
DVD-53C

An Overview of Electronics Assembly

Below is a copy of the narration for DVD-53C. 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.

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Electronic products are becoming more and more integrated into our daily experience. Year after year there are innovations. Products get better and better, they're easier to use and in many cases they actually cost less. Can you think of any other areas of our lives where this has been true?

Electronic products have become useful in our work, as well as our leisure time entertainment. Today, almost everyone has a cell phone, does some banking electronically, has a personal computer with internet access and has some sophisticated home entertainment system. We pretty much take these products for granted.

But there are people who invent the product, design the electronics, fabricate the different parts and assemble the pieces into a finished product. And that's our industry. Did you know that the electronics industry employs more people than the aerospace, steel and automotive industries combined?

Here's how it works. All electronic products consist of components and interconnections. Components are devices that alter the flow of electricity. Some of these are resistors, capacitors and semiconductor chips. The interconnections are the pathways where the electrons flow between the components. In today's products, the pathways are almost always printed circuit boards.

Discrete wires are another type of pathway that interconnects front panel switches to components. But the heart of most electronic products are the printed circuit assemblies. In this program, we'll be providing an overview of this segment of the electronics industry known as electronics assembly. Assembly basically consists of attaching components to lands on the circuit board and soldering them to make both a mechanical and electrical connection.

We'll start by taking a brief look at the manufacture of printed circuit boards and semiconductor chips. Then we'll examine the organization and business of companies that perform electronics assembly. The video will conclude with a journey through the various assembly processes. Finally, we'll show electrical testing and the hardware buildup that creates the finished product.

Printed circuit boards come in lots of different varieties. There are single sided boards where all the interconnections are on one side of the circuit board. Typically, all the components are also mounted on one side of the board. Double sided boards have interconnections on both sides. The more complex multilayer boards have innerlayers which provide even more interconnections.

Most printed circuit boards are rigid. There are also flexible circuits that can fold, twist and even flex into a rolled up configuration. In addition, there are combinations of rigid and flex circuits. You'll find these circuits in products such as lap top computers and cell phones.

Manufacturing a printed circuit board is a complex operation which may consist of many individual process steps. These operations fall into three general categories – photographic, mechanical and chemical. Printed circuits are basically a pattern of electrical conductors that are formed on an insulating base material called a substrate. These conductors are then used to interconnect the electronic components.

Now, let's turn our attention to the components. Of all the components, semiconductor chips usually receive the most attention. These tiny marvels begin as a bare silicon wafer. Imaging and manufacture take place in environmentally controlled cleanrooms. The circuit lines on the chips are so close together that the tiniest particle of dust would contaminate and ruin parts of the wafer. After processing, these wafers are cut into the individual chips, or die, that are usually attached and sealed in ceramic or plastic packages.

These packages will be either through-hole or surface mount. Both types of packages serve some important functions. For example, they provide protection to the chip inside, dissipate heat and serve as the intermediary between the chip and the board on which they are mounted.

Through-hole components contain leads that are inserted into holes on the circuit board. An example of this is a dual-in-line package, or DIP. Through-hole components like resistors and capacitors come in axial or radial leaded packages. Through-hole components have been around a long time.

Surface mount technology is newer, and has become increasingly popular because the components are smaller. Leads are located closer together, allowing more interconnections in less space. The leads or terminations of surface mount components are placed directly onto lands on the surface of the circuit board. This microprocessor resides in a quad flat pack, or QFP with gull wing leads. There are also components with J-leads. Surface mount resistors and capacitors are called chip components. They have termination bands instead of leads.

The typical assembly operation begins with the incoming inspection of both the circuit boards and electronic components that will be used for a particular job.

But before we begin our examination of the assembly processes, let's take a look at the organization of the companies that do assembly. There are two types of companies that perform electronics assembly Original Equipment Manufacturers, or OEMs; and members of the Electronics Manufacturing Services Industry, also called EMS Providers.

OEMs are companies that design and manufacture their own electronic products. Usually, these companies do all or some of the assembly work themselves. For a variety of reasons, there are times when OEMs send out all, or some of their assembly to EMS providers.

EMS providers are differentiated from OEMs in that they don't produce their own products. They provide services. First, they purchase the components and circuit boards specified by the OEM. Then these circuit boards and components go through processes to create the soldered assemblies. After processing, the assemblies are tested.

The EMS provider may also do any rework or repair that's needed. Occasionally, the EMS provider also performs the hardware buildup and/or system integration necessary for the finished product. In addition, system and reliability testing may also be done.

A current trend has been for some of these companies to also assume some of the CAD layout responsibilities for the OEM. It is rare, however, for EMS providers to offer circuit design since circuit design is how OEMs differentiate their products from the competition.

