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Fiber Optic Wavelength-Division Multiplexing

The EMPF is working on a project to replace shipboard Ethernet cables with a high speed fiber optic network. Rather than point-to-point connections from one shipboard location to another, all the Ethernet communication signals from each location will be combined onto one fiber and transmitted throughout the ship. This will eliminate a large number of cables and their associated weight and costs. The fiber optic network will be easier to install, maintain, and will provide higher bandwidth, growth capability, and reconfiguration flexibility.

This project is focused on the manufacturing challenges of combining both electrical and optical components on printed circuit board (PCB) assemblies associated with wavelength-division multiplexing (WDM) technology. Current manufacturing processes for PCB assemblies with optical components are costly and labor intensive due to the attached fiber pigtails. Manufacturing methods are being developed to automate the attachment of these electro-optical components and the soldering of all electrical and optical components on the PCB. These manufacturing developments will significantly reduce assembly time and increase reliability of the electro-optical assemblies.

Fiber optics is the technology of transmitting information down thin strands of transparent fiber using pulses of light. It began in the 1970s in R&D laboratories, but by the early 1980s, major cities across the country were connected with a network of fiber.

In general, fiber optic communication systems have many advantages over copper. In copper based Ethernet networks, loss increases with signal frequency (Figure 1-1). Higher data rates increase power loss and therefore decrease transmission distances. Optical fiber signal loss does not change with signal frequency. Data can be transmitted much faster and much further in fiber optic networks than in copper. Fiber cable is also much smaller in diameter (Figure 1-2) and weighs less than a similar copper cable.

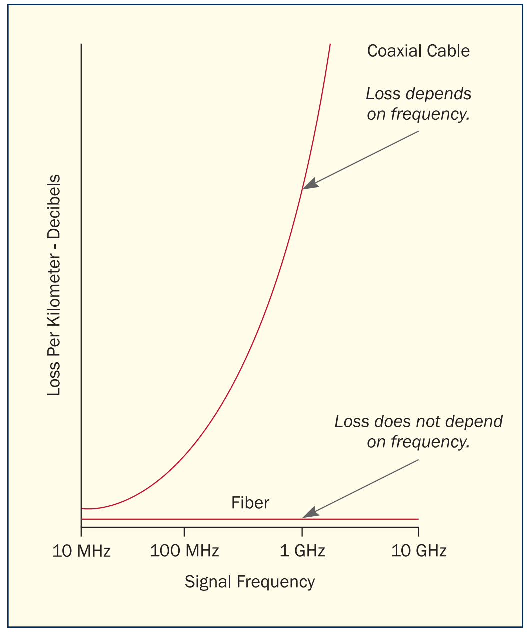

Figure 1-1: Signal loss as a function of frequency.[1]

Installation can also be more favorable for fiber optic cabling. Ethernet copper cables have a 25 lb pull tension limit before damage occurs that can reduce bandwidth, while fiber can be pulled with a force eight times greater for standard cables.[3]

Since fiber signals are optical rather than electronic, they are not affected by electromagnetic interference (EMI) or radio frequency interference (RFI). This allows information transmission with less noise, error, and crosstalk and makes them ideal for placement near electronic devices that can cause

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Ask the EMPF Helpline!

Pad Cratering

Recently, a customer contacted the EMPF Helpline to perform analysis on a lead-free assembly which exhibited intermittent functionality.

A customer recently submitted a lead-free assembly exhibiting intermittent functionality when pressure was applied to the ball grid array (BGA) packages. Industrial adaptation of a RoHS compliant solder standard has created a new host of failure modes observed in lead-free assemblies. Pad cratering occurs when fractures propagate along the epoxy resin layer on the underside of the BGA connecting pads. While originating from process, design, and end use conditions, it is the combination of a rigid lead-free solder with inflexible PCB laminates that has advanced the prevalence of this condition. Pad cratering is simply the end result of mechanical stress exceeding material limitations.

An X-ray inspection revealed subtle anomalies at the interface where a ragged and flattened appearance of several solder balls was observed (Figure 2-1). An endoscopic examination further confirmed that gapping at the interface had indeed occurred (Figure 2-2). To confirm this condition, microsection failure analysis was performed using enhanced SEM (scanning electron microscopy) magnification. Pad cratering was observed throughout the BGAs. In addition, fractures at the solder joint/gold pad interface and within the PCB were observed indicating an overstress condition (Figure 2-3).

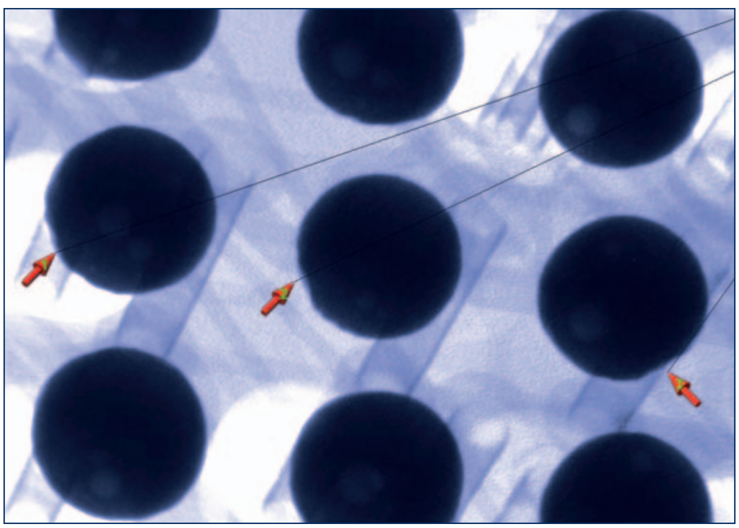

Figure 2-1: X-ray inspection of BGA showing flattened appearance of several solder balls.

While it is unlikely that this specific occurrence was the root cause of the assembly failure, it may be indicative that a complete separation has occurred elsewhere; creating intermittent failures. Solder fracturing along the path of these "craters" can compromise connecting traces and vias resulting in an electrical failure. An examination of the metallurgical structure of the fractured solder joint was found to be consistent with a well controlled lead-free soldering process. This further strengthened the conclusion that the solder fracture resulted from pad cratering.

