empfasis

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The EMPF is a U.S. Navy-sponsored National Center of Excellence focused on the development, application and transfer of new electronics manufacturing technology by partnering with industry, academia and government centers and laboratories in the U.S.

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Link-16 Low Cost Terminal Project

ACI has undertaken a Navy ManTech program to develop a highly manufacturable Power Amplifier Interface (PAI) unit for the Link-16 terminal. The PAI unit will incorporate state-of-the-art technology while fulfilling the low cost requirements.

F/A-18

ACI will focus on key electronics manufacturing issues resulting in the cost reduction / technology upgrade of an essential military communication system. The knowledge gained from this project will also be transferred to industry, and government agencies in support of the US Navy's Manufacturing Technology (ManTech) Program at the National Electronics Manufacturing Center of Excellence, the EMPF.

Link-16 is a data and communications and navigation system that significantly enhances the platform's survivability and lethality, and is designed to meet the most stringent requirements of modern combat by providing reliable situational awareness (SA) for fast moving forces. Link-16 compatible hardware has a definitive impact on major Navy weapon systems (i.e., F/A-18, EA-6B, P-3C, S-3, Ships, E/F-18) and future Naval capabilities. Link-16 systems are extremely

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Link-16 (Continued from page 1)

sophisticated radio terminals. Their unique mix of capabilities in voice, data communications, real time navigation, self-identification, totally distributed network operations and super-high resistance to self interference jamming or enemy jamming, all in hardware that meets military performance requirements, represents a significant challenge to industry.

This project proposes to re-partition, re-layout, and re-package the 200 Watt PAI portion of the Link-16 Terminal Multifunction Information Distribution System, that is currently employed on F/A-18 and F-16 platforms, to reduce cost and position the equipment for inclusion in smaller size terminals. MIDS LVT, jointly developed by the U. S. Government and Industry, is among the second generation of Link-16 hardware. MIDS is compatible with first generation terminals known as Joint Tactical Information Distribution System (JTIDS). The purpose of the proposed PAI affordabilities work is: to use industry state-of-the-art technologies in circuit boards, semiconductor packaging, heat-transfer, and to incorportate new technologies (including Wide Band Gap (WBG) semiconductor devices) that enable low/no tune strategies to enhance the producibility and significantly reduce the cost of the PAI. Additionally, the purpose of this work is to demonstrate transferability of this PAI into smaller form factors.

ACI's set technical tasks include:

1) *Perform Technology Assessments* of the following areas to ensure that the redesign incorporates the latest "state-of-the-art" technology with knowledgeable decisions made in cost/performance tradeoffs:

- WBG high power semiconductor devices (SiC being the leading candidate). ACI arranged and participated in technical exchange meetings between WBG device suppliers and the MIDS LVT PAI power amplifier design engineers.
- Semiconductor packaging and level 2 interconnects with emphasis on modular construction of standardized designs.
- Thermal modeling and finite element analysis of components, subassemblies & modules, and the complete MIDS PAI unit. Theoretical calculations, FEA modeling, and empirical experimental results are the three techniques that are planned..
- Organic materials applicable for use in the PAI unit including conformal coatings, conductive adhesives, under-fills, and encapsulates.
- Small signal electronics: digital, analog, FPGA's, ASIC's, etc.
- Mechanical assembly and fabrication techniques
- Process analysis of the testing and tuning adjustments required during the manufacturing cycle.

2) *Fabrication and evaluation of "test vehicles"* to validate the designs and processes developed for the redesigned PAI unit. ACI will manufacture and test components, materials, subassemblies / modules, and manufacturing processes that result from the early design concepts.


EA-6B Prowler

3) *Do a Technology Transfer of the "lessons learned"* on this project (exclusive of any detailed subcontractor proprietary information) for the benefit of other Navy / military programs and the electronics manufacturing community in general.

Upon completion of this project, the US Navy will have a new affordable, miniaturized PAI, validated through independent testing by ACI, and the EMPF (Navy Center Of Excellence for Electronics), and ready to be qualified for use in current and future MIDS terminals. Additionally, this PAI will be size-positioned for new smaller terminals which will better fit disadvantaged users such as UCAV, patrol boats, armored vehicles, and rotary platforms. The MIDS IPO is currently asking industry to study options for size reduction of Link-16 terminals as part of their "MIDS Migration to JTRS" program.

This program will also be among the first implementations of WBG semiconductor technology. The advantages of using WBG technology include:

- Advanced interconnect technologies for RF devices.
- Major cost reduction by enabling no/low tune manufacturing process.
- Miniaturization, permitting use of the PAI on volume-limited weapons such as missiles and torpedoes.
- Creation of a critical insertion path for inclusion of Link-16 capabilities into other Navy programs.

Additionally, all US Government equipment programs will benefit from the semiconductor, packaging, and manufacturing technology that is being advanced and transferred across industry. Specifically, MDA programs desiring the use of WBG semiconductors will benefit by an earlier implementation of this technology for various communication and RADAR architectures. ACI will promulgate industry standardization of modular and WBG packaging methods based on lessons learned during execution of the program. This effort will include evaluation of various methodologies to mitigate the thermal challenges that accompany WBG devices.

Manufacturability and Affordability of Power Modules

For several years, the EMPF has been building its expertise in the field of power electronics. In 1999 and 2000 ACI, through the EMPF, developed a Power Electronics Training Facility (PETF) and curriculum to further educate industry members on improvements to power packaging. A significant influence to this effort was the Power Electronic Building Blocks (PEBB), a means to meet the affordable power generation for Naval applications.

As part of its commitment to be a rapid response technical resource to the Navy, ACI is currently contracted on a program called REPTILE (Regional Electric Power Technology Insertion and Leveraging Enterprise).

One key element of this project is the evaluation of Integrated Power System (IPS) prototype power conversion modules (PCM). The goal is to improve the manufacturability and thus the affordability of PCMs being developed for advanced surface combatant platforms which employ a zonal Integrated Fight Through Power concept.

The IPS concept consists of three basic PCMs:

- A 3 megawatt (MW) 3-phase, 4160 VAC to 1000 VDC rectifier/filter
- A 1000 to 800 V DC/DC Converter module configurable to deliver 500 kW to 3 MW
- An 800 VDC to 3-phase, 450 VAC inverter module configurable to deliver 500 kW to 3 MW

ACI is working with two independent teams working with the competing equipment manufacturers. The teams are each tasked with an in-depth review of the prototype design to conduct:

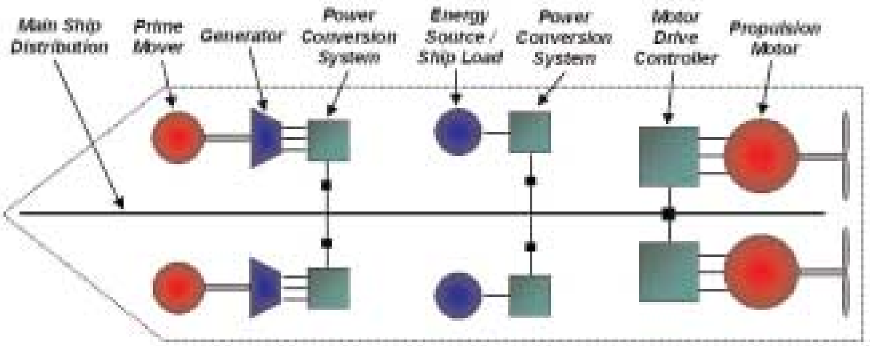
- Technology assessment
- Design for manufacturability assessment
- Manufacturing process evaluation

Following this, the teams are to deliver a comprehensive list of their findings. Ultimately, the ACI teams may be working with their respective manufacturers, and the Navy, to implement the findings and improve the manufacturability and affordability of the equipment.

Technology Assessment

The technology assessment is an objective review to determine if the design philosophy is consistent with cost minimization. A simple example would be that of over-design; a larger than necessary filter inductor may provide superior filtering, but it makes the end item larger and more expensive than required.

