MODULE 04

FOR B2 CERTIFICATION

ELECTRONIC FUNDAMENTALS

Aviation Maintenance Technician Certification Series

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REVISION LOG

VERSION	EFFECTIVE DATE	DESCRIPTION OF CHANGE
001	2016 01	Module Creation and Release
002	2017 02	Format Update

ELECTRONIC FUNDAMENTALS

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SEMICONDUCTORS

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PRINTED CIRCUIT BOARDS

An electric circuit is typically comprised of various components connected together by wire. In many cases, the circuit performs a function that doesn't require the circuit or the components to be large. The development of solid-state devices and the use of transistors have enabled many required electric functions on an aircraft to be carried out with small electronic circuits saving both space and weight. These circuits are often created on Printed Circuit Boards (PCB), which provides electrical connections as thin conductive metal tracks on a dielectric substrate, which also support the components. PCBs are used in nearly all electronic devices from a simple mouse ***(Figure 2-1)*** to the computer itself.

There are three types of printed circuit boards: single layered boards, double-layered boards, and multi-layered boards. Also, there are three technologies used to connect components to the circuits on the PCB: through hole, plated through hole, and surface mount. The following sections will discuss each of these board types and interconnection technology.

PCB MANUFACTURING PROCESS

All printed circuit boards are constructed from a thin sheet of non-conductive material often just $\frac{1}{16}$ inch (1.5 mm) thick. The board can be sized as needed to contain the required circuit(s) and components or to fit the housing designed, such as the example of the mouse, to contain the PCB. Two common materials used to make PCBs are epoxy resin impregnated paper and epoxy resin impregnated fiber glass cloth, often called pre-preg. Typically, copper foil is bonded to the surface of the board in a heat press operation. The circuit traces are applied as a pattern using etch-resistive ink. Then, the unwanted copper is etched away using a photo sensitive chemical process (ammonium persulfate or ferric chloride) leaving only the conductive pathways of the circuits, called traces. ***(Figure 2-2)***

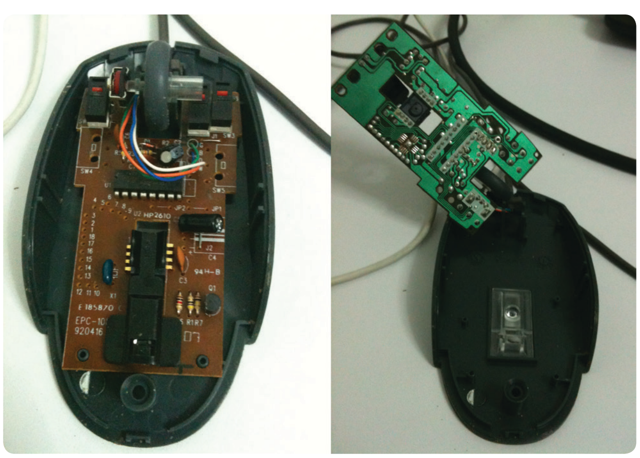

Figure 2-1. Typical computer mouse printed circuit board.

SINGLE-LAYER BOARDS

Single layered boards have the electronic components mounted on the opposite side of the board where the copper traces are exposed. ***(Figure 2-3)*** Early PCB's had holes drilled at the connection points of the components. The conductive paths, or traces, were created with the copper foil on one side of the board and components located on the opposite side. Component leads were passed through the holes to be soldered to the copper foil traces on the other side of the board, as shown in ***Figure 2-4***.

Through-hole technology later evolved into plated-through holes to provide better electrical properties and mechanical stability with the components mounted on the top on the PCB. The difference between non-plated through holes and plated through holes is the presence of copper inside the insulating board material. ***(Figure 2-5)*** Plated through holes have less resistivity at the joint and provide a degree of mechanical stiffness. PCBs with non-plated through holes are, of course, less expensive and take less time to manufacture.

DOUBLE-LAYERED BOARDS

Circuit boards can be single-sided, but more often are double-sided with copper circuit traces and components on both sides. Also, in the past, most components had lead wires that were inserted through corresponding holes on the PCB and then soldered. Through hole technology has since evolved to what is called Surface Mount Technology (SMT). Instead of placing the leads of the components through holes for soldering on to the copper traces, surface mount components are placed on the board as the same side as the copper traces and small leads that lie flat are soldered on to copper circuit pads, which provide not only an electrical connection, but mechanical rigidity as well. Surface mount technology allows more components and circuits to be placed on the same PCB since they are attached on both sides of the board. The only disadvantage is that it is more difficult to align and solder SMT components in place. ***(Figure 2-6)***

