Surface Mount Technology

Repair
Touch Up
Hand Solder

Can These Be Controlled?

by Jim Bergenthal

P.O. Box 5928
Greenville, SC 29606
Phone (864) 963-6300
Fax (864) 963-66521
www.kemet.com

F2103A 10/91
Reprinted 6/04

Introduction

Surface Mount Technology has been around now for some time, and has proven that the benefits anticipated are in fact real. The benefits of reduced space, reduced cost, and improved performance (quality, reliability, and electrical performance) have been proved and continue to fuel the drive to increased implementation of surface mount technology.

One aspect of surface mount technology that has been difficult to deal with is repair, touch up and replacement. This is a complex field when all part types are considered. Many of the repair and touch up aspects of this bulletin will be applicable to all part types, however, some of the very complex repair issues will require even further evaluation. Use the information as a thought starter and take it from there.

Why and When?

Many of the benefits of surface mount technology are derived from the automation and process control available with this technology. The tight spacing of parts and the different types of solder joints have caused us all to relook at what is acceptable and what needs to be repaired. It has been proven that Printed Circuit Assemblies (PCs) that have not been repaired will have a much higher success rate at final test and in use, compared to PCAs that have been repaired. Failures of parts and solder joints that have been repaired, and failure of parts and solder joints in the vicinity of repairs are common.

This emphasizes that surface mount technology was not invented to ease repair. The high degree of automation of SMT does give the opportunity to reduce the necessity of repair, and with the proper attention to details most rework and repair can be eliminated. The industry has come to accept rework, repair, etc. as a part of manufacturing the conventional through-hole printed circuit assembly. It is not necessary to carry this acceptance with the new SMT thechnology. Something can be done about it.

With this in mind we invite you to think of repair, touch up, and replacement in the following manner.

If It Isn't Broken----Don't Fit It!!
If It Isn't Right----Find The Cause!!
If The Cause if Known----Fix It!!
Repair Is Best Under Controlled Conditions.

In General

There are many items to consider when trying to minimize repair and rework. In a very simplistic view, the total manufacturing cycle for a surface mount product breaks down into four categories, each one of which should be reviewed with rework and repair in mind.

1. The design and standards for the product. These are the base lines for manufacturing process, equipment, fixtures, training, inspection criteria, and repair/rework capability in regards to the product. If the product is designed and the standards selected well, the manufactured product will require little repair and what repair is required will be successfully performed.
2. The second area is the manufacturing process itself. This includes whatever is necessary in manufacturing the product to minimize repairs and rework. Design of mounting pads, selection of printed circuit board location tolerances, placement accuracies, soldering process controls, selection of solder pastes, operator training, etc; all of these are important to minimize rework. The "Do It Right the First Time" attitude goes a long way in SMT Technology Assemblies.
3. The third area is the inspection process. Visual inspections are the most prevalent method today, with "Automatic Optical Inspection" equipment being developed and fine tuned for the more difficult and the more astute of operations. Which method to use will depend on the product being manufactured and to some extent on the capital ($) available. It is important to recognize the limitations of each to recognize these in the standards required of the product and process.
4. The fourth area is the actual rework and repair of the process. This is further broken down into a number of classifications. Each of the classifications will require different levels of training and different types of equipment to be used. These classifications are:
   a. Touch-up: This is the repair of a solder joint which has excessive solder or which requires more solder.
   b. Re-alignment: This is the actual movement of a part either in wet solder paste, wet adhesive, or after soldering.
   c. Removal: This is the removal of a part because the part has failed, because the part or the circuit pad did not solder well, because the placement of the part is not on the circuit pad, or because the wrong part was placed.
   d. Replacement: This is the soldering of a part by hand or by semi-automatic means to replace one which was removed or which was missed in the placement process.
   e. Cleaning and inspection: After any soldering process it will be necessary to clean and re-inspect the repaired area, including the area around the repair and rework performed.

Details

1. Designs for Rework and Repair

Various design elements of the product can be oriented to lessen the need for repair, and improve its changes for success when repair is needed. Each company should maintain a set of design standards for layout, and these standards should be updated regularly as process problems are identified. The standard should include items regarding the following.

a. Proper design of the circuit mounting pad will result in better part location accuracies. Do not forget the accuracy of the PCB tooling holes and the part placement machine when designing the circuit pad. Tombstoning is more influenced by this single characteristic then any other (except maybe the solderability of the part/circuit pad).

The circuit pad should also be extended to allow room for the soldering iron tip and solder wick should repair be needed. The tip must not come in contact with the part or surrounding parts (see touch-up techniques). When geography allows, a design spacing between circuit pads of at least 0.1 inches is desirable.