In 1997 Electronics Manufacturing Services was an 18 billion dollar industry having a 22% share of the 80 billion dollar electronics industry.

Now that you have a better understanding of assembly companies and the business of assembly, let's begin our journey through the assembly processes.

We'll start with through-hole assembly. Remember, through-hole components have leads that are inserted through the holes in the circuit board. Automatic insertion machines make it possible to insert many components into a circuit board in a very short time. There are three types of automatic insertion machines -- DIP inserters, axial inserters and radial inserters.

Let's look at a typical DIP inserter first. DIP components are generally stored in tubes that are placed in specific feeder locations. There are universal circuit board fixtures that position the board to exact locations in the machine. These fixtures move the board underneath the insertion head as the components are being placed.

Let's see how the machine does the job. The picker moves to pick up the component from the proper tube. Then it drops it into the insertion head.

A spreader now lines up the component leads as the board fixture moves underneath the insertion head. The insertion head comes down and inserts the leads into the corresponding holes in the circuit board. Then an anvil, consisting of two pieces of metal and a cutter in the middle, cuts the leads and slightly bends them so the component is mechanically attached to the board. This bend is called a clinch.

Now, we'll take a look at axial inserters. The axial components are supplied on tape reels. A sequencer is used to cut and retape the components in a specific order, or sequence, for the automatic insertion. Sometimes the sequencer is part of the axial inserter. Sometimes the sequencer is a separate machine.

Once the components are sequenced, they are moved by metal feeders to the insertion head. A driver with forming fingers preforms the leads and places the leads into the holes on the board. The anvil now cuts and clinches the leads to secure the component to the board. Operation of radial inserters is similar to the axial insertion machines.

You've just seen auto insertion. However, as the industry has shifted more and more from through-hole to surface mount, a given electronic product may have very few through-hole components on a board. Therefore, these components may be inserted manually. In addition, there are some components, because of their size and shape, that can't be inserted automatically. The leads of these components will have to be manually inserted into the holes of the circuit board.

The leads of these components are usually preformed prior to insertion. Following insertion, the leads may be cut and clinched with a crimping tool.

At this point, almost all of the through-hole components have been mechanically attached to the board. The wave soldering operation will now complete the electrical and mechanical connection of the components to the circuit board.

Wave soldering consists of three basic parts -- fluxing, preheating and soldering. Fluxing is the process of applying flux to the underside of the assembly. Flux is made up of a combination of chemicals. The purpose of the flux is to remove oxides and other contaminants from the surfaces of the metal parts to be soldered. Oxides begin to form on the component leads and through-hole lands whenever these metals come in contact with air. If these oxides or contaminants are not removed by the flux, the solder won't form a reliable bond between the leads and through-hole lands.

The next part of the wave soldering process is preheating. During preheating, the entire assembly is slowly heated to a temperature that will activate the flux. This enables the flux to react with and condition the metals for the soldering operation.

Following preheating, molten solder is delivered to the underside of the assembly in the form of a wave. As the bottom of the assembly passes over the crest of the wave, the solder flows up through the holes to the top of the board in a capillary action. Although the solder also touches the base, or laminate material of the board, it won't stick to these nonmetallic materials if they are properly cured. As you can see, wave soldering allows thousands of solder joints to be made in a very short time.

An assembly may also contain some temperature sensitive components, such as batteries and switches, or unsealed parts that will have to be manually inserted and hand soldered after the wave soldering operation.

Now that you've seen what's involved in through-hole assembly, let's turn our attention to surface mount. Remember, the leads or terminations of surface mount components are placed directly onto lands on the surface of the circuit board not through holes in the board.

The surface mount assembly operation consists of three basic steps -- solder paste application, component placement and reflow soldering.

Solder paste is a mixture of flux and solder in paste form. The application of solder paste is commonly done using a stencil printing process. Solder paste is pressed through openings in a metal stencil onto the corresponding circuit board lands with a squeegee. The squeegee may be made of hard rubber or stainless steel.

Once solder paste has been applied to the lands, the board is moved to one or more automatic placement machines for component placement. Surface mount chip components may be supplied on perforated tape wound around a reel. The reel is loaded onto a feeder. The feeder is then connected to the placement machine.

The high speed placement machines for these components are called chip shooters. They have rotating turrets with many nozzles for placing the chip components with machine gun speed. The turret rotates around to the feeder, picks up the component, orients it correctly and places it onto the lands.

Larger surface mount components and fine pitch parts are generally supplied in trays, tubes or reels. These slower pick and place machines have heads that may be fitted with nozzles of different sizes. These nozzles pick up the components from the trays, tubes or reels, and accurately place them into the solder paste on the lands of the circuit board.

