empfasis

A publication of the National Electronics Manufacturing Center of Excellence *May 2006*

American Competitiveness Institute

ISO 9001-2000 Certified

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The EMPF is a U.S. Navy-sponsored National Electronics Manufacturing 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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In This Issue

Advanced Sensor Installation at NSWC Philadelphia

Advanced sensors will play a vital role in monitoring the condition of present and future military power generation, distribution and protection systems. Presently available sensors are capable of basic measurements of current, voltage, and temperature within distribution switchgear and power generation control modules - as well as reporting on fault conditions for those power systems. They also tend to be large, heavy, and limited in capacity of measuring short duration or significantly high amplitude transients.

The currently utilized sensors are also susceptible to the effects of stray fields, electromagnetic interference, and most are electrically conductive. New fiber optic based advanced sensors are made of all-dielectric non-conductive materials, and have increased capability for detecting high speed / high magnitude transients, while weighing considerably less. In order to determine if these sensors are applicable to the U.S. Navy's integrated power system (IPS) platforms, ACI will develop testing scenarios to determine the full capacity and operation ranges of procured devices. In direct support of Navy shipbuilding and leveraging the EMPF National Center of Excellence's Navy ManTech thrusts, ACI will work with NAVSEA PMS500 in realizing the potential of these sensors.

ACI will evaluate the following sensors: a flexible optical current sensor, a fiber optic temperature/pressure sensor, and a partial discharge detector system. Presently, ACI is working with our partners at the Naval Surface Warfare Center, Carderock Division - Philadelphia, PA (NSWCCD-Phila) Land Based Test Site (LBTS) to monitor medium voltage switchgear. A multiple time frame recording system provided by NxtPhase for monitoring electrical power systems is being used to record events and anomalies within the switchgear. All of the sensors' control electronics assemblies and data recorder are installed in a NEMA 4 Advanced Sensor Cabinet enclosure adjacent to the switchgear. For current measurement, ACI is utilizing a single-phase flexible optical metering system also by NxtPhase which consists of an optical sensor unit and an optical electronics chassis unit. The optical sensor is a flexible, hermetically sealed, all-dielectric current sensing optical fiber cable loop of a variable length. The optical electronics chassis unit consists of sensor, status monitoring, alarm, low energy analog (LEA) output, and power supply modules. Also included with the chassis unit are 50 meters of fiber and electrical interconnecting cable assemblies. (See Figure 1-1).

Figure 1-1 – Current Sensor Assembly

The single-phase current sensing loop is measuring the load-side current of a switchgear compartment's breaker. The current is sensed on the measured conductors using interferometric optical technology. A light source sends light through a waveguide creating two linearly polarized light waves. Via an optical

continued on page 2

Advanced Sensor Installation at NSWC Philadelphia

(continued from page 1)

fiber, the light passes through a quarter wave plate creating right and left hand circularly polarized light from the two linearly polarized light waves. The two light waves traverse the fiber sensing loop around the conductor, reflect off a mirror at the end of the fiber loop, and return along the same path. While encircling the conductor, the magnetic field induced by the current flowing in the conductor creates a differential optical phase shift between the two light waves due to the Faraday Effect. The two optical waves then travel back through the optical circuit and are finally routed to the optical detector where the electronics de-modulate the light waves to determine the phase shift. The magnitude of the phase shift between the two light waves is proportional to the current, and an analog or digital signal representing the current is sent to the data recorder for real time or trending current measurement.

For partial discharge (PD) sensing, ACI is using a new RF-based predictive maintenance system by Eaton/Cutler-Hammer. Partial discharges generally occur when dielectric properties of an aged insulation system under high potential are not sufficient to withhold applied electrical fields. Analysis can detect the following forms of partial discharges:

- PD inside solid insulation systems
  (due to delamination - or voids in insulation)
- PD between a high-voltage conductor and insulation
  (if a void had developed between a high-voltage conductor and insulation, or due to bad impregnation)
- PD between the conductor insulation material and ground
  ("slot discharge" between winding and laminations)
- Surface Tracking
  (due to surface contamination of an isolator)
- Arcing and sparking

Therefore, a high level of measured PD can be an indication of insulation fatigue or arcing / sparking due to worsening electrical connections. It can also indicate surface tracking discharge due to particulate contamination of insulation. The basic PD sensing system is made up of integrated partial discharge 3-Phase coupling capacitor sensors (IPDS), and a radio frequency current transformer (RFCT) sensor. Integral to the system are additional sensors to monitor compartment temperature and humidity. One of the benefits of the coupling capacitors is that they can detect PDs in adjacent compartments along with PDs within the buss work of their own compartment. Each IPDS is bolted directly between each phase bus and ground and can be mounted to either - effective ground isolation meeting the ratings of the medium voltage switchgear allows this. The RFCT identifies PDs related to the feeder cabling and is placed around the common cable ground shield. All of the sensors are connected to the PD monitor mounted in the Advanced Sensor Cabinet, which displays readings and records data. This monitor is then interfaced with the data recording system enabling real time or trending data accumulation.

Over time within electrical connections, vibration and heat can loosen lug connections, and oxidation can build up between dissimilar metals. Both of these effects can cause an increase in the resistance at the connection, which in turn can lead to higher than designed current flow through those connections - effectively the development of "hot spots". With increased current and resistance comes increased temperature, and if these connection temperatures get too hot, reduced efficiency can be expected, or failures can occur as a worst case scenario. However, if the connection temperatures can be monitored for trending analysis, impending failures may be averted.

