DVD-17C
Electrical Test for Assemblies

Below is a copy of the narration for DVD-17C. 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

Tests are part of our daily lives. There are tests of endurance; tests of patience; tests of ability. These tests are a way of measuring our performance against an expected result. How we do on a test provides an opportunity to see where we are - and how we can improve. In the world of electronics assembly, testing is done to guarantee that products work the way they're supposed to. It's comforting to know that when you turn on your CD player, sounds come rocking out. Without testing, electronic products may be unreliable.

For the consumer, operational failure of an electronic product is usually just an inconvenience. But in some applications it can lead to loss of life. Let's begin by reviewing what's involved in manufacturing a typical electronic assembly. First, the product is invented. Then an engineer designs the electronic assemblies. The circuit boards are now manufactured. Next, the components are attached to the boards using different types of automatic insertion and placement machines. Components may also be inserted manually.

Finally, the component leads are soldered to the lands. This is done with wave soldering or reflow soldering equipment. At this point we have the finished assemblies. They should perform properly if every step of the assembly process was done correctly. But how do you know for sure? What if an assembly has a solder bridge between circuit traces or lands? That will cause a short circuit. Or how about an open circuit? Or a defective solder joint? Or a defective component? What if a component is inserted incorrectly? Or if the wrong component has been installed? Or how about if a component's missing? The list can go on and on. Performing electrical tests on assemblies is critical for the economic well-being of a company. Products that work the way they're supposed to means satisfied customers - which usually means more business. Testing can also reveal specific problems related to the manufacturing of assemblies, or to the design. When these manufacturing problems are checked and corrected, there will be less rework and repair - which means higher profit margins.

Here's an illustration of how the cost of fixing an error goes up in each phase of testing. If it costs fifty cents to catch a defect at incoming inspection, it will cost five dollars by the time it's detected on a finished assembly. It will cost fifty dollars if it is found after the end product is assembled, and five hundred dollars if detected after the product has been shipped.

This program will introduce you to the different types of testing done on electronic assemblies. Your company's test department will have a set of standard operating procedures. It is important to follow these procedures as you learn to use the test equipment. The more you understand about how the testing is done, the more effective you'll be at your job.

Before we get too far along, let's address a critical handling issue for your company's test department -- electrostatic discharge, or ESD. ESD occurs when static electricity from your body comes in contact with and is discharged into an electronic component. This electricity can degrade or destroy the functionality of certain types of components. There are a wide variety of materials and techniques to eliminate the build-up and discharge of static electricity. IPC has both a detailed video and a computer based training program on ESD prevention.

There are two basic categories of testing done on assemblies -- 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 verifies that the customer is getting exactly what he's 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 operation.

Functional test is performed on both the assembly and on the finished product. ICT is only executed on the assembly. One method of functionally testing the assembly is done on an automatic tester. The assembly can also be tested on a technician's bench. Special test electronics are designed to create an operational environment for the assembly that's similar to the finished product. The actual testing of the finished product is called final test. Final test verifies operation of the product. This is the last test done before the product is shipped -- unless you are doing reliability testing.

Now that you've been introduced to the types of testing, let's take a look at a typical automatic test system. These testers consist of a computer monitor; a keyboard with keypad and/or mouse; a message printer; memory and processing units; test fixtures; and a manual probe. The monitor gives you a visual display of the test results. It may also prompt you to perform specific actions during the testing procedure. Although these testers have full keyboards or a mouse for test programming, you will probably interact with the test system with a simple keypad. These keys allow you to load a test program.

You can also start or continue a test. In addition, the keypad lets you select programmed test options when required. The message printer provides the test results. It also prints out fault messages and any repair instructions. The memory and processing units provide storage and computer power to run the assembly test programs. Included in the internal software are various test instruments, such as voltmeters and oscilloscopes, to measure electronic signals on the assemblies.

The purpose of the test fixture is to connect the tester to all of the assembly's solder connections. ICT uses a fixture called a "bed of nails." The bed of nails consists of a series of spring loaded probes. These probes are custom designed to contact the connection points, or nodes on a particular assembly. Functional testers will usually have a special connector fixture to gain access to the connection points. This fixture is designed to mate with a connector that's already on the board. Sometimes the assembly will be plugged directly into an edge connector fixture.

Functional test can also use a bed of nails fixture. Finally, let's examine the manual probe. This probe is used to verify that there are connections between specific nodes on the assembly and the corresponding nails on the fixture.