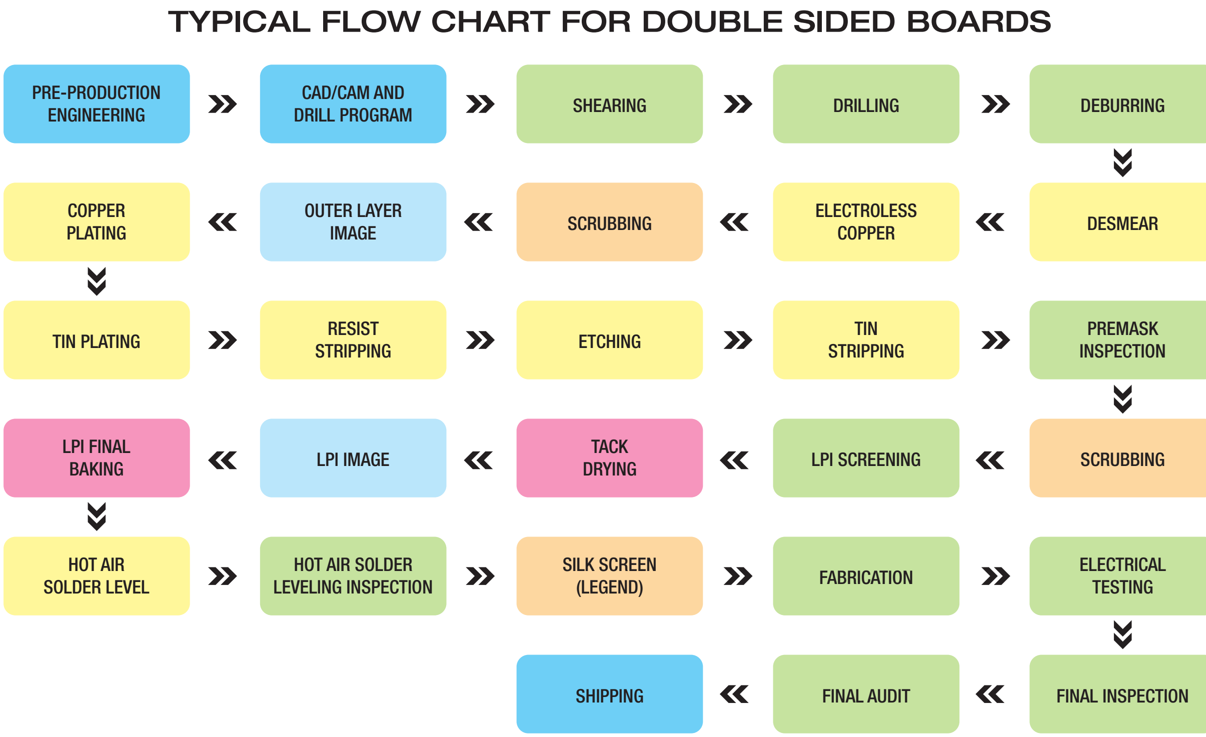

Figure 2-2. Printed circuit board manufacturing process.