To aid this, ACI is utilizing an optical temperature sensor system by Prime Photonics to measure these electrical connections. A temperature sensor is bolted directly to the bus work and an optical fiber safely carries the signal out of the compartment and to the Advanced Sensor Cabinet. The interrogator generates a light wave, which is sent through the optical cable to the sensor. When the temperature is applied to the sensor, fundamental parameters of the light, such as intensity, or wavelength, are changed. The modified light is reflected back through the cable to the interrogator, where it is carefully measured to determine the amount of change in the light wave. Algorithms are then used to convert the optical signal to a calibrated electronics signal which is connected to the data recorder. When more points of measurement are realized in the future, a fourth component, a fiber optic switch will be utilized to sweep up to 32 points of measurement. Two fiber optic switches can be utilized per interrogator, and multiple interrogators can be linked together to make for an extensive fiber optic condition monitoring system. Additionally, due to extremely low optical losses during light transmission through the fiber, this photonic sensor is ideally suited for applications where the interrogator box must be separated from the sensor by large distances (up to several miles).

By completing rigorous adverse condition testing of these emerging technology sensors, and leveraging the efforts of the EMPF, ACI is providing advanced condition monitoring solutions to the U.S. Navy. Optical fiber sensors and advanced technology sensors have the tremendous benefits of light weight and small size. They are highly reliable with long operational lifetimes, and are uniquely suited for high temperature and high pressure applications, are corrosion resistant and self-compensating. All of these sensors have high sensitivity resolution and high frequency response - therefore, more accurate measurements. Additionally, the fiber optics are immune to electromagnetic interference (EMI) and radio frequency interference (RFI), and are intrinsically safe.

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Design for Manufacturability

Bridging the market share gap between one's competitors is the driving force of many companies. The ability to react to market changes, coupled with the flexibility to bring new products to market faster, while meeting increased quality standards, all at lower cost, are the challenges facing today's electronics manufacturing businesses.

The concept of design for manufacturability (DFM) has resulted in a number of published references and case studies hailing its success in a variety of manufacturing environments. As an integrated component of the design process DFM bridges the gap between design and manufacturing considerations ultimately affecting the cost, performance, and how producible a product can be. Design for manufacturability requires a commitment to establish a model that systematically addresses manufacturing, assembly, testing, and performance concerns concurrent with product realization.

A company has to organize for and support the DFM discipline. Best manufacturing practices suggest a team approach that includes customers and suppliers. Design projects must be organized to address producibility. This can be accomplished by forming multi-disciplinary, integrated teams that facilitate communication between groups by including as much knowledge from key stakeholders as possible. Seven to ten member teams can effectively examine and disseminate the relevant information and provide problem solving resources while still allowing for unplanned changes.

DFM moves some risk to the initial phases of the design cycle where it is less likely to have a negative impact. It is crucial to identify and manage one's exposure to risk by limiting the potential inability to achieve product goals and reducing the probability of a failure.

The impact of design decisions vary depending on the methods and materials in use at each process step. At the EMPF, the engineers specialize in electronics manufacturing and assembly, particularly at the packaging level. In the design and production of electronics, producability is best addressed before the project builds inertia. At its heart, DFM has the following guiding rules:

- ♦Estimate the cost of manufacturing to identify cost reduction areas.
- ♦Reduce the number and cost of components.
- ♦Reduce the number of assembly operations by reducing the number of parts.
- ♦Make the assembly operations easy to perform.
- ♦Reduce the cost of supporting production.
- ♦Consider the impact of DFM decisions.
- ♦Employ Design Guidelines.
- ♦Establish rules based on expert knowledge and lessons learned.
- ♦Base guidelines on specific capabilities including equipment and human resources.
- ♦Employ benchmarking by comparing best practices of others in related fields.

Properly implemented, DFM principles will reduce design time, decrease the cost of manufacturing, improve quality and performance, and reduce the cost of service and maintenance of the end product.

Let's look at some key DFM considerations in the electronics assembly design process.

DFM rules should be established for each process step. As a part of the design sequence, the design review should ensure that every manufacturing process step is known. The most rigorous implementations include validation of manufacturing process steps as the design is being developed.

Although a design may be limited to the components required for functionality, the proper selection of those components can have a great impact on the overall manufacturability and cost effectiveness of the design.

Electronic assemblies can be designed with a variety of components from different suppliers. Some components have leads that pass through holes in circuit boards. Some are attached by means of surface mount leads, while others are leadless. There are also components with hidden terminations that must be secured to assemblies with special adhesives.

Some components are compatible with standard epoxy circuit cards, while some call for the use of exotic materials where high temperature or high frequency performance demands preclude the use of standard circuit substrate materials.

As a manufacturer, consider the possible benefits of having your design group in sync with your manufacturing group. Your design engineers will know the requirements and limitations of your assembly processes and be able to compensate at the design stage, where 80% of a product's life cycle cost is set, instead of at the production stage where design changes become expensive. Designing for manufacturability to your specific processes should be the rule and not the exception. The EMPF can help achieve this goal through our Design for Manufacturability training.

For information on the EMPF's DFM course, please contact the registrar at (610) 362-1320, or via email at registrar@empf.org

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Vibration/Shock & Thermal Testing

Selection of a Vibrational/Shock system, for electronic packages used in Air and Ground transport devices, must be carefully considered for its capabilities to provide the necessary data and information pertinent to the specifications set forth by MIL-STD-810F. The advent of combining environmental conditions such as vibration, shock and heat has presented test engineers both a challenge and opportunity to observe the behavior of electronic assemblies, while simultaneously maintaining the required thermal and shock conditions. Knowing the limitations, performance capability, and physical dimensions of the AGREE (Advisory Group on Reliability of Electronic Conditions) system, which includes both the vibration and thermal units, is necessary in defining the specific equipment suited to meet the required needs. Not to be overlooked is the importance of having the right facilities in place to accommodate the size and weight requirements of the test equipment.