ACI feels that identifying issues such as this, is a valuable service to both the Navy and the supplier. Providing equipment exactly to specification should naturally be the supplier's goal and the end-user's expectation. Supplying equipment that exceeds specification may provide superior performance, but places the supplier in a non-competitive position. The role of ACI is to highlight areas where the proposed design performance exceeds specification, and allows the end-user to decide whether to change the requirements. This is a win-win condition. The end-user can elect to adopt a change and the manufacturers manitain competition.



The Basic Architecture of an Integrated Power System
Courtesy of NSWC Philadelphia

DFM Assessment

The potential suppliers have a proven history of delivering equipment of the highest grade to the Department of Defense on previous contracts. However, in recent years, a combination of changes in government acquisition policy, massive cost saving initiatives, and substantial realignment in the supply chain (where many traditional American suppliers have abandoned on-shore production or been absorbed into global entities) has made procurement an arena of constant change.

One element in this environment is the transition to commercial-off-the-shelf (COTS) procurement. Additional factors include:

- Supply line reliability: Are the selected parts available from two or more sources?
- Parts selection: Are MIL-grade parts used where industrial grade/ COTS parts will perform satisfactorily? (Particularly in areas where redundancy and spares availability will offset potential reductions in reliability.)

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Manufacturability and Affordability of Power Modules

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- Design: Are mechanical designs based on standard stock material with a minimum number of unique mechanical drawings? This an area where some additional non-recurring engineering costs can be more than recovered through reduced production material acquisition costs, smaller inventories and increased savings through a broader supplier base.

Manufacturing Processes

This is the assessment of the actual assembly process in an effort to drive down the project manufacturing cost. One significant area, which ACI is pursuing, is in parts commonality throughout the design that leads to inventory reductions. This impacts not only the material side, but also the accompanying labor costs of procuring, stocking, and kitting.

Mechanical assembly hardware or, more specifically, the sheer number of different fasteners is one area worth investigation. On the surface, it may not appear to be an area of substantive savings, but reducing the variety of fasteners used for assembly of complex equipment has ripple effects that are often ignored. Typically, 40 to 70 per cent of the line items on an assembly's bill of materials are fasteners. This hardware has to be kept organized. Since it needs to be conveniently available to many assemblers on a production line, the fasteners take up room at many different workstations. Each bolt or screw generally has an accompanying set of locks and/or flat washers and nuts, and its own torque requirements. When a wide variety of fasteners is used, each operator needs to have a larger tool set and maybe larger tool boxes; the potential for assembly error increases; and on and on.

Substantial gains have been made in industry through outsourcing the production of particular subassemblies to a combination of specialty suppliers with specific areas of expertise, such as harnesses or mechanical subassemblies.

Manufacturing process assessments should include the inputs of the assemblers themselves. It is they, through the experience of assembling the prototype assemblies, who have valuable insight into areas where substantial savings in assembly time may be made, sometimes through simple design changes not obvious to the designer early in the program.

Conclusion

ACI believes that through the design and manufacturing assesment of PCMs for Naval IPS, manufacturability and affordability will improve through implementation. A valuable service to both the Navy and suppliers will be realized as the issues are presented, and rectified through technological upgrades and/or manufacturing improvements.

Electronics Manufacturing Boot Camp

The processes, by which companies create functional devices from the diverse collection of components and materials which we associate with electronic devices, demand diverse knowledge. The phrase "You cannot inspect quality into a product" is not a meaningless mantra. As package size shrinks, and as we push the limits of the materials and methods employed to produce electronics goods, the fact that quality is the result of applied knowledge becomes increasingly clear. This knowledge crosses disciplines taught in institutes of higher learning. These disciplines are normally associated with organizational functions within companies.

Production Managers, Process Engineers, Design Engineers, Manufacturing Equipment Applications Engineers and Support Technicians, Materials Suppliers, Applications Engineers, Quality Engineers and Auditors have all benefited from attending the Boot Camp.

Perhaps your company is too small to support a staff of manufacturing engineers. Perhaps you need one or two or three people to act as Sales and Technical Representatives, Managers, Design Engineers, Technicians and Instructors, and all must share in the development of manufacturing processes. Do they understand how their particular knowledge can help optimize the entire manufacturing process? Can you afford to learn by trial and error? Product life cycles are shrinking. Profit margins are shrinking. Meanwhile, technical demands in manufacturing are increasing.

Tomorrow's electronic manufacturing personnel are today's students. Everyday, young engineers, production managers, and supervisors are challenged by new demands in the field of electronics. Electronics manu-

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Electronics Manufacturing Boot Camp

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facturing is not taught in most colleges. Prospective engineers are typically "trained" in the expensive school of hard knocks or, if your company is large enough, through the on-the-job (OJT) process of watching veterans do their job. There is no substitute for OJT and hard knocks experience but these stimuli will not teach process optimization. Peripheral processes may indirectly affect the primary process or the process of focus.

The Electronics Manufacturing Boot Camp program ties knowledge from disciplines of statistics, physics, metallurgy, electronics and materials science together to provide a comprehensive understanding of the processes used to manufacture electronic devices. Attendees will learn how design choices may influence yield at the manufacturing level, how materials and process input variables affect process output and interact with subsequent manufacturing processes, how manufacturing processes are designed and monitored. All students of the Boot Camp will enjoy hands-on participation in the primary processes for manufacturing electronic assemblies.

There are 22 modules, short courses, in the Boot Camp. Most of the modules are designed as a combination of lecture and laboratory experience. The target is 40 percent lecture, 60 percent demonstration and hands-on experience. Modules are sequenced to provide an overview of the entire manufacturing cycle, materials used in the cycle and industry-standard expectations for process control and end-item acceptance.

Boot Camp starts with the goal of providing a base understanding for practical use of Statistical Process Control, Design of Experiments and Design for Manufacture/Assembly. The first week of the program also includes modules on Bare Board Fabrication, Printing (solder paste and adhesives), Dispensing (adhesives and underfills) and Component Placement.

The second week of Boot Camp continues with manufacturing processes; Wave Soldering, Reflow Soldering, Cleaning, Hand Soldering, Coatings, and Rework Techniques. There are modules also on Process Control Tools, Thermal Profiling, Cleanliness Testing, Reliability Assessment, and No-Clean Processing.

One recent attendee commented, "Probably the most value added training that I have ever attended". Another wrote, "Great course, perfect introductory background [to] electronics manufacturing."

Students receive all course materials in binders, Component ID Guide Book, Surface Mount Manufacturing text, as well as a Boot Camp shirt. The Electronics Manufacturing Learning Center (EMLC) provides lunch during the weekday sessions at the Getaway Restaurant in the International Plaza.

The EMLC in conjunction with the Electronics Manufacturing Productivity Facility (EMPF) Equipment Partners provides lecture facilities and a modern, fully equipped factory floor. The facilities are adjacent to the Philadelphia airport.

After completing the course and experiencing the manufacturing process from start to finish, one recent student wrote, "...definitely worth my time and money ...I now feel confident about going home and starting up our own automated manufacturing . . . The mixture of lectures/labs really helps in understanding the processes..."

In addition to the standard Boot Camp sessions, we also can customize the class for large groups of students from the same company. Contact us for details.

Electronics Manufacturing

BOOT CAMP

Week A - August 4-8

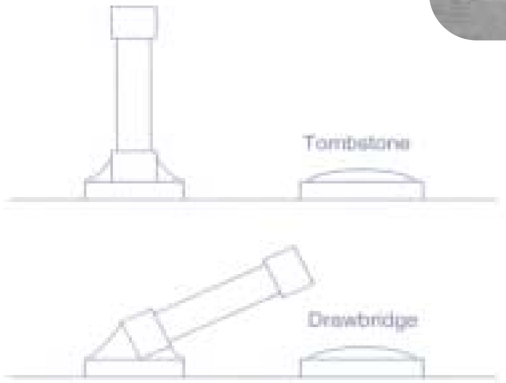
Week B - August 11-15

For more information or to register, please contact the registrar:
registrar@empf.org or

Solder Paste Inspection

Solder paste deposition, usually the first step in most SMT PCB manufacturing processes, plays a critical role in the acceptability yield of the end-product PCB assembly. Due to the importance of this critical process step, inspection of the printed PCB substrate is vital prior to additional processing. The ability to detect solder paste bridges, skips and depleted deposits at this stage of the process will save a tremendous amount of end product rework time and labor. Depending on the complexity and density of the PCB substrate, unaided visual inspection of the solder paste deposits may not be comprehensive enough to reliably detect any solder paste deposit anomalies.