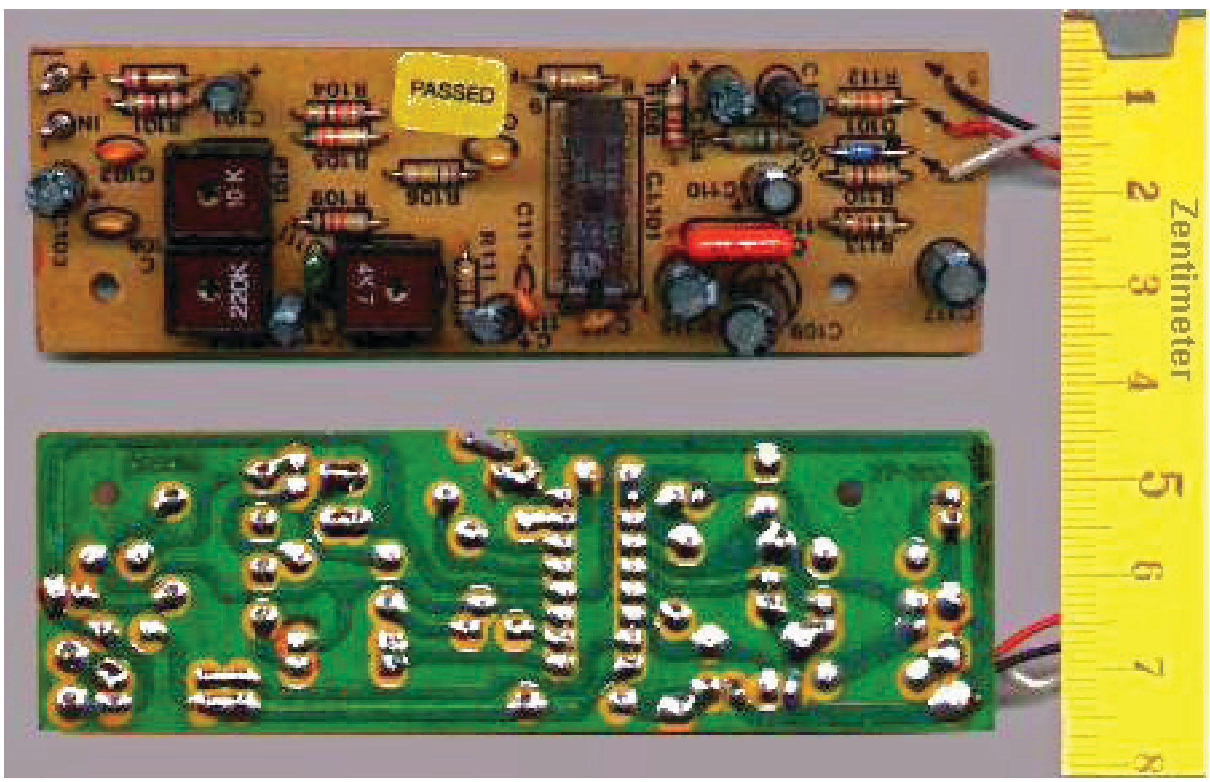

Figure 2-3. A single layer printed circuit board with traces and solder connections on one side and the soldered components on the other side.

A variation of surface mount technology that takes up even less space on the board is Ball Grid Arrays (BGA) components. ***(Figure 2-7)*** In this type of package, the leads are replaced with small solder balls located on the bottom of the component. BGA packages have the advantage of higher pin density compared to other methods, but it requires special equipment, instead of a simple soldering iron, to install or remove BGA components.

The changes in mounting technology have brought with them changes in soldering techniques as well. Hand soldering with soldering irons was common practice long ago, especially with single-layered circuit boards. That has since evolved into two automated soldering principles used today, flow soldering and the reflow method. In high volume manufacturing, a robot will pick and place the various electronic components from assorted bins and place them on PCBs at pre-programmed locations on the board. The circuit board is then moved to a conveyor belt where the board is dipped in molten tin-lead solder and the solder is sucked up through the plated-through holes to form the joints, as shown in the top illustration in ***Figure 2-8***.

With the introduction of surface mounted technology components came the reflow soldering method, whereby solder paste is applied to the copper mounting pads and the components are picked and placed on to the board and held in place with an adhesive. The board is then subject to controlled heat using a reflow oven to melt the solder paste and form a electrical connection and mechanical bond with the copper pads on the PCB. ***(Figure 2-8 bottom)***

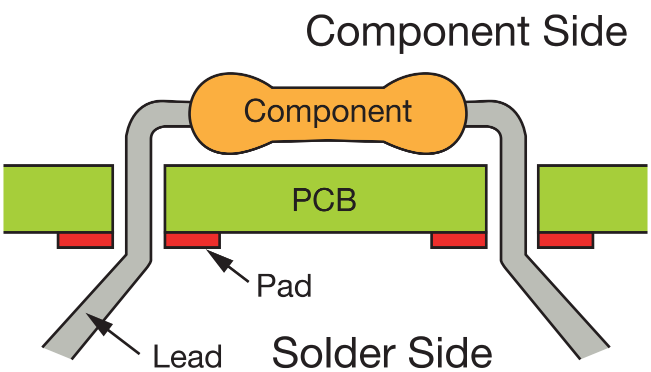

Figure 2-4. Components mounted on one side and soldered on the opposite side.

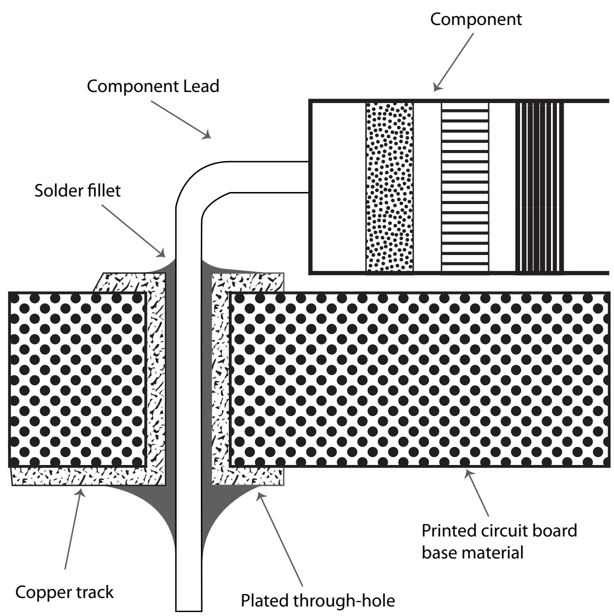

Figure 2-5. Plated through holes offer better electrical conductivity and mechanical stability.