Pad cratering is found to be more common at BGA locations for a variety of reasons. A BGA solder joint does not have the inherent stress relief as would be found on a gull wing lead connection. BGA solder lands typically have a low individual surface area, and due to their large size, BGAs are more susceptible to damage as a result of vibration (due to high mass) or deflection of the substrate (due to high footprint area).

Prevention of pad cratering requires measures that either reduce the stress on the interconnect site or mitigate the effects of stress. Reducing stress may require layout modification of the PCB or redesign of the next higher assembly. Adhesives can be applied as underfills or as external package perimeter bonding to provide additional mechanical strength, but this application may not be practical and has not yet proven to be sufficient in certain situations. Changes to the material specification for the PCB laminate can also be an effective strategy to prevent pad cratering. The material composition (fillers) and fabrication methods (cure process) require changes to increase the thermal resistance and dimensional stability in laminates for lead-free processing. These changes also tend to increase the propensity for pad cratering, especially when coupled with the lead-free solders.

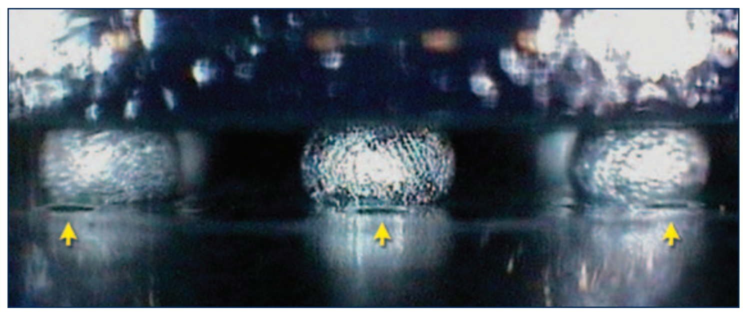

Figure 2-2: Endoscopic examination confirms gaps at the interface as indicated by the yellow arrows.

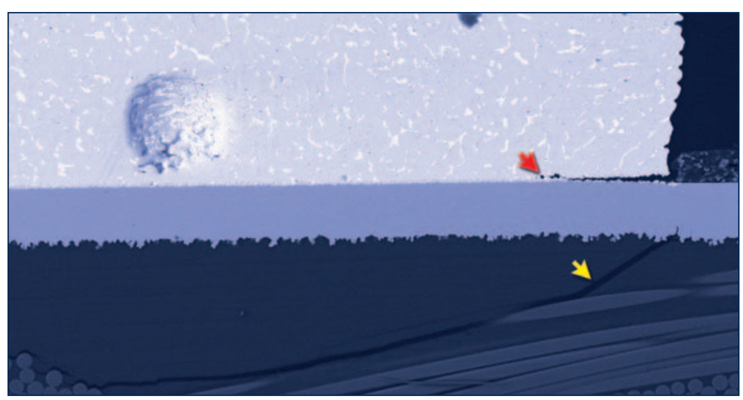

Figure 2-3: SEM micrograph showing fractures at the solder/gold pad interface (red arrow) and within the PCB (yellow arrow).

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Attaching Fiber Optic Modules

Optical fibers transmit information in the form of pulses of light. The advantages of optical fibers over traditional copper wires include: higher throughput, greater signal distance and speed, smaller cable mass and diameter, greater pull tension limit, and resistance to electromagnetic interference (EMI) and radio frequency interference (RFI). The disadvantages of fiber optics when compared to copper wires include: end-face defects, cleanliness, and the ease of attaching connectors to electronics assemblies (Figure 3-1).

End-Face Defects

End-face defects adversely affect the optical performance by creating air gaps and blockages in the light path that prevent direct physical contact during mating. The types of end-face defects include: loose contamination or dirt; oil contamination; scratches; and pits, chips, or other defects. Loose contamination can include dust or debris that can be removed with proper cleaning. Oil contamination is typically introduced via fingerprints and can also be removed with proper cleaning. Scratches are features that are typically caused by the cleaning or polishing processes and require re-polishing of the fiber. Pits, chips, and other defects may require cutting off the damaged section and re-polishing.

Cleanliness

Dust in the optical path is a concern, because the contamination can increase the insertion loss (IL) and decrease the return loss (RL), both of which are undesirable. IL is the loss of signal power resulting from the insertion of a device in an optical fiber and is usually expressed in decibels (dB). RL is the loss of signal power resulting from the reflection caused at a discontinuity in an optical fiber and is usually expressed as a ratio in decibels (dB). The return loss is high if two optical fibers are well matched. A high return loss is therefore desirable as it results in a lower insertion loss.

A recent study by iNEMI[1] showed that dust particles can accumulate and redistribute at the connector end face during repetitive connector mating and de-mating cycles. In the study, they found that electrostatic charge force was one of the mechanisms responsible for the particle accumulation, redistribution, and their movement in and towards the core area.

The effect of dust accumulation at the core of the fiber was reduced by application of ionized air or use of a fluid cleaning process, with both methods neutralizing the electrostatic charge at the connector end face. Applying ionized air or using cleaning fluids were good techniques for minimizing movement of particles during the service life of connectors in optical systems.

Attachment Techniques

There are multiple methods to use for attaching fiber optic modules to an electro-optics assembly, and may include: soldering, conductive adhesives, or mechanical assembly. The main concerns for the fiber optic module connector are its sensitivity to cleanliness and heat. In a standard reflow process, flux, surfactant, and water residues could damage or reduce the performance of the optical components. Low temperature alloys can be used with any of the soldering techniques to attach fiber optic modules, especially when the conventional soldering temperatures may damage the component.

To reduce the likelihood of heat damage, the fiber optic module is added after the other components are processed. To increase reliability and reproducibility, automated soldering process, such as selective soldering, robotic soldering, or selective laser soldering are favored over hand placement and soldering. Other attachment techniques are available, including anisotropic conductive films and conductive epoxies.