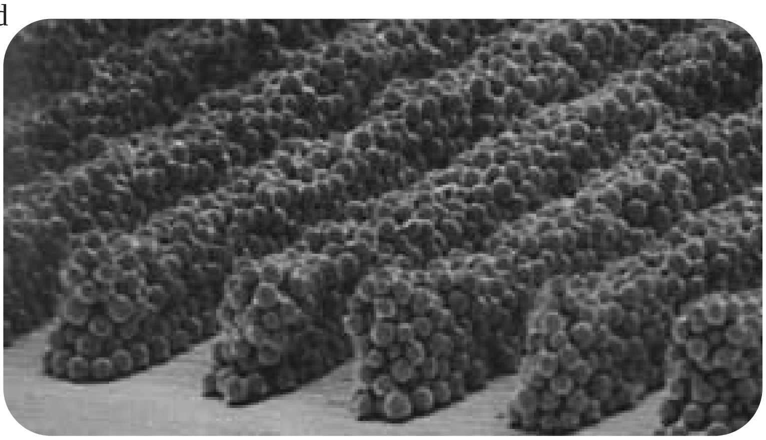
The use of manual optical inspection devices such as stereo microscopes, although beneficial, are not totally comprehensive and are a slow process at best. The recent introduction of automated optical inspection systems has proven to be very beneficial and cost effective due to their combination of speed and accuracy. Coupled with their speed and accuracy, the ability of these systems to measure, log and calculate solder paste deposits on a PCB substrate makes them an extremely valuable process verification and inspection aide.



Inconsistency of solder paste deposits causes an increase in surface tension on one side of the component during reflow, this will cause tombstoning and drawbridging.

Knowing the importance of the solder paste deposition process, the EMPF has incorporated into their SMT assembly line, automated in-line optical inspection capability for verification and measurement of PCB substrates printed with solder paste. The in-line inspection system uses high-resolution optical imagery to calculate vital statistics such as solder paste deposition height, total area of the solder paste deposition and volumetric measurements of the solder paste deposit. The ability of the system to calculate and store these measurements makes the system a valuable tool not only for inspection, but also for process development and control.

The versatility to inspect any PCB pad geometry, either square, rectangular or circular, ensures us the capability to reliably detect any solder paste deposit anomalies. The ability to calculate and log any measured variables in the solder paste deposits from one area of the PCB to another, provides valuable SPC data and ensures coplanarity of the solder paste deposits across the entire substrate. This will help to alleviate any potential solder joint irregularities. By inputting the length and width of the PCB pad and setting a reference point for height, the system will calculate height, area and volume of the solder paste deposit automatically and log this information into a database for later comparison. The ability to rapidly and reliably detect irregularities in the solder paste deposits, at this stage of the process, enhances the overall end product yield and reliability.



Solder Paste Deposits on 20 mil pitch QFP lands
(NOTE consistency of deposits)

If you would like further information on Automated Optical solder paste inspection processes or any other process related to SMT PCB manufacturing, please contact the EMPF Helpline at 610-362-1320 or log onto the EMPF website @ www.empf.org

State-of-the-Art Batteries

Effective, safe and economical packaging for batteries, utilized through the US Navy and US Army activities, are becoming a greater issue everyday. Two major reasons for this challenge are (1) commercial cells are being packaged in a case suited for military applications and (2) the higher energy densities are raising the level of danger. In most applications, battery power is provided by several cells joined in series to form a set of cells. In this case, volumetric power density is a function not only of individual cells but of the assembled cell sets. Prismatic and pouch cells utilize space more completely than do cylindrical cells in most applications.

Battery packaging ranges from the assembly of a battery containing 10 Watt-Hours of capacity for radios up to batteries with a storage capacity in excess of 1 Megawatt-Hour for underwater vehicle applications. A specific application is the development of small, quiet, unmanned Navy vehicles for military operations and surveillance. This vehicle, Wide Area Surveillance Projectile (WASP), creates unique requirements for innovative battery packaging.

The WASP micro air vehicle illustrates unique battery packaging. It replaces separate battery and wing structure components with a multifunctional structure/battery material system that supplies electrical energy for propulsion while carrying mechanical and aerodynamic wing loads.[1] This program is exploring materials that combine the function of structure with another critical system function such as power, repair, or ballistic protection.
The power supply for the WASP micro air vehicle must not only be rugged and reliable, but also as compact and lightweight as possible for Navy operations. The dual use of material, for structural integrity as well as for the wall of the battery itself moves in this direction. However, another powerful factor is the type of battery that is chosen for the task. The accompanying charts (on the following page) illustrate the advantage of lithium batteries for energy supply where weight and volume are critical. The only other common battery type that is in the same energy output range is the zinc-air battery. However with its high internal resistance the zinc-air battery is not adaptable to high load applications such as are typical for most Navy systems.

Air crew systems needed a low-cost energy source for the PRC-112 Survival Radio used by the US Navy, Airforce and Marines. This need brought to light an opportunity to utilize commercial technology in a military application. The current energy source is a custom-designed primary battery. ACI, working with the US Army CECOM, has delivered a primary battery option based on non-rechargeabe lithium-ion batteries and rechargeable NiMH batteries. The goal of the battery program was to provide air crews with a lower cost solution with similar capacity. The results indicate the primary version has approximately 90% of the life of the current battery. Designed to allow the insertion of COTS AA batteries, the cost of use is significantly reduced. The US Army estimates a potential savings of $10M over the life of the program.

The WASP Micro Air Vehicle is an example of unique and effective battery packaging.
See www.darpa.mil/body/news.html

Lithium Batteries

Lithium rechargeable batteries for military applications have several advantages over current battery chemistries currently in use namely:

- High cycle life
- Demonstrated no memory effect
- High energy density

The disadvantages of lithium rechargeable batteries are:

- Limited operating temperature; typically -20ºC to +55ºC
- Limited Storage Temperature; typically no greater than +60ºC

Safety Considerations

Typical safety considerations that must be addressed when developing a packaging methodology for batteries are:

- Effect of Short Circuits/High Rate Discharge
- Effect of Altitude
- Effect from Punctures/Crush
- Effect from Over Charge
- Effect from Over Discharge

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State-of-the-Art Batteries

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When considering lithium batteries for US Navy applications, S9310-AQ-SAF-010 Technical Manual for Batteries, Navy Lithium Safety Program Responsibilities and Procedures is followed. Other types of battery chemistry have similar testing requirements prior to use with the US Navy.

Comparison of Lithium and Alkaline Batteries for Navy Applications

Unfortunately, lithium batteries are relatively expensive, particularly with reference to the common alkaline batteries with their widespread commercial use. Thus it was of interest to directly compare the output of lithium and alkaline primary cells, in equivalent AA size packages.

Data achieved at ACI and presented in the following graph clearly shows the greater power of lithium AA batteries (type L-91) in comparison with alkaline AA batteries. Note the voltage decrease of the alkaline battery as well as the shorter lifetime. The graph also presents data for the alkaline AAA cell, for comparison.