Garnering information for a thorough technical assessment of a functional shock system, can be generally achieved by leveraging the parameters found in the specifications set forth by MIL-STD-810F - Test Method (TM) 516.5. This standard defines mechanical shock environments as frequencies not exceeding 10,000Hz, at time durations of not greater then 1.0 seconds. The major share of applications for shock require frequencies < 2,000Hz and durations shorter than 0.1 seconds, a condition most vibration/shock systems are designed to simulate.

Sorting out the requirement as per TM 516.5 for a specific application can be a rather circuitous process and is not always so well defined. There are eight procedures listed in the TM to provide the basis and assistance in collecting and interpreting the information for the item under shock. The AN/ARS-6A, a multiple service Combat Search and Rescue (CSAR) radio being redesigned for sustainment at the EMPF, was used as a specific example for this investigation to determine the proper AGREE system to meet the conditions and requirements, as outlined by the Certification Test Plan. Any Vibration/Shock equipment considered for the ARS-6A would have to meet the Functional Shock and Crash Hazard criteria, as prescribed by Procedure I and V of TM 516.5.

The operational requirements for any vibration/shock system that is designed to meet TM 516.5 criteria can be generally narrowed down into two areas, Input and Output. The Input is the shock response parameters chosen to simulate the test conditions, for example acceleration and duration, while the output considers what form the material characterization response takes, i.e. the generated spectra.

MIL-STD-810F differentiates its test conditions between having adequate historical measured data, and insufficient data as a basis of Shock Response Spectrum (SRS) selection. Table 2-1 illustrates the requirement for applications where a lack of statistically significant measurements and insufficient data cannot justify the criteria for employing a historically accurate test spectrum. Essentially, the standard does allow for selection of parameters outside of the required conditions listed below, if the historical time measurements are available, and there is ample justification. In new applications the SRS response is not known, and follows the recommended parameters in Table 2-1.

Test	Peak Acceleration	T_e (ms)	Cross-over Frequency
Functional test For flight equipment	20	15-23	45
Functional test for Ground equipment	40	15-23	45
Crash Hazard for Flight Equipment	40	15-23	45
Crash hazard for Ground Equipment	75	15-23	80

Table 2-1 - Mil-STD 810F Table 516.5-1 Test shock response spectra for use if measured data not available.

Once the test parameters have been implemented, the item responses need to be analyzed, recorded, and tailored appropriately to reveal the relevant information. TM 516.5 considers four descriptive estimates to characterize the measurement responses of duration, amplitude, and frequency. The vibration/shock system that is selected should have the capacity to characterize the following responses:

Effective Shock Duration (T_e) - Describes the minimum length of time that contains > 90% of the RMS time history amplitudes that exceed 10 % of the peak RMS magnitude for a specific shock event. The response is a measure of time and amplitude (g force), and exposes events along the time axis that can be characterized as a function of frequency.

Shock Response Spectrum (SRS) - Describes the natural undamped oscillation frequency over a given range of time as determined by the T_e and measures the shock response of the material over the frequency range of interest. The response from the SDOF (Single Degree of Freedom) is damped and expressed as the Q factor, with a Q of 5 being recommended where the characteristic spectrum response is not known. Essentially, for multiple random breakpoints, it is desirable to suppress the natural frequency oscillations of the material from confounding the SRS.

Energy Spectral Density (ESD) - The Fast Fourier Transform (FFT) of the total shock is computed and graphed as function of amplitude and frequency (g^2-sec/Hz). This shows the distribution of the spectral energy along the frequency band, resultant from the various shock breakpoints.

Fourier Spectra (FS) - Where ESD measures the

continued on page 6

Ask the EMPF Helpline!

A Helpline customer recently requested Design for Manufacturability review of a design for a Printed Circuit Board assembly planned for harsh environment, high temperature use. The response of the EMPF included the requested DFM and prototype assembly fabrication, but also re-balling of a BGA (Ball Grid Array) at the EMPF factory.

The EMPF Helpline and demonstration factory have combined resources to provide solutions for insertion of electronics assemblies into high reliability applications. Recently a Helpline customer requested the development and documentation of a robust manufacturing process for a high-reliability PCB (Printed Circuit Board) assembly. In addition to process development using the demonstration factory equipment, and subsequent documentation, a DFM (Design For Manufacturability) review of the assembly was conducted at the EMPF, noting any issues of concern affecting the producibility of the assembly.

A test vehicle representative of the prototype product was provided by the customer. The PWB was high-temperature Rogers substrate material with 12 layers that included blind and buried vias. The goal of the project was to solder both ceramic and metallized ball grid array packages simultaneously to this substrate at high yield and good reliability of the final assembly.

The project addressed 10 different processes used to manufacture and test the circuit assemblies. The three following processes are addressed in this article:

PWB (Printed Wiring Board) Fabrication
PWA (Printed Wiring Assembly) Manufacturing
BGA (Ball Grid Array) Re-balling Processes

High Reliability, Low Cost PWB Fabrication

ACI reviewed the design provided by the customer for applicability in high reliability applications. The ACI engineering and design staff compared the bare PWB design to IPC guidelines for printed wiring board design. Many of these design rules can be found in the IPC 2220 series of documents. Several suggestions were provided for improving manufacturability and reliability.