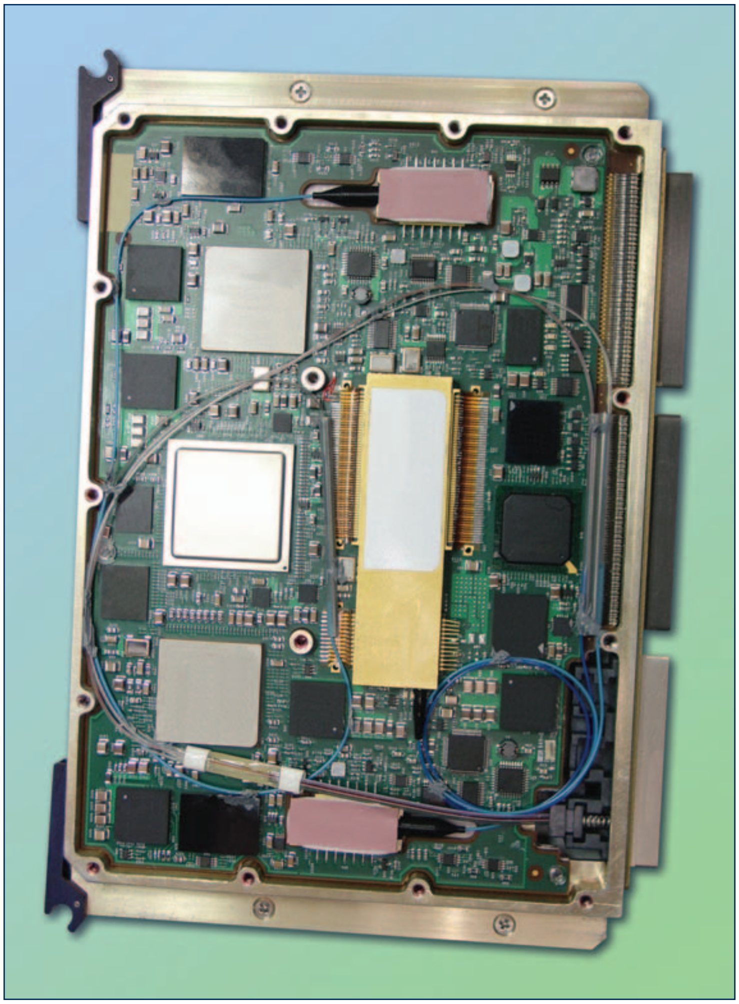

Figure 3-1: Circuit card assembly combining fiber optic components with electronics.

Pick-and-place systems use vacuum heads with x-y positioning control to pick up and hold the components. Cameras are used to verify alignment of the components, boards or panels of boards using fiducials. Cameras also aid in the placement of the components in the appropriate board locations to which solder paste has been applied.

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Tech Tips: Fiber Optic Cabling

Fiber optic harnesses appear simple, but they have been designed to maintain all of the critical areas of aligning two fibers and minimize the losses associated with a break in the transmission path. In order to understand how the connectors overcome alignment issues, we must first understand the issues. Fiber optic communications networks use specific wavelengths of light (or colors) to transmit information through a clear fiber at high speed. They use the property of internal reflection along the fiber's axis to contain the light and keep the optical power high enough to be detected at the receiving end.

Light in a fiber can "bounce" within the fiber when the angle that the ray approaches the edge is less than a critical angle that is determined by the refractive indexes of the core and cladding (Figure 4-1).

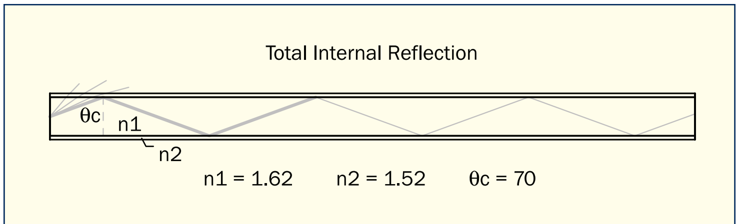

Figure 4-1: Critical angle for total internal reflection.

Fibers can be joined together to allow the light to transmit data over long distances. There are two basic ways to join fiber: by fusion, which creates a permanent connection, or by utilizing a connector, which creates a removable junction. This article will focus on the technology of fiber optic connectors.

Fiber optic connectors are designed to minimize the losses that occur when joining fibers. In order to understand the features of the different types of connectors, one must first understand the types of losses. Fiber optic cabling creates a path to transmit light from one system to another. Any change in the path can lead to a loss; an escape or redirection of the light energy. Losses can come from a rough fiber face or a misalignment of the fiber (Figure 4-2).

The typical fiber optic connector will have a spring loaded mechanism to maintain the fiber ends in direct contact, a core ferrule to ensure the fiber core is aligned straight, a keying system to ensure that the connection is repeatable, and a mechanical locking feature to ensure that the connector will not decouple during system operation. Some of the common types of fiber optic connectors are the straight tip (ST), fiber connector (FC), mini-BNC, biconic, subscriber connector (SC), and fixed shroud duplex (FSD).

Most of these connectors are available in flat, physical contact (PC), or angled physical contact (APC) based on the shape of the fiber end polish. Flat polish is the default and is usually unspecified. With a flat polish, the fibers physically touch, but any imperfections in the flat surface will cause an air gap and associated losses. As the forward transmission losses increase, the back reflections (light energy reflected back toward the source) also increase causing possible data loss and laser heating.

