Flexible Testing: Don't Be a Test Dummy

by **BOB NEVES**

When the word "testing" is used regarding flexible PWBs, most people think of point-to-point electrical continuity testing. Volumes have been written about point-to-point test while comparatively little has been documented on the large volume of alternative testing. In this article I will give an overview of these non- "point to point" tests, as well as touch on some specific testing highlights. Unfortunately after you perform these "other" tests, the flex PWB is usually unfit for shipment to your customer. This is because testing of this type usually involves burning, breaking, peeling, crushing, folding, spindling, and mutilating flex PWBs and materials to see how they will perform under a variety of extreme situations.

When the bean-counters evaluate the testing and laboratory areas for value, they typically find that it is a pure cost center with no production "value added" processes. This can unfortunately mean that the test area is not always at the top of the funding wish list. It always seems easier to justify a new etcher or drill than a new microscope for the lab. Decreased margins and increasing material/labor costs are forcing many manufacturers to make hard choices when it comes to their test areas. Independent test facilities often replace in-house facilities for tests that are not deemed cost-effective to perform.

THE BIG PICTURE

For those of us whose lives revolve around testing, there is a Bible of sorts called IPC-TM-650. This sacred tome contains almost all of the tests typically conducted on PWBs (rigid & flex) and associated materials. There are also "lesser" test method documents written by the military, JPCA, IEC, ASTM, BSI and a variety of other "somewhat holy" standards organizations. Unfortunately, these various methods do not always agree on the correct method to perform a particular test. From a big picture standpoint, the types of testing discussed here can be grouped into five separate categories: 1) Research and Development (R&D); 2) Product/Lot Conformance; 3) Reliability Assessment; 4) Product Qualification; and 5) Failure Analysis.

Research and development testing is typically the most fun of the testing categories (if testing can be called fun at all!). R&D work typically involves dealing with the latest flexible materials, PWBs and technologies, pushing their limits and kicking the tires to see just how they will perform when they are unleashed into the production environment. There is typically a lot of thought and engineering that goes into R&D work unlike some of the other testing categories. Depending on the type of testing required, R&D testing can be performed on flex PWBs, test coupons, or raw materials.

At the opposite end of the fun spectrum is Product/Lot Conformance testing. Glamorous it is not, but this type of testing makes up the bulk of what goes on in the testing world. Conformance tests are the "lot-to-lot" types of checks performed on deliverable flex product to make sure nothing has gone haywire during the manufacturing process. Conformance tests can be performed on both production flex parts and test coupons representing those production parts. The frequency and requirements for these tests are usually found in the Customer's Procurement Documentation (drawing, PO, referenced documents, etc.).

One step above Conformance testing on the fun scale is Reliability Assessment. This kind of testing involves accelerating the expected in-service parameters of the flexible board or material to a level that will greatly hasten its death. No one wants to wait around 25 years to see if his flex PWB or material is going to last 25 years. People want to know in weeks and months whether the flex product will last through its expected lifecycle. Learning exactly which parameters to accelerate, and for how long is the $64,000 (and maybe more) question. Squeezing years of performance into weeks or months of testing is a theoretical science at best (or worst, depending on your perspective). In contrast to performance testing, reliability assessment is typically performed on a periodic rather than lot-by-lot basis, and can be performed on flexible materials, boards, or coupons representing the boards.

Running just above reliability assessment on the fun scale is Qualification Testing. Qualification Testing usually comprises a combination of both conformance tests and reliability assessment to give a snapshot in time of a manufacturer's capability to make a conforming and reliable flexible board or material. This snapshot is typically a one-time deal, and the government and OEMs alike use qualification testing as a tool to screen their supplier base.

Failure analysis can be both fun and dreary. Many times failure analysis is accompanied by a great deal of pressure to find out "who dunnit." This necessitates a bit of detective work both in preserving the evidence and tracking down the possible suspects. Many failure analysis jobs are doomed to begin with because proper preservation techniques were not utilized on the flex PWB or material before it gets to the lab. It is important to have a good PWB to analyze along side the failed PWB as it can aid solving the mystery surrounding a failed board or material. Asking the right questions is also essential to finding the suspects. How many parts had problems under the same circumstances? Are the parts from an individual production lot or group of lots? What changes in production or assembly occurred around the time when these parts were produced? Was the flex board or material in good condition when it arrived at the user's facility, or could it have been destroyed there? Time is of the essence as the evidence trail gets colder as time passes due to manufacturing processes change, and the ability of people to remember problems or circumstances surrounding the fatality diminishes rapidly.