In addition, appropriate solder mask dams should be used to prevent scavenging of the solder available for the solder fillet. The circuit traces leading from the circuit pad should also leave the pad in a straight fashion as opposed to on an angle. The angle could apply rotational forces to the part as the solder becomes liquid.

Circuit via holes should not be part of circuit pads. These result in scavenging of solder from the fillet. In addition, if the part termination could be placed on the via, the via surface is generally not flat and the part could move off the pad. The via's barrels are also subject to cracking if rework is required on the circuit pad fillet.

Parts which share the same circuit mounting pads will have a tendency to have excessive solder fillets. This mounting is not always desirable.

Special designs are now available which allow the solder to drain from the trailing edge of circuit pads for fine pitch parts. This prevents excessive solder mounds and solder bridging.

For additional information regarding circuit mounting pad designs refer to KEMET's Engineering Bulletin "Surface Mount Mounting Pad Dimensions and Considerations F2100".

b. Location of other parts are very important. One of the most difficult to deal with parts used in products today is the strip socket and pin combination. This part's function is to interconnect two circuit assemblies. Since its pin acts as a connector pin, it is often required that solder be present only in a very small length up the pin. This makes it near impossible to attach with any method other than hand solder. It also requires a very delicate hand solder technique to result in the correct solder location, and unfortunately also requires some rework and clean up. With all this challenge to the solderer it is very important that other parts be placed as far as possible from this part. Parts placed too near this part not only make the hand solder very difficult, but also can result in the adjacent parts being damaged by coming in contact with the solder iron. Many of the adjacent solder joints can be reflowed by the heat required to solder this part to the board. Other parts which will require hand solder attachment should also be treated similarly. The location of these parts should be carefully considered. For additional information about part damage when contacted by the soldering iron, see "Touch-Up" in the following sections.

c. Unfortunately some parts are more prone to failure than others. Some of these are known. Newly designed ICs may be one, process sensitive parts are others. Each product may have some design quirk which makes circuit performance dependant on some other variable. Many times the part which must be replaced requires use of a repair tool which applies heat in a significant area of the board. The goal is to minimize these situations, and intentions are none but the best. However, while the improvement is in process, repair is necessary and is possibly damaging other parts. Placing these "replacement prone" parts as far away from other parts will greatly enhance the success of the replacement, and allow more time to correct the real problem without the added complication of the additional rework and repair of damaged parts. Refer to the "Part Damage" section for additional information.

d. Shadowing is a very real problem which adds significantly to the repair load. Shadowing results from the shielding of terminations from either the heat source or the solder, and results in a solder skip or small solder fillet. In wave soldering a termination could be shadowed by the pallet, by tooling used to protect edge card connectors, by the location of a lead through the board, by the proximity of other taller surface mount parts, by a ripple in the wave height caused by the conveyor fingers, and other similar situations. Shadowing in a reflow solder process is also possible, although the heat source is generally not as likely to be shadowed. Examples such as tall parts near the edge of the board shadowing surface mount parts even nearer to the edge, or board location on the conveyor where the heat profile has cooled due to edge effects are common. It is important to place the parts as far away from the edge of the board as feasible, and to review the proximity of all terminations to items which could result in shadowing.

e. Bridging is also a very real problem in wave solder operations. While bridging can be controlled with the correct process parameters, it will also be minimized by correct spacing of parts and circuit pads. Dual wave solder machines with air knives also assist in minimizing bridging. Circuit pads can be made to drain excess solder from areas prone to bridging, such as the trailing edges of closely spaced parts. This works well to minimize the amount of solder in joints which are consistently excessive. Bridging can also occur in reflow soldered assemblies. Most cases of this are due to moving or sliding the parts after they are placed in the solder paste, or due to inaccurate placement of the parts, or dirty solder stencils.

f. Regardless of the degree of automation in the process the boards must be handled. Parts must be placed away from the edge of the board. Parts near the edge of the board could be moved either in wet paste prior to reflow soldering, or in wet adhesive prior to curing and wave soldering. This moving could occur by operators unknowingly touching parts, by conveyor or load/unload systems directly touching the parts, or by edges of magazines touching the parts.
The board design should again keep the parts from the edge of the board, thus allowing safe transportation of the cards.

2. Visual Inspection Standards

The standards for visual inspection and for identifying repair candidates are also very important in attempting to minimize repair. Inspection and repair standards should be developed under very controlled conditions. Do not copy someone else's attempt. Other standards could be used to generate ideas, however the product being manufactured is unique, so it makes sense that the inspection standards are equally unique.

a. Ask why a certain condition should be repaired.
b. Are there facts to go along with it?
c. Are the risks of the repair/replacement larger than the risks involved in not repairing?
d. Once deciding on a reasonable standard that makes sense for the product, ask whether the process can produce product which meet the criteria on a regular basis. (If not, a relook at the process or the inspection criteria is suggested.)
e. Do not build repair into the process. Repair only by exception and then use history to improve the process and reduce repair.

