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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MEMS IMUs for Gun-Hardened Applications

Microelectro-mechanical System (MEMS) based Inertial Measurement Units (IMUs) are currently receiving a great deal of DoD focus due to their potential of providing needed navigational capabilities to precision-guided munitions and other applications involving high-gravity (high-g) environments. IMUs are units containing both accelerometers to measure linear acceleration as well as gyroscopes, which measure angular rates (see Figure 1). For many weapon systems, MEMS IMUs can provide the needed navigational accuracy at lower cost and smaller size than other types of inertial units such as ring laser gyroscopes or fiber optic gyroscopes. Small size and low cost are vital to the precision guided munition application, and being able to produce a gun-hardened IMU is one of the keys to making precision-guided munitions a reality.

The guidance for the precision-guided munition is mainly provided by the global positioning system (GPS) in conjunction with deployable canards on the munition that adjust to alter the round's flight path. GPS needs to be supplemented by an inertial device (one that does not depend on external reference). The IMU provides the initial guidance for the round until the GPS signal is established. Examples of precision-guided munitions programs include the Army's Excalibur, or XM-982, and the Navy's Extended Range Guided Munition (ERGM). The ERGM round is approximately 5 feet long and includes a rocket motor that fires briefly after leaving the gun barrel.

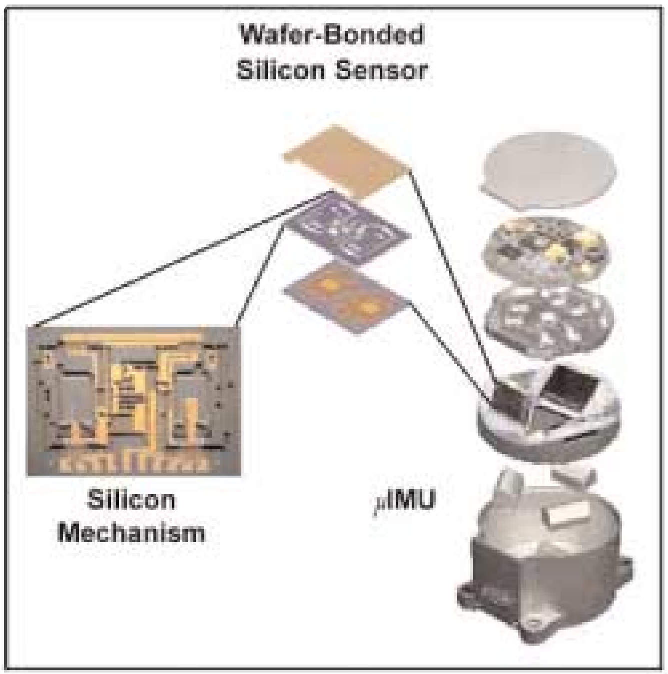

Figure 1. MEMS IMU from L-3/IEC.

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MEMS IMUs for Gun Hardened Applications
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One of the main technical challenges involved with using MEMS IMUs for precision guided munitions is the fact that the IMU needs to operate after withstanding the high g's associated with the gun firing. Munitions of this type typically experience gun shocks of 10,000 to 20,000 g's. Obviously, for the IMU to fulfill its navigational role, it needs to be able to withstand the initial high-g gun shock and then function properly. IMUs contain circuit boards, connectors, and the MEMS device itself. The nature of the MEMS devices such as those used in the IMUs consist of many tiny, micromachined features in the silicon chip (see Figure 1). Two examples include the tines associated with vibrating beam MEMS IMU architectures as well as the fingers on the comb drive MEMS designs. In addition, MEMS devices for IMUs often contain fine features, such as "springs" or thin silicon legs, used to allow motion of the sensor portion of the MEMS die. The MEMS die need to be able to withstand the gun shock from a physical and a functional standpoint. Finite element analysis (FEA) is used to predict the maximum stresses on the device features. The analysis includes the material properties of the MEMS devices, such as the bulk silicon as well as the metallization layers.