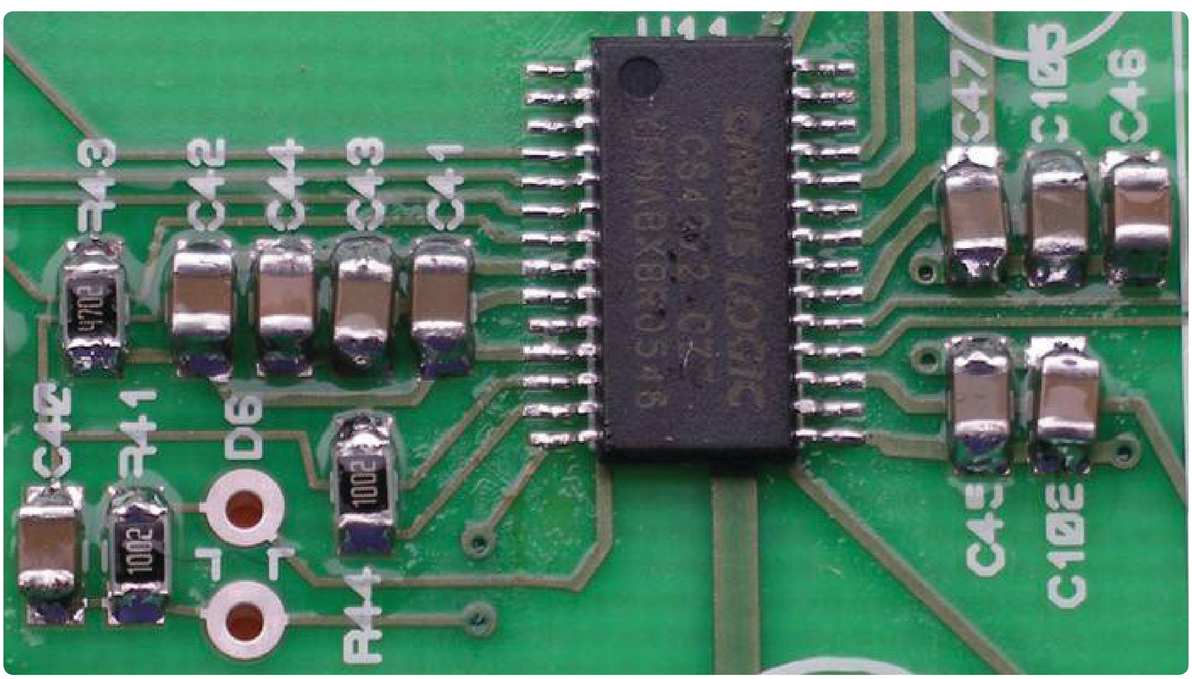
Figure 2-6. Surface-mounted technology solders components on to traces on the same side.

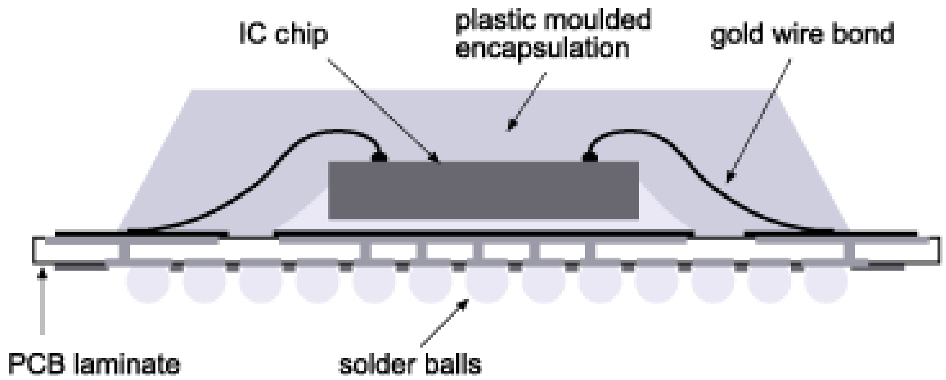

Figure 2-7. A Ball Grid Array SMT component.

