DVD-95C
Rework Stations

Below is a copy of the narration for DVD-95C. The contents for this script were developed by a review group of industry experts and were based on the best available knowledge at the time of development. The narration may be helpful for translation and technical reference.

Introduction

Once upon a time it was a pretty simple job to rework or repair electronic assemblies that didn't function. First, we identified the defective component. Then all we needed was a basic soldering iron and a hand held vacuum extractor, or solder sucker. Almost all electronic components had leads soldered into the holes on the circuit board. There was plenty of room to get in there and do the job.

Today's rework and repair operations have become a lot more complicated. That's because surface mount technology has gained increased popularity. Surface mount components are attached directly onto the surface of the board. This means they can be made smaller because they don't need holes. The drilled holes required the lead spacing, or lead pitch, to be greater. Therefore, the components can now take up less room on the circuit board and can be placed closer together.

Smaller is a big advantage when it comes to making products more compact. But it makes rework and repair much more difficult. Now, it's necessary to have excellent vision and incredible dexterity to rework these high density assemblies.

Even when we have the skills, doing rework on high lead count Quad Flat Packs, also known as QFPs, or other fine pitch components, can become tiring and overwhelming.

To deal with these challenges, specialized hand tools have been developed to make surface mount rework more manageable. These hand tools are especially effective in low volume rework applications. IPC has a series of training videos that discuss how these specialized hand tools are used.

Today, there are component package styles that make it virtually impossible to perform manual rework operations. A couple of examples include ultra fine pitch leaded parts and Ball Grid Arrays, or BGAs. The rework requirements for these types of components have resulted in the development of "rework stations." Rework stations are self-contained systems that provide controlled removal and replacement of surface mount components.

There are other reasons for using rework stations. Rework stations are often purchased for anticipated high volume rework. This is because they can be programmed to do the same thing again and again. Repeatability is a big advantage when doing rework. There is more process control since variability from operator to operator is reduced.

Sometimes hundreds of assemblies are manufactured before they are tested. If one component on each board was placed and soldered with an incorrect polarity orientation, we would have a high volume rework situation. Or there could be an incorrect component, a misaligned component or incorrect heating profiles during reflow resulting in some unacceptable solder joints. On the other hand, the cost of rework stations is significantly higher than hand tools.

In some facilities, rework stations are used as assembly stations. These assembly stations allow for the placement and soldering of components that can't be assembled on production surface mount equipment.

Many companies produce rework stations. Each station can have different features and options. Your company's rework needs will determine the level of sophistication of the rework station they purchase.

This program will describe the general features and options; discuss their advantages and disadvantages; and provide step-by-step procedures for performing component removal and replacement.

Before we go into the specifics of rework stations, let's do a quick overview of the basic operation for removing and replacing a component. First, we need to position the assembly in the fixture. Next, we select the proper "temperature profile" and nozzle for the component being removed.

At this point, there is an optional flux application onto the component leads. Flux may help to transfer the heat faster to the solder joint. The downside of using flux is you'll need to clean the assembly later.

The system then adequately pre-heats the assembly before bringing the component connection areas up to reflow temperature. Once full reflow of the solder connections has occurred, a vacuum pick-up is used to gently lift the component from the area.

Now the connection areas must be prepared for component reattachment. Then solder paste, pre-forms or bumps are applied.

A new component is now placed on the machine. The component leads are accurately aligned to the corresponding land patterns on the board. Then the assembly is again pre-heated and reflowed to complete the operation.

Now that you've had a chance to see a typical rework operation, let's take a look at the primary technical issues involving rework stations -- the heat source, pre-heating and the alignment of the component leads to the circuit board lands.

There are three different categories of heating systems. These are conductive, infrared and convective. Conductive heating, or contact heating, is the most direct form of applying heat to the solder connections.

Infrared systems rely on the heat in the infrared spectrum to heat the connection areas. The radiation travels from its source and is absorbed by the material to be heated. The absorption of this energy is what actually creates the heat to reflow the solder connections.

Think about the difference in wearing a white shirt or a black shirt on a sunny day. The white shirt reflects the sunlight. The black shirt absorbs the sunlight. So you're much hotter in the black shirt.

The most common heat source for rework stations is convective. Convective systems use hot air or hot gas. The hot air or hot gas is directed at the solder connections. This type of heating has the ability to heat more evenly -- regardless of the component packaging.