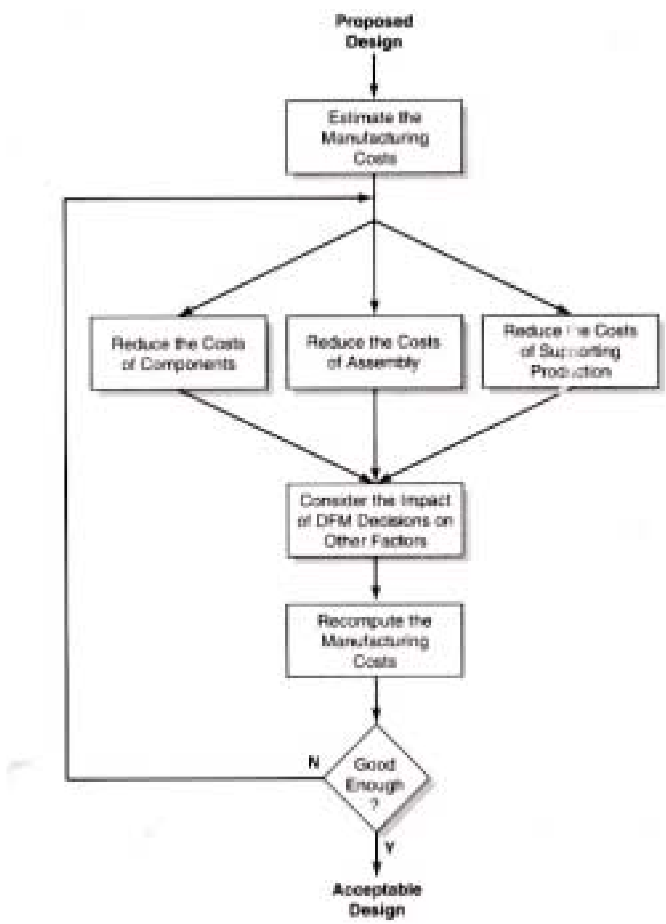
Some of the main tests used to evaluate an IMU for gun-hardening include centrifuge testing, air gun testing, rail gun testing, and a soft-recovery vehicle (SRV) test. Centrifuge testing is typically a laboratory scale test that spins the IMU in a fixture so that it experiences up to 20,000 g's. This testing can be used to determine the structural survival limits of the device (test until physical breakage observed). This type of testing can also be used to verify that the FEA was accurate in predicting failure levels and locations. Air gun testing can involve operational IMUs. The IMUs are placed in a test fixture that in turn is loaded into a piston. The piston is then loaded into an air gun breach for firing. The breach can be pressurized to different levels for testing. In order to accomplish set forward acceleration, the test fixture is inverted in the piston. The rail gun test environment closely resembles an actual live firing. This type of testing provides both high set back and set forward accelerations. SRV testing involves an actual firing of a test munition, but with the benefit of parachuting back to Earth so that the hardware can be recovered and studied in tact for any failures.

In general, non-functional IMUs are tested with some of the less advanced tests to determine physical survivability. After this is established, functional units are later tested. The IMUs can be tested for continuity or undergo functional testing. For instance, it is desirable to have the IMU accelerometer bias and scale factor show a minimal change in value after high g testing compared to their pre-test values. The bias term refers to the accelerometer output when the IMU is not undergoing any acceleration. Bias is due to residual internal forces on the proof mass after being zeroed. The scale factor is the proportionality constant relating the actual acceleration with the indicated acceleration. A minimal change in these values is one indication that the accelerometer portion of the IMU functionally survived the high g test. The IMU angular rate output can be tested on a rate table before and after the high g test to determine if it indicates the known angular rate change applied by the rate table.

MEMS based IMUs are a developing technology for high g applications such as guided munitions. Raytheon recently reported the successful testing of a MEMS based IMU in an ERGM round actual test firing. ACI is currently involved with the Office of Naval Research Manufacturing Technology program to improve the manufacturability of MEMS based IMUs. With continuing technical success, as well as progress towards a lower per unit cost, gun-hardened MEMS based IMUs are expected to enable the wide scale introduction of precision guided munitions into our nation's warfighting capability.

Design for Manufacturability

Would you like to improve your product's time to market and manufacturing yield while decreasing manufacturing costs? This can be achieved by adherence to some basic principals intended to address complex manufacturing issues during the design stage of a product. Elimination of manufacturing issues prior to manufacturing a product saves not only on material costs but also saves on rework time and labor as well.