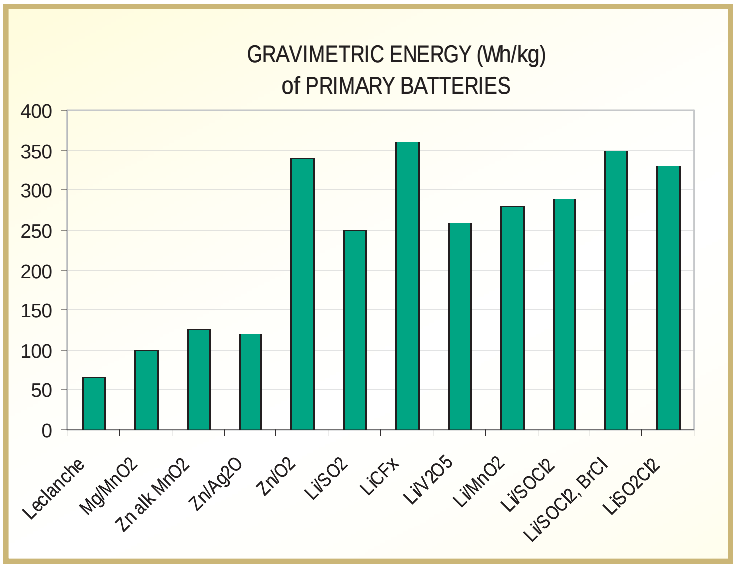
Battery Selection Criteria

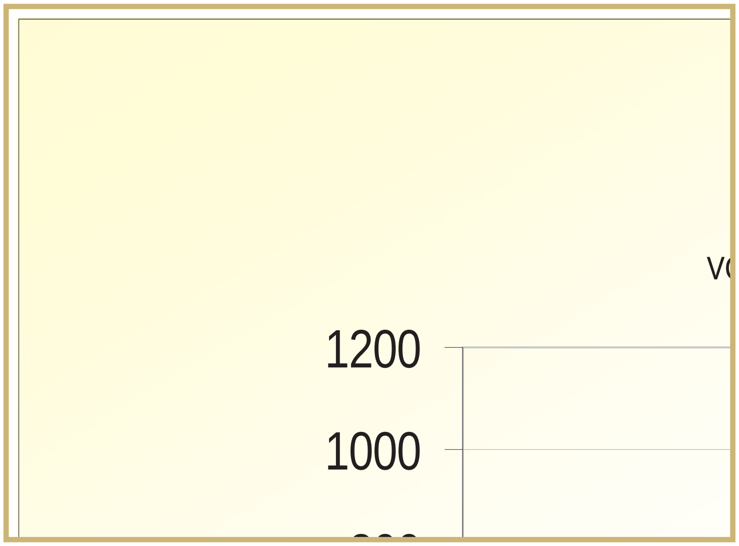
The selection of the current battery type, based upon environmental conditions, use and storage, can either reduce or adversly impact the total cost of ownership of a system. The battery application determines the appropriate choice for battery type and chemistry. The criteria that must be considered in selecting the correct battery type for a given Navy application, and for choosing or designing an efficient, effective Navy product, can be summarized with the convenient mnemonic VITALES:[2]

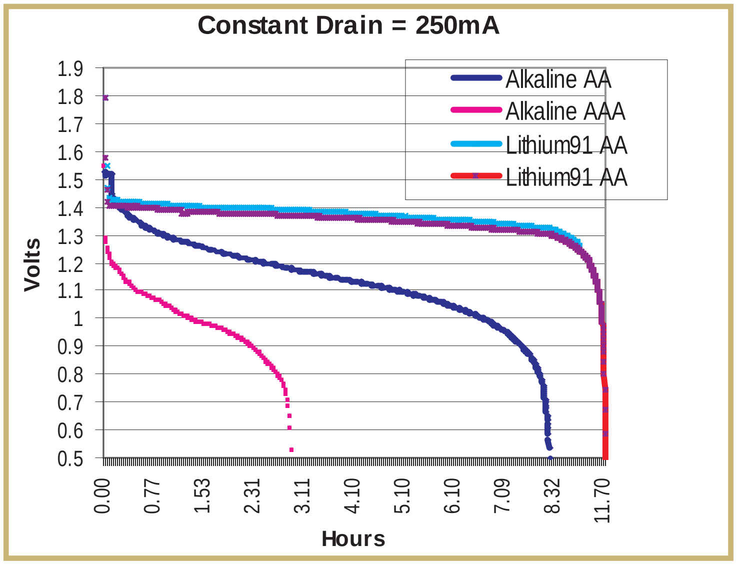
V oltage
I = Current
T emperature: operational and storage ranges, plus anticipated extremes
A ctivation mode (for reserve batteries)
L ifetime (storage and operation)
E nvironmental requirements
S ize: weight, volume, configuration

References

[1] John McHale, Military & Aerospace Electronics, December 2002.
[2] Discussion with Clint Winchester, December 2002.







Discharge Curves: Lithium AA and Alkaline AA/AAA Batteries

COTS for Communication Electronics

The advancement of commercial electronics in the communication arena has created a great opportunity for the United States military to glean the benefits without cost of development. From the electronics perspective, the technology improvements have resulted in smaller, lighter weight, more reliable radios. From the electrochemistry perspective, advancements in energy storage have resulted in higher density systems that allow the user to operate portable radios longer, while carrying less weight. This article will discuss the improvements of both technologies and the benefit that is acquired by both the military and civilian population.

Communication Electronics

From the days of "land-lines" in World War I to the hills and mountains of Afghanistan, the need for the war-fighter to communicate has reached a fevered pitch.

Early radio systems that permitted world-wide communication were very large, bulky and heavy. In addition to their overall size, the amount of power that was required to operate the radio was a limiting feature and inhibited the warfighters from performing their mission. Smaller packages began appearing in use, but these radios were designed for specific applications. The relative size and power consumption of the radio, while being smaller than the radios of earlier conflicts, were still a burden for the radio operator. The range of operation limited the warfighter's ability to wage a coordinated mobile operation.

The commercial world has taken the lead in this effort. Communication from land, sea and air all require complex systems. The current complex worldwide systems vary from the cell phone to the satellite phone. The satellite phone offers the user the ability to communicate from anywhere a satellite link can be achieved to anyplace on the earth. The latest generation communications have encompassed several technologies born in the commercial world and brought into a military application. What do these new systems provide the warfighter? These systems provide accurate position data, secure and clear two-way communication and the ability to receive and transmit images.

The Warfighter has two issues with the commercial electronics; the ability to withstand the harsh environments and the ability to have these devices powered from a diverse set of energy sources.

Activities at ACI

ACI is working with our industry partners to bring to the warfighter reliable, fully capable and long lasting communication systems. The initial effort has centered on reducing the cost of operating survival radios, specifically the AN/PRC-112. The current custom-designed battery provides the radio an energy storage source that allows this survival radio operation for approximately 24 hours.

ACI, in conjunction with Engineering Professional Services, EPS, and the US Army Communications and Electronics Command, CECOM, undertook the task to:

(1) Examine the commercial alternatives,
(2) Determine how to package the selected battery, and
(3) Build prototype battery packs and confirm the suitability of the design.

ACI surveyed the achievements in the commercial battery market and developed a package that would replace custom-designed primary batteries with either a low cost primary or a secondary, rechargeable, battery - complete with recharger.

As the advancements in electrochemistry continue in the commercial environment (cell phone batteries continue to get smaller, contain more power and are capable of more and more recharging), ACI is continuing to search out alternatives which will support the needs of the warfighter and reduce the life-cycle cost for operating these communication systems.

In addition to improvements with radio communication systems, ACI is working on a redesigned ARS-6 personal locator and TRN-30 beacon that will support the needs of the US Army. Beacons, GPS locators/receivers and transmitters are becoming vital resources for the land-based warfighter and the need to reduce the life-cycle cost for these systems is just as critical as radios.

ACI continues to seek out systems and methods that will reduce the cost of various military communication electronics. Working with our industry partners and other government labs, the EMPF's mission to support the improvements in military electronics continues to evolve with technology.

Ion Chromatography

Ion chromatography (IC) is an analytical laboratory technique that uses the principle of ion exchange to separate and quantify organic and inorganic ions. Historically, it has remained in the biological arena where this analysis method was used to separate amino acids.[1] However, in the electronics manufacturing industry, it is an important tool for determining specific levels of common ionic contaminants from flux residues.

Prior to the use of ion chromatography, the technique known as Resistivity of Solvent Extract (ROSE) was used to quantify the ionic cleanliness of PWBs and assemblies. ROSE measures the total conductivity of the extract solution and relates the measured conductivity of the solution to a known level of ionic contaminants in units of micrograms Sodium Chloride per liter of extract. Ion chromatography has the advantage over ROSE because it quantifies the breakdown of the sources of ionic contamination, in this case: fluoride (F-), chloride (Cl-), nitrite (NO_2-), bromide (Br-), nitrate (NO_3-), phosphate (PO_4^{-3}), and sulfate (SO_4^{-2}).