Another technical consideration for rework stations is pre-heating. Most systems have the ability to pre-heat the assembly prior to rework. Some systems use both top side and bottom side pre-heating. Pre-heating allows the temperature to slowly ramp up so that the board and adjacent components are not damaged by the sudden shock of the reflow temperature. Pre-heating is an important part of the "thermal profile."

A thermal profile can be represented by a chart. This chart includes the pre-heat temperature and the ramp up to reflow temperature as related to time. Each assembly will have a thermal profile - or specific heating cycle - that is related to the solder paste being used, the mass of the circuit board and the type of component being reworked.

In some cases, heating an assembly up to reflow temperature in a localized area can cause the board to warp or bow. In other cases, it may be necessary to pre-heat because the assembly has a large thermal mass. Due to this mass, it would take too long to reflow the solder connections without pre-heating the assembly.

Pre-heating may also be needed to slowly condition the component up to reflow temperatures. Some components can be damaged if the temperature ramps up too quickly. For some assemblies, the heat provided from the rework station nozzle is gradually increased until reflow. This may eliminate the need for a separate pre-heating cycle.

As we said before, each assembly will have its own thermal requirements. Your company's approach to these requirements will be identified on your rework documentation.

Now that you've been introduced to the different types of heating systems and the possible need for pre-heating, let's take a look at component alignment.

The alignment of the component leads to the lands of the circuit board is usually accomplished by a vision system. The vision system is part of the rework station. Precision alignment is usually accomplished through the use of an X/Y table. This table allows you to make fine adjustments in the X and Y axis for precision part placement. There is also rotational movement which is called theta. These systems make it easier for you to see the fine placement details, and to make the necessary adjustments for accurate alignment.

Component Removal

Now, let's take a detailed look at the component removal process. The first step is to examine your process documentation. This paperwork is usually called a "traveler." The traveler specifies the type of rework, the temperature profile, the nozzle to be used and any special instructions regarding flux and solder paste.

In this instance, we'll be performing rework on ultra-fine pitch QFPs. We'll use a nozzle that perfectly fits around this QFP. It's essential to install the nozzle that matches the size of the component being reworked. If the nozzle is too large, it can adversely affect the heating of adjacent components. If the nozzle is too small, there won't be adequate heat applied to the component we want to rework.

Next, we visually inspect the assembly. It's important to remove any components that will interfere with the rework operation, and to remove or shield any temperature sensitive components. A heat shield can be placed around an adjacent component to protect it from heat.

Now, we have the option of applying flux onto the leads of the QFP to be removed. Your company will let you know whether this optional fluxing operation is required.

The assembly is then mounted onto the rework station. Now we align the nozzle to the QFP being removed. The next step involves pre-heating the assembly and reflowing the solder connections. The temperature profiles that will be used may be stored in the reflow station computer, or can be manually entered using front panel switches.

Many reflow stations use thermocouples that monitor the heating of the circuit board at critical locations. These include the sides of the board, the component site, and around adjacent components.

Once the assembly is sufficiently preheated, additional heat is then applied to the top side of the QFP to be removed. Now the temperature will safely ramp up to the "set point." This should be the temperature in the thermal profile where the solder connections will reflow. Once reflow is achieved, the QFP can be lifted off the assembly with a vacuum pick-up.

That's all there is to it. But there are a number of things that can go wrong. If there's not enough heat, the solder won't reflow, then the component can't be removed. This can occur if we have an improper temperature profile.

Excessive mechanical stress, meaning the nozzle is too far down; excessive thermal exposure, meaning it's too hot for too long; or excessive convection pressure, meaning too much air -- can all damage the component or the circuit board. For example, excessive mechanical stress can warp the board.

If the nozzle is too far away from the component, it can adversely affect reflow times or the heating of adjacent components.

It's also important to allow the rework area to cool prior to any reheating. If this cooling step is overlooked, delamination or measling of the circuit board surface can occur.

Now that you've seen some of the things that can go wrong, let's take a look at removing the same QFP using a different rework station. Finally, we'll remove the same QFP on a rework station that uses infrared heat instead of hot air. Again, we have the option of fluxing the leads of the QFP. Next, the assembly is mounted on the rework station. Then we make sure we have the matching nozzle to fit the QFP to be removed. The nozzle is aligned to the QFP.