Inspection and repair standards should state boldly.

a. If the part location or solder joint is acceptable, do not repair it.
b. If the part location or solder joint is marginal, do not repair it. Ties and near misses should go to the accept area.
c. If the part location or solder joint is definitely bad, first find out why, correct this situation, then repair under controlled conditions.

3. The Manufacturing Process

This should be fairly obvious. To minimize the repair the manufacturing process should be optimized and operated to isolate the cause of repair and correct the situation. We won't go into a lot of areas for concern other than to mention that Engineering Bulletins are available from KEMET which discuss the Wave Solder Process and the Reflow Solder Process and how it can be optimized to minimize the rework and repair. Other literature is available which will assist in improving the process. The manufacturing process is the key to minimum repair and rework.

4. Visual Inspection

The visual inspection of the best available work is one of the most important items in the cycle. The product was designed to be produced without repair, millions of dollars were spent to automate its production and the product is now a full fledged member of the latest state of the art "SMT" Technology----- and now an ordinary human is going to judge this masterpiece and (Heaven forbid) is going to say it "NEEDS REWORK"!!

It is important to realize that visual inspection for defects is at best a difficult proposition. Many tests have been conducted to qualify the eye/brain vision system of the human inspector. Inspecting for acceptable/rejectable defects has a certain success ratio. It has been found that a large improvement in success can be attributed to defined standards that are black and white. Gray judgment calls tend to reduce the success of the inspection very rapidly. For example, a requirement that a solder fillet be 25% or higher of the termination height with a positive wetting angle (described with pictures) is much easier to inspect than a requirement that the solder fillet be greater than 0.010 inches. If the marginal solder fillets are acceptable this even makes the inspection more credible. Visual requirements stated as one third, one half, one quarter are also easier to judge than requirements stated in inches or in odd percent ages like 20%, 15%, etc. The best standards will include written requirements, photographs of acceptable, marginal, and rejectable items for each requirement, and further sketches if needed for clarity. Procedures should be such that second guessing close calls is not done. If this style of inspection is not acceptable for the product, then a need exists to investigate the automatic visual inspection systems. There are some very good systems which can also double as a process control system for the solder process. Costs can approach $1 million. The use of an automatic visual inspection does not mean that accept/reject criteria are automatic. Close attention to this is going to determine if the potential of over repair will be present and increase the risk of damage to the product.

5. **Inspection and Repair Techniques Training**

Since we are going to trust the acceptance of the product to the visual inspector, it follows that the inspector should be trained as well as possible to know a true defect and to know when the product is acceptable. A well documented training program with graduated levels of certification for inspectors and rework/repair personnel is very important. This program should be developed and conducted by personnel from within the company. This gives the inspector the slant and opinions of the company, not a generalized view of a consulting company. Consultants could be workwhile for a start up situation, but should be replaced as soon as possible with in-house personnel who will be training the people as the company requires. A shell of a training program is given to promote ideas and to assist in the beginning or modification of your program. Please take it as a beginning and improve on it.

Training Program - Visual Inspection and Rework/Repair
Surface Mount Processes

Introduction: *This should be an introduction to the “language” of surface mount. Associating names of parts with samples and outlines, schematic symbol conventions, concepts of polarization, concepts of ESD and protection, measurement techniques, names and some basics of tools (solder, flux, cleaning agents, magnifiers, pliers, solder irons, etc.), and some general discussion of the processes of surface mount.*

Visual Inspection: *This should start with a classroom experience of the visual inspection criteria, followed by some initial experience with production level (scrapped) boards with known visual defects, followed by an initial testing program to insure the trainee understands the fundamentals.*

After successfully demonstrating an understanding of the fundamentals, the trainee would be assigned to a certified inspector and allowed to work on the production line in a controlled fashion. All of the trainees work would be reinspected by the certified inspector, with corrections being regarded as hands on training. Dual view microscopes or TV view microscopes are particularly useful for the training operation. When the trainee and inspector agree the trainee is ready, another testing program should be administered hopefully resulting in certification of the visual inspector.