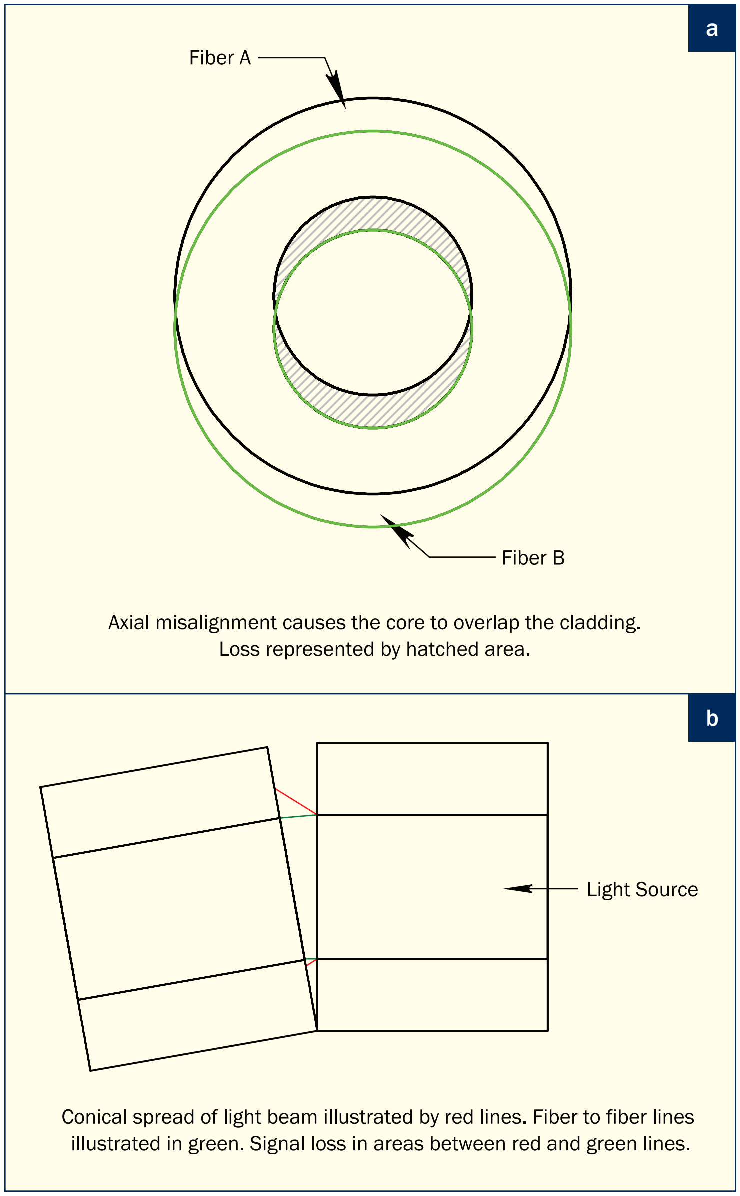

Figure 4-2: Junction losses: axial misalignment (a) and angular misalignment (b).

PC fiber ends are ground and polished with a slight radius, this allows a single point of contact between the fiber ends with no air gap and smaller back reflections.

APC fiber ends are polished with an angle that is exactly 8º from perpendicular. This angle is greater than the critical angle needed for internal reflection so any reflected light enters the cladding and does not harm the laser source. APC ends require a connector that has an alignment key to ensure that the angled fiber ends meet correctly.

With any fiber optic connection, the key to achieving good signal transmission is to have a clean contact area with no scratches in the fiber

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Manufacturer's Corner: PCB Assembly Line

Design and Start-Up of a Circuit Board Assembly Plant

Designing a functioning surface mount production line from scratch is easy for those with experience. However, for those without this start-up experience, the Electronics Manufacturing Productivity Center (EMPF) can provide the kind of hands-on exposure to make a fresh factory start-up a smooth and trouble free operation. As a working factory and stationary trade show with over 60 pieces of equipment, the EMPF provides an opportunity to examine individual items of equipment and more importantly, how to lay-out and assemble all the equipment into a modern and efficient assembly line. Tours of this facility are free and complementary to those people in the trade.

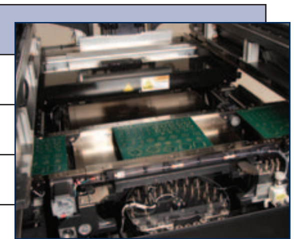
There are several reasons companies choose to install their own production lines. There is more control of production scheduling, direct quality control of the all the processes, and higher security than when a product is out-sourced. Build speed is quicker (a prototype line can produce a populated board in half a day) and time to market is shorter when you control the production facility. In contrast, job shops and contract manufacturers have little financial incentive to set-up and run small jobs at the expense of the larger and more profitable production runs.

All of the equipment at the EMPF is state-of-the art and provided by vendors for demonstration to customers. All stages of a surface mount assembly line are represented. Stencil printing, chip placement, reflow, and cleaning are some of the pieces equipment that populate the EMPF manufacturing floor. The goal of the EMPF is to provide a superior example of current machine technology and performance in each specific type of equipment category, and further to have two of every type of machine, differing in design intent, features, and markets served. The EMPF has two stencil printers, two pick and place units, two reflow ovens, and two circuit board cleaning machines, along with several rework stations and other equipment. For example, at the upper range of machine capability, the MPM Speedline stencil printer can automatically apply solder paste to the stencil, clean the stencil, and with an onboard pattern recognition system, measure the coverage of paste on the pads of a circuit board. This is a high end, feature rich machine. Other manufacturer's machines can apply paste well, but rely on the operator to inspect for paste coverage on the pads and clean the stencil. Table 5-1 lists a few equipment features to consider in the selection process.

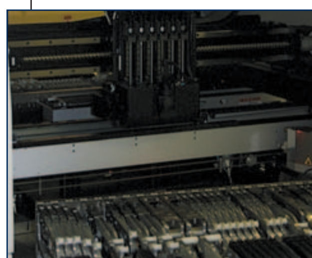
A company considering pick and place equipment can review the capability differences of a Samsung 321 and a Manncorp MC-392. While the Samsung has four pick-up heads and can place 20,000 chips per hour (CPH), the Manncorp has two heads and can place 5500 CPH. Both are well made machines, but serve different markets and have different performance characteristics and prices.

Reflow ovens also differ in capability, design intent, and features. With at least two reflow ovens on the manufacturing floor, the careful assessment of what features are required for a specific product is possible. The number of heating and cooling zones, computer control features, reflow profiling software, width of belt, and source of heat can all be evaluated.