Theory

Ion chromatography incorporates a mobile phase and stationary phase. The mobile phase in this case is usually water and some buffer mixture. Buffers are mixtures of acids and their salt or bases and their salt, and maintain the pH of solutions. In ion chromatography, pH is a critical parameter and must be kept constant. The stationary phase is the column which contains an active resin. The unknown is usually in the form of a liquid sample that is injected onto the column. The sample is pushed through the column by the force of the constant flow of the mobile phase. As the sample contacts the column, the dissolved ions in the sample will have an affinity for the column and replace less retained ions like those which make up the buffer. This exchange process is continuous, however, and the length of time that the various ions retain themselves on the column is what delays their travel through the column. Since each ion has a different affinity for the column, some will spend less time while others will spend more time in the mobile phase. The fact that each ion has a different residence time in the mobile phase allows for its separation. Eventually, each ion will come out of the column and be detected by the conductivity detector. The result is a peak and the area under each peak represents the relative amount of each ion. When compared against known standards, the amount of each ion can be determined.

Practical Information

The industry-standard procedure used in electronics manufacturing is IPC TM-610 2.3.28 "Ionic Analysis of

As an example, an electronics manufacturer wanted to determine the levels of ionic contaminants on populated printed wiring assemblies (PWAs). The customer supplied boards and sample of low solids VOC-free no-clean flux for wave-soldering were examined as per ACI lab procedure and IPC-TM-650 2.3.28. Briefly, the PWAs were extracted in a 75% isopropanol/25% water at 80^{o}C for one hour. The extract was then examined using a Dionex DX-500 ion chromatograph (IC) for fluoride, chloride, nitrite, bromide, nitrate, phosphate, and sulfate anions. ACI's maximum recommended amounts of fluoride, chloride, bromide, nitrate, and sulfate are 5, 10, 15, 15 and 20 µg/in2 respectively. These limits were developed in conjunction with industry leaders and apply to typical component packages on FR-4 or a like substrate.

Results show that all the anions tested for were well below the recommended levels except for sulfate, which was two to five time the recommended value (<20g/in2). Testing of the flux by ion chromatographic analysis showed the sulfate peak in the chromatogram is likely due to an organic acid within the flux. An authority in the area of flux and flux residues stated that this should not be a reliability issue as sulfur is typically bound tightly in the flux residue chemistry. Knowledge of the tolerance of the materials used on the board should be kept in mind however.

One example that readily stands out are common resistors that have silver/palladium terminations. There may be certain environments that allow sulfur bound within the flux residue to meet the affinity that silver has for sulfur.

This example shows a situation where IC analysis has limitations on only determining the amounts of ionic residues remaining on a PWA. To supplement the testing, surface insulation resistance (SIR) can aid in determining the impact that the observed contamination levels may have on long-term reliability.

Ion Chromatography *(continued from previous page)*

Circuit Boards, Ion Chromatography Method". The analysis procedure is summarized below:

Bare PWBs, PWAs or components are extracted with a 75/25 Isopropyl alcohol/water solution using an 80°C water bath for 1 hour. The extracts are analyzed against known standards to confirm the presence of and to quantify each anion in units of µg/ml. The total surface area of the sample is determined and the final results reported in µg/inch^2.

The procedure is applicable to bare PWBs, PWAs or individual board components (resistors, capacitors, transistors, etc.) It should be noted that the analysis is also applicable to board washings or cleaning residues. In that instance, the extraction step with 75/25 Isopropyl alcohol/water is not necessary; the samples can be analyzed directly if in a liquid form.

Some considerations to the individual ions when analyzing IC data:

- High levels of bromides observed are most likely from fire retarding chemicals in the solder mask, component packages, and board substrate. It is possible that the presence of bromide ions could be a product of depaneling the boards. FR-4 often contains bromide residues from the fire retardant added to the epoxy polymer.

- For high chloride levels on the PWB, the two most likely sources are poor handling (e.g. sweat or salt from someone's hands) and/or improper/incomplete cleaning after bare board fabrication. A chloride amount of greater than 6 mg/in^2 present on the cleaned board is considered moderate, and may cause a concern in a high reliability and/or a high humidity environment by causing dendrite growth, leakage current, or corrosion.

- Sulfate peaks are likely due to an organic acid present in flux residue.

- Surface insulation resistance (SIR) testing can also aid in determining the impact that the contamination levels observed may have on long-term reliability. A SIR test and/or an electrochemical migration (ECM) test can be performed at ACI to determine the impact of the ionic residues on the surface of the production board. If the board fails the SIR or ECM test, the production process of these boards needs to be examined in terms of cleaning issues.

ACI can perform both ion chromatography and surface insulation resistance testing to determine residual ion contamination on electronic circuit boards and components. Knowledge of this is important to ensure proper reliability and conformance to specifications. Call the EMPF Helpline (610-362-1320) for more information about your Ion Chromatography needs.

References

[1] Practical High Performance Liquid Chromatography, 3rd; Veronika R. Meyer p.172.

Training in Failure Analysis & Reliability Testing

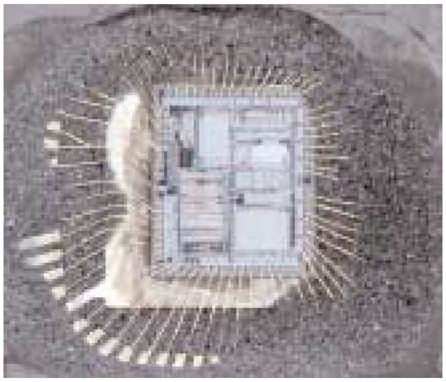


Figure 1. Decapsulation of an Integrated Circuit showing the die and bond wires

The EMPF's Learning Center offers a "Failure Analysis and Reliability Testing" course that is tailored specifically to address the most prevalent electronic components, manufacturing and packaging issues. The course objective of Failure Analysis and Reliability Testing is to prepare the participant to make informed decisions when troubleshooting an electronics manufacturing problem, as well as understanding and working with an analytical or failure analysis lab. The continuous shrinking of components and increasing of board complexity makes it crucial to understand what techniques and equipment provide the resolution required for accurate analysis.

Both novice and experienced students can benefit from a failure analysis and reliability course, even those who do not work in these areas directly. Failure analysis engineers learn both standard industry methodology as well as state-of-the-art techniques for determining the cause and solution for a number of electronics manufacturing-related issues. Quality control engineers, manufacturing engineers, managers, and technicians, who either perform failure analysis or collaborate with analytical labs, gain knowledge that can be used to improve their product or manufacturing process. The class is designed to provide an excellent learning experience that relates directly to the students' needs and level of experience.

The most prevalent electronics manufacturing-related issues are the focal point of the class. Also covered are topics that are process- or component-specific. The program is based on test methods and specifications.

ACI's own experience in operating a failure analysis lab, learning center, and manufacturing facility helps to supplement the material presented. The instructors have a very large collective knowledge base and can answer individual questions with details. Incorporated in the curriculum are the operation of the instruments and techniques used to troubleshoot failures as well as the identification of common failure modes and mechanisms. Some of the topics covered in the class include:

- Microsectioning
- Microscopy
- Failure Analysis Methodology
- Solderability
- Processing Failures
- Integrated Circuit Failure Analysis
- Thermal Analysis
- Accelerated Reliability Tests and Analysis
- Cleanliness Testing
- ElectroStatic Discharge (ESD) Analysis

Topics such as material properties, thermal expansion, advanced packaging failure, cyclic fatigue, integrated circuit fault isolation and spectroscopy are also discussed in depth from an analytical viewpoint.