Soldering: *The same general program of teaching, fundamental testing, hands on training under the wings of a certified person, and testing for certification is a good program. It is highly recommended that trainee solderers be certified inspectors prior to applying for solder school, as in many programs the solderer finishes the task by re-inspecting the area. Important items to be included in training should be proper control and maintenance of the soldering station, cleaning and tinning of the tip, acceptable tip configuration and when damaged tips should be replaced, life of fluxes, cleaners, tips, and other tools.*

It is also recommended that the certification and training be divided into different levels, such as touch-up, replacement of parts based on tools used, and replacement of the difficult to replace parts which may require use of semi-automatic tools. Another level of training should be used for operators who routinely will be doing hand soldering of parts which cannot be machine soldered. Specialized techniques such as hand soldering connectors, reapplying gold to tabs, repairing multi-layer circuit boards, circuit trace repair, etc. should also require specific certification. A case has been made that the operator of the complex SMT repair equipment needs to understand the needs of the total SMT process. The complexity of replacing a large pin count IC may require 30 minutes to an hour of time. For this reason this level of repair, the operator may need to be a technician. Pretesting to insure manual dexterity may also be important.

The training department needs to be an innovative and ongoing portion of the total operation. This training activity should be ongoing and include training for any new part or new fixtures used in the products.

Trouble Shooting: *There are sometimes a group of personnel who are required to isolate and repair failures of the circuit as a result of electrical test. These are typically technicians or special trained personnel. The program could have these people identify the repair to be done, and forward the board to the certified rework area. This approach has the tendency to disrupt the train of thought of the trouble shooter as it is sometimes a trial and error situation. A better solution is to train and certify the trouble shooters to inspect the rework of the boards.*

Re-Certification: A testing program or other ongoing monitoring of the inspector/repair personnel should be used to determine when additional training is required.

Rework and Repair Techniques

As stated earlier, rework and repair can be divided into a number of different classes; touch-up; re-alignment, removal and replacement, and clean and inspect. Each will be discussed below.

Touch-Up

This is an interesting area. Many manufacturer's have conducted studies, or at least heard of studies, where PCAs have been inspected for defects, then sent down a touch-up line, and reinspected to see what solder joints were actually touched up. The results are amazing, in that many solder joints than needed are being resoldered or touched up. After all, the operators are called touch-up solderers; therefore, they touch up solder joints. This is a hazardous situation for surface mount technology assemblies.

Training cannot be over emphasized, and the certification test should include grading for touch up joints which do not need rework.

How to do it!

1. Touch up means a few different things.
   a. Not enough solder (maybe none) is present to make an adequate solder fillet.
      Inspect for cause.
      Common reasons include paste smear or improper paste screening (reflow solder), shadowing or skipping (wave solder), and non-wetting of circuit pads or part terminations. These can be improved by using a touch-up method. Other reasons for insufficient solder, such as part misalignment with pad, tombstoning, adhesive on the pad, etc.; should be repaired by replacing the part. See "Part Removal and Replacement" for details of this technique.

      The Proper Method to Use for Adding Solder
      1. Use an iron with enough wattage that it is not cooled as it comes in contact with the solder pad. (A good judge of excess tip temperature is the time to reflow the solder. If it's reflowing in less than 1 to 1.5 seconds, the tip temperature is likely excessive and makes the solderer's job very difficult. On the other hand if the solder does not reflow in about 3 to 3.5 seconds, either the tip temperature is insufficient, the tip is cooling when applied to the circuit board, or the board thermal capacity in the area is so high that a preheat cycle is required.) Soldering iron temperatures can be monitored through the use of non-contact temperature measurement tools.
      2. Apply a small amount of flux to the part termination and the circuit pad. (The new synthetic no residue fluxes are excellent.)
      3. After tinning the iron, the iron tip should be placed on the circuit pad at the edge furthest from the part. The iron need only be in contact with the pad for 1.5 to 3 seconds. If it is necessary to keep the iron on longer than 3 seconds, the part should be replaced, or if the circuit pad is at fault it may require repair of the pad under special conditions.
      4. The solder should be added at the solder iron tip and will flow from the pad to the part termination. <u>Only enough solder to make a minimum solder joint should be added. Do not overdo. UNDER NO CONDITIONS SHOULD THE IRON TOUCH THE PART.</u>
         This is a major cause of part damage. Use extreme care not to touch adjacent parts with the iron, as well as the parts being worked on.
   b. Another reason to touch up a solder joint is the removal of excess solder. After the solder is removed, a good solder fillet is desired. Bridges, splatter, and solder peaks are examples of excess solder conditions which generally require correction. Other examples of a need to remove solder are the cases where the solder joint has partially wet to the board or to the part due to contamination of some sort. If it is deemed that the contamination can easily be removed with the solder or after the solder is removed; then this is a worthwhile effort. If a fair amount of effort is required to remove the contamination, then the part should be totally removed and replaced. For example, excessive adhesive may have seeped unto the circuit pad. Do not attempt to solder over the adhesive. This joint has a higher probability of failing when temperature cycled. The part should be removed, the adhesive cleaned from the circuit pad, the pad inspected and re-tinned if needed, and a new part soldered in place. Other examples of the need to replace a part are when the termination has been excessively leached by previous repair, non-solderable terminations, damaged parts, poorly placed parts, damaged circuit pads, etc. Continued repair by removing and adding solder will only make these parts and connections more tenuous.