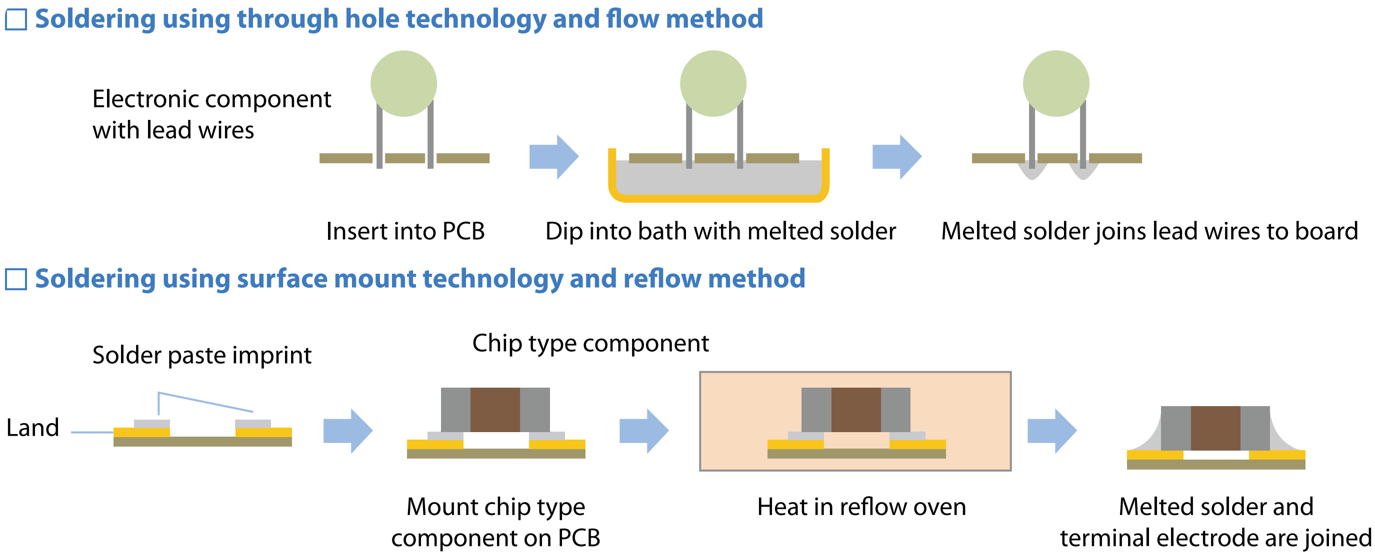

Figure 2-8. PCB soldering techniques.

MULTI-LAYER ED BOARDS

As previously discussed, miniaturization has been a key driving force in the electronic industry since the diode and transistor first replaced the vacuum tube in the 1960's. As electronic components have reduced is size, so have the methods used to connect them, principally through the evolution of the printed circuit board to multi-layer technology. Multi-layered PCBs are used where several layers of boards are stacked to provide an even greater density of components. ***(Figure 2-9)***

Multi-layered boards are joined electrically by what looks like a hollow rivet, called a via. Vias resemble the early holes used to attach components, but are actually conductive paths between layers of the circuit boards. Corresponding positions on different layers of the board that are electrically connected through a hole in the board is where vias are found. The hole is made conductive through electroplating or by inserting a hollow rivet. ***(Figure 2-10)***

A through-hole via (1) consists of a conductive tube and two pads at each end of the barrel connected to the circuit trace. High density boards may have blind vias (2) that are exposed to only one side of the board, or buried vias (3) that connect internal layers without being exposed to either surface. Thermal vias are used to carry heat away from power devices and are typically arranged in an array. Multi-layer PCBs are designed by computer software programs due to their complexity and requirements for extremely precise registration of circuit traces between the various layers. Very complex circuits are possible with the attachment of all types of electronic devices, including resistors, transistors, and integrated circuits in dual-in line and BGA packages, and microprocessors in BGA packages. ***(Figure 2-11)***

It is important to note that as circuit designs have become more complex and constraints on space have increased, problems have occurred in multi-layer board designs, particularly for high frequency applications,