ACI insisted that the PWB line spacing should not reduce the manufacturability of the PWB substrate. As a rule for most economical PWB fabrication at the average fabrication facility, 0.005" traces with 0.005" spacing are the desired minimum, usually available for no premium over wider line boards in bare board price. PWB lines and spaces down to 0.0015" are available usually at a premium price. The line spacing to adjacent copper features should not be less than 0.005" in order to guarantee suitable insulation resistance between conductors and other features. Long parallel traces are difficult to produce and subject to crosstalk, and should be avoided for enhanced producibility of the base substrate board.

ACI also made suggestions about the copper used for internal and external traces. Copper weight and density should be balanced on all layers (assuming ½ ounce copper cladding of the starting laminate) to avoid excessive warp and twist of the finished multilayer board after lamination. Heavier copper, usually used for higher current carrying capacity, reduces etch accuracy, because copper etching is isotropic, thus narrowing the imaged lines as it etches through the thickness of the foil cladding. Also, copper planes should not be exposed on PWB edges when routed from the substrate.

For high reliability surface mount electronic assemblies, land patterns must conform to IPC-SM-782 design rules for IPC class 3 solder fillets. BGA land patterns should be equal in size.

For the wave soldered PTH components, general requirements for Plated Through Holes (PTH) and annular rings must conform to IPC-2221 and IPC-2222 for class 3 assemblies.

PCB Assembly Manufacturability

To properly assess the manufacturability of the test board design, ACI performed a small R&D build of the prototype design. The build was designed to gather as much information regarding the manufacturability as possible. A small set of test boards were printed, placed, reflowed, inspected, and reworked using automated equipment. Notes were obtained about every aspect of the assembly process. A number of recommendations were produced as a result.

Since test is an important part of manufacturing, the customer was advised to consider in-circuit test - design in nodes and test points for access where possible. Silk screen part outlines, polarity, pin 1 indicators and reference designators where possible to improve test, inspection and repair of the assembly.

To properly design for reflow - be sure that heavy components are on the primary side of the board so they will not drop off when the secondary side is wave or reflow soldered. Remove vias from under BGA components that are to be underfilled so that the underfill material will not run down the vias. Location and size of tooling holes should be appropriate for the equipment requirements.

Fiducial marks should be placed so they are not obscured by equipment rails (a minimum of 0.100" from edges is adequate in most cases). Add local fiducial marks to BGA components to improve placement accuracy.

Soldermask defined lands for BGA components that are to be underfilled are recommended, to keep the underfill from encapsulating the pad edges. Allowance of a 0.100" keep-

continued on page 11

Vibration/Shock & Thermal Testing
(continued from page 4)

distribution of energy, the FS is used for isolating outstanding frequency components within the band.

Another aspect of considering shock systems is the ability of the equipment to accommodate shocks in both directions along each of the three orthogonal axes.

The illustration in Figure 2-1 shows a range of motion occurring in both directions simultaneously. The force being applied in the three orthogonal axes stipulates that the item be rotated as such to accommodate the applied force and maintain center of gravity for the accurate application of the test conditions. In the case of the AN/ARS-6A, for example, rotation of the item would require specifically designed head plates, and in the case of simultaneous thermal testing, head expanders. Each application may require specific tooling, and in some instances, where center of gravity may be difficult to maintain, a Trunnion reaction Base may be needed to pivot the shaker- not a minor item both in cost, weight, and installation.

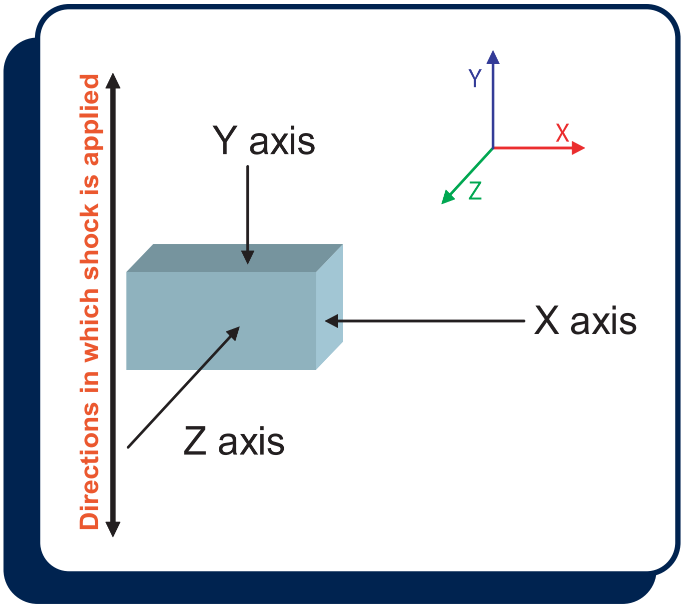

Figure 2-1 – Rotational axes in which force needs to be applied

The other part of the AGREE equation is the Thermal environment in which shock occurs. This is where familiarity with the requirements of a specific application is essential to prevent unnecessary costs or unacceptable test conditions. MIL-STD-810F does allow and encourage the use of concurrent conditions to simulate real life environments that would be encountered during operational and stationary phases. The specification does not always define the environmental parameters and conditions required for a particular combination of tests. This is often left to the discretion and judgment of the engineers in simulating the appropriate environment. The stipulation, however seems to imply that any combination used, has the necessary elements of both (i.e. for shock and high temp) conditions in order to meet the level of acceptability.