The Proper Method to Remove Excess Solder Involves:
the same techniques used in adding solder described above. In addition to the soldering iron, a solder material extractor is required. Copper braid solder wicks and vacuum solder extractors are good tools in the hands of trained operators. Keys here are the same as in adding solder.

1. Enough soldering iron wattage to maintain a hot tip.
2. Time on the solder joint not to exceed 3 seconds.
3. Do not touch the part, its termination, or adjacent parts with the soldering iron.
4. Removal of the wicking device or solder extractor needs to be done prior to the solder cooling. Failure to do so will result in solder peaks or lifted circuit pads. This is a key part of the training program.

Both adding and removing solder is a simple enough task that it should be done with a soldering iron under controlled conditions. Use of hot air tools, heated tweezers, and other complex gear should be restricted to removal of parts; and soldering of complex devices after extended training.

Realignment

This is an area of repair that is between touch-up and replacement. It should be rarely done. Under special conditions some parts can be realigned. The need to realign parts should be a temporary issue. The causes are easily corrected and the results of realignment are poor at best.

One of the times when realignment is possible is when parts have been misplaced in wet solder paste. Moving these parts into position is best done by lifting the part (a vacuum pencil may work), and then realignment and pushing the part into the paste. Moving the part with tweezers or by hand, or sliding and rotating the part should never be attempted. The hazards of tweaking parts in wet solder paste by an method are numerous. Increased bridging, tombstoning, solder balls and splatter, and missing parts can all be expected as the solder paste form will be disturbed. Correct the cause of the problem at the placement machine, paste stencil, or circuit pad design as soon as possible. Interim correction means of over printing solder masks may be better than tweaking the parts in an attempt to realign the part.

A second time when realignment is possible is when parts are misplaced in wet adhesive and the adhesive has not been cured yet. The best method of realignment in this situation is to remove the part, remove most of the adhesive from the specific board location, cure the adhesive and other parts, add new adhesive for the missing part, replace a new part, and cure the board again. Realignment of parts in wet adhesive by sliding or rotating the parts will result in increased levels of adhesive on circuit pads and open solder joints later, missing parts due to insufficient remaining adhesive to hold the parts, and disturbance of adjacent parts causing increased levels of defects. Correct the cause of the problem at the placement machine, circuit pad design, or use better adhesives as soon as possible. Remember adhesives have pot lives and will degrade with time. Adhesive slump will result in increased levels of misplaced parts. Replacement of parts in the best of ways will still increase the levels of wrong parts, excessive adhesive, and overall defects in the product.

Realignment of parts after soldering or after adhesive has been cured should not be attempted. These parts should be removed and replaced. The rework personnel might be tempted to use heated tweezers, or combinations of hot air pencils or stations and had tweezers. This is hazardous to the part and in addition will result in excessive solder bridges, opens, and solder spatter.

Removal

1. Removal of parts which have been soldered and which have not been glued to the board is probably the simplest. Tools are available which assist and make this task easy to perform without damaging adjacent parts or traces. <u>Remember these parts are not going to be used again so care for the part is not as important as care for the board and adjacent parts.</u> Heated tweezers, or for the two terminal parts such as resistors and capacitors, a forked blade addition to the soldering iron can be used to remove the part. When the solder melts, apply a little twist to the tool. If it twists readily then lift the part. The peel strength of circuit pads at the temperature of reflowing solder is near 0.75 oz. per inch of pad. This is a critical situation to prevent lifting the pad and scrapping the entire board. The time the heated tool is applied should still be less than 6 seconds to minimize damage to the board. If the solder reflows in less than 1.5 seconds, the tip is too hot. The feel for the right force to apply without damaging the circuit pads is acquired in the training program.

   If failure analysis of the part is desired than care for the part should be maintained and some of the solder removed by wicking.

Complex parts with high heat masses such as PLCCs represent special cases. Preheat with hot gas, or eated bars may be appropriate, however, this method should be developed in the lab and then transferred to production through careful training. Though it takes a long time, pre-wicking of the solder joints will make the removal of all parts easier. Use of the hot gas and hot air stations can increase the level of deterioration to adjacent parts, solder joints and the board. At least one of the new repair systems has a computer controlled heat profile which allows controlled preheat under the repair area, controlled heat ramps, and controlled time above liquidus temperature. To make effective use of this system, each part type should be profiled, and the adjacent area heating should also be considered. If these complex types of equipment are used to reflow, or replace simple SMT parts such as resistors, capacitors, transistors, inductors, etc., the profile should be adjusted such that the solder reaches liquidus temperatures within 3 to 6 seconds after heating begins. The solder should be above liquidus for as short a time as possible. The heat source should be directed at the circuit pad as much as possible.