Case studies provide the forum for problem formulation, investigation, and resolution. These case studies exemplify typical and atypical issues that encourage independent thinking as well as group discussion. As with many of the other courses offered at the EMPF Learning Center, students are trained with a combination of presentation material and practical experience. Students will get hands-on lab experience in many areas including:

- Scanning Electron Microscopy (SEM)
- Optical Microscopy
- Decapsulation of Integrated Circuits
- Scanning Acoustic Microscopy (SAM)
- Fourier Transform Infrared Spectroscopy (FTIR)
- Transmission X-ray
- Differential Scanning Calorimetry (DSC)
- Shear/pull testing
- Solderability testing

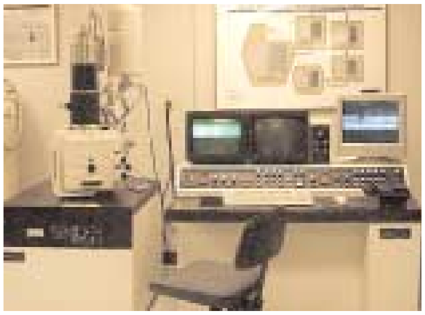


Figure 2. Scanning Electron Microscope (SEM) with Energy Dispersive Spectroscopy (EDS)

Coupled with the lab exercises, the class includes scheduled time to address specific problems encountered by the students at their workplaces. Students are encouraged to bring with them samples for investigation and discussion. A three-day course layout provides the proper format for comprehensive understanding. Each student who successfully completes the course leaves with a better understanding of manufacturing-related issues as well as course notebooks of all the information presented for future reference and as an aid in resolving business decisions related to failure analysis and reliability issues.

Manufacturer's Corner

Concoat Systems

Conformal coating technology has become a vital part of many electronic manufacturing operations to assure reliability and long-life operation of the finished electronic assembly under adverse conditions. A conformal coating (a dielectric material) protects the circuit assemblies against contamination. These coatings provide a secure envelope around a circuit board and its components while acting as a barrier against moisture, fungus, dust, salt spray and other environmental contaminates. The coating materials also act to immobilize various types of particulate on the surface of the PCB assembly and function as a protective barrier to the various devices on the PCB assembly. Furthermore, when applied properly, conformal coatings also enhance a circuit's reliability by elimination of detrimental conditions such as leakage from high impedance while allowing for closer circuit traces required with high component density.

The EMPF Demonstration Factory is using the Concoat DC 2002 Dip Coater. Concoat is a British company specializing in application engineering chemical compounds for the electronics industry for nearly 20 years.

Concoat DC 2000 Dip Coater

Conformal Coatings are applied over electronic circuitry in a thin layer (typically a few mils). They are usually applied by dipping, spraying, or simple flow coating. Conformal coatings prevent corrosion of conductors, solder joints and minimize dendritic growth and the electromigration of metal between conductors. In addition, the use of conformal coatings protects circuits and components from abrasion and solvents. Stress relief is also provided, as well as protection of the insulation resistance of the circuit board.

In the past, due to the cost of the coating itself as well as the cost of applying the coating to the board, only the most expensive boards or those with especially demanding needs for reliability were coated (mostly for military use). With advances in application and process abilities, the cost of using conformal coatings has improved. Additionally, as circuit sizes decrease and components become increasingly delicate, the need for a protective coating has become a necessity in many cases.

Types of Conformal Coatings

The physical and chemical compositions of various coatings differ and thereby offer varying degrees of protection. However, there are five basic types of conformal coating: Acrylic, Epoxy, Urethane, Paraxylylene and Silicone-based materials.

Acrylic

Acrylic coatings are typically solvent based and are easily repaired. They are usually low cost and are tough, hard, and transparent. Along with good pot life, they exhibit low moisture absorption and have short drying times. However, this type of coating does not demonstrate resistance to either abrasion or to chemicals.

Epoxy

Epoxy coatings are very hard, usually opaque, and are good at resisting the effects of moisture. Epoxy is usually available as a two-component thermosetting mixture. It possesses excellent chemical and abrasion resistance, but can cause stress on components during thermal extremes. Epoxy is fairly easy to apply but is nearly impossible to remove without damaging the components.

Urethane

Urethane coatings are tough, hard and exhibit excellent resistance to solvents. Along with excellent abrasion resistance and low moisture permeability, they offer good low-temperature flexibility. Their limited high-temperature capability and inability to be repaired often prevent their use.

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Manufacturer’s Corner - Concoat

(continued from page 13)

Paraxylylene

Paraxylylene coatings are very uniform and yield excellent pin coverage. Their limitations include high cost, sensitivity to contaminants and the need for vacuum application technique.

Silicone

Silicone coatings range from elastoplastic (tough, abrasion-resistant) to soft, elastomeric (stress-relieving) materials. Silicones are typically used in high-temperature environments. Silicone coatings are easy to apply, have low toxicity, offer good resistance to moisture, abrasion and humidity and are useful over a wide temperature range. Although their dielectric strength is less than other types of coatings the ease of application and excellent adhesion to previously applied coatings allows for the build-up of a thicker film and improves dielectric strength. They possess the following characteristics:

- Heat cure or RTV cure
- Usefulness over a very wide temperature range
- Good moisture and humidity resistance
- Processing versatility
- Easy reparability
- Low toxicity

Coating Process

Before coating a PCB assembly, it must be cleaned and de-moisturized within 8 hours before conformal coating. De-moisturizing may be accomplished by an oven bake at 93ºC +/- 5.5ºC, for a minimum of 4 hours.

The coating material is applied using a method that will yield complete coverage without excessive filleting or runs. Common coating methods include spraying, brushing, dipping or a combination thereof. Chemical vapor deposition is the process used for Paraxylene.

EMPF

The EMPF is using the Concoat Systems DC 2002 Dip Coater in the conformal coating process. This model was selected for this process due to the controlled extraction rate of the PCB assembly from the conformal coating. The entire PCB Assembly is dipped into the holding tanks with a controlled removal from the conformal coating to obtain uniform thickness.

The assembly designed by ACI is a communication module for military aircraft. The conformal coating is being used to protect the assembly against condensation from humidity and other fluids (Hydraulics, water coming in from an open cockpit window etc.,) which could possibly cause this communication unit to fail. The intercom system, which is used in utility helicopters, enables the crew to communicate within the aircraft, with the ground and with other aircraft through radio interconnections. ACI is providing this assembly to be form, fit, and function compatible to the original unit in an effort to decrease the substantial cost of repairing the legacy boards.

**If you would like more
information
or a demonstration of the
Concoat DC2002,
please call Jeff Stong
at (610) 362-1200 x224
or e-mail jstong@aciusa.org**

Electronics
Manufacturing
Productivity Facility

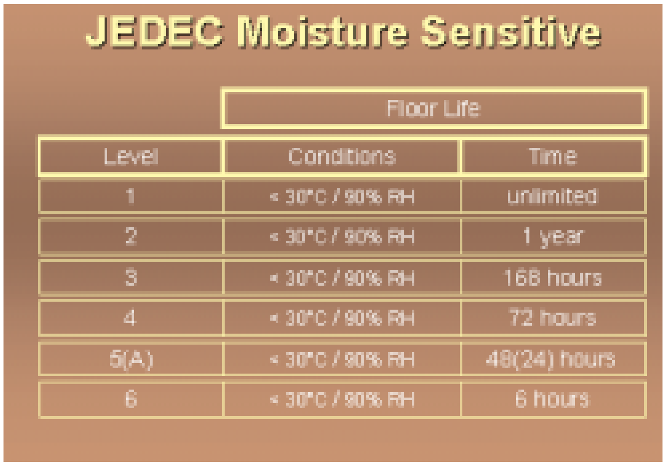
TECH TIPS...

Re-balling BGAs

It may not be a sound economic decision to reball and reuse a BGA component that has a low initial cost. However, many custom ASIC's and even some "off the shelf" BGA components, because of their complexity can be very expensive with limited availability and excessively long lead times. For these types of components it can be rather cost effective to have the ability to reuse components that have failed due to soldering defects. In this article we will discuss some considerations that must be addressed in order to successfully perform reballing of BGA components.

Package Specifications

It is important to know the component package specifications before attempting a reballing process. These specifications include maximum thermal limits for the component materials, alloy type (either eutectic or high temperature), ball size, moisture sensitivity level and most importantly the manufacturer's recommendations for the maximum number of reflow cycles the component can withstand. This information can be obtained from the component data sheets or directly from the component manufacturer.