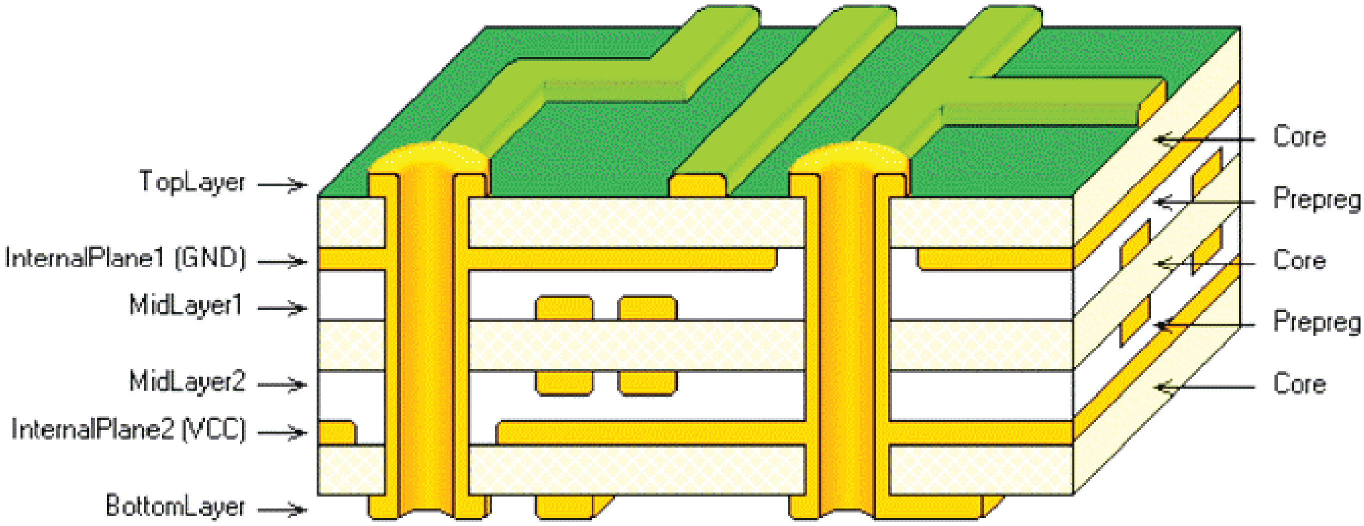

Figure 2-9. Multi-layered boards typically have one layer for Vcc and another for ground.

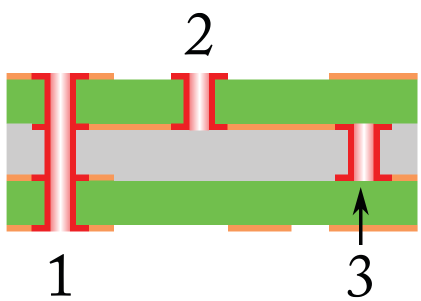

Figure 2-10. The gray and green layers are non-conductive pre-preg material while the thin orange layers (copper foil traces) and the vias are conductive.

due to various unintended capacitive and inductive coupling mechanisms that appear between the various layers. As such, modern PCB design uses computer modeling to mitigate such issues. For example, at a frequency of 100MHz, any circuit trace smaller than 30 square centimeters can cause radio frequency coupling interference.

PCB REPAIR

The soldering process required for attaching components to printed circuit boards requires special equipment with precise heat control and is not performed in the field. Removable PCBs, or Line Replaceable Modules (LRMs), allow replacement of defective units or repair in an equipped shop by knowledgeable technicians. ***(Figure 2-12)*** Often, the boards with components attached are coated with a protective laminate substance that must be removed before repairs can be made. The following sections will discuss the risks and possible damage to electronic components and how they must be handled when conducting a PCB repair.

RISKS AND POSSIBLE DAMAGE

Static electricity is a simple fact of nature. It is around us all the time and is caused by friction. Most work environments have non-conductive floors and no means of controlling the humidity. As the humidity drops below 20%, a static charge builds up on a person's body. The faster the person walks, the higher the charge. Simply walking across a carpet can generate 1 500 volts of static electricity at 65% relative humidity and up to 35 000 volts of static electricity at 20% relative humidity. Plastics used in most products will produce charges from 5 000 to 10 000 volts. Once the person sits down at the work station, the electrostatic field surrounding their body is enough to cause damage to sensitive electronic components without even touching them. However, when the person touches the component, an electrostatic discharge or spark occurs, and zap, the component is most certainly destroyed. ***(Figure 2-13)***

Electro-Static Discharge (ESD) is defined in U.S. military handbook DOD-HKBK-263 as "transfer of electrostatic charges between bodies at different potentials caused by direct contact or induced by an electrostatic field". In other words, an electrostatic charge on one body can be imparted to another body through induction from an electromagnetic field, or through conduction via physical contact. If an electronic component that is charged is then suddenly grounded, the charge will dissipate to ground, but in the process, the component will be damaged due to excessive heat from breakdown of the dielectric material within the component.