Stencil Printer: Features to Consider
Alignment of board to stencil
Automatic cleaning of stencil
Vision system management of pad coverage
Automatic paste placement loading
Automatic positioning of board supports for large boards



Pick and Place: Features to Consider
Units (components) placed per hour
Smallest component that can be repeatably placed
Feeder capacity
Vision system capability
Accuracy of placement



Reflow Oven: Features to Consider
Number of zones
Temperature of zones
Nitrogen capable
Profiling software
Overall software features

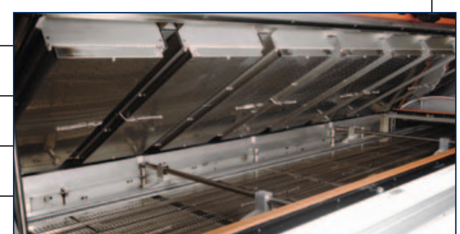


Table 5-1: Features to consider during the decision-making process prior to an equipment purchase.

Utility requirements can and must also be considered for a new production line. Power requirements (both single and three phase), exhaust air requirements, deionized water for a circuit board washing, compressed air, refrigeration to store the solder paste can all be estimated and planned based on the production lines at the EMPF.

With two operating assembly lines and dozens of separate equipment items, both government and commercial companies have gained valuable experience with the variety of equipment that make up a modern assembly line. For more information or demonstrations of EMPF capabilities, please contact Mike Prestoy at 610.362.1200, extension 241.

Mike Prestoy | Senior Applications Engineer

In April 2010 the IPC published a new revision of IPC-A-610: Acceptability of Electronic Assemblies with changes and additions that reflect the evolution of the electronics manufacturing industry. Some of the more significant changes will be described in this article, but the IPC has made available to the public a document that highlights each change from Revision D at the following web address: http://www.ipc.org/4.0_Knowledge/4.1_Standards/IPC-A-610E-redline-April-2010.pdf.

The first significant change to IPC-A-610 is the use of statements with the word **shall** to define requirements on materials and processes. This is a departure from previous revisions where IPC-A-610 limited the scope of the requirements presented to those that could be verified through visual inspection. An example of this new scheme includes the requirement that leads cut after soldering for Classes 2 and 3 "… **shall** be visually inspected at 10X to ensure the original solder connection has not been damaged … [or] the solder connections may be reflowed."[1] A new Class 3 requirement also specifies that leads must be reflowed (rather than inspected at 10X) if cut into the solder fillet.

Three new definitions were introduced with the new standard. Wire Overwrap (see Figure 6-1a) is defined as "[a] wire/lead that is wrapped more than 360° and remains in contact with the terminal post."[2] Wire overwrap is acceptable for all classes for all wrap-type terminals. Wire Overlap (see Figure 6-1b) is defined as "[a] wire/lead is wrapped more than 360° and crosses over itself, i.e., does not remain in contact with the terminal post."[2] Wire overlap is typically considered acceptable for Class 1 but a defect for Classes 2 and 3 for wrap-type terminals. The final new definition is Nonfunctional Land, defined as "[a] land that is not connected electrically to the conductive pattern on its layer."[2] A nonfunctional land is referenced in 4.3.2 (Press Fit Pins).

Chapter 5 (Soldering) saw changes to existing criteria in 5.2.11 (Lead Free Fillet Lift) and 5.2.12 (Lead Free Hot Tear/Shrink Hole). All defect conditions were removed from those two phenomena which in effect makes each acceptable as long as all other solder joint requirements are met and no impact on form, fit, function, or reliability can be expected.

The requirements found in 5.2.5 (Cold/Rosin Connections) were surprisingly missing from previous revisions on IPC-A-610. These conditions are now defined as defects for Classes 1, 2, and 3 when the condition prevents conformance to all applicable solder joint requirements.

Chapter 6 (Terminals) has been reorganized to increase the usability of the document. Each terminal type section (turret, bifurcated, slotted, etc.) now contains a table to summarize all wire or lead installation requirements and the installation and solder fillet requirements are now found together for each terminal type.

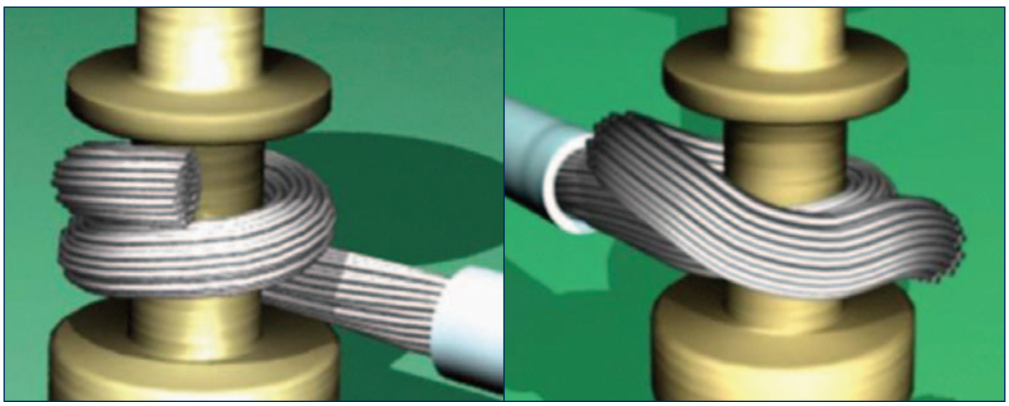


Figure 6-1: Wire overwrap (a) remains in contact with the terminal post while wire overlap (b) crosses over itself and does not remain in contact with the terminal post.

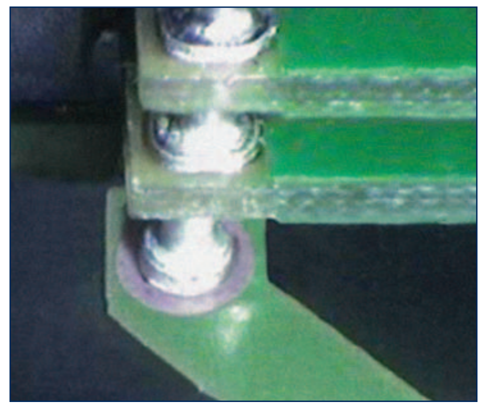


Figure 6-2: Flattened post connection.