In-Circuit Test

Before we take a detailed look at in-circuit testing, let's watch the operation. Seems pretty straight forward, doesn't it? Basically, an assembly either passes or fails. You put the boards that pass on this cart... and the ones that fail on this cart with the error message attached. The ones that pass go on to functional test... and the ones that fail go over to rework. There doesn't seem to be much happening - but that can be deceiving.

Let's see what's really going on during ICT. As we said earlier, the in-circuit tester uses a bed of nails fixture to access all the circuitry on the board. The bed of nails is custom built for each particular assembly and typically has hundreds, maybe even thousands of test nails. These nails are actually spring loaded probes. Each probe is carefully positioned to come in contact with the soldered leads, test pads and vias on the board. The soldered side of the through hole assembly is placed on the fixture. A vacuum is activated which pulls the board down onto the nails. Some systems are pneumatic, meaning air pushes the assembly onto the nails. Now the tester has direct contact with all the circuit nodes.

Any surface mount components on the assembly are accessed through special test nodes. These nodes are connected from the soldered side of the circuit board to the surface mount components. In this way, all testing can be done with one fixture on one side of the board.

An important feature of in-circuit testers is the ability to isolate the component being tested from the rest of the assembly. This technique is called "guarding." Guarding means that the electronic signals coming from components on the circuit board are blocked from the component being tested. With guarding, only the probes from the bed of nails fixture are involved in applying signals to the component. Then a measurement is taken to make sure the component is working correctly. If the component wasn't "guarded," you wouldn't know whether it was working properly. This is because there would be stray signals from other components that would change the measurement.

Guarding is a complicated technique. When you have an idea of what's going on inside a machine, you're more likely to enjoy your work and to contribute to the team. Now we'll continue our discussion on how the tester does its job. Once the assembly is loaded onto the bed of nails and the start button is pressed, the program defines the types of signals needed for testing... and tells the test system which probes or nails will be used. The tester then sequences through a simple test to detect opens and shorts... then tests each passive component, one at a time, against pre-defined values.

The tester also applies power at the appropriate times to test active components such as integrated circuits and operational amplifiers. At the end of the test, the system displays PASS or FAIL. If the assembly fails, the system prints out an error message describing the failure, or saves it on disk. Now that you have an understanding of how a typical in-circuit tester operates, let's examine how you'll actually do your job. This group of assemblies will arrive at ICT accompanied by a "traveler."

The traveler contains the part number of the assembly, the correct test program to call up and the proper bed-of-nails fixture to load. It is important to make sure the test program you've called up is the same revision level as the one noted on the traveler. Also, check that you are loading the proper bed-of-nails fixture. Once you've loaded the correct program and fixture, place the assembly onto the fixture using the orientation shown on the documentation. Press the START button on the keypad. Verify that the vacuum has moved the assembly in contact with the fixture.

When the test is complete, the monitor will display PASS or FAIL. If the assembly passes ICT, remove the board from the fixture and load it onto this rack. Some companies place an ICT sticker, or stamps the assembly when it passes the test. If the assembly fails ICT, an error report will be printed. There may also be a prompt on the screen. Let's say the system detected a failure in an integrated circuit. The tester doesn't really know if the component actually failed, or whether an open circuit or faulty test nail is responsible for the problem. The system will prompt you to check the leads of the integrated circuit by taking the probe and quickly drawing it against the leads of the component. As the probe comes in contact with the leads, the number of that pin jumps outside the line drawing. Probing lets you know whether the component is really defective, or whether there's just a bad connection.

Sometimes further troubleshooting is required to determine the exact cause of a failure. This type of fault isolation is normally done by an advanced operator or a technician. The rework department needs to know what failed so the assembly can be repaired. As we said earlier, the failure could be an open or short circuit; a missing component; the wrong component; improper orientation; or a defective component. By staying alert, you can be aware of a failure pattern such as a particular component having incorrect polarity on every assembly. This information can be passed on to manufacturing. Modifications can then be made to the assembly process. In-circuit testing continues until all the assemblies in the run have been tested. Remember, the boards that pass will go on to functional test... and the boards that fail will be reworked and tested again.

Functional Test

During this last section of the tape we'll be discussing functional test. Remember, functional testing is done on both the assembly... and on the finished product. You may ask, "why have

another test when all of the components and circuit traces on the board were passed at ICT?" With today's complex assemblies, no
in-circuit tester can possibly test all of the possible circuit combinations on every board. For example, microprocessors have more than 300 leads. This means that lots of electronic signals are constantly going into and out of the component. Because there are so many different operations going on, the component can't be tested at ICT.