Next, we place thermocouples on the assembly in critical locations. We also make sure we have the correct temperature profile for the board and QFP. Because of the nature of infrared heating, the method of achieving the temperature profile will probably be slightly different than the hot air convection system -- even though some convection heating is used with the infrared.

After the assembly is pre-heated, we use the infrared heat to safely ramp up to the set point where the solder connections will reflow. Finally, we gently remove the component with a vacuum pick-up.

Site Preparation

In this section we'll be discussing site preparation and solder paste or solder application -- prior to component replacement.

The first step is to remove residual solder from the lands. We do this to flatten the lands so that the leads of the replacement component will make good contact with the lands. It's also important to remove any lumps of solder that may have been left on the assembly during the component removal process.

There are two different techniques for removing the leftover solder. Let's discuss the solder braid procedure first. Some companies require that you use a thin solder braid to prepare each individual land - one at a time. The use of additional flux is optional. It will help to increase the capillary action of the solder braid.

We're also using a fine point tip to avoid overlapping the solder braid. Notice how we move the solder braid along the length of each land as the solder melts. Learning how fast to move takes a little practice. Also, see how we apply the tip of the iron onto a clean portion of the braid each time we begin to clean a new land. After a certain point, we'll need to clip off the used braid whenever the braid becomes awkwardly long.

It's important to be very careful and gentle to avoid damage to the lands. One technique is to come straight up and down with the solder braid rather than moving it across the lands. The moving or scraping action can cause damage to the lands. It's also a good idea to remove the iron and the braid at the same time to prevent lifted lands. This process is repeated until all of the lands are prepared. Then clean all of the used flux residue off the lands before you begin the component replacement process.

Now let's talk about the continuous vacuum extraction process for site preparation. The continuous vacuum extractor has a heated tip with a hole in the center. When the vacuum switch is activated, the molten solder is sucked up into a storage chamber. As we remove the residual solder it's important to maintain a flat and even level from one land to the next.

Once this residual solder has been removed, you may be required to clean the residue with an approved solvent. Allow the area to cool prior to cleaning. If the area is too hot, the lands could be washed off during the cleaning procedure. Finally, blot the area with a lint free material, or dry with oil free low pressure air.

When the site preparation is complete, the lands should be free of all lumps of solder. There should be a thin, level and uniform coating of solder on all the lands.

Next, we'll look at solder paste requirements. It may not be necessary to add solder paste if sufficient solder has been left on the lands during site preparation and the component leads are pre-tinned. Your company will have a policy on when to use or not use solder paste for rework.

If solder paste is required, you can use either a mini-stencil, a programmed dispenser or manually dispense the paste. If space allows, a mini-stencil can provide excellent results. When using a mini-stencil, we first align and position the stencil on the QFP site. Next, we apply the solder paste. A mini-squeegee is used to print the paste onto the lands. Then we gently lift the stencil off the site and inspect for paste uniformity. Using a mini-stencil provides precise and repeatable solder paste deposits.

For programmed or manual dispensing, you can lay a "bead" of paste, or dispense individual dots of paste on each land. Dots can provide better results, but they're more time consuming and become more difficult as the pitch decreases. The amount of paste will vary - depending on the width of the applicator tip, how fast you move and other variables. You'll learn how much paste to apply with experience.

Regardless of how solder paste is deposited, correct solder paste volumes are essential. Too much solder paste increases the height of the fillet. This can result in bridging between the finely spaced leads. Too little solder paste can cause unreliable solder joints -- or even open circuits.

Another method of solder application is "bumping the lands." The disadvantage of this method is that crowned, or rounded bumps can result. These bumps make it difficult to reposition the component. It's also hard to maintain consistent solder volume.

Component Replacement

Now we'll take a look at replacing the QFP component. We begin by making sure that solder paste has been printed properly onto the site, or that a level coating of solder has been left after removing the residual solder.

The next step is component alignment. This will be accomplished by a vision system. Most rework stations will have their own vision system. Some vision systems are relatively simple. They might consist of a top side camera, a television monitor and a microscope.

Other vision systems can be very sophisticated. They utilize both top and bottom cameras and a beam splitter to perform the alignment. This type of system provides precision alignment for BGAs and ultra-fine pitch components.