Chapter 7 (Through-Hole Technology) has received considerable attention in the new revision. Section 7.2.2.1 (Component Securing - Adhesive Bonding - Nonelevated Components) has been updated to reflect the requirements initially introduced in *J-STD-001DS* and carried over to *J-STD-001E*. A change was made to the Class 2 exception found in 7.3.5.1 (Supported Holes - Solder - Vertical Fill) which allows either 50% or 1.19 mm minimum vertical fill, whichever is less. As always, use of this exception requires that the plated through-hole in question is connected to a ground or thermal plane. Through-hole jumper wire requirements have been moved from Chapter 11 (Discrete Wiring) to the end of Chapter 7.

Requirements were introduced for soldering of daughter board subassemblies in 7.3.5.12 (Supported Holes - Board in Board). Requirements for Classes 1 and 2 are presented. Since no requirements have been established for Class 3, assemblies required to conform to Class 3 requirements must use the guidance found in 1.4.1.7 (Specialized Designs). This directs the manufacturer to use the existing requirements as guidance and recommends that unique acceptance criteria be developed in conjunction with the customer. "For Class 3 the criteria **shall** include agreed definition of product acceptance."[3]

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Fiber Optic Wavelength-Division Multiplexing

(continued from page 1)

RFI and EMI disruption in copper networks. They also offer a higher degree of security since fiber optics do not radiate electromagnetic signals.

Fiber optics are safe for high voltage areas. Since they are insulators, devices can be connected of different electrical potentials without arcing.

The biggest advantage is that more information can be carried over longer distances in the least time with fiber optics than any other system. Using fewer cables, fewer repeaters, less power, and less maintenance, fiber optics is the most cost effective choice for data transmission.

Multiplexing

Fiber optic communication occurs by first converting an electrical signal into a modulated light beam. This is done by either directly modulating the input power of a laser or light emitting diode (LED) or by changing the intensity of the beam after leaving the source. Next, the signal is relayed along the optical fiber while maintaining signal strength and accuracy. Finally, the signal is received and converted back to an electrical signal.

Similar to other communication systems, optical signals are often combined or multiplexed to take advantage of the huge capacity of the fiber. Three types of multiplexing can be used: directional, time-division, and wavelength-division.

While signals can be sent in opposite directions in the same fiber, directional multiplexing works best when different wavelengths are used to reduce interference.

By combining data from several different signals into a timed sequence, a time-division multiplexed signal can be formed carrying interleaved data. As shown in Figure 1-3, four 10 Mbit/s signals can be combined into a single channel carrying 40 Mbit/s of data. By decreasing the width of the incoming pulses more signals can share the output fiber, increasing the information carrying capacity (bandwidth) of the fiber. The receiving end of the fiber uses a demultiplexer to sort the samples into their original form so the information can be recovered.

Analogous to the frequency-division multiplexing used to electronically combine many television channels onto one coaxial cable, wavelength-division multiplexing combines optical signals of different wavelengths onto a single fiber. Figure 1-4 shows how inputs from four fibers can be combined using multiple wavelengths. In this example, 10 nanometer spacing was used, but using a dense wavelength-division multiplexing (DWDM) system design, wavelengths can be as close as a few nanometers before interference occurs. Typically, 100 GHz frequency spacing is used between channels or 0.8 nm wavelength difference. Starting at 1550.0 nm, the next two channels would be 1549.2 nm and 1548.4 nm. The relation between wavelength and frequency is determined by the following formula.

wavelength = c / **frequency**

l = c / **n**

where: **l** = wavelength in meters

c = the speed of light = 3×10^8 m/s

n = frequency in Hertz (cycles per sec)

In a WDM system, each wavelength is modulated separately with its own transmitter and receiver. The example shown in Figure 1-4 would require four transmitters and four receivers which can be packaged together into a single WDM transmitter and a single WDM receiver (using a single fiber between them). The speed of the modulation (the on or off cycle of a light pulse) determines the data rate.

Figure 1-2: A single fiber optic cable can transmit the same amount of data as thousands of copper wires.[2]

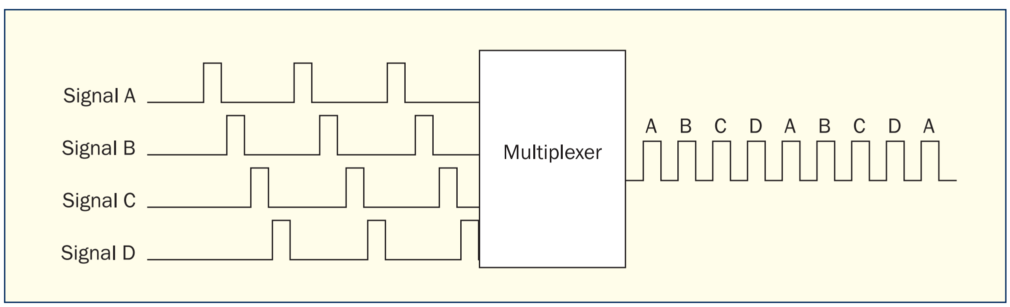

Figure 1-3: Time-division multiplexing combines several slow signals into one faster signal.[1]

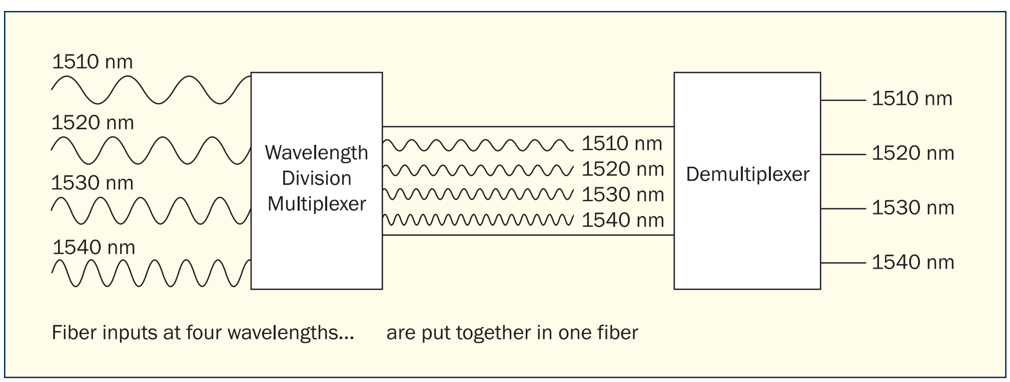

Figure 1-4: Wavelength-division multiplexing combines multiple wavelength signals into one high bandwidth signal.[1]

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Fiber Optic Wavelength-Division Multiplexing

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The light intensity can be varied by directly driving an LED or laser output. To achieve higher speeds (10 to 40 Gbits/sec), an external modulator is used to essentially chop a steady light beam using an interference phenomenon.