As we said earlier, the difference between functional test and ICT is that functional test doesn't check a particular component. It tests the different functions, or electronic operations designed into the assembly. For example, because our microprocessor plays an important role in almost all the electronic operations on the assembly, it would be thoroughly exercised and checked during functional test. There are two types of functional assembly level tests. One is done on an automatic test system and one performed on a technician's bench with special test electronics.

We'll take a look at the automatic test system first. Usually, one test station is customized and dedicated to a particular assembly. Unlike ICT, the fixture is hard wired to the tester. Another tester would have a different fixture to interconnect another assembly. There are two different types of fixtures for plugging the assembly into the tester. There may be a test connector that will mate to a connector mounted on the assembly... or an edge type connector. This connector allows the assembly to be plugged in directly, just like it would be connected in the chassis of the finished product.

As we did in ICT, the first step is to load and initialize the test program. Then the assembly is connected to the tester and the START button is pressed. The functional test is performed... and PASS or FAIL is displayed on the monitor. Depending on the complexity of the assembly, functional test may take longer to perform than ICT. If the assembly fails, an error report is printed, or displayed which pinpoints the functional circuit that failed. It usually takes a highly trained technician to troubleshoot the circuit and isolate the problem to a defective component -- especially if there are no diagnostic tests.

Let's watch these steps one more time. First, load and initialize the functional test program for the assembly to be tested. Next, connect the assembly to the test fixture. Make sure this connection is secure. Then press the START button to begin the test. When the test is completed, the monitor will display PASS or FAIL. The assemblies that pass the test are stamped or given functional stickers, and are placed on this rack. They will eventually be sent on to final assembly. A failed assembly will require troubleshooting to isolate the error. After the problem is diagnosed, the assembly is sent to rework and the defect is repaired.

Based upon the needs of the customer, some assemblies may require a functional test called a bench test. The functional bench test is performed by an advanced operator or technician. It is called a bench test because the special electronics used to test the assembly are designed to operate from a technician's work bench. This "dedicated test set" consists of hardware and software that exercises the assembly in an operational environment similar to the finished product. For example, this assembly controls the movement of the arm of this map plotter. An emulation program creates the environment on the assembly to exercise all of the possible movements of the plotter arm. The operator or technician notes the test results. The boards that pass are sent on to final assembly. The assemblies that fail this functional bench test go through a troubleshooting procedure to isolate the fault. Then they are sent to rework.

`The last type of functional testing is done at final test -- after the end product is completely assembled. This test is performed to make sure that the product to be shipped actually works the way it's supposed to. Final test can be as simple as plugging in this video projector and verifying that it is projecting an image. Or it can be very complex. All of the functions of this computer are being checked by a diagnostic program. Units that pass final test are shipped to customers or distributors. Troubleshooting and repair are done on units that fail final test. But why would a product fail final test after all the assemblies have already passed their tests?

The answer is there could possibly be a defective front panel switch; or a loose connection; or faulty wiring. Another possibility occurs when a component suddenly stops working -- even though it functioned properly during ICT and functional testing. It doesn't necessarily make sense, but it happens. Companies often use reliability, or stress testing to weed out components that may fail after the first few hours of operation. This type of testing usually guarantees a higher level of reliability for the product. A simple version of a stress test is to turn a product on and off many times, and to verify it still operates properly.

A more comprehensive reliability test is to place the assemblies in a high temperature oven over a period of time. During this time, temperatures are gradually raised and lowered. We call this type of stress testing "environmental stress screening" or ESS. After the assemblies are removed from the oven, they are given a functional test. Passing the test indicates the assembly should work reliably for many years under normal operating conditions. Stress testing also validates the manufacturing process.

Since the operational life of the assembly has been accelerated during ESS, this type of stress causes questionable solder joints to fail. A dewetted solder joint may work for a while. But, over time, the heating and cooling cycles that happen when power is turned on and off can cause a slight crack to get bigger and bigger -- until a failure occurs. This program has provided an introduction to many different types of electrical testing in electronics assembly.

We've seen how testing is used to detect problems and improve the assembly manufacturing process. The sooner a problem is found, the sooner the process can be fixed. This type of relationship between testing and manufacturing can give your company a competitive edge. Remember, the cost of repairing an assembly after it's been shipped can be one hundred times higher than if the problem was caught during in-circuit test. Then we took a look at a typical automatic tester... we went through the procedures for conducting in-circuit and functional tests on an assembly... then we examined the final test performed on the finished product. Finally, we discussed some of the reasons for reliability testing.

It's important that you understand what's involved in the electrical testing of assemblies. This will make you a valuable team member. Follow the standard operating procedures for your company. When you're not sure about something, feel free to ask a question. Your performance on the job can make a difference.