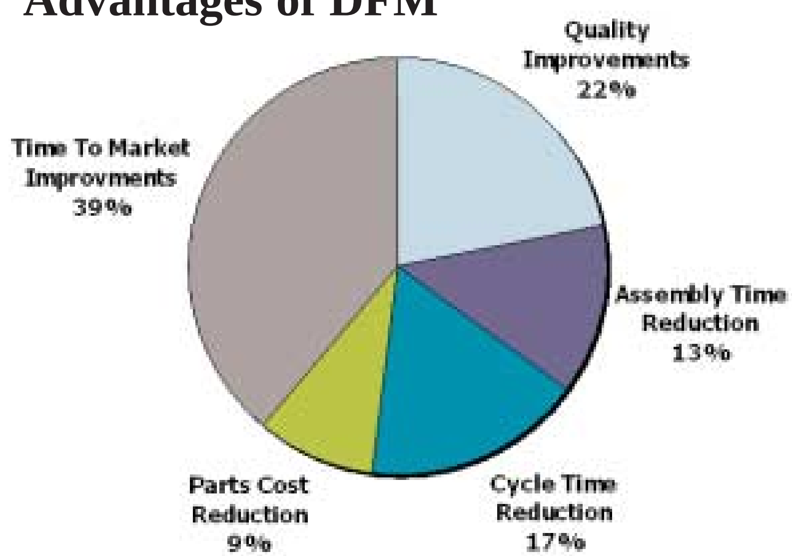


The Electronics Manufacturing Learning Center offers a two day "Design For Manufacturability" (DFM) curriculum, specifically designed to address the complex manufacturing issues associated with modern assembly and manufacturing processing. The curriculum is geared towards design engineers and is based on the IPC-2220 series of design documentation. Also the curriculum introduces the student to the renowned Boothroyd-Dewhurst Design for Assembly (DFA) methodology. Among the topics covered throughout the course are the following:

- DFM, DFA producability reference
- DFA Boothroyd-Dewhurst Methodology
- Assembly process overview
- Through-hole clearances
- Surface mount component clearances
- IPC-2220 series of design documents
- PWB and panelization strategies
- Component selection and packaging
- Future design issues (e.g., BGA, microBGA, Chipscale, Wirebonding)

Among the numerous benefits of incorporating a DFM methodology into your front-end design discipline are improvements in assembly manufacturability, circuit performance, assembly testability, assembly maintainability, product cost effectiveness and improved time to market. Although product design accounts for only a small portion of the overall costs, the influence a design has on other costs such as material, labor and overhead is great.

Advantages of DFM



By following these simple step by step guidelines, the influences we have on the overall cost of a product is great while also benefiting from a faster time to market and improvement in overall product quality.

For additional course information, please contact the EMPF's HELPLINE at 610-362-1320, or visit us online at www.empf.org.

Miniaturization of DC/DC Converter

American Special Forces, including the Navy's elite SEALS, are seeing an ever expanding mission, particularly in the war on terrorism. One way of increasing Special Forces capability is through the priority development of electronic warfighting capabilities.

In the past year, ACI developed a six-output low voltage DC-DC converter, called a Variable Power Distribution Unit (VPDU) for use in the development of electronic warfighter equipment.

This equipment, pictured in Figure 1 is designed to be powered by a 12-volt battery and features independent precision control and monitoring of each of the outputs in addition to several supervisory features. The six outputs are:

- Four channels which can provide 2.5 to 6.0 VDC at 0 to 4 Amps
- One channel which can provide 6.0 to 12.0 VDC at 0 to 4 Amps
- One channel which can provide 6.0 to 12.0 VDC at 0 to 50 Watts, with short term capability of up to 10 Amps or 75 Watts for pulsed loads.

The VPDU serves as a power source for devices being evaluated in a lab or field test environment for Special Forces use . These devices are all compatible with the VPDU and include:

- A weapon subsystem which comprises key electro/optical components such as the weapon-mounted Thermal Weapon Sight (TWS), video camera, and the laser range finder/digital compass.
- An Integrated Helmet Assembly Subsystem (IHAS) -mounted computer and sensor display, the soldier's interface to the subsystems and to the digital battlefield; and a Night Sensor Display with an image intensifier.
- Computer/Radio System (CRS) and global positioning system (GPS) modules.

Having completed the VPDU project, ACI's next area of interest is the refinement and miniaturization of this design for use by the electronic warfighter or civilian use, such as SWAT teams or fire fighters. The following are some of the issues that will be addressed.

System Supervision

Depending on its state of charge, the battery voltage can range from 8 to 16 volts. At present, each element of electronic equipment has its own scheme to operate with the voltage from the battery supply. By configuring the system thus, it is likely a number of regulation and supervision functions are duplicated, or worse, not being managed at the system level at all.

ACI believes that employing a central power management unit, which would add 'Smart' control to a miniaturized VPDU-like converter would eliminate the need for unique regulators for each piece of equipment, each with it's own magnetic devices and other regulation circuitry.

Figure 1: DC-DC converter designed to be powered by a 12-volt battery

To maximize the range and affectivity of Special Forces, the prime goal must be the reduction in weight and size of the equipment the soldier is tasked with carrying. By centralizing the regulation function, ACI feels the total parts count can be significantly reduced.

All extraneous functions not essential to mission success, such as duplicated circuitry, voltage readouts, and indicator lamps, would also be eliminated to reduce size and power consumption.

