3. The parts used should be robust under the use conditions. Large size 1825 and 2225 capacitors should not be wave soldered.**
4. KEMET has **the** Robust Ceramic Chip Capacitor.

Notes:

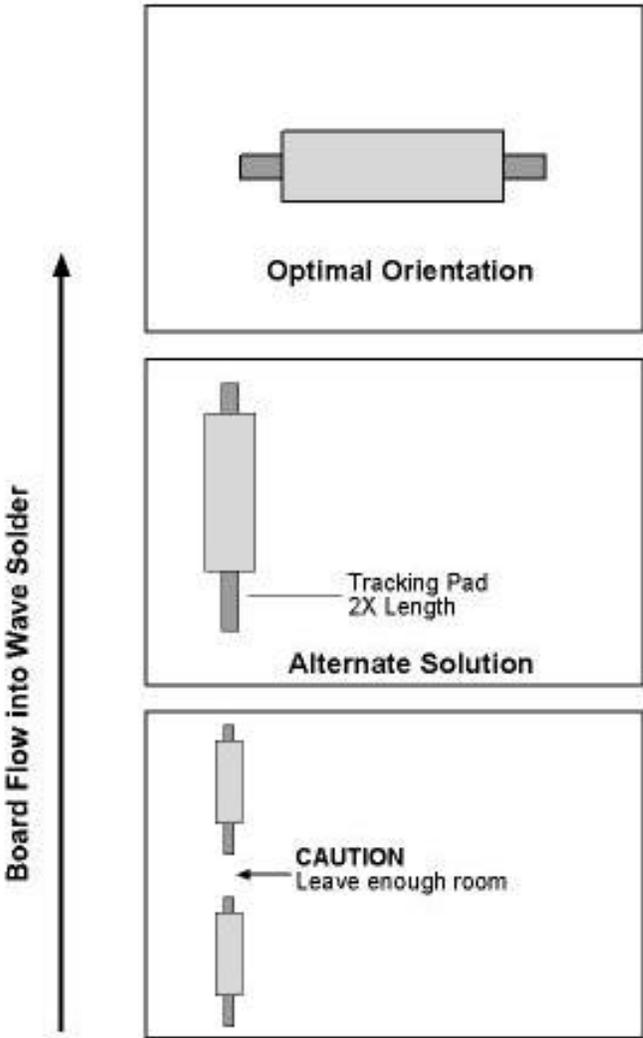
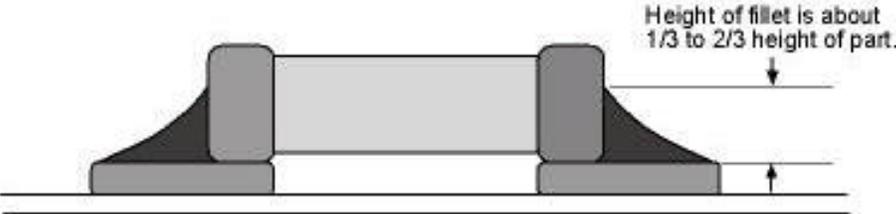
- * If 1812 size capacitors are to be wave soldered, this difference should be near 80°C, or less.
- ** The user should discuss thermal robustness with the part's suppliers. Adjustments to the profile may be necessary for less robust parts.

Reference List

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Optimum Wave Solder Fillet

Figure 1.



Preferred Circuit Pad Orientation

Figure 2.

Optimum Solder Wave Profile Maximizes SMT Process Goals

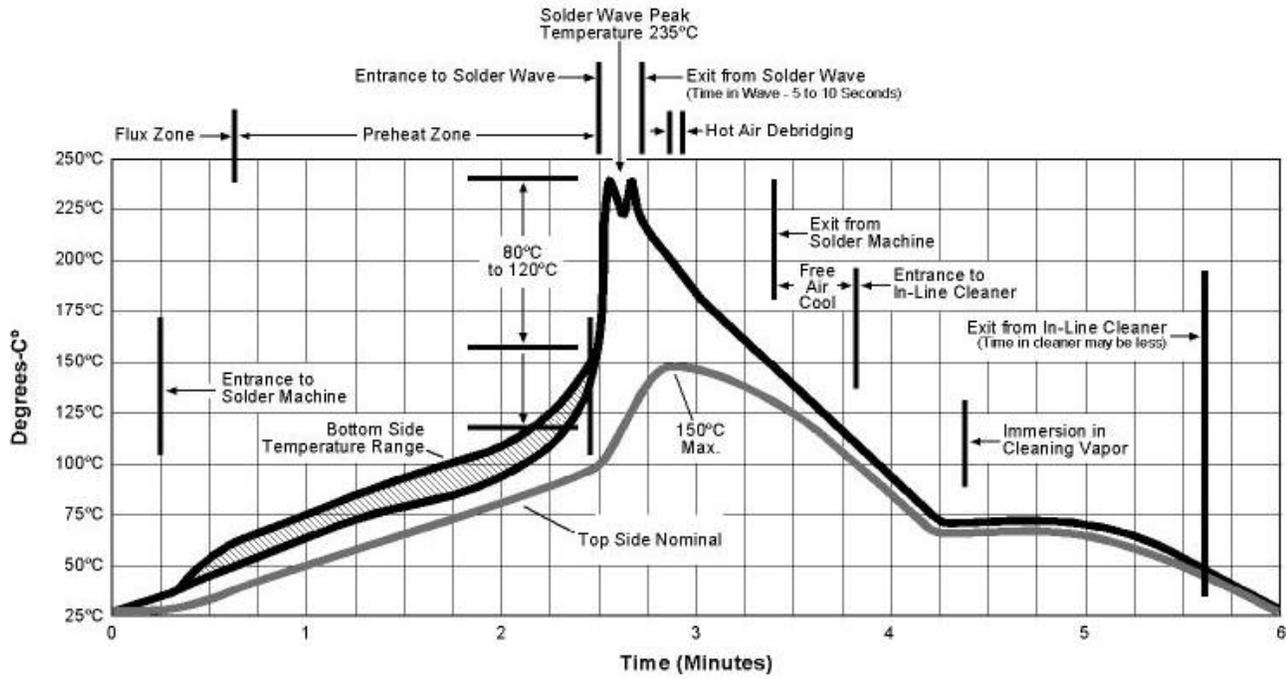


Figure 3



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