
DVD-27C

Introduction to Through-Hole Assembly

Below is a copy of the narration for DVD-27C. 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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PC BOARD

(sophisticated female voice)

Hello. I'm a printed wiring board, or PWB. Some people call me a printed circuit board, or a PCB, or a circuit board, or just a board. But let me tell you, I'm never bored. Action is my middle name.

COMPONENT 1

(male, cute and manic)

Yeah, but we supply the action. Talk about us. Nothing happens without us.

PC BOARD

You'll get your turn. Just let me finish introducing myself.

COMPONENT 1

Okay, okay.

PC BOARD

Think of me as having three parts -- a laminate, copper conductors and drilled holes that are sometimes plated with copper and tin lead to connect one side to another or a layer in-between.

My laminate is constructed with epoxy glass in the middle and copper foil on the outside. The epoxy is an insulating material meaning it won't conduct electricity.

Generally when I'm made, holes are drilled and plated through with copper and tin lead so my friends here, the components, have a place to attach and connect to. And sometimes I have innerlayers for even more connections.

Then all of the copper is removed except for my conductors. These copper conductors are like paths or roadways to let the electricity move all over me.

COMPONENT 1

So we put our little legs in the holes just like this and get attached to her back surface with solder. This connection is called a solder joint.

PC BOARD

Then the electricity can really flow.

(pauses)

So now it's your turn. Tell them what you're about.

COMPONENT 1

We're electronic components. It's our job to move the electricity around in a regulated manner. I myself am an integrated circuit, or IC for short. Some people call me a microchip. I can keep track of all kinds of stuff, do lots of arithmetic and move information all over the place. Sometimes I'm the brains of a computer. I don't wanna sound like I'm bragging or anything, but these other guys are pretty simple compared to me.

COMPONENT 2

(another voice, tough guy)

You think you're so smart, but I'd like to see what'd happen to you without the rest of us. I'm a resistor and my job is to slow down the flow of current so you don't get too much electricity which'd probably make you pop your top, y'know.

COMPONENT 3

(another male voice)

And I'm a capacitor. I store electricity over a period of time, then discharge it over a longer or shorter period of time to keep everything running just right.

COMPONENT 1

Okay, okay -- you made your point. There are lots of us and we each do a particular job in moving electricity around the board to accomplish what we're designed to do. We can slow it down, stop it, increase it, redirect it, store it and pulsate it -- all in a prescribed way. Get the picture?

NARRATOR

This videotape will provide you with an introduction to the Through-Hole Assembly method for connecting electronic components to printed circuit boards. These boards are manufactured to exacting standards. For more details on the workmanship standards for printed circuit boards, you can refer to IPC videotapes VT-61 and VT-62.

IPC also has instructional videos on safety and handling considerations during assembly operations. It is very important that you wear heel and/or wrist straps for electrostatic discharge when handling the boards throughout the assembly process. Your company will have specific policies regarding product handling and assembly safety.

The circuit boards usually have colored print that identifies the locations for component placement and indicates the polarity and orientation of the components. The locations of the components are based on a grid system of letters and numbers. Many circuit boards have letters running along the sides and numbers along the top or bottom.

For example, to find location 10F on this board, locate the number along the top; then find the letter along the side; and trace the point where these lines intersect. This is where the component leads are inserted into the holes.

Each type of component is identified by a specific letter, or reference designator. For example, the letter U is for an IC. Resistors and capacitors are identified by the letters R and C. It is important to learn these symbols so you can identify components.

At this point, let's take an overall look at the through hole assembly process, and then we'll come back and explain each process in more detail.

We'll begin with automatic insertion. There are many types of automatic insertion machines that can handle a wide range of components. For the purpose of this program we'll be examining two kinds of automatic insertion machines.

This automatic insertion machine is called a DIP, or dual-in-line package, machine.

Dual-in-line packages have two rows of leads. There is a polarity marking indicating the loading direction. From the polarity marking the pin count is always counter-clockwise. For example, with this marking facing you, the pin one position is to the right side with the rest of the numbering going in a counter-clockwise direction.

These ICs are usually received from the component manufacturer in tubes. The tubes are placed in locations determined by program for the most effective and shortest path for the insertion head to follow in inserting the DIP components.

Once these components are attached to the board, the assembly is taken to a second automatic insertion machine called an axial inserter. Axial components are parts such as resistors and capacitors that have only one wire or lead coming out of each side.

Axial parts are usually received from the component manufacturer in tape and reel. This axial inserter has a sequencer which cuts parts and retapes them in a specific sequence for automatic insertion. Sometimes the sequencer and axial inserter are separate systems. The straight leads on the axial components will be formed or bent to fit to the exact dimensions between a pair of holes on the board. A computer program controls this lead forming process and the insertion location.

Following automatic insertion, the boards are taken to manual insertion stations where components that cannot be inserted automatically are assembled onto the board. Some of these parts can include sockets to hold removable components; axial components too large for automatic insertion; and "can type" parts such as transistors, relays and transformers.