Smart Technology

Battery life is a key factor in mission duration. Duty cycle (how often and for how long power is required by a given device), energy conservation and load supervision are in turn key factors in battery life.

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Miniaturization of DC/DC Converter

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For these and other reasons, smart technology can more easily come to play through centralized power flow monitoring and management. This could include electronic supervisory circuitry to monitor battery state of charge, load priority, control and, as the battery reaches low charge state, load shedding to preserve vital functions. This can only be accomplished using a 'watchdog' controller; otherwise, the several independent devices compete for power from the battery, putting the soldier, team and mission at risk.

Placing such functions in the battery itself are an option, but this approach impacts battery complexity and cost. Since the battery is a consumable and will be procured in much higher volumes, this increases overall program life cycle costs.

Environmental Definition

The thermal environment is a particular concern; as is resistance to other environmental factors, such as shock and vibration, moisture, salt water or chemical agents which will be part of the operating environment. These are all elements which complicate and have the potential to compromise an otherwise compact design. Close coordination between the electrical and mechanical designers is necessary for a successful downsizing.

To provide optimally-designed equipment, it is paramount that a strong working relationship between the design activity and the end user be established at the beginning of the design cycle. This is especially true for the miniature battery-powered DC/DC converter suitable for Special Forces.

Electromagnetic Compatibility (EMC)

Special Forces depend on stealth as a vital part of Mission Success. Electromagnetic Radiated Emissions (RE) can compromise invisibility, so control of RE is critical throughout the development cycle at the system level. Packaging and interfaces too are critical to radio invisibility.

Like every other element in the equipment, if additional shielding is necessary to control RE, it impacts weight and sometimes the ability to dissipate heat or provide current paths. Given that there is no such thing as total electronic invisibility as long as the equipment is powered, successful miniaturization requires balancing the trade-offs between performance, reliability and emissions control.

Topology Selection

Modern converters operate in what is known as switch-mode; a key feature of which is the opening and closing of one or more transistor switch to convert the input voltage to the necessary levels. Switching typically occurs at a frequency between 20 kHz and 1 MHZ. Generally, the higher the frequency, the smaller the size for a given power level; with the trade-off being thermal dissipation and EMC; but a converter designer too willing to trade efficiency to get to the smallest package may sacrifice that reduced size to increased power dissipation and the need for a larger battery or a resultant shortened battery life. Increased power losses, which accompany higher frequency operation, can also complicate the packaging design through the need to provide better thermal dissipation paths.

Each particular topology has characteristic advantages and disadvantages. In the VPDU, a topology known as Forward Conversion was selected at the start of the design. The advantage is simplicity because only a single switching transistor is required; but, experience proved this topology is not optimal for operation with a 12 volt battery source, which can go as low as 8 volts. Battery system currents are 10 to 15 times as great as operation from a 120 VAC source.

In the VPDU design, the theoretical maximum time the transistor switch could be ON per switching cycle was 50%. (In practice it is somewhat less.) This doubles the currents compared to a conversion technique known as Push-Pull, which uses a more complex approach employing two switching transistors. Transistor losses increase as the square of the current, so the losses using forward conversion are four-times as high compared to push-pull. This not only impacted efficiency directly, but also necessitated the use of forced cooling. Fan cooling should almost never be used with a battery-powered system and definitely should not be used for soldier-borne equipment.

Other techniques which may contribute significantly to power supply efficiency are resonant topologies, synchronous rectification and soft switching. As always, there are trade-offs, typically in complexity of control circuitry and operating limitations, but these techniques are worth consideration once details of the actual loads are more clearly defined.

Packaging and Interfaces

Layout and packaging become the next step in the exercise. Target size and weight goals will be specified; but designing the converter/controller for mobility, comfort and safety may require several iterations to optimize for:

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Miniaturization of DC/DC Converter
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- Cooling
- EMC
- Materials constraints
- Reliability and maintainability
- Manufacturability; and of course
- Cost

There are additional issues such as connector requirements and limitations; and ergonomics, such as how the equipment is to be worn or carried, controls, indicators and ease of access.

Many of these same connector and ergonomic issues were addressed by ACI in a successful ManTech Initiative effort to design an electronic warrior power and signal harness set using COTS components.

Additional benefits to reduction in the overall system parts count are increased reliability and longer battery life. Almost without exception, every additional part takes up space and consumes power. Everything that consumes power dissipates heat and reduces battery life.

Summary

ACI has recently completed production of a battery-powered, six-output Variable Power Distribution Unit for Special Forces applications. A next step would be miniaturization to a size small enough for use by the individual electronic warrior. A critical element, which could only be provided by a central power controller, would be 'Smart' power supervision to optimize mission support. Additionally, close coordination of all design teams will be critical for optimization. Finally, critical design elements include environmental parameters, EMC, proper topology selection and ergonomics.