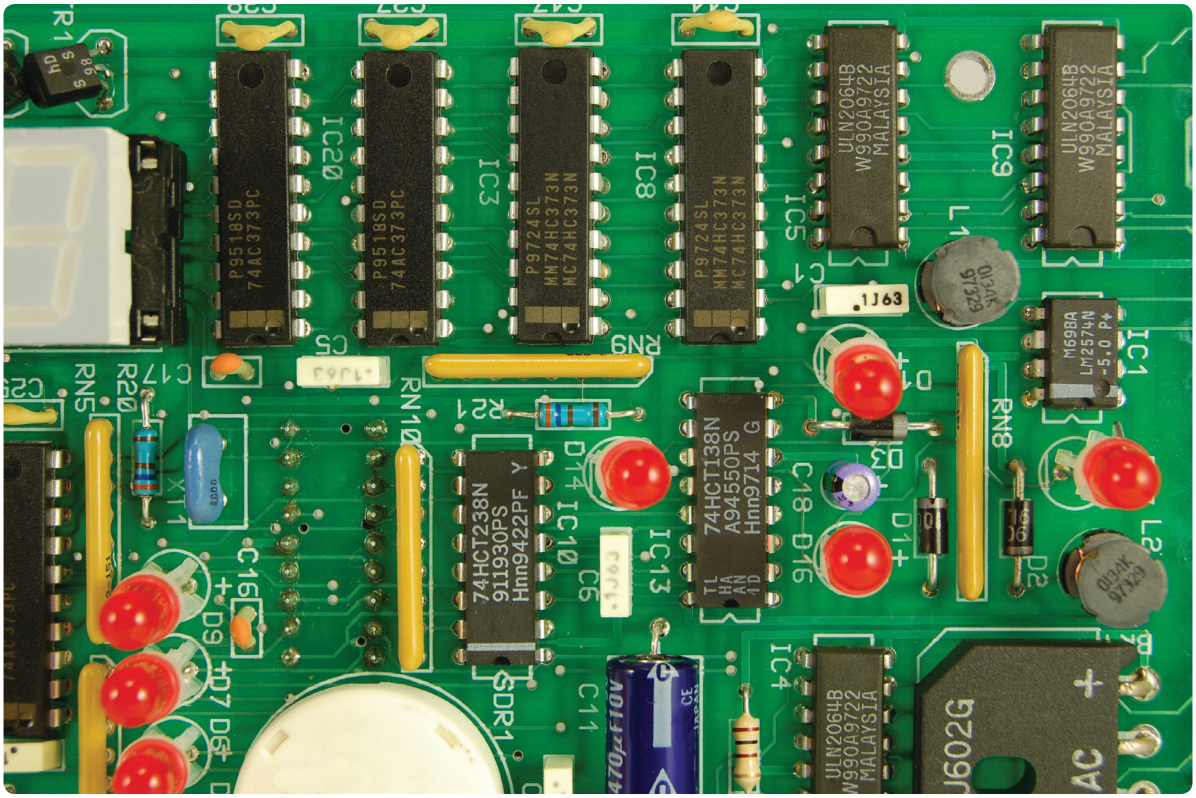

Figure 2-11. A multilayer printed circuit board with LED's, microprocessors and various other components and traces mounted on both sides of the board.

Figure 2-12. Repair of a printed circuit board.

Figure 2-13. Electrostatic discharge.

Electrostatic induction occurs when a charged object induces the redistribution of charges in another object. A classic example of this is picking up pieces of paper using a comb that was rubbed against fur. In ***Figure 2-14***, the comb is charged negative, meaning that there exists an excess of electrons built up on the comb. The side of the paper closest to the comb will end up being slightly positive due to the attraction of opposite charges, while the opposite side of the paper will be slightly negative due to the repulsion of similar charges.

MIL-STD-1686C is the U.S. military standard for "ESD control programs for the protection of electrical and electronic parts, assemblies, and equipment". It recognizes two classes of ESD-sensitive items: Class I for 100 to 1 000 volts and Class II for 1 001 to 4 000 volts sensitivity. Most electronic components are in Class I. For example, bi-polar transistors are susceptible to ESD between 380 to 7 000 volts; CMOS devices are susceptible between 250 volts and 3 000 volts; and EPROMs, used in computer memories, are susceptible to as low as 100 volts.

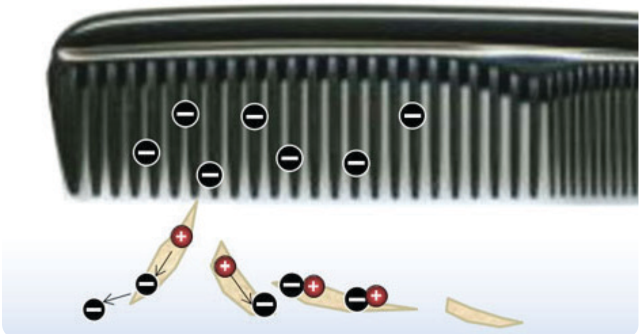

Figure 2-14. Electrostatic induction.