THE PROBLEM WITH FLEX

The testing of flexible PWBs and materials poses some unique problems not found in rigid PWBs and materials. We all know flex materials like to soak up more water than is healthy, but there are also fixturing, handling, and machining issues unique to flex boards. Most electrical and environmental tests require the test samples be wired up to supply a voltage followed by taking a measurement. Getting a small piece of flex material to stay where you want it to with five long wires hanging from it presents quite a challenge to the test technician. Getting flexible boards and materials to stand up and not blow around in circulating ovens and test chambers is also quite a trick! Flex samples are not machine-routable, so custom dies and cutting tools are required for preparing many test samples, increasing both cost and time.

THE SPECS

The problem (and benefit) of the IPC-TM-650 tome is that it does not contain acceptability requirements. The requirements for testing of flexible PWBs are typically found in response to a controlling specification. The most common flexible performance and acceptability specifications for flex PWBs are IPC-6013, IPC-A-600, MIL-PRF-31032, and MIL-P-50884. Many customers also have their own controlling documents which utilize the tests called out in IPC-TM-650. The IPC documents that govern the qualification, conformance and reliability standards for the materials used in flex PWB manufacture are IPC-FC-231, IPC-FC-232 and IPC-FC-241.

BURN, BABY, BURN

Another issue in testing of flexible PWBs and materials is Underwriters Laboratories (UL) approval. Until the recent publication of UL 746F, UL's flexible PWB requirements were contained in UL 746 (without the "F") along with rigid PWBs. This new specification for flexible PWBs was needed for a variety of reasons, one of which is the changing face of what a flexible PWB is. Traditionally products from the flexible PWB industry were just that—flex, flex-rigid, and stiffened flex PWBs. These bare, unpopulated boards were the only things that UL has historically listed/recognized under the old specification. Some OEMs are now requiring flex PWB fabricators perform certain assembly types of operations prior to shipping the PWB, while still supplying a UL flame-rated product. These hybrid end-products are not currently referenced in UL 796, and their status in the UL chain of recognition has been shrouded in mystery. UL 796F was published in an effort to address these and other testing concerns that have come up over the years when dealing with flex issues.

NEED FOR SPEED

Electronics in general is headed in one direction—up—with higher speeds and lower operating voltages. It is not uncommon to require a bandwidth 10–20 times that of the clock frequency of the circuit. This translates into a >1Ghz analog bandwidth for 50–100Mhz clock frequencies. This is the source of our testing pain, and drives the practical future of the electronics industry. It is also what demonstrates some of the futures greatest test difficulties will be. In order to determine the high speed characteristics of a material we use testing tools to determine Impedance, permittivity, and dissipation factor of the product.

Impedance—Impedance is described as the resistance offered by an electronic circuit to an AC signal. Impedance can be described in two fashions: 1) Circuit Impedance "Z" (load); or 2) Characteristic Impedance "Z0" (transmission line). Circuit Impedance is the resultant interaction between the resistive, capacitive, and inductive portions of the electronic circuit. Both the capacitive and inductive portions of circuit impedance are dependent upon the frequency of the AC signal applied to the circuit. Characteristic Impedance is defined as the ratio of voltage to current of a wave moving down a transmission line, and is what we measure when we test for impedance.

Time Domain Reflectometry (TDR) is the technique employed to derive the Characteristic Impedance (Z0) of a transmission line/trace. A commonly misunderstood fact is that TDR techniques derive and do not directly measure Characteristic Impedance. The derived Z0 is only an approximation of the actual Characteristic Impedance. TDR instruments utilize a pulse generator and an oscilloscope in a system best described as "closed loop radar." As a pulse from the generator starts down the test path, it begins to charge the inductive and capacitive portions of the test circuit with current flowing in accordance with actual impedance. When that initial point in the pulse encounters a change in Z0, some of its energy is sent back toward the signal source. This action is called Reflection, and is the basis for TDR measurement techniques. The oscilloscope portion of the TDR test system measures both the voltage of the pulse as it leaves the generator, as well as those reflected back from the circuit under test.

Permittivity—The Permittivity of a dielectric material has both real and imaginary mathematical representations. The imaginary part of Permittivity is represented in mathematical equations as epsilon double prime (e") and describes the energy loss from an AC signal as it passes through the dielectric. The Permittivity of a material describes the relationship between an AC signal's transmission speed and the dielectric material's capacitance. The real part of Permittivity (e', epsilon prime) is also called Dielectric Constant or Relative Permittivity. When the word "relative" is used in front of permittivity, the implication is that the number is reported relative to the dielectric properties of a vacuum. All measurements that you and I will ever use are Relative Permittivity numbers. The Relative Permittivity number can then be used to mathematically calculate the Impedance of a given circuit, helping the PWB designer optimize a circuit for Impedance matching characteristics.

Dissipation Factor—The simplest way to define Dissipation Factor (loss tangent) is the ratio of the energy dissipated to the energy stored in the dielectric material. The more energy dissipated into the material, the less is going to make it to the final destination. This dissipated energy typically turns into heat or is radiated as RF (Radio Frequencies) into the air. The optimal goal is to have 100 percent of the signal pass through the interconnection network, and not be absorbed in the dielectric. With "high power" signals, a material with a large dissipation factor could result in the development of a tremendous amount of heat, possibly culminating in a fire (advanced dielectric heating). When the signals are very weak, a high loss material means that little or no signal is left at the end of the transmission path.