IPC-7711/7721 Certification

This course provides participants with a hands-on approach to the restoration of electronic assemblies. Certification, which is valid for two years, is received upon successful completion of the course.

The focus of IPC-7711 is on the rework of electronic assemblies. Students will learn and practice the techniques necessary to properly remove through-hole and/or surface mount components utilizing the latest tools, materials, and technology available. All component acceptability criteria, based on IPC-A-610C, is reviewed for each module. Upon successful completion, students will obtain IPC Operator Certification in the areas where proficiency is demonstrated.

This course is geared towards technical and manufacturing personnel involved with rework and/or repair of printed wiring assemblies with through-hole and surface mount devices, and others who wish to learn "best rework/repair practices" for through-hole and surface mount assemblies.

Course Content

- General Requirements
- Wire Splicing
- Removal and Re-installation of Various Through-Hole & Surface Mount Components
- Land Preparation
- Repair of Pads/Lands
- Eyelet Installation
- Jumper Wire Installation
- Repair of Damaged Laminant
- Removal & Replacement of Conformal Coatings

IPC-7721 concentrates on the repair of electronic assemblies. Students will learn the latest techniques used to repair circuits and laminates, including conformal coating/solder resist removal and re-application. Upon successful completion, students will obtain IPC Operator Certification to IPC-7721 in the areas where proficiency is demonstrated.

SCHEDULED IPC-771/7721 CERTIFICATION DATES FOR 2003:
March 17-28 & September 22 - October 3

Electronics Manufacturing Productivity Facility

TECH TIPS...

Dot Adhesive Dispensing

With today's conversion of through-hole component manufacturing to surface mount manufacturing, dot dispensing has become a critical part in the assembly process. Mixed technology manufacturing has evolved over the years as more and more SMT components are added to the printed circuit assembly. This has led to an increasing amount of adhesive dispensing for chip SMT components that are glued on prior to the wave soldering process step. This month's Tech Tips will explore the critical parameters and different methods utilized in the dot dispensing process.

Surface Mount Adhesive (SMA)

The adhesive, typically referred to as chipbonder, should consist of characteristics that include good green (tackiness) and cured strength, consistency, and a high dot profile. The fluid should keep the process within tolerances of today's chip components (e.g. 0.50mm or 0.02").

Choosing the proper needle

Due to the importance of accuracy and volume, the type of needle utilized is a critical factor. There are a variety of needle shapes and sizes that are either plastic or metal and have straight, bent, and tapered tips. The size of the needle is identified in wire gages 14-30. In dot dispensing the size of your dot should be the same diameter as your needle tip.

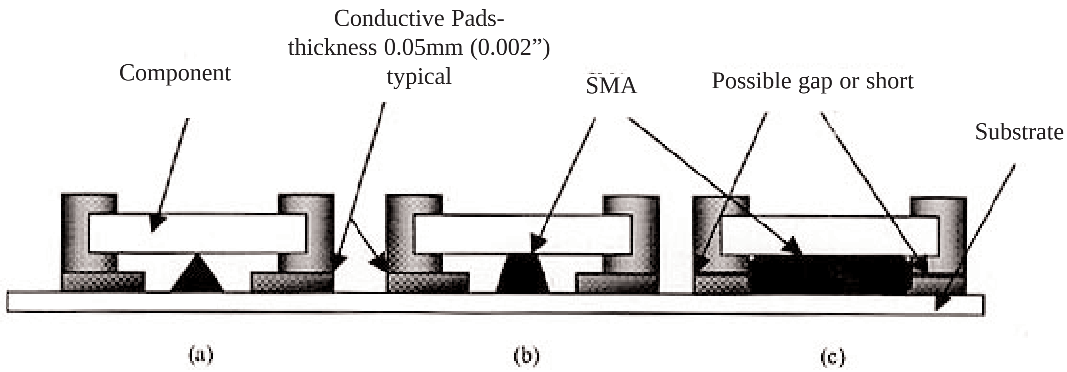

Figure 1: Examples of components applied with: (a) insufficient SMA; (b) correct amount SMA; (c) too much SMA. Courtesy of Asymtek

Dot Dispensing By Volume

The actual volume for dispensing dots is derived from a formula that results in a "Hershey's Kiss" shape. You need to make be certain you have the correct diameter and height of the dot. This is determined by the volume required, which is based on component size and mass using the formula V=1/4D2h. A chip bonding dot that is too big will smear onto the pads, preventing a solder fillet. A dot that is too small will not be enough to hold the part during the curing process. (See Figure 1)