After component placement, the surface mount assemblies are ready for reflow soldering. In convection systems, air or nitrogen is heated and blown onto the circuit board to reflow the solder.

The first area inside the reflow soldering machine is a preheat zone. Preheating allows for a gradual temperature rise. If all the required heat were applied immediately, the board and some of the components might be damaged from thermal shock. The preheat operation causes the flux in the solder paste to activate. This activation allows oxides to be cleaned from the metal surfaces.

The assembly proceeds to the next heating zones where higher temperatures cause reflow and solder wetting to take place. Reflow soldering completes the surface mount assembly process.

But there's one more surface mount operation we haven't mentioned yet. It's called adhesive application and it's a very critical process. In many of today's double sided circuit board designs, surface mount chip components are attached to the bottom side of the board, and a combination of the larger surface mount components and some through-hole components are attached to the top side. This combination of surface mount and through-hole components on the same board is called a mixed technology assembly.

The purpose of adhesive application is to keep the surface mount components that are placed on the bottom side of the board from falling off before they're securely soldered during wave soldering.

Let's look at a typical process for assembling a mixed technology board so you can see where adhesive application fits in. We start with the top side of the board using the standard surface mount assembly sequence that you just observed.

Now we're ready to begin the surface mount assembly operation for the bottom side of the board. The first step is to apply the adhesive dots in the precise locations where the chip components will be placed. Notice how the adhesive dots are dispensed between the lands rather than on the land itself. If the glue were placed on the land, the component wouldn't be able to be reliably soldered to the land. The adhesive would block the solder.

After the adhesive is applied, the components are positioned typically using a high speed chip shooter.

The adhesive is then cured in an oven. Curing allows the glue to achieve its full strength. The chip components are now securely attached to the bottom side of the board.

Now, we begin the through-hole component assembly sequence. Remember, we use three different automatic inserters to attach DIP, axial and radial components. And some components require manual insertion.

The fully assembled board is then passed over a wave of molten solder. The solder wicks up the holes to solder the leads of the through-hole components. The surface mount chip components that are glued to the bottom side of the board are also soldered at this time. The wave soldering operation completes the assembly process for this double sided mixed technology assembly.

Regardless of whether the assembly is through-hole, surface mount or mixed technology, the step following soldering is a cleaning operation. Cleaning removes undesired contaminants including any flux residue left over from soldering. Companies that use low residue fluxes in a no-clean process may omit this step.

Once the assemblies have been soldered and cleaned, they are tested. Testing is done to guarantee that the assemblies work the way they're supposed to.

There are two basic categories of testing -- in-circuit test, or ICT, and functional test. ICT checks the assembly for unwanted open and short circuits, then tests each component on the board -- one at a time -- for manufacturing defects. Functional testing checks the operation of the entire assembly. This test actually verifies that the customer is getting what he or she is expecting.

The difference between functional test and ICT is that functional test doesn't check a particular component. It is actually testing the different functions, or electronic operations designed into the assembly. Many components may be used to carry out a particular electronic function. Functional test can be performed on both the circuit board and on the finished product. ICT is only executed on the assembly.

When an assembly fails in-circuit or functional test, it goes through troubleshooting. Once the problem is isolated, the assembly can be reworked and/or repaired. Rework and repair can be done manually, or on sophisticated rework stations.

At this point, some assemblies, depending on their function, are conformally coated. Conformal coating protects the assembly from harsh environmental conditions such as moisture, dust, oils and dirt. These assemblies are then retested.

The circuit board assemblies that pass these tests can then be installed in their products. We call this phase of the overall assembly process final system assembly or box build.

During system assembly, all of the hardware required for the finished product is installed into the equipment chassis. This includes racks, cables, wires, heat sinks, fans, front panel switches and connectors, as well as the electronic assemblies.

The finished product is given a final functional, or system test to make sure it is operating properly. There may also be more exhaustive reliability testing done before the finished product is shipped to customers and distributors.

The electronics assembly industry has been growing rapidly during the past decade. The electronics industry is an industry where products have become better and less expensive. Just look at the way prices of computers and other electronic equipment has dropped over the past few years. In every other industry prices have generally increased. Not only that, but the performance of the products have increased significantly. For example, today's computers are faster, have higher storage capacity and are even easier to use.

Our industry is fueled by innovation – emphasizing research and development, and improving processes and process control. Technologies are changing rapidly. New techniques like chip scale packaging, ball grid arrays and chip on board are allowing products to become faster and even more compact.

We've been able to reduce costs and cycle times. We've improved control of materials and processes. And -- most importantly -- our customers are satisfied. It's these factors that have kept the electronics industry successful in an increasingly competitive world marketplace.