By using a combination of time-division multiplexing and wavelength-division multiplexing, a variety of signals of different data rates can be combined onto a single fiber for high speed transmission lines. The EMPF is working on a project to replace shipboard Ethernet cables with a high speed fiber optic network. Rather than point-to-point connections from one shipboard location to another, all the Ethernet communication signals from each location will be combined onto one fiber and transmitted throughout the ship. This will eliminate a large number of cables and their associated weight and costs. The fiber optic network will be easier to install, maintain, and will provide higher bandwidth, growth capability, and reconfiguration flexibility.

For more information on wavelength-division multiplexing and electro-optic assembly, please contact the EMPF at 610.362.1320, via email at helpline@empf.org or visit the website at www.empf.org.

References

[1] Hecht, Jeff. *Understanding Fiber Optics*. Upper Saddle River, NJ: Prentice Hall, 1999. Print.

[2] "The FOA Reference For Fiber Optics - Fiber To The Home." *The Fiber Optic Association*. Web. <http://www.thefoa.org/tech/ref/appln/FTTH.html>.

[3] Crisp, John. *Introduction to Fiber Optics*. Oxford: Newnes, 1996. Print.

Paul Bratt | Senior Packaging Engineer

Ask the EMPF Helpline!

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IPC-4101 (Specification for Base Materials for Rigid and Multilayer Printed Boards) requires a minimum trace peel strength but may not be sufficient for all designs and service environments. Peel strength testing per IPC-TM-650 Method 2.4.8 (Peel Strength of Metallic Clad Laminates) Condition A (as received) can be used as a comparative test between different laminate materials. Condition B (after thermal stress) can be used to compare laminate materials after exposure to soldering processes. Samples for testing should be sourced from qualified PCB suppliers and can be as provided per IPC-TM-650 Method 5.8.3 (Peel Strength Test Pattern) or per IPC-2221A (Generic Standard on Printed Board Design) specimen C or N.

Peel strength testing should also be performed periodically by PCB suppliers to ensure their "as received" laminate is in compliance with applicable specifications and to ensure the PCB fabrication process does not degrade the laminate and increase the likelihood of pad cratering on the completed assembly.

The EMPF offers a variety of analytical instrumentation and techniques for failure analysis and qualification testing of PCB suppliers to ensure compliance to all applicable IPC specifications. X-ray, endoscopy, SEM/EDS (Energy Dispersive X-ray Spectroscopy), and optical microscopy capabilities are available to investigate possible issues and determine root causes. Assistance can also be provided for peel strength testing as well as testing of various adhesives and underfills to mitigate pad cratering. Contact the Helpline at 610.362.1320, via email at helpline@empf.org or visit the website at www.empf.org for more information.

Ron Sauro | Chemist

Ask the EMPF Helpline! *A direct connection to electronic manufacturing support.*

Contact the Helpline via: *phone* **610.362.1320** | *e-mail* **helpline@empf.org**

Attaching Fiber Optic Modules

(continued from page 3)

Selective laser soldering is a technique where a 2 to 80 W average powered laser is used. The parameters depend on the solder joint dimensions and the required speed. Solder mask coatings are more damage resistant to lasers emitting in the 940 to 980 nm range. Some of the parameters to consider in selective laser soldering are: average power (watts), pulse time/length (ms), pulse duty cycle (% on/off), power density (intensity, watts/cm^2), and laser focus position. Each of these variables can be optimized for minimizing the soldering time, the amount of energy delivered to solder joint, the rate of heat delivery to solder joint, the rate of the soldering process, and ensuring good solder joint quality. The laser system is mounted to a precision x-y positioning table or robotic arm coupled with a camera and imaging system that allows for coaxial viewing of the laser beam in real time.[2]

Robotic soldering is similar to selective laser soldering in that a soldering iron is mounted to a precision x-y positioning table and robotic arm with a camera and imaging system that allows for viewing of the soldering process in real time. The actual soldering process is much like hand soldering, only that higher precision and reproducibility is gained by using a robotic system to form each solder joint.

Selective soldering is similar to wave soldering except only a small area of the board is contacted at a time. The assembly is attached to a precision x-y positioning control system and is selectively moved over a small solder fountain and carefully lowered into and out of the molten solder. Alternate selective soldering machines can precisely move a small solder pot under a stationary circuit card assembly.

Whenever one uses automated placement and soldering processes, it is important to remember that each system requires programming of the component variables and bare board coordinates, as well as the soldering parameters necessary to form quality assemblies. The up front time spent on programming the systems pays off with fewer soldering errors, a more reliable manufacturing process, and a more reliable product.