Dot Diameter Equation:

The following example is based on the IPC surface mount design standards of a 0603 size component. The distance between the land pattern pads (P) is 0.60mm. By subtracting (P) from the nominal machine of 0.08mm (M) and subtracting the adhesive direction accuracy of 0.12mm (A) it will result in a dot diameter of 0.40mm;

$$D=P-M-A$$

Dot Height Equation:

To figure out the dot height for a 0603 component, the pad thickness at 0.05mm (T) is added to the chip's conductor which is typically set at 0.025mm (C). This will give you a dot height of 0.075mm (h) that is squashed and cylindrical in shape.

$$h=T+C$$

Dot Volume Equation:

$$V=1/4D2h$$

D=0.40 mm, h=0.08mm, V=0.015 mm^3

Choosing the proper Dispensing System

There are four basic ways to dispense; time and pressure, rotary auger pump, positive displacement and jet dispensing. The material being applied will dictate the type of dispensing system required. This is based on the viscosity and application of the material. Even though these materials are associated with a particular dispensing system, this does not mean that the materials are not interchangeable.

1 - Time and pressure

Time and pressure systems are a controlled, pressurized systems with a nozzle valve that is used on such applications as chip bonding, conductive adhesion, and solder paste dispensing. It is advan-

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tageous because of its speed and complexity in dot sizes. It falters however in dispensing consistency and material handling.

2 - Auger Pump

An auger pump works using a pump with a lead screw rotating in a body to add energy to the adhesive path within the body, pumping measured amounts of adhesive by turning on and off the screw's electric motor. This system is primarily used for underfilling and encapsulating because of its accuracy and flexibility. It is not a good system to use for high volumes due to its inconsistency at high speeds.

3 - Positive Displacement Pump

Also known as a piston pump, a positive displacement system operates by the movement of a piston in a closed chamber. Much like the time and pressure pump, the piston pump works best with materials such as chip bonding fluid, conductive adhesive, and solder paste. It is constant at high speeds and is capable of large dot sizes. The disadvantages are the complexity of cleaning and its sensitivity to air bubbles in the dispensed material.

4 - Jet Dispensing

A new method of dispensing called jet dispensing uses a fixed piston pump in which a spring loaded pin or "hammer" is used to force the material through a nozzle. It differs however because of a higher velocity that "jets" the material for faster dispensing. Jet dispensing is also unique because the dispense head does not move in the Z-axis. Instead it uses air pressure to force a dot through its nozzle taking a ballistic path between the nozzle and its target on the board. Its specialty is chip bonding adhesion but can be used with other materials to make dots. The advantages are non-contact dispensing, increased dispense speed and consistency. The downside is its limitation to only one dot size per jet.

Equipment Setup

After determining the dispense system and needle that will work best, the next phase is to setup your machine for dispensing. This means checking such things as the Z-height, dwell time, needle gap, X, Y axis speed and air pressure. The Z-height is determined by the needle size and the application of the material. A Z-height that is too low will not dispense enough fluid, where as one that is too high will dispense a "blob" of fluid. The dwell time specifies how long the dispense tip will stay in a dispense position before retracting. A greater dwell time allows the fluid to wet onto the surface reducing stringing, where as shorter time reduces the amount of fluid deposit as well as increasing your chances of stringing. The needle gap is the distance between the surface of the board and the tip of the needle. This is usually ½ of the desired bead width. The last two parameters, X, Y speed and air pressure will affect the consistency and throughput of your machine. These settings are usually set on a trial and error basis according to the viscosity and application of the material.

Reliability Issues

A dot of adhesive must mechanically hold the SMD component but should not encroach the PCB solder pads. When an SMD component is placed, squashing occurs to the dot. This squashed dot must have enough contact area on the component so the adhesive shear strength is not exceeded under a specified sheared force.

Application Issues

The application issues that sometimes crop up from a combination of improper settings are tailing, satellites and popcorning. Tailing occurs when the adhesive strings back during the dispenser's retract stage. This can cause problems if any of the tail reaches conductive pad areas. Satellites are small outlying dots that are prominent during high speed dispensing. This can result in not enough adhesive being applied to hold the component. Popcorning is caused by air or moisture getting into the adhesive and popping out during the cure stage. Expired or out-of-date fluid creates this condition.

Manufacturer's Corner

Techcon Systems model TS4545

Dispensing technologies are advancing, in concert, with other sectors in manufacturing. The EMPF is currently utilizing the Techcon Systems model TS4545 automatic dispensing system for the SMT Boot Camp training classes. In this class, students are taught the fundamentals of dispensing, the process of dispensing specific materials such as solder pastes, fluxes, adhesives, and the selection of dispensing needles based on the volume and properties of the materials to be dispensed.