Figure 2-15. Warning sign for an ESD controlled area.

The ESD issue is not going away. In fact, the problem is getting much worse. As component technology continues to advance to achieve higher speeds and greater functionality, their physical geometries are shrinking, which is causing components to become even more susceptible to lower discharge voltages. The following section will discuss special handling of ESD-sensitive components and anti-static protection devices which must be used to protect these sensitive electronic components from the dangers of electrostatic discharge.

ANTI-STATIC PROTECTION

Controlled Environment

Static electricity can't be eliminated. It can only be controlled. Therefore, it is essential to only handle ESD sensitive devices in static-safe controlled environment. Signage must be placed outside any ESD controlled areas to warn people that special precautions must be taken before entering the controlled environment. ***(Figure 2-15)*** Any insulating materials, such as nylon, mylar, vinyl, rubber, mica, ceramics, fiberglass, wood, styrofoam, and plastic, will store static electricity, and therefore, should be kept out of the work area. Technicians should only enter the work area wearing anti-static (steel mesh) smocks and conductive (leather-soled) footwear. If wearing an anti-static heel strap in place of conductive shoes, the grounding cord must run into the sock in order to make contact with the skin.

Static-Safe Workstation

Conductive materials, including personnel, must be grounded. The floor surface should be covered with conductive paints or coatings, anti-static floor finishes, or anti-static vinyl flooring. As shown in ***Figure 2-16***, the work station should have a static dissipative floor mat and table-top mat that have a surface resistivity of 105 to 1 012 ohms per square inch. The conductive mat not only provides a surface that is free of static charge on which to work, but must also remove the static charge from conductive items placed on it. Both the floor and table-top mats should be connected through a 1 mega-ohm resistor connected to a common ground point. The resistor is required to protect personnel in the event the ground becomes electrically live.

Anti-Static Wrist Straps

The same safety requirement holds true for the anti-static wrist strap ***(Figure 2-17)*** in that the coil cord must be plugged or clipped into a receptacle with a 1 mega-ohm resistor connected to a common ground point. The wrist strap must be secure around the wrist at all times while seated at the work station so that it makes good electrical connection with the skin to dissipate any electrical charge to ground before touching sensitive electronic components.

Figure 2-16. Static-safe workstation.

Figure 2-17. Anti-static electricity grounding wristband.

Grounding Test Stations

All anti-static devices should be tested before entering the static-safe controlled environment. ***Figure 2-18*** is a picture of a typical grounding test station used to determine whether the anti-static devices are working properly. A green indicator light means that the wrist strap is worn properly and is working as intended. The test station can also be used to test footwear, heal straps, and coil cords as well.

Figure 2-18. Typical grounding test station.

Ionizers

Since it is not practical to raise the relative humidity to high levels due to operator discomfort and the fact that it would cause metals to rust, the controlled environment should be equipped with ionizers to neutralize any charged insulators commonly found in the work environment. Because positively or negatively charged surfaces will attract ions of the opposite charge, an air stream containing both positive and negative ions is used to neutralize the charged surface. Once the surface is neutralized, it remains so as long as the ion stream is present.

Ionizers are available in high-pressure, low-volume air guns for periodic localized cleaning, and low-pressure, high-volume wall-mounted units designed to be suspended over the work station with the ionized air blowing down over the area to be protected against an ESD event. ***(Figure 2-19)***

Figure 2-19. Hand-held and wall-mounted ionizers.

Designed to cover a work station area, the ionizer will neutralize even the highest electrostatic charge. Normally the system is mounted 30"-36" above the area to be controlled, producing a balanced ionization pattern of approximately 36" wide x 48" long. It is highly recommended to use an electrostatic field meter to detect static charges in the work area to be assured that the ionizer is functioning properly before handling sensitive components. If the ionizer is not working properly, topical anti-stats should be sprayed in the work area to control the generation and accumulation of electrostatic charges.

Special Handling

All ESD sensitive components should transported in a closed conductive container (e.g., LRU or a tote box). The container must be stored on a grounded rack, and when moved to the work station, it must make contact with the grounded table mat. Any accumulated charge on the human body should first be discharged, by wearing the grounded anti-static wrist strap, before opening the protective container containing the ESD sensitive component. Also, always use a grounded soldering iron to install ESD sensitive components.

All ESD sensitive components should be packaged is an electrostatic shielded conductive bag. These laminated bags are made from an outer layer of transparent metalized sheet or an aluminum foil material, a middle insulation layer, and an inner anti-static layer. Finally, the bag is sealed with a label warning that there is an ESD sensitive component inside. ***(Figure 2-20)***

Figure 2-20. Laminated metalized bag for storing ESD sensitive components.