An additional method to be considered exists when the main object is to save and repair the assembly, and it is recognized that the part will be lost forever. The body of the part may be removed by cutting the leads or otherwise destroying it. The individual leads are then easily unsoldered without damaging the board.

2. Removal of parts which have been glued to the board and then subsequently soldered is simply an extension of the above procedure. If enough solder can be removed by wicking, this is preferred. The adhesive can be released by applying rotational force to the part. The adhesives are generally weakest in torsion and should release without damaging the board. If all of the solder cannot be wicked easily, the rotational force can be applied with the heated tweezers or forked tip or the iron. This has a little more tendency to damage the adjacent parts or the board as the tool may slip after the adhesive releases. Again, the heated tool should not be in contact with the circuit pad for more than 6 seconds.

Replacement

Prior to placing a new part, the area of part removal should be cleaned up and prepared. The circuit pads should be wicked of excessive or uneven solder. Some solder should remain to assist in wetting to the circuit pad and the part. The pads should also be inspected to determine if lifting or other damage occurred during the removal process. If adhesive was used to attach the previous part, the pads should be inspected to insure they are free of adhesive. Also if a circuit trace was routed under the part, the solder mask might have been removed with the adhesive. This area should be inspected to insure shorting will not occur when the new part is soldered. Solder splatter and solder balls should be removed now, while area is easier to access.

When the area has been adequately prepared the new part can be attached. For the simple parts such as resistors, capacitors, inductors, SOT23s and even lower pin count SOICs; the parts can be hand soldered in place. The circuit pad should be pretinned or prepared with solder paste. The part should be handled by a vacuum pick up tool or tweezers (non-metallic and preferably teflon) and located as required. Heat should be applied at the end of the circuit pad, and with the same precautions mentioned above for touch-up. For multiple pin count parts such as SOICs, the opposite corner pins should be soldered first followed by the remainder. The use of heated tweezers to reflow solder for replacement parts is not recommended as the temperature and pressure applied are not recommended as the temperature and pressure applied are not easily controlled. The heated tweezers are also prone to excessive bridges and tool marks, and it is also very hard for the operator to see the result of the solder joint. With adequate training and care in the process, the replacement can be almost as good as if the part were placed and soldered correctly to begin with.

Replacement of the complex parts such as very fine pitch ICs, PLCC ICs, and other parts with high heat capacities, is very complex. Many pieces of equipment are available today which are advertized as making this an easier task. The industry has come to grips with the repair of these complex parts and recognizes the repair/replacement process to be a microcosm of the whole assembly process. The use of this complex equipment requires strict procedures, training and process controls. We suggest that prior to choosing a process or a piece of equipment, an evaluation be conducted. Important items to be considered are:

- Temperature and time required for each part type.
- Control of heat transfer to adjacent areas.
- Can the solder joints of adjacent components be kept below liquidus?
- Are the optical magnifications and angles sufficient. Four sided vision alignment systems are important for alignment accuracy and lessening of operator fatigue. Can the operator see the solder joint?
- What level of control on actual temperatures is provided?
- Electrostatic Discharge Generation by repair machine.

Some units use heated bars as a means of attaching gull-wing leaded parts. Since not all the leads are co-planer the heated bar pushes the leads into the solder joint and results in a solder joint tension as it cools. The solder strength under tension could result in early thermal cycle failures.

Other units use hot air or hot gas as a means of reflowing the solder joints. This generally requires a longer time to reflow the solder, and results in a greater transfer of heat to adjacent areas. Use of heat shields may lessen this, however, a good deal of the heat transfer will be conducted through the board and its copper layers. Adjustments for time are usually available with increased pressures and temperatures. These can increase the heat transfer to wider areas of the assembly as well. Artificially aged conformal coatings have also been reported when hot air/gas systems have been used. Hot air/gas systems also tend to heat the entire part to the same elevated temperature as the lead. This can be very detrimental to the part. Control of the hot air/gas systems is also important. Control of gas or air flow, and closed loop control of temperatures are important. The proper nozzle match for the part type is also important.

Laser rework systems have now been introduced which have good promise for the best control through finely focused beams, and more uniform temperature for soldering. The laser systems are reported to heat the solder from inside out.