JEDEC Moisture Sensitive

	Floor Life	
Level	Conditions	Time
1	< 30°C / 90% RH	unlimited
2	< 30°C / 90% RH	1 year
3	< 30°C / 90% RH	168 hours
4	< 30°C / 90% RH	72 hours
5(A)	< 30°C / 90% RH	48(24) hours
6	< 30°C / 90% RH	6 hours

Component Substrate Preparation

Before attaching the new component interconnects, the component substrate must be carefully prepped by removing all remaining residual solder. The most efficient method is to use solder braid and a wide blade soldering iron tip. The use of flux during this process will increase the effectiveness of the solder braid in wicking the residual solder from the component substrate. Care must be taken to avoid "scrubbing" the substrate surface with the solder braid and iron tip during this process, which can increase the risk of component substrate damage.

Once all of the residual solder has been removed from the component substrate, it should be thoroughly cleaned using isopropyl alcohol (IPA) to remove any remaining flux residues. The component substrate should then be inspected for any evidence of component substrate damage.

Site Preparation

- Solder Braid
  - Advantages
    - simple
    - inexpensive
  - Disadvantages
    - pad lifting
    - time (200+ I/Os)
    - possible board damage

Process Options For Eutectic Interconnects

Once the component has been properly prepared for attachment of the new interconnects (balls), a process for accomplishing this task must be selected. The three main options available when reballing with eutectic balls are either the preform method, the screen method or a relatively new method based on the screen method which employs a vacuum pick-up for holding the alloy spheres in place. The screen method requires specialized fixturing to place individual solder balls over the corresponding component substrate land pattern. Once all of the lands have a new ball in place, the entire fixture is sent through the reflow process to melt the solder balls onto the component. An alternate method is to use solder preforms in conjunction with a simple frame sized to match the outside dimensions of the component. This method has proven more efficient and reliable than the screen method. The solder ball preforms are available in literally thousands of package configurations and are very easy to use. The preform consists of precisely spaced balls sandwiched between a lamination of cardboard that has been impregnated with a water-soluble flux. Simply apply a water-soluble tacky flux

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Design For Manufacturability

at the EMPF Learning Center

Overview

The Design for Manufacturability (DFM) program helps companies respond to a simple fact... the opportunity to influence the cost of a new product is greatest early in the life cycle of a product. ACI has developed a program that provides a combination of lecture and factory experience to enable companies to setup effective DFM programs in their own facilities.

The first of the two-day program provides students with classroom sessions and templates for use in their own facilities. Day Two provides hands-on factory experience assembling and processing a demonstration PWA (printed wire assembly) which is intended to show the benefits and consequence of compromises made at the design level.

Who Should Attend

Program managers, design engineers, quality managers, engineering managers, and other personnel responsible for taking a design concept through inception to market will benefit from this course.

Course Content

- **DFM Overview:** The Who, What, Where, and When of DFM. What is DFA? DFM? Producability, and risk assessment?

- **DFA:** Introduction to the Boothroyd-Dewhurst DFA Method. A discussion of Assembly, Circuit Card Assembly, Printed Wire Board Fabrication, Interconnects and Sheet Metal Fabrication

- **Industry Standards:** A quick look at IPC-2220 series of documents and IPC J-STD-001C

- **Assembly Process:** The automated assembly line sequence, equipment limitations and considerations.

- **PWA Considerations:** Land design, board fabrication processes, component clearances, check list. Printed Wire Board Panel Usage: Strategies for harmonizing usage and assembly performance. Fiducial Mark: tooling and vision aids for automation.

- **Component Selection:** Preferred components, non-preferred components, and assembly sensitivities

- **Solder Mask and Conformal Coatings**

Benefits

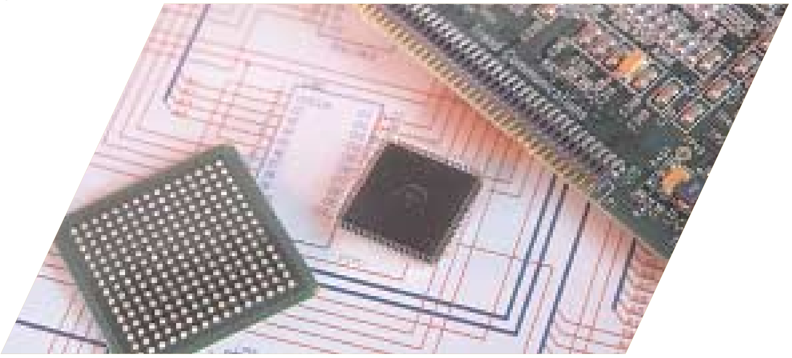
- Reduce design to market cycle time
- Improve product quality
- Reduce parts costs
- Reduce production cycle time

Duration

2 days

Scheduled Dates

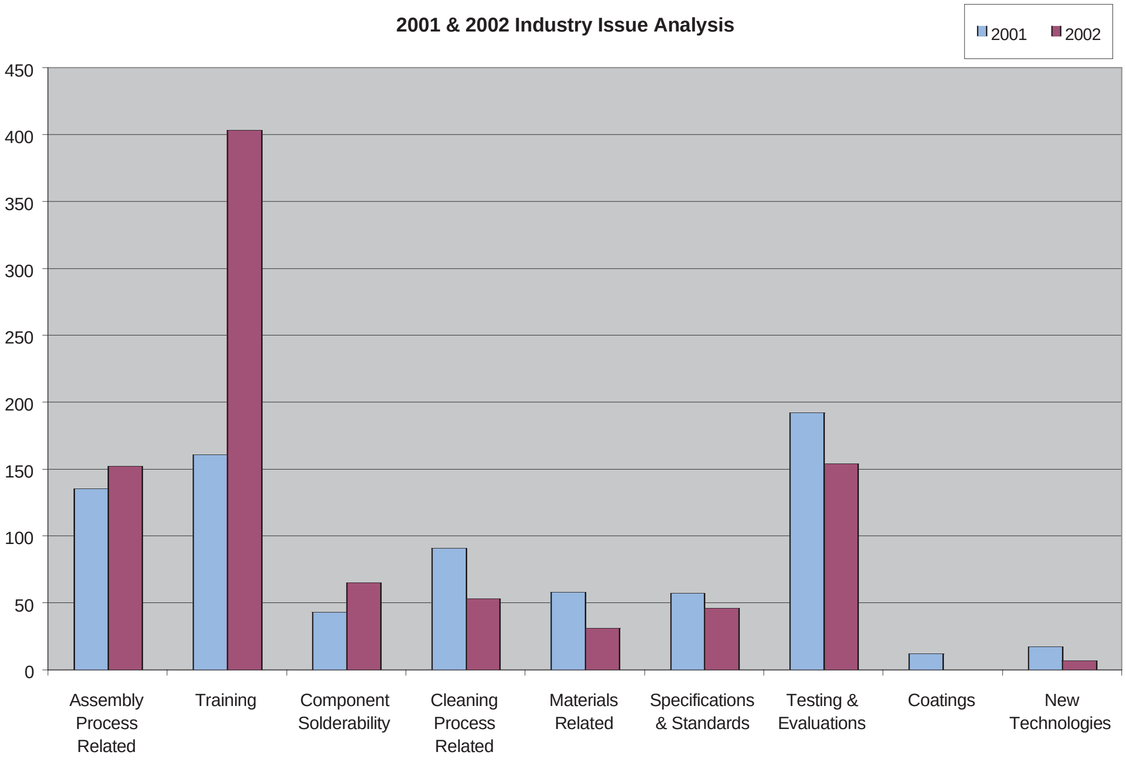
May 19-20
August 18-19
November 17-18



Registration

Contact the EMPF Learning Center at:
phone: 610-362-1320
email: registrar@empf.org
www.empf.org

EMPF Helpline 2001-2002 Summary



Since its inception in 1984, the EMPF Helpline has fielded thousands of questions regarding many of the common and uncommon issues in the military and commercial electronics manufacturing industry. ACI supports the EMPF Helpline by utilizing the nation's top scientists, engineers, technicians, and instructors. With a diverse work force averaging 16 years of experience, 65% of all Helpline calls have been resolved within 24 hours or less.

Within the past two years, the Helpline has answered nearly 1700 calls with topics ranging from training to coatings as well as issues related to assembly and cleaning processes, component solderability and materials. As the chart to the right shows, data collected over the past two years illustrates a shift in the types of calls that are being received.