The air transport, handling, and deployment requirements (MIL-STD-810F, Part I- Pg 13-14) which includes rotary and fixed propeller, call for the following TM's where temperature simulation is required:

501- High temperature (Dry/Humid)
502- Low temperature (Freezing)
503 - Thermal Shock
520 - Temperature, Humidity, Vibration, Altitude

Whatever thermal system is selected, discretion must be used to select a chamber capable of providing conditions appropriate for the assembly that is being tested. The "One size fits all" chamber may not be necessarily the best.

Concurrent environmental testing has been occurring for quite some time, but has gathered more momentum in the past several years as more regulatory organizations other than the DoD begin to contribute some definition around test methods. The most common AGREE chamber is the thermal cycling unit in combination with a shock/vibration system. One unit under consideration for the AN/ARS-6A system was capable of achieving a temperature range from -77°C to 173°C, with a maximum ramp rate of 6°C/min over the entire range, to simulate both hot and cold environments.

The vibration systems should be capable of being placed underneath the cycling oven and modified to fit into the chamber. A thermal kit comprising of a neoprene gasket is used to insulate, seal, and isolate the vibration unit from the temperature chamber. The head expanders and fixtures attach to the head plate, and are the only parts of the shock unit exposed to the oven chamber. A chamber with dimensions of 30x30x30 inches, has enough flexibility to fit various test size assemblies and accompanying fixtures.

Based on the specifications outlined in TM 516.5, some important performance metrics must be taken into account when choosing a shaker system. Velocity, Displacement, and Force are physical attributes of a shock vibration system which can produce the required g force and Transient Duration Time needed for the SRS. Estimating the amount of force needed is not always as simple as F=MA, which assumes a flat response over the frequency spectrum. In choosing a system one should observe the sine, random, and shock force ratings and be aware that often times, unless specified, the ratings may only include the weight of the shaker armature, not the test fixtures or the test specimen itself.

continued on page 9

Cut here and save!

Tech Tips...

How to Test for Hermeticity

Measuring hermeticity can be performed a number of ways but the concept is the same; a pressure difference between the internal package volume and the external atmosphere causes gas or liquid to diffuse through the seal material, or through a path created between the seal-to-surface interface, or a crack or pore. The mechanism for the seal to be breached and the leakage level (gross vs. fine leak) will determine the type of technique for measuring hermeticity. The standard for fine and gross leak testing of cavity style packages has been MIL-STD-883G, Method 1014.11.

Test A: Fine Leak Testing using Helium
A1: Fixed method - The sealed package is pressurized or "bombed" in helium at a specific time and pressure. The test package is removed and connected to a mass spectrometer which determines the amount of helium escaping. Rejection criteria will vary with test conditions and cavity size.

A2: Flexible method - This test utilizes the same procedure as the fixed method except that the bomb conditions are chosen based upon the minimum detection limit of the mass spectrometer. These chosen conditions, internal volume of the package, and the maximum equivalent standard leak rate limit are utilized to calculate the measured leak rate. As with the fixed method, the failure criterion is internal cavity size dependent. The fixed method has been superseded by the flexible method in the most recent revision of the TM 1014 unless specified differently in procurement documents.

A4: Open Can Leak - Does not involve pressurizing the package, but exposing the package to a flow of helium and observing any localized leakage greater than 1×10^{-8} atm cc/s.

Test B: Radioisotope Fine Leak Test - This test is similar to the helium leak test except the tracer gas is a mixture of radioactive krypton-85 and dry nitrogen. Leaks are determined through measuring the response of a scintillation detector which counts the krypton-85 particles. As with the helium leak test, cavity size will determine failure leak rates.

Test C: Fine and Gross Leak Test Techniques
C1: Gross Leak "Bubble" Test - Leaks are determined by exposing the package to a lower boiling fluid (type I fluid, boiling point < 100° C) followed by a higher boiling fluid (type II fluid, boiling point > 125° C) and elevating the temperature of the higher boiling fluid while the package is immersed in it. Failures are indicated by the presence of bubbles of type I fluid. This test is combined with a fine leak test as fine leaks are not often able to be detected with this method.

C3: Gross Leak, Perfluorocarbon Vapor Detection - This test is similar to C1 except that immersion in the type II fluid is not done and leak detection is done in a 125° C heated chamber. Failures are considered when more than 0.167 microliters of type I fluid is observed evolving from the package.

C4/C5: OLT Optical Leak Detection (Gross and Fine) - This test measures lid deflection in response to a change in ambient pressure. If the device has a good hermetic seal, then the lid will deflect in response to the pressure difference between the cavity and the outside atmosphere. A gross leak will be indicated by a lack of deflection as the pressure inside the package and chamber come to equilibrium quickly. One requirement of the test is that some observable lid movement is necessary to perform this test.

Test D: Gross Leak using a Dye Penetrant - This destructive test utilizes a fluorescent dye in which the device is immersed under pressure. After a set time and pressure the package is opened and a UV light source is used to detect the presence of dye within the package.

Test E: Gross Leak by Weight Gain Measurement - Through weighing the package before and after pressurizing in a bath of a low VOC type III detector fluid, any weight gain of more than 1.0 milligram for a package of less than 0.01 cm^3 and more than 2.0 milligrams for a package of greater than 0.01 cm^3 are considered failures.

MIL-STD-883 Method 1014, MIL-STD-750D Method 1071.7 and JEDEC Standard No. 22-A109-A are variants of each other. Recently, issues with these tests have been brought forth. All the tests are limited by the fact that a cavity is necessary for the test or test conditions to be applicable. Even then, the large-volume cavities are a problem for the RGA (Residual Gas Analysis) tests like the helium leak tests as the cavity volumes mask the test by diluting the helium. Packages with high cavity vacuums have the same problem as the large-volume cavities. With extremely small cavity volumes (nano-liter cavities), a different problem arises, that of being able to detect such small volumes of residual gas upon its removal from the cavity. "One-way leakers" are a problem because once the pressure differential is removed, the leak reseals itself and the RGA test becomes invalid. The Radioisotope Test Method is the exception as lower detection capabilities are possible.