Now, let's take a look at the entire replacement process using a basic vision system for component alignment. First, we'll utilize the rework station's pick-up tool to move the QFP from the parts tray over to the assembly. Next, we use the X-Y table controls and the television camera to make sure that each lead of the QFP lines up precisely with the corresponding land on the assembly. Then we carefully lower the QFP onto the lands and recheck for correct alignment.

After the QFP has been properly placed, we move the assembly beneath the nozzle. Then we lower the nozzle and begin the reflow cycle. It's important to make sure that you're using the correct pre-heat and reflow temperature profiles.

After the reflow cycle is complete, we raise the nozzle and allow the solder to solidify. At this point, the assembly can be removed from the rework station. Always check that the assembly has cooled sufficiently to handle it safely.

Now, let's take a look at the replacement sequence again - this time using a more sophisticated vision system for precision alignment of our QFP.

Again, we'll utilize the rework station's pick-up tool to move the QFP from the parts tray over to the assembly. This vision system uses a beam splitter to look at the QFP and the corresponding lands on the circuit board. It then superimposes the two images.

The circuit board is moved until both images line up. An advantage of this type of vision system is that it makes it easier to see these fine placement details -- especially with ultra-fine pitch components.

After alignment and placement are achieved, we lower the QFP nozzle to the circuit board and begin the reflow cycle. Again, a pre-defined replacement pre-heat and reflow profile is used. After the reflow cycle is complete, we'll let the QFP cool down before removing the assembly from the rework station.

Now, let's look at what could potentially go wrong during the replacement operation. If the leads of the QFP haven't been properly aligned to the lands on the board, there may be unacceptable component to land misalignments.

Incorrect temperature profiles are another source of potential problems. For example, too short of a heating cycle can result in poor wetting or partially reflowed solder. An overheated solder connection will appear dull and grainy. This type of solder joint will be brittle and unreliable.

Excessive thermal "gradients," meaning that things heat up too quickly, can cause the board to bow. Distortion can actually break the interconnections within the board.

Let's watch the entire replacement operation one more time on a different type of rework station. First, we align the leads of the QFP to the corresponding lands of the circuit board. The nozzle containing the QFP is then lowered onto the circuit board. Using the correct temperature profile, we begin the reflow cycle. Finally, we allow the QFP to cool before removing it from the rework station.

Cleaning and Inspection

This final section explains the requirements for cleaning and inspecting the reworked assemblies. The acceptance requirements are contained in IPC's J-STANDARD-001, the IPC-A-610 and other industry specifications, and your own company's internal specifications.

When cleaning is required, flux residue should be removed as soon as possible after soldering -- usually within the first hour. Flux residues tend to harden with time. This means that the longer they are left on the assembly, the more difficult they'll be to remove. Remember to allow the assembly to cool prior to cleaning.

Now, we'll take a look at inspection requirements. Visual inspection is normally done under a microscope. Not only should the reworked component be inspected, but also the adjacent components and their solder connections. Here are the most common soldering defects related to rework stations.

Solder bridging can occur if there is any movement during the placement operation. Movement can cause the solder paste to smear. Movement during reflow will also produce bridging. Bridging also occurs when excessive solder paste has been applied to the lands.

Opens typically occur when there's not enough heat during reflow, or when there's not enough solder paste or flux. Gross misalignment can also result in open circuits. Another cause of opens is when one or more of the component leads have coplanarity problems - meaning the lead is not on the same plane as the land. Therefore, the lead never gets soldered because it's not in contact with the solder paste covered land.

Finally, incomplete reflow can result when there is insufficient heat, or when the wrong thermal profile is used. Incomplete reflow results in a weak and unreliable solder connection.

This program has described the general procedures required for surface mount rework stations. We looked first at the advantages and disadvantages of using rework stations compared to sophisticated hand tools. Rework stations offer repeatability for high volume rework applications, and precision alignment for ultra fine pitch components. They are also significantly more expensive than the hand tools.

Then we examined the step-by-step procedure for component removal, site preparation and component replacement. We also touched briefly on some issues related to cleaning and inspecting the reworked assemblies.

Unfortunately, rework is a fact of life in the production of electronic assemblies. The quality of every soldering operation can affect the functioning of an entire electronic system. Careful attention to detail will help make sure that your company's products work properly and are reliable. You are the key to this success.