HARSH ENVIRONMENTS

Flex PWBs are now placed into some very harsh environments these days, and in order to see if they will last, a variety of accelerated conditions have been developed. These conditions typically fall under the reliability assessment category of testing and are performed on a periodic rather than lot-to-lot basis.

Thermal Shock—The thermal shock test originates from MIL-STD-202 which has its roots in antiquity (I believe it may have been part of the Dead Sea Scrolls). This method utilizes a PWB coupon with an electrically interlocking pattern through which resistance is measured. This method subjects the test coupon to 100 cycles of externally induced thermal shock from -65°C to 125°C with a two-minute transition and fifteen-minute durations at the extremes. The electrical resistance through the test coupon is monitored periodically during the cycle. Degradation of this resistance value is the key reliability factor evaluated. The samples are also typically microsectioned to evaluate the physical integrity of the plated through hole after thermal excursion. There are others (Delco, Motorola, Bellcore, etc.) who have come up with reliability programs that rely upon the basic thermal shock philosophy. These programs typically vary from the MIL-STD-202 method due to specific product requirements and proprietary research and development.

Thermal Cycling—The thermal cycling test is a kinder, gentler, and substantially longer reliability test program. The key change that makes this test different than the thermal shock programs out there is the rate of change between extremes. This rate can vary from 5°C to 15°C per minute which allows the product to adjust more gradually to the surrounding environment. The temperature extremes are also typically milder than the thermal shock test (≥55°C & <95°C) and typically relate more to an extension of the end-use application of the product.

Surface Insulation Resistance (SIR)—SIR testing has prompted much discussion and disagreement within the electronics community. SIR test patterns are usually interweaving combs of conductors. These Combs consist of one to four sets of coupons for the measurement of the insulation resistance on a surface. The samples are exposed to high humidity and elevated temperature environments that vary by test method. SIR Testing is a tool which can (if used properly) finely detect the presence of surface contaminates and/or the lack of integrity of an insulating material.

Electromigration Resistance (EMR)—As high temperature/humidity and sunlight promote the growth of plants in the jungle, high temperature/humidity and electrical potential (supplied during the test) promotes metal growth on the PWB. The general term for this growth is Electromigration. Electromigration is defined as "the current induced transport of metal ions in a metal conductor." Basically, the electrons conducting the electricity scatter metallic ions in the direction of current flow. Electromigration is typically accompanied and accelerated by ionic contaminates (typically chlorides) present on the surface. Another form of metal migration is Electrochemical Corrosion. Corrosive residues left on the surface from fluxes or other cleaning materials can attack the metal of a circuit, placing metal ions into the moisture/residue solution on the surface. As the metals de-plate from a test circuit, the resultant electrical filament forms a temporary short. This short typically cannot handle the resulting current and is destroyed, much like a fuse. The result is often a carbonizing of the board surface in the outline of the filament.

SURFACE ANALYSIS

When a contamination is suspected or evident, it can become important to identify the type of contaminate present. Elements and compounds can be characterized in a variety of ways. Scanning Electron Microscopy (SEM), Energy Dispersive X-Ray (EDX), and Auger (amazingly, pronounced "O.J.") can be used to identify the elemental composition of a material. These techniques use the unique energy given off by each element in the periodic chart when exposed to high voltage electrons. This energy is captured and analyzed against known energies, and an elemental map can be made of the surface of the material under evaluation.

CHEMICAL COMPOSITION

Chemical Composition analysis techniques can be broken into organic and non-organic identifications. Organic materials all have Carbon and Oxygen in them so instead of just looking at the elemental structure (which doesn't tell you much), you must evaluate the way the Carbon and Oxygen bond to each other. Various types of Infrared analysis (IR, FTIR, etc.) use the fact that each different organic bonding structure absorbs a different wavelength of infrared light. These absorbances from an unknown material are compared to that from a known library in order to determine the match. Inorganic materials are typically analyzed by weight, or energy given off when decomposed in some fashion. These techniques have names like Atomic Absorbtion (AA), Mass Spectometry (MS), Ion Chromotography (IC or ICP), and a few others I won't mention. Each of these tools has benefits and drawbacks, and it is important to discuss those with a qualified technician or consultant to see if they are right for your situation.

TIP OF THE ICEBURG

I hope this article has peaked some interest in the general subject of testing. There is a wealth of information about test below the surface that you need to know. This article is just a teaser, and for those of you who would like further information about these techniques, I will be giving a tutorial at the IPC Expo titled "Analysis and Test for the PWB Industry."

Contact the IPC office at 847-509-9700. ■