With these tests and today's changing reliability requirements, establishing what level of hermeticity is acceptable and how that level is established is the challenge. The need to perform environmental stress screening (ESS), as performed routinely at the EMPF, is the key to measuring reliability. The RGA limits are based upon an inert fluid or gas which measures the degree of the leak, but not the effect of the leak in a given environment. As a result, a number of screening tools from recognized standards (JEDEC, IPC, ASTM, etc.) are available which address reliability concerns. These include, but are not limited to: temperature and humidity exposure, thermal cycling, highly accelerated stress test (HAST), high accelerated life test (HALT), vibration salt fog exposure, high temperature operation life (HTOL), humid sulfur environment, and mixed flowing gas.

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Current Sensor Comparison

One of the operational requirements for new ships built for the US Navy is automatic control and monitoring of the ships' electrical systems. Such systems include power converters, generators, and load centers. At present, current and voltage sensors are heavy and require much space. Therefore, an evaluation of current sensor technologies is needed.

In recent years, optical current sensors have reached technological maturity and are now competing with more conventional current sensors. Optical current sensors are easily installed and integrated into existing systems. These sensors are appealing for measuring electrical current, electric fields, and magnetic fields. Optical current sensors provide galvanic isolation of the sensor head from surrounding electronics, in addition to overcoming several of the challenges posed by their conventional counterparts.

Electrowinning

Electrowinning is the process of using electrolysis to recover metals from solutions. The production of chlorine and metals like zinc, magnesium, copper, and aluminum requires DC currents as high as 500kA. These high currents are measured frequently in order to maintain process control and to protect equipment. The accuracy of these measurements should be within ±0.1%.

Hall effect current sensors are traditionally used to measure high DC currents, such as those associated with electrowinning. However, several disadvantages are posed by Hall effect current sensors. Often, the process of installing Hall effect current sensors is intricate and time consuming. The magnetic field distribution output from Hall effect current sensors must be analyzed to minimize cross talk and other errors. Conventional Hall effect systems can also weigh up to 2,000 kg and consume up to 10kW of power.

Interferometric current sensors (Figure 5-1) can replace conventional Hall effect current sensors in the electrowinning process. Interferometric current sensors can measure up to 500kA of current with an accuracy of +0.1%. Furthermore, electronic crosstalk does not degrade sensor performance. Large bandwidths enable detection of current ripples and those transients can be recorded. The sensor output is digital, which may inspire new data acquisition and processing capabilities. Interferometric current sensors are lighter and less complex than their Hall effect current sensor counterparts. Installation is straightforward and power consumption is negligible.

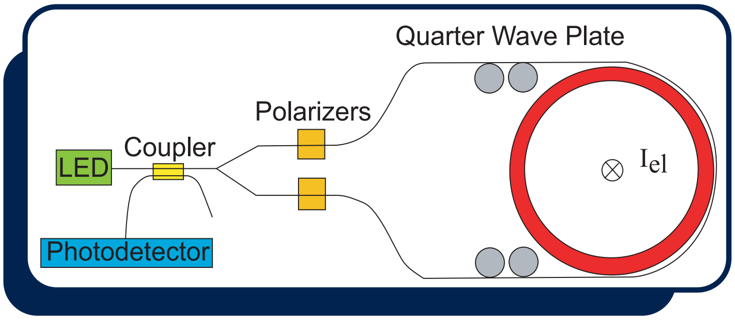

Figure 5-1 – Interferometric current sensor

Power generation and distribution

Current sensors are used for power generation and power distribution systems. Within power generation systems, currents up to 150kA must be measured with an accuracy of a few amps. Current is measured at several locations within power distribution systems in order to protect expensive equipment. Spikes of current must be detected and eliminated within milliseconds to protect system circuitry. Current sensors also help measure energy flow for billing purposes.

Often, Current Transformers (CT) are used to measure current within power generation and distribution systems. Nevertheless, CT sensors require thousands of copper windings, making them large and costly. Furthermore, CT must be placed outside the power generators.

Polarimetric current sensors (Figure 5-2), on the other hand, can be installed within the generator and thus reduce the overall size of the power generation and distribution system. This size reduction can lead to decreased system cost as well. Furthermore, polarimetric sensors weigh only a few ounces and can measure up to 300kA of currents.

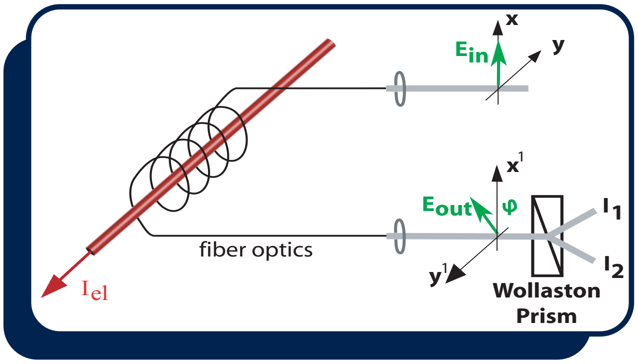

Figure 5-2 – Polarimetric current sensor

Fault detection

A common type of electrical failure occurs when electrical conductors come into contact with a ground potential. This type of fault, also called a short circuit, allows large electrical currents to flow from the energy source through all available ground paths and then back to the energy source. Power system faults must be quickly isolated in order to maintain the functionality and stability of the system.

continued on page 9

Current Sensor Comparison

(continued from page 8)

Current transformers are often employed to protect the energy source. However, during high fault conditions, the resulting magnetic fields frequently cause the iron core within transformers to saturate. This saturation distorts subsequent current measurements. All current transformers will saturate unless built with excessive steel for prevention. However, incorporating exorbitant amounts of steel into each transformer is impractical.