Manual Dispensing

The low end of material dispensing process is the manual form. Basic components: A material to be dispensed, i.e., adhesives, sealants or lubricants, and an applicator. A typical manual system includes a dispensing barrel and a stopper filled with a material. Manual dispensing is suitable for low volume applications where production yields of 70 to 80% are acceptable. In operations which require less than one million units per year and where dispensing repeatability of greater than 10% is acceptable, manual dispensing is viable and an economical fluid delivery process. Although a typical operator can dispense materials for approximately 4000 units per day, dispensing accuracy is inconsistent, since operators must control both the time and pressure characteristics of the dispensing cycle. This process variability can result in higher reject rates or lower yields.

Time/Pressure Dispensing

A Time/Pressure Dispensing (TPD) system is the next step in the process's evolutionary cycle, which eliminates many dispensing inaccuracies. Generally, the TPD adds a regulated pressure control and timing circuit on top of the manual dispensing system to provide a means to increase product throughput and yields. Because dispensing accuracy is greatly affected by pressure and timing, adding regulation to these variables significantly increase a system's accuracy.

A typical TPD system operates in the following manner. An electronic controller delivers a measured air pressure for a specific amount of time to a dispensing syringe barrel. This controlled shot of air forces the material out of the delivery end of the barrel, through a dispensing tip and to the application surface. Standard dispensers control the discharge via an adjustable regulator and gauge that varies air pressure from 1 to 100 psi.

Because TPD systems are more accurate and permit tighter process control, they offer higher product yields and greater overall throughput than manual systems. Yields of greater than 95% are frequent, while repeatable errors of less than 3% are commonly achieved with TPD systems. However, while faster than manual methods, TPD systems remain limited by operator constraints and do not provide the means to increase throughput beyond certain volumes. Applications that require higher throughput must look for more advanced dispensing alternatives.

The EMPF uses the Techcon TS4545

Automatic Dispensing

Automated dispensing systems are the next technological step and offer options ranging from simple X-Y axis movements to sophisticated autonomous, vision controlled robotic operation. There are two main characteristics of an automated system: time/pressure regulation (temporal control) and motion (spatial control). Automatic dispensing systems combine the tight dispensing control of TPD with the head placement accuracy of stepper and servo motor control resulting in a highly accurate, repeatable and reliable dispensing process.

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Manufacturer's Corner - Techcon Systems

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With an automated dispensing system, a microprocessor driven controller regulates time and pressure while the gantry arms are controlled by precision servo motors. The dispensing program is developed and managed by Windows-based software and can be used or modified as needed.

Why Automation?

Reasons for automating a dispensing process generally relate both to increased productivity and product quality. For example, an automated system is capable of dispensing fluids on 3,600 parts per hour or approximately one each second. This is contrasted with manual dispensing rates of 500 parts per hour and an immediate throughput increase of 720 percent.

A more important reason for automating a dispensing process relates to improved product quality. By increasing dispensing accuracy, overall product yields increase due to lower material waste, rework costs and reject rates. Depending on production volumes and assembly and rework expense, the cost savings because of higher product quality can be significant.

Factors to Consider

The first step in considering process automation is to completely understand the dispensing process's requirements and how it is used in production assembly. Some key questions include:

- What material must be dispensed?
- What volumes are to be dispensed and at what rates?
- What are the dispensing patterns?
- What are the operators limiting factors? Can they be engineered out?
- Do the parts lend themselves to palletization?

Understanding these requirements, allows for determining whether the process can be automated. In cases where the exact dispensing parameters are not well understood, manufactures are urged to contact their automated equipment suppliers for a more detailed analysis of the dispensing process.

The second step in considering automation is cost analysis. Some major points include:

- What is the cost of the automated dispensing machine?
- What are the production/labor rates for operating the machine?
- What are the current product yields and how much can be saved by increasing them?
- What is the anticipated increase in throughput and how much incremental revenue will each additional part generate?

While the factors influencing automation of a dispensing line vary by application, there are many common parameters. Generally, processes that require a consistent and repeatable operation on similar parts are good candidates for automation. Also, automation is best suited for medium to high volume applications or processes that dispense more than one million parts per year. Parts with high per unit cost and a high degree of value-added labor also are prime candidates for an automated dispensing machine.

As manufacturers grow and assembly processes evolve, the number of options for automation fluid dispensing also increases. Manual dispensing processes have inherent limitations in quality and throughput, of which time/pressure systems may resolve. Applying both temporal and spatial control to the dispensing process significantly increases the quality and reliability of dispensing, which equates to increased product yields and greater overall assembly line efficiency. Current technology offers manufactures unprecedented opportunities to automate their dispensing processes efficiently, quickly and cost effectively.