Anisotropic conductive films (ACFs) allow for the interconnection of circuit lines through the adhesive thickness (in the Z-axis), but are electrically insulating along the plane of the adhesive (in the X-Y plane). The film is a heat-bondable, electrically conductive adhesive film, composed of thermoplastic and thermosetting epoxy/acrylic matrix with conductive particles. Application of heat and pressure, using a thermo-compression (hot bar) bonder, causes the adhesive to initially flow and to bring the circuit pads into contact, trapping the conductive particles between the component and circuit pads.[3]

Screen printed conductive epoxy can be used to attached fiber optic modules. Conductive epoxy can have a coefficient of thermal expansion (CTE) that more closely matches that of the epoxy used in the circuit board, minimizing failures due to cracking of solder joints due to thermal cycling. Non-conductive epoxy can be used to provide additional mechanical strength. Another advantage to using conductive epoxy rather than solder is that the manufacturing process has fewer steps, eliminating the pre-tinning, prebake and flux removal steps of the typical electronics manufacturing process. The terminals of the components may need a AgPd surface finish to reduce the likelihood of increased resistance due to tin oxide formation and diffusion within the adhesive joints when using pre-tinned components.[4]

Rework Considerations

To rework a soldered connection, standard techniques can be used, such as hot air or infrared radiation equipment to heat the location above the reflow temperature. The part is removed, the site prepared for a new component, and a new part is re-soldered.

To rework an ACF, one heats the bond-line area to above 100°C with an appropriate rework tool and peels the circuits apart. The bond site requires cleaning with a solvent, such as acetone, and the circuits can be re-bonded with a new piece of ACF.

To rework conductive epoxy, one heats the epoxy above its glass transition temperature (T_g), removes the defective component, and attaches a new one, with no additional steps.[5]

Summary

There are a variety of technologies to attach fiber optic modules or other heat sensitive components. Localized soldering technologies such as selective laser, robotic, and selective soldering provide joints familiar to the conventional electronics manufacturing industry. Anisotropic conductive films and screen printed conductive epoxy provide alternatives with fewer steps for attachment as well as rework.

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[2] Hoult, Tony. "Laser Solutions for Soldering." *Circuits Assembly*, Feb. 2004. Web. <http://www.coherent.com/Downloads/circuitsassembly0204Rev2.pdf>.

[3] "Anisotropic Conductive Films." *3M Global Gateway Page*. Web. <http://solutions.3m.com/wps/portal/3M/en_US/electronics/home/productsandservices/products/TapesAdhesives/AnisotropicConductiveFilm/>.

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Tech Tips: Fiber Optic Cabling

(continued from page 4)

or debris in the connector. With fiber optic cores as small as nine microns, even a one micron particle can significantly block data transmission. Contamination should be prevented by:

- leaving protective caps in place on unplugged connectors
- never touching a fiber endface
- never reusing cleaning materials

Microscopic inspection of the fiber end prior to assembly is essential to ensure a good connection. Cleaning can be performed using a dry cleaning method (air spray, lint-free wipes or swab) or a wet cleaning method using a solvent such as isopropyl alcohol (IPA). After inspection and cleaning, a re-inspection is critical before the final connection.

Contact the EMPF at 610.362.1320, via email at helpline@empf.org or visit the website at www.empf.org for more information or assistance with fiber optic cables and assemblies.

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Chapter 8 (Surface Mount Assemblies) has also seen significant changes, most notably to 8.3.12 (Surface Mount Area Array). This section has been updated to describe requirements for ball grid array (BGA) components with non-collapsing balls and column grid array (CGA) components. Section 8.3.12.3 explicitly adds head on pillow as a defect for Classes 1, 2, and 3. (See Head on Pillow Defects on BGA Assemblies from the March 2008 issue of *Empfasis* for further information regarding head on pillow.) New requirements have also been added in 8.3.12.6 (Surface Mount Area Array - Package on Package), which essentially repeat the standard requirements for BGAs with collapsing balls.

Section 8.3.13 (Bottom Termination Components) has been renamed to demonstrate that this section applies to a family of similar part types, rather than just to a single package type. Section 8.3.15.2 (Flattened Post Connections) has been added to reflect Class 1 and 2 requirements for this termination type (Figure 6-2). Finally, the jumper wire requirements specific to surface mount assemblies have been moved from Chapter 11 to the end of Chapter 8.

Chapter 9 (Component Damage) has been reorganized to incorporate damage requirements that were previously located in other areas of previous revisions of the standard. Examples of where damage criteria was moved from elsewhere in the standard are 9.8 (Connectors, Handles, Extractors, Latches), 9.9 (Edge Connector Pins), 9.10 (Press Fit Pins), 9.11 (Backplane Connector Pins), and 9.12 (Heat Sink Hardware). New damage criteria have been added in 9.6 (Relays) and 9.7 (Transformer Core Damage).

Chapter 10 (Printed Circuit Boards and Assemblies) has been updated to reflect the requirements originally found in *IPC-A-610D Amendment 1* with regards to printed circuit board measling. New requirements are found in 10.2.3 (Laminate Conditions - Weave Texture/ Weave Exposure) that defines "surface damage that cuts into laminate fibers"[4] as a defect for Classes 2 and 3. Section 10.2.7 (Laminate Conditions - Depanelization) has been added to cover the common practice of routing or the use of breakaway tabs to separate single assemblies from multi-board panels. The requirements in 10.2.7 mimic the edge damage criteria from 10.2.4 (Laminate Conditions - Haloing and Edge Delamination). Section 10.5 (Marking) and 10.5.6 (Marking - Using Radio Frequency Identification (RFID) Tags) add information and requirements for the use of RFID tags on assemblies. Section 10.9 (Encapsulation) adds new requirements for the use of encapsulant materials which duplicate the requirements found in *J-STD-001E*.

The final obvious change to the standard is the formatting change to Chapter 12 (High Voltage). Although no changes to requirements are present, the chapter has been organized in a manner to increase the ease of use by presenting all target criteria on a single page, all acceptable criteria on a single page, and all defect criteria on a single page.

Certified IPC Trainer (CIT) certification is now available through the EMPF. Training materials for Certified IPC Specialist (CIS) certification are now available from the IPC. Contact the EMPF Registrar at 610.362.1200 or via email at regsistrar@empf.org for further information regarding the availability of training to the new revision of IPC-A-610.

References

[1] *IPC-A-610E: Acceptability of Electronic Assemblies*. Bannockburn, IL: IPC - Association Connecting Electronic Industries, 2010. 7-53. Print.

[2] *IPC-A-610E* 1-5.

[3] *IPC-A-610E* 1-4.

[4] *IPC-A-610E* 10-9.

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