Saturation can be avoided by using interferometric current sensors since optical sensors contain no magnetic components and no iron core. As a result, interferometers significantly reduce the system's complexity since saturation is not a factor. Interferometric sensors can detect faults quickly since their response time is less than five microseconds. Also, current faults reaching 500kA can be detected.

Advantages and disadvantages

The electro-optic Kerr effect (EOKE) can degrade the performance of both interferometric and polarimetric current sensors. The EOKE is a change in a material's refractive index in response to an electric field. All materials display a Kerr effect to an extent, but some materials display the effect more strongly than others. Current sensors operating in high electric fields will have distorted responses or altered characteristics because of the EOKE. To minimize the effect, several precautions must be implemented. The sensor should be strategically placed and the polarizer correctly aligned. Also, optical fiber current sensors on high voltage lines need screened, low electric field locations to minimize the effect.

In high electric field environments, interferometric current sensors are more stable and less prone to wave form distortion by the EOKE than polarimetric sensors. Nevertheless, polarimetric sensors have smaller temperature dependence than interferometric sensors.

When compared to polarimetric sensors, interferometric sensors are larger and have slower sampling rates. Nevertheless, interferometric sensors measure higher currents and operate at a wider temperature range.

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Vibration/Shock & Thermal Testing

(continued from page 6)

The Crash Hazard shock test parameters as defined by TM 516.5 can effectively require a 75g force with duration of 15-23 milliseconds. In the case of the AN/ARS-6A System 4, an estimated 7500 lbs of force is needed assuming a total of 100 lbs of mass. These are estimates, which depend also on pulse shape as well as other factors, even though the biggest contributor to achieving maximum force is the total load. For shock test environments, a variety of factors may impact performance such as pulse and peak amplitude, pulse duration, and test load.

A typical frequency range for sinusoidal and random tests is generally specified between 20 and 20,000Hz. The maximum displacement is critical at lower frequencies, while limited by acceleration at the higher frequencies. Random vibration depends on a power spectral density with a fairly flat response over the entire frequency range. Resonant damping of the mechanical armatures and other moving parts is critical to preventing competing or offsetting frequencies, which may interfere with the natural characteristic frequencies of the test part. A large number of programmable breakpoints and bandwidths are desirable in providing random harmonics.

Finally, and certainly not the least important aspect of selecting an AGREE System, are the available facilities to house such an immense system. The weight of the shaker system alone may exceed 6000lbs over a 3 x 3 foot area. Adding the additional thermal chamber can well top the typical floor load rating of 200-300lbs/sqft. Additionally, an isolated room would be necessary to dampen the noise and vibratory effects of the running unit. Given all of the factors, it may still be worth the test flexibility and long term cost savings, of installing the needed facilities to perform the AGREE test on a critical system such as ARS-6A.

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Manufacturer's Corner
SEICA - ATE

The EMPF is constantly involved with both electronic manufacturing and depot repair centers building military/aerospace systems. These installations are continuously challenged to assure rework, maintenance and repair of returned new product and legacy-based Shop Replaceable Units (SRU) and Line Replaceable Units (LRU).

Over the last five years, the EMPF has noted that SEICA's Automated Test Equipment (ATE) can provide cost controlled migration solutions from well known ATE, including CA Marathon, Teradyne L300 and LASAR simulator, and Schlumberger S790. They have gained major understanding on how to design new ATE technology with an eye to old practices and requirements.

To support this endeavor, SEICA ATE was deployed at critical installations together with a number of Test Program Sets (TPS) and dedicated fixtures for each specific program or application.

Digital test flexibility was achieved by the ability to provide drive/detect and load capability at each I/O (Input/Output) of the SRU or LRU with enough flexibility to deal with all available technologies (TTL, ECL, and CMOS). Parametric analog tests were enabled by providing access, for each channel, to a centralized bank of DC/AC proprietary or IEC Standards driven instrumentation.

The guided probe of the equipment allowed diagnostics to the component level, with data generation either from a known good board (KGB) or from simulation.

When the older ATE can no longer be kept in operation, migration of the entire logistic to a new ATE becomes critical to support the requirements of test.

By carefully planning the routing of the instrument(s) to the points of test coupled with the flexibility of the ATE architecture, a high rate of test coverage in the transition was realized.

When possible the original test program should be converted intact to preserve the formal structure and validated to insure performance should new instrumentation be identified and implemented.

Another issue is the awareness that fixtures age and wear out; requiring an inspection to validate operational conditions. When catastrophic defects are found, replacement of the unit or refurbishing of the unit to print may become considered but not economically viable, particularly when fixtures include active electronics.

An accepted option is building a fixture adapter between the new ATE receiver and the old fixtures provided the new ATE is configured to provide an adequate number of non multiplexed independently programmable analog/digital resources per pin.

The process in reviewing program migration must include the availability/access to the new ATE environment, the TPS, and fixture/adapter costs.

Migration of test programs and fixtures from GR1795, GR1796 and GR1799 to a modern ATE is in great demand.