Once all of these parts are attached, the assemblies are ready for the wave soldering operation. Wave soldering is simply defined as a continuous flow and circulating mass of molten hot solder. When the solder flows against the backside of the board assembly, it wicks up the component leads and through the plated through holes to form solder fillets. The solder fillet is the junction where the two surfaces meet. This junction forms the electrical and mechanical connection between the circuit board and the component.

Certain sensitive components such as relays, connectors, unsealed parts, plastic standoffs and other plastic parts that couldn't be safely wave soldered are now assembled and hand soldered.

After soldering, the assemblies may be cleaned. If no clean flux is used, this operation may not be required.

The assembled boards then go through various tests before they are installed in the products they were designed for.

Let's stop for a moment and review the information we've covered so far.

Now let's examine the insertion of through-hole components in more detail.

Your company will have some method of specifying the circuit boards that require through-hole assembly. A circuit board can come in different sizes and shapes, and can be assembled with various kinds of components depending on how it is intended to function. These considerations determine how the automatic insertion machines will be set up.

Here is an example of a set-up sheet for a DIP inserter. This sheet specifies the part number and revision letter of the board, the program to be run, the fixture to be used, and which tubes of components will be loaded for insertion.

In addition, the polarity, or the direction of the part in the tube is identified. The components may have an inked or molded dot, a stripe, a recessed half circle, or a notch to indicate polarity.

We'll examine the automatic insertion of these DIP components first. It's important to verify that the location of the component tubes match the components specified in the set-up sheet. If different tubes were left from a previous job, you should remove those and load the proper tubes of components in the specified locations.

There is a different fixture for each of the different sized boards. It is important to load the correct fixture for the boards that are to be assembled. The fixture moves the board to exact locations underneath the insertion head for component placement, as well as holding the board in place during this operation.

There should also be a book containing the programs used and instructions on how to set up the machine. The assembly program will automatically control the sequence of placing the components.

The instructions regarding the program and setting up the machine need to be followed precisely in order for the automatic inserter to function properly.

The operator checks the machine, inserts the tubes of components into the right locations and loads the program.

The first circuit board to be assembled is loaded into the fixture. The DIP machine is "zeroed" to set the starting point. The components are now automatically inserted into the programmed locations. To ensure correct set-up and operation of the machine, this first board should be assembled and carefully checked before continuing.

Now let's take a closer look at how these components are inserted and attached to the board.

The "picker" moves to get the component from the proper tube, then drops it into the insertion head. A spreader now lines up the leads as the board fixture moves underneath the insertion head. At this point, the exact component insertion location on the board is directly underneath the insertion head. The insertion head comes down and inserts the leads, or legs of the component through the 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 attached to the board. This bend is called a clinch.

Let's observe the automatic insertion of these components for a moment so you can understand how this operation works.

Assuming the first board was assembled properly, the operator loads another board and again starts the machine. Components continue to be inserted until this second board is completed.

Although the machine does this assembly operation automatically, it is important to monitor the insertion process.

If the machine stops, an experienced operator can run a series of computer checks to determine the problem. Common problems include tubes of components in the wrong locations, improper adjustment of the holding fixture, and dirt or contamination in the machine mechanisms.

Once this part of the operation is completed, the partially assembled circuit boards are moved to the second automatic insertion machine.

This axial inserter assembles the axial components onto the board. Again, the set-up sheet will specify the part number and revision letter of the board, the board fixture to be used, the program to be run, and the components required.

On this machine, the axial components are on tape reels - which are in assigned dispensing stations. There is a sequencer that cuts and retapes the components in a specific order for automatic insertion.

The component feeders need to be properly adjusted so the components remain centered as they are fed to the sequencer. If the components aren't centered, the feeder will jam.

There are often several extra component dispensing stations that can be custom fitted with parts for specific boards.

The program is now loaded and the machine is set up. The program will automatically control the insertion sequence of the components and the way in which the leads are formed to fit to the exact dimensions inside the holes on the board.

Again, one test board should be run to ensure the sequencer and axial inserter are working properly.

Now let's take a detailed look at how the machine inserts and attaches the axial components. Metal "feeders" move the sequenced components from the tape reel to the insertion head. A driver with forming fingers "preforms" the leads and places the leads into the holes on the board. An anvil now cuts and clinches, or bends the leads to secure it to the board.

Let's watch the insertion of axial components for a moment so you can understand the operation of the axial inserter.

In the same manner as the DIP machine, the axial inserter operation needs to be monitored for proper insertion. If something goes wrong, the machine should be shut off immediately.

If the operator can't solve the problem, the maintenance department should be alerted.

Assuming the machine is operating properly, components will continue to be inserted and attached. As one board is completed, another board is loaded -until all the boards in the run are assembled.

The final phase of this insertion sequence is the manual insertion of components that can not be inserted automatically.