Cleaning and Re-inspection

After the repair and rework of the board has been accomplished, it is important to reclean the assembly. The remnants of the repair process can include solder flux, solder particles, fibers of the board, copper particles, adhesive residues, etc. The extent of the material to be cleaned is dependent on the extent of the repair made. The ideal situation would be to reclean the assembly with the in-line production cleaning process. However, many times the assembly has had additional parts hand soldered in place after this step, and these parts cannot withstand the cleaning process materials or temperatures. Other barriers to use of the in-line cleaning process are the application of bar code labels or any other labels. The cleaning solvent will attack the adhesive and result in peeling of the labels. Thus, unfortunately, the compromise of repair/rework now causes another compromise in the cleaning of the assembly. A localized hand cleaning method causes another compromise in the cleaning of the assembly. A localized hand cleaning method must be used. These traditionally involve the brushing on of cleaning solvents, and visual inspection for cleaniness. Problems include solvent residue, attack of plastics and formal coatings by the solvent, attack of the brush fibers and adhesives by the solvent, and difficult to clean areas as a result of the close spacing of other parts. The use of the new no residue fluxes will help and may even minimize the need for cleaning. This cleaning step should be well documented and included in the training programs.

Part Deterioration Possibilities

If repair/rework cannot be minimized, the potential of damaging parts and the circuit board itself will increase. If the repair/rework operation is not conducted with well thought out procedures and with trained and conscientious personnel, the potential of damaging parts and the circuit boards will be much higher. Examples of specific damages are given below.

Circuit Board

Damage to the circuit board itself is the most disastrous of all possibilities. In most cases the circuit board cannot be repaired, and the assembly will end up in the scrap barrel. Examples of difficult to deal with damage include burning of the board, measles (localized de-lamination), lifted or destroyed pads, cracked via barrels, blistering, open or significantly reduced circuit traces, charred surface coats, and excessive warp and twist caused by uneven heat application. All of these are a result of excessive temperature uncontrolled rework or replacement situations.

Ceramic Capacitors

Damage to ceramic capacitors during repair is primarily a result of thermal shock. The capacitor material, including the termination, must not be touched directly by the solder iron tip. If hot air is used it also should be focused on the circuit pad, with the solder reflowing on the pad first and then wetting to the part termination. Large temperature differentials applied to the part can induce minute cracks. These cracks do not always result in immediate part failure, but may in time cause the part to fail in the product. The failure mode is a short and is usually detrimental to the product. These part types are also easily damaged by the excessive concentrated forces of tweezers.

Resistor and Capacitor Chips, and LCCC ICs

These parts have precious metal terminations, and in most cases a barrier metal to assist in preventing termination leaching during the production solder process.

Excessive repair temperatures and times can still result in excessive leaching of the termination and result in tenuous connection to the part. Excessive repair temperatures applied to the resistor cermet material itself may result in microcracks and a possible degradation in tight tolerance resistor values.

Plastic Encapsulated Parts

Some plastic encapsulated parts such as tantalum capacitors, film capacitors, variable resistors or capacitors, crystals, and inductors have internal connections which depend on solder joints. The supplier of the part does not intend for the internal joint to reflow and has designed the part with a high temperature solder. Application of uncontrolled heat directly from a solder iron or from a hot air rework device can result in temperature sufficiently high to reflow the internal solder. In addition, these parts are typically manufactured on a lead frame. The coefficients of thermal expansion of the lead material and of the molding epoxy are very different and excess heat applied to the terminal can cause expansion and even cracking of the molded case. While not necessarily detrimental in itself, the case cracking can lead to increased introduction of moisture and cleaning solvents which could lead to deterioration in part performance.

Some of these part types also might utilize a resilient internal material such as silicone to act as a cushion for the differences in thermal coefficients of expansion, or as a sealing material. If during the rework cycle, excessive temperature was applied and then a cleaning solvent was used while the case remained open to the solvent, the silicone may react to the solvent and expand, which in turn will lead to cracking of the case and further part damage.

Summary

Repair, rework and hand solder for surface mount applications are difficult and require high amounts of training, and in some cases large investments in capital tools. The goal of the program should be to eliminate repair and rework, and should be designed to track the process improvements made. Without care in this area many of the benefits of Surface Mount Technology will be lost.

References

1. “Fable for our Time: Slaying the Sabre-toothed Solder Joint”, R. Corey; Electronic Manufacturing, November 1988
2. “Component Removal and Replacement on Surface Mount Boards”, R. Buggle; SMT Nutshell News, August 1988
3. “Editorial”, Printed Circuit Assembly, November 1988
4. “Techniques for Through-hole and Surface Mount Rework”, J.K. Bausell, E.S. Siegel; Printed Circuit Assembly, November 1988
5. “Hand Soldering Surface Mount Circuitry”, N. Rusinguolo; Surface Mount Technology, December 1988
6. “Field Repair through the U.S. Navy Electronic Repair Program”, J. Crawford; SMTA ‘88 Proceedings
7. “Current and Future SMT Repair Processes”, S. Stach; SMTA ‘88 Proceedings
8. “A New Methodology for Surface Mount Rework”, M. Martel; Expo SMT ‘88 Proceedings
9. “Process Development in SMT Rework”, L. Abbagmaro; Circuits Manufacturing, December 1988
10. “The Lowdown on Rework”, M. Martel; Circuits Manufacturing, December 1988

Other Available Information

1. “Another Look - Wave Solder Process for Surface Mount Applications”, J. Bergenthal; KEMET Bulletin F2105
2. “Surface Mount-Mounting Pad Dimensions and Considerations”, J. Bergenthal; KEMET Bulletin F2100
3. “Reflow Soldering Process Considerations for Surface Mount Applications”, J. Bergenthal; KEMET Bulletin F2102.