The software and hardware architecture of SEICA's modern ATE system has thus been adapted to bend new technology to old requirements. There is a great lesson to be learned: given the unchanged needs of the military/aerospace industry to warrant a program's life across many decades. The EMPF, in partnership with SEICA, plans to incorporate the SEICA ATE equipment (Figure 6-1) on the EMPF Demonstration Factory floor in support of this premise.

Figure 6-1 – SEICA ATE system

For further information or a demonstration of this, or any of the other electronics manufacturing equipment at the EMPF's Demonstration Factory, please contact Bob Berta at (610) 362-1200, extension 253, or rberta@aciusa.org.

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Ask the EMPF Helpline!

(continued from page 5)

out distance around BGA's for rework and underfilling is an additional aid to manufacturability.

All components should be placed away from board edges a minimum of 0.050" for handling requirements. Land patterns must be isolated from adjacent features and lines by solder mask over bare copper - exposed copper should be no closer than 0.050" to the features to be soldered to prevent inadvertent shorting.

If possible, all active components should be placed on the same side of the assembly - avoid placing BGA components directly behind each other on opposite sides of the assembly

BGA Component Re-Balling Process Development
This process was developed by the EMPF using the customer supplied ceramic components. Fixturing occurs by applying a 4 mil deposit of solder paste to the ceramic component prior to application of the high temperature balls. Once the high temperature balls are affixed to the component via solder paste, the component is then subjected to the reflow process, melting the solder paste and forming a permanent attachment of the balls to the component.

Process Steps for Re-Balling BGA Components
The BGA components for the assembly were supplied having incorrect solder alloy ball contacts. It was therefore necessary to re-ball these BGA components with the proper alloy solder balls before assembly onto the PWB substrate.

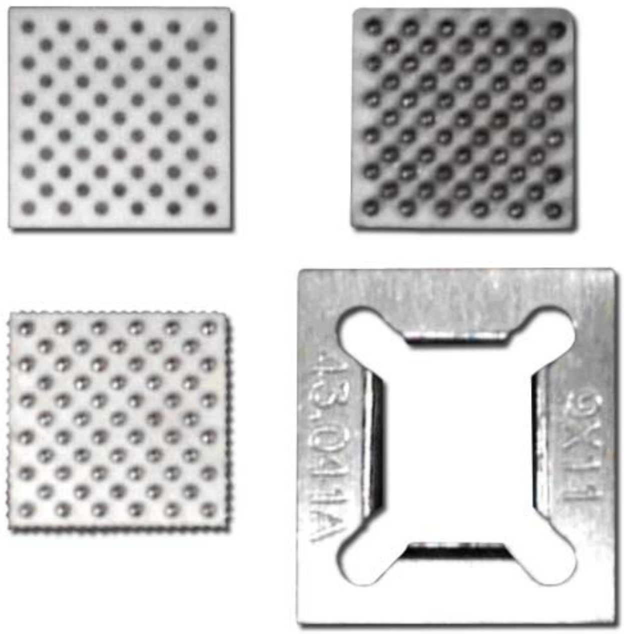

Figure 3-1– Ceramic component prior to reballing (upper left), reballed component (upper right), solder preform (lower left), and reballing frame (lower right).

First, water soluble solder paste was applied to the component substrate using the designated "paste on part" fixture (See Figure 3-1).

With the component still on the fixture, the fixture and component were installed onto the Metcal 550 rework station. Then, using the vacuum pickup nozzle of the rework station, the pasted component was slowly separated from the fixture. The solder preform with the correct alloy was inserted into the reballing frame and the frame was accurately positioned on the rework station platform under the pasted component.

The component and solder preform were then reflowed together using the specified reflow profile. Upon completion of the reflow process, the paper backing was removed from the reflowed component and visually inspected for missing balls. Finally, the component was cleaned using DI water. The EMPF recommended that components be baked at 125º C for 24 hours prior to use.

Using the customer supplied PWB substrates and components, the EMPF was able to establish and implement these assembly processes for BGA reballing, PWB design, and PWB assembly in the EMPF demonstration factory. A thorough DFM (Design for Manufacurability) review was performed on the assembly, the printed wiring board, and the BGA component designs. Principles of pad design and component placement for high reliability in harsh environments were applied during the DFM review. This resulted in the recommendations to the customer on optimal manufacturing of the assembly using high temperature materials in its intended introduction into a high-stress, high reliability application.

By following these basic DFM principles and instituting the reballing procedure developed at the EMPF, the customer was able to achieve a higher yield and a higher volume manufacturing of this PCB assembly.

For more information, or to learn more about applying DFM principles to your product line, please contact the EMPF helpline at (610) 362-1320, or email us at helpline@empf.org.

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EMLC Upcoming Course Schedule 2006

Skills

BGA Manufacturing, Inspection & Rework
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Certifications

IPC J-STD-001 Instructor Certification
July 17-21

IPC-A-610 Instructor Certification
July 10-14

IPC Challenge
July 19

WHMA-A-620 Wire Harness Manufacturing (Operator)
October 3-5

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July 31 - August 4

J-STD-001 Instructor Recertification
July 20-21

IPC-A-610 Instructor Recertification
July 17-18

IPC-7711/7721 Certified IPC Specialist (CIS) SMT Rework and Circuit Repair
September 11-15

IPC-7721 Certified IPC Specialist (CIS) Circuit Repair
November 2-3

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

For a complete course schedule, visit: http://www.empf.org/html/empfasis/emlcupcoming.pdf

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issue:05-06

Empfasis is a publication of the
American Competitiveness Institute and the EMPF
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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