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

Ask the EMPF Helpline!

CUSTOMER ISSUE: The EMPF Helpline received a call from an Electronic Manufacturing Services (EMS) provider who had been experiencing open circuits on PWAs (Printed Wiring Assemblies) during temperature cycling reliability screening. The PWAs were built on a Flex-Rigid substrate PWB (Printed Wiring Board) that had BGA (Ball Grid Array) components on it. The Flex-Rigid board was composed of polyimide flex bonded to FR-4 on both sides with a facing layer of Epoxy-Aramid (Thermount) laser drilled with blind microvias. The opens occurred between the I/Os (Input/Output terminals) of chips housed in the two BGA components. There were numerous PTHs (Plated Through Holes) and blind HDA (High Density Assembly) laser-drilled vias in the Flex-Rigid boards, with several of these features occurring along the electrical path between the BGA pads showing the open circuit. The customer wanted to know whether their BGA assembly process could be the cause of the opens.

The EMPF Helpline Response

The following Failure Mode Analyses (FMA) were performed on a sample Flex-Rigid assembly with its BGA components:

- Surface Acoustic Microscopy (SAM) analysis to look for voids in the laminate material that may have occurred during the PWB substrate fabrication or the PWA assembly in the customer's shop.
- X-ray analysis of the BGA component connections, including those in the electrical path showing the open circuit, to determine any BGA assembly workmanship effects as evidenced by the shape and size of each ball contact, or the inclusion of excessive voids in the solder ball contacts.
- Cross-sectioning/Scanning Electron Microscope (SEM) analysis to look for cracks in the solder joints.

Results

The SAM analysis showed no internal laminate voids coincident with the open circuits in question.

From the x-ray analysis, it was determined that the workmanship and solder joint quality of the assembly were within good commercial practice limits. Voids in the solder joints, which are normally occurring features, were less severe than that deemed suspicious by IPC guidelines. It was tentatively concluded that the BGA assembly technique used by the customer was not responsible for the open circuits experienced.

Cross Sections of the microvias in the open electrical path in the assembly showed no cracking or open circuit conditions due to microvia cracking or metallization issues.

Finally, cross sections of the larger conventionally drilled PTHs (that extend through the central 4-layer core of the Flex-Rigid substrate) were made and examined in the SEM. These showed that the open circuit in the electrical path between I/O sites was due to "barrel cracks" or annular cracks occurring around the PTH wall at or near the mid-plane of the hole. This crack location determination confirmed preliminary customer results as well as the X-ray and SAM results.

ACI then researched the commercial specifications for Flex-Rigid printed wiring boards. The relevant document describing Flex-Rigid is ANSI/IPC-2223 "Sectional Design Standard for Flexible Printed Boards". Section 5.2.2.2 of that document, "PTH Reliability for Flex-Rigid" clearly states that the acrylic adhesive used in the fabrication of Flex-Rigid PWBs is a suspected cause of reliability concerns in thermal cycling. The low Tg (Glass transition Temperature) of the acrylic based adhesive is responsible for this.

The customer Flex-Rigid is made by the PWB vendor using adhesively bonded copper on 0.001 inch thick polyimide film. The adhesive layers bonding the copper foil to the polyimide in the flex circuit component of the Flex-Rigid laminate occur near the center of the stack of rigid and flexible substrate boards that are laminated together to form the Flex-Rigid starting material. Cracking observed in the customer submitted Flex-Rigid Laminate took place at the adhesive rich mid-planes of the PTHs, just as the IPC document indicates. A second PWB fabricator was also consulted, and confirmed the preferred use of adhesiveless flex for Flex-Rigid.

Recommendations

It was recommended that Flex-Rigid boards used by the customer be changed to PWBs that use adhesiveless flex. In this type of flex PWB, there is no adhesive between the copper and the Polyimide because it is made by metallizing the polyimide directly. This recommendation comes from both the IPC document and general industry practice. Adhesiveless copper clad polyimide flexible PWB laminate material is somewhat more expensive than the adhesive type, but much less likely to cause cracking of PTHs during thermal cycling.

In addition, the PWB vendor recommended laser-ablation to remove the facing Epoxy-Aramid (Thermount) material directly over the mechanical drill sites to improve through hole wall quality by limiting the exposure of the mechanical drills to the Aramid fibers, which tends to dull mechanical drills.

If you have an electronics manufacturing problem, call the EMPF Helpline at (610) 362-1320

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