These parts can include axial parts that were too large for the automatic insertion machine, sockets that removable components plug into, "can type" parts such as transistors, relays and transformers, and any hardware mounted components such as heat sinks.

In the same manner as automatic insertion, each company will have some way of identifying the circuit boards and components that require manual insertion.

And each circuit board will have documentation containing clear and precise instructions regarding where and how each specific component is to be inserted and attached.

Let's take a look at how several types of parts are manually inserted.

Here's how larger axial components are inserted. This is a lead preformer. It is operated with air. There are changeable dies that match the size of each part. Using the die, the operator "preforms" or bends the leads to the exact dimensions to fit inside the appropriate holes on the board.

The components are now inserted into the board. Next, a bend and clipping crimper is used to cut the leads and clinch or bend them over. This is done so the component is securely connected during the wave soldering operation that follows.

Your company will have a workmanship standard for lead height and length, as well as other insertion parameters. ANSI J standard 001 specifies the requirements of lead lengths for soldered components. These standards should be followed exactly to make sure the job is done correctly.

Sockets and "can type" parts are inserted without the cut and crimp steps because their leads may be too short, thick or fragile.

Let's watch the manual insertion of parts for a moment so you get a better understanding of this.

At this point, we have an assembled board that is ready for the wave soldering operation.

Let's stop for a moment and review the information we've covered in this section.

Now let's take a look at the wave soldering process. The purpose of wave soldering is to complete the electrical and mechanical connection of the components to the circuit board. The wave soldering operation may also be computer driven to set parameters such as board size, conveyor speed, and temperature profile. These terms will be explained as we review the wave soldering process. IPC has a two part video series which details the fundamentals of wave soldering.

Wave soldering is divided into four parts: fluxing, preheating, soldering and cleaning.

The first step is to apply flux to the underside of the board. Flux is made up of a combination of chemicals whose purpose is to clean off any oxidation from the metals of the assembly. Oxidations forms on metal whenever its surface contacts air. If these oxides are not removed, the solder will not form a proper bond between the leads.

Next, there is a bottom and top side preheat operation which burns off any moisture and heats up the board and the component leads and metals. This is done to bring up the temperature of the metals to a level closer to the actual solder temperature. Preheating prevents the board and some of its components from being damaged by receiving all the required heat at one time. The preheater also serves to heat up the flux. Flux doesn't start working until it is activated by high temperatures.

After preheat, the boards are ready for solder application. The molten solder is applied to the assembly in the form of a wave. A pump pushes the solder up through a nozzle where it can contact the bottom of the board. As the bottom of the assembly passes the crest of the wave, solder touches the metals to be joined. Although the solder also touches non-metallic parts, it won't stick to these materials.

Some systems have an air knife which provides hot pressure to blow off any excess solder. This stops "bridging." Bridging occurs when solder forms a conductive path between two solder joints. This condition can cause short circuits.

Generally, the boards now go through a wash and clean operation to clean off undesired contaminants including any remaining flux residue. These contaminants can attract dust - which could cause short circuits and other electrical failures.

Following the wave soldering operation, some or all of the boards may be tested for cleanliness. A solution with a known electrical conductivity is compared against a solution containing any ionic contamination of the soldered board. These ions, or units of contamination, occur from residues left on the board from flux or from people's hands. If the assembly is not clean, it will register a lower resistance reading than the electrical conductivity of the standard solution. Ionic contamination can result in electromigration. This is where metal grows and eventually causes short circuits on the assembly.

A visual inspection of the assembly will reveal areas where there is not enough solder, where there is bridging between the solder joints, and other soldering defects. These boards can be manually touched up in a rework station.

In most companies, a serial number is put on the soldered board along with a date code that specifies when the boards were assembled.

Components that couldn't be wave soldered or cleaned are now inserted and hand soldered onto the board. These types of parts include unsealed parts, relays, connectors, and other plastic parts.

Once again, your company will have workmanship standards for the assembly and soldering of all of these components.

The boards are now hand cleaned to remove flux residue from areas around hand soldered components. If no clean, low residue flux was used this operation may not be required.

The boards are brought to the test area where they are tested for electrical continuity, meaning opens and shorts, and for proper parts installed correctly. The assemblies are also given a functional electrical test to make sure all the components are working properly.

Next, the assemblies may be placed in high temperature ovens for a specific period of time. When they are removed, they are again tested for proper operation. These tests are called "stress tests." Stress testing is done to verify the reliability of the assembly in demanding operating conditions.

Following test, the assemblies may be conformally coated. This coating provides protection from dust, dirt and moisture. Prior to this operation certain heat dissipating components and mating connectors are masked off so they are not coated.

The completed boards can now be installed in the products they were designed for.

Now let's review the information we discussed in this final section.

It's important that you have an overall understanding of the through hole assembly operation. Ask questions. A single error can result in costly rework, and can even ruin a circuit board assembly. In the competitive environment that exists in our industry today, your company's ability to compete will depend on each employee doing the best quality job possible.