There was an increase in calls regarding training and educational services while experiencing a decline in calls concerning actual manufacturing issues. Questions concerning training comprised 44% of the total Helpline calls in 2002, more than doubling the percentage of calls from the previous year. This was likely a result of companies adopting a quality system for their manufacturing process. Assembly and rework standards, such as the criteria established by IPC, have forced organizations to certify their operators, inspectors and rework technicians. In addition, companies who have conducted their own training and certification programs in the past are being forced to make cuts in an effort to reduce overhead costs. The end result has seen businesses outsource any training required to meet the needs of their quality system. Some of the more popular classes offered at the EMPF include IPC-7711/7721, IPC-A-610C and J-STD-001C certification-based training.

In 2001 however, the trend focused more towards the test and evaluation services offered by the EMPF. As much as 25% of the calls received that year were for failure analysis, spectroscopy, or reliability testing. Some of the most common evaluations involved the investigation of chip components and through-hole solder joints. These investigations often included scanning electron microscopy (SEM) and microsectioning. In 2002, the EMPF did not experience the same call volume for this area. Roughly 17% of the calls received last year were related to test and evaluations. The investigations performed at the EMPF were more diverse in scope, involving issues ranging from substrate delamination to solder joint fractures to component failures at the die level.

A number of automobile and aerospace electronics manufacturers contacted the EMPF Helpline this past year to solve contamination and corrosion problems. Techniques such as scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR), ion chromatography (IC), and energy dispersive spectroscopy (EDS) were used to identify the contamination on assemblies, bare boards, components and conformal coatings. Corrosion and contamination found during these investigations have been shown to have devastating effects on the reliability of their assemblies by causing field failures and returns. This, in turn, has compromised the reputation and profitability of the companies involved.

The EMPF Helpline is a complimentary service providing support to the electronics manufacturing community. Whether you have a complex failure or a common electronics manufacturing defect, please call the Helpline at (610) 362-1320. You can also contact us via e-mail (helpline@aciusa.org) or visit us at our website (www.empf.org) and click on the "Helpline" link. Here you will find many of the common industry questions being asked as well as monthly case histories.

Ask the EMPF Helpline!

CUSTOMER ISSUE: A customer called the EMPF Helpline with a request for help in changing from an all Plated Through-Hole (PTH) technology to one that was mostly surface mount while still maintaining a two-sided board. The customer was also concerned that changing from a PTH technology to a Surface Mount Technology (SMT) would impact the Next Higher Assembly (NHA) due to changes in board dimensions often experienced when changing technologies.

Detailed Description:

- The customer's concerns regarding component selection was that the replacement parts had to perform the same as the original ones.
- The customer was concerned that relaying out a board may have issues due to the change in technology.
- The customer’s main concern about routing was that some of the traces were critical to the functionality of the circuit and assistance was needed.
- The customer wanted the ability to test the functionality of the board while operating, which was easily done in an all PTH design.
- The customer wanted to be able to have the board manufactured as quickly and as inexpensively as possible and to maintain industry standard practices.

Recommendations

Component Selection: A major concern when changing from a PTH device to an SMT device is that the SMT equivalent is often smaller than its PTH counterpart. Although this appears to be a benefit, heat dissipation may be a problem. The top two heat dissapation paths are through the leads and convection to ambient. Because the SMT device is smaller, both the lead size and case surface area are smaller. The smaller lead size has increased electrical resistance and a smaller surface area. The increased resistance is caused by the decrease in cross-sectional area of the lead. This results in an increase in heat due to i^2R. Fortunately, because the leads are much shorter, the effective resistance is equal to, or lower than the PTH version. The smaller surface area of the leads means that the vast majority of the heat dissipation must occur through the case. The smaller case size causes an increase in the thermal resistance to ambient (q_{JA}). This causes a large build up of heat in a small area on the board, requiring the components be spaced out farther.

Layout: Smaller packages for a fixed board size gives the designer greater freedom, however, there are things to consider. The components may require more space due to thermal considerations. Secondly, the relative locations of support components, resistors, capacitors, inductors, etc. for integrated circuits (ICs) may need to be altered to allow for proper routing. Another point to consider is that if two or more components have ground leads close to each other, they can share a ground via, thus reducing the number of vias.

Routing: One of the biggest concerns regarding routing is that even though the leads are smaller, they still have to carry the same amount of current. Since the amount of current a trace can carry is directly proportional to the cross-sectional area of the trace, the designer has two choices as to how to increase it. One is to increase the copper weight, which increases the cross-sectional area. However, increasing the height of the copper increases the minimum trace width that manufacturers can etch. Leaving the copper weight the same, means that the trace width must increase in order to maintain the current carrying capability of the trace. However, the traces of SMT boards are often much wider than the leads that they are connected to, which would cause shorting. The industry’s accepted method of dealing with this problem is to leave the trace width the same size as the PTH version and "neck down" the trace as it enters the lead.

Another point of concern is fanout. PTH technology permits the pins of the component to pass through all layers of the board, while SMT devices only connect to the placement layer. Since the board in question was two-layered, the top side was used for component placement and routing traces, while the bottom side was used as a ground plane. That means that the ground connections of the components required using a via to the ground plane. Adding these vias caused congestion. The best way to avoid this is to space components away from each other, particularly near ground leads, thus allowing for more routing space.

A final point on vias is that the more you introduce, the more you disturb the ground plane. Since the customer’s board had all of the board-level power and signal pins located at one side, the majority of the ground current flowed in a horizontal direction. The few traces required on the bottom side of the board were also oriented horizontally so that the ground currents could flow around the traces with minimal impact.

Testability: The best method of testing a design is under actual operation. Since the board in question has all of the components on the top side and only a ground plane on the bottom, a bed of nails type circuit tester is an ideal choice. However, since the traces are almost all on the top side, a via must be added to each electrical net that does not already have one so that the tester can probe that particular net from the bottom side to determine voltage, current, and impedance.

Manufacturability: A significant cost of board manufacturing is the hole count. The customer’s board contained a large number of different sized holes. The EMPF worked with the customer to reduce the number of hole sizes.

Another point to consider regarding manufacturability is panelization. A panel can be assembled and tested quickly. It is critical to keep components, traces, planes, etc. away from the outer edges to avoided damage during the routing cut.

Conclusion

The customer was able to revise the board maintaining Form, Fit and Function (F3), and testability while increasing manufacturability.

Contact the EMPF Helpline for free expert advice on your electronics manufacturing issues! 610-362-1320 or helpline@empf.org

American Competitiveness Institute - 2003 EMLC COURSE SCHEDULE

Electronics Manufacturing

BOOT CAMP A - Week 1
May 5-9
August 4-8
October 13-17

BOOT CAMP B - Week 2
May 12-16
August 11-15
October 20-24

Skills

SMT Manufacturing
June 16-20
October 6-10

BGA Manufacturing, Inspection & Rework
June 23-24
August 25-26
December 1-2

NEW!
Chip Scale Manufacturing
September 10-12
November 5-7

Certifications/Recertifications

IPC J-STD-001 Instructor Certification
June 2-6
July 14-18
September 8-12
October 27-31

IPC-J-STD-001 Instructor Recertification
May 19-20
August 18-19
November 17-18
December 8-9

IPC-A-610 Instructor Certification
June 9-13
July 21-25
September 15-19
November 3-7

IPC-A-610 Instructor Recertification
May 22-23
August 21-22
November 20-21
December 11-12

IPC Challenge
May 21
August 20
November 19
December 10

IPC-A-600 Acceptability of Printed Boards Instructor Certification
October 8-10

NEW!
IPC-7711/7721 Rework, Repair and Modification of Printed Boards and Electronic Assemblies (Operator)
September 22 - October 3

Continuing Professional Advancement in Electronics Manufacturing

NEW!
Design for Manufacturability
May 19-20
August 18-19
November 17-18

Failure Analysis and Reliability Testing
September 24-26

Characteristic Properties of Materials
August 27-29

For more information, please call (610) 362-1320 or e-mail: registrar@empf.org

issue 01/02-03

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The EMPF is the U.S. Navy's National Center of Excellence dedicated to advancing the state-of-the-art in electronics and increasing domestic productivity in electronics manufacturing.

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