KEMET Electronics Corporation

World Sales Headquarters
P.O. Box 5928 • Greenville, SC 29606 • www.kemet.com
Phone: (864) 963-6300 • Fax: (864) 963-6521

USA/Canada Locations

KEMET Electronics Corporation
2350 Mission College Blvd., Suite 972
Santa Clara, CA 95054
Phone: 408-986-0424
Fax: 408-986-1442

KEMET Electronics Corporation
Schaumburg Corporate Center
Suite 350, 1515 Woodfield Road
Schaumburg, IL 60173
Phone: 847-517-1030
Fax: 847-517-1037

KEMET Electronics Corporation
66 Concord St., Suite Z
Wilmington, MA 01887
Phone: 978-658-1663
Fax: 978-658-1790

KEMET Electronics Corporation
8445 Freeport Parkway, Suite 320
Irving, TX 75063
Phone: 972-870-9530
Fax: 972-870-9537

KEMET Electronics Canada Ltd.
105-7145 West Credit Ave., Bldg. #2
Mississauga, L5N 6J7, ON
Canada
Phone: 905-542-7930
Fax: 905-542-7949

KEMET Electronics Canada Ltd.
6001 35th Avenue
LavaL West, Quebec, Canada H7R 3P7
Phone: 450-962-0806
Fax: 450-962-6462

Europe/Africa Locations

KEMET Electronics S.A.
1-3, Avenue de la Paix
P.O.B. 76
CH-1211 Geneva 20,
Switzerland
Phone: 41-22-715-0100
Fax: 41-22-715-0170

KEMET Electronics Ltd.
Waterfront House, 55/61 South St.
Bishop's Stortford
Hertfordshire, CM23 3AL
United Kingdom
Phone: 44-1279-757201
Fax: 44-1279-757188

KEMETElectronics GmbH
Elisabethstrasse 89-91
D-80797 Munich, Germany
Phone: 49-89-456-4200
Fax: 49-56-5908-1303

KEMET Electronics S.A.R.L.
ZAC Paris Rive Gauche
118-122, avenue de France
75013 Paris, France
Phone: 01-33-01-4646-1009
Fax: 01-33-01-4646-1599

Asia Locations

KEMET Electronics (Shanghai) Co., Ltd.
2/F, No. 7 Bldg., 330 Xiya Rd.
Waigaoqiao Free Trade Zone
Pudong, Shanghai 200131, China
Phone: 86-21-5046-0983
Fax: 86-21-5046-0981

KEMET Electronics Asia Ltd.
Rm 605, Citic Bldg.
No. 19 Jian Guo Men Wai Da Jie
Beijing, 100004, China
Phone: 8610-8526-3628
Fax: 8610-8526-3626

KEMET Electronics Marketing PTE Ltd.
8-2-04, Sunny Point Kompleks
Jalan Batu Uban, 11700 Penang
Penang, Malaysia
Phone: 60-4-6595200
Fax: 60-4-6595220

KEMET Electronics Marketing PTE Ltd.
101 Thomson Road, #23-03
United Square
Singapore, 307591, Singapore
Phone: 65-6353-6636
Fax: 65-6353-6656

KEMET Electronics Asia Ltd.
Rm. 825 & 826, 8/F, Renminan Road
Kerry Center
Shenzhen 518001 China
Phone: 867-55-25181306
Fax: 867-55-25181307

KEMET Electronics Asia Ltd.
30 Canton Rd., Room 1512
Silvercord Tower II
Tsimshatshui, Kowloon Bay, Hong Kong
Phone: 852-2305-1168
Fax: 852-2759-0345

KEMET Electronics Corporation
Taiwan Branch, 3-4F, No. 148, Section 4
Chung-Hsaio E. Rd.
Taipei, Taiwan ROC
Phone: 886-2-27528585
Fax: 886-2-27213129

NOTICE: Place 011 in front of the above Phone and Fax numbers for Europe and Asia, when dialing from a United States exchange.
Note: KEMET reserves the right to modify minor details of internal and external construction at any time in the interest of product improvement.
KEMET does not assume any responsibility for infringement that might result from the use of KEMET Capacitors in potential circuit designs.