Experiences with the transition to Surface Mount Technology in ECET Labs

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abstract

The author has been actively involved with the use of surface mount technology (SMT) in Purdue's ECET labs for 10 years. In that time the department has expanded its use of surface mount devices (SMDs) from use solely in an undergraduate SMT class, to use of SMDs in half of the upper-division courses. During that time the department has also expanded its use of electronic computer aided design (ECAD) software for the design and analysis of circuits and for the design of printed circuit boards (PCBs). The department has purchased equipment suitable for use on SMDs, has actively pursued donation of SMT parts, and has added a second course on electronic manufacturing.

background

Surface mount technology (SMT) was developed in the 1960s & 1970s by IBM and others to reduce the size of electronic component packages and thereby reduce the size of electronic devices designed with those packages (1,2). The technology has other advantages, including reducing package-related parasitic capacitance and inductance, with concomitant increases in operating speeds, and allowing high-speed assembly automation. Disadvantages include the difficulty of heat dissipation from smaller packages with less surface area, difficulty in rework and repair, and difficulty in breadboarding prototypes. The advantages and disadvantages of SMT implementation have been well documented (3).

body

In 2002 the worldwide production of integrated circuits showed 86% of IC production to be in surface mount packages. This impact of SMT on IC production leads us to the conclusion that both the basic concepts of SMT as well as design using SMT design for manufacturability (DFM) and design for testability (DFT) principles must be presented in BS programs.

Likewise, the advantages and disadvantages of designing with SMT are also well documented. The advantages include:

- Smaller component packages
- Smaller printed circuit board (PCB) designs
- Lower package and PCB parasitic capacitance and inductance
- Fewer circuit board layers required relative to the same design in THT
- Many newer components are only available in SMT packages.

The disadvantages include:

- More difficult to breadboard prototype circuits
- More difficult rework
- Automated assembly required for some packages
- Thermal problems associated with differences in coefficient of thermal expansion (CTE) between certain packages and the PCB substrate – typically FR-4.

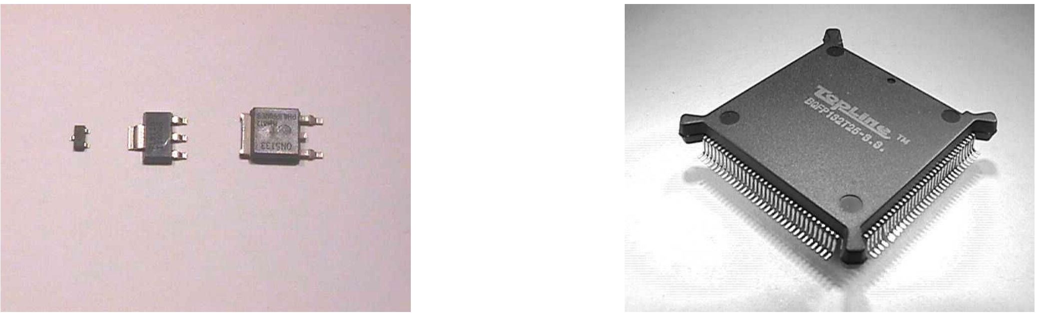

Figure 1. Typical SMT component packages:
left, small outline (SO) transistors, right 132-pin quad flat pack (QFP).

The author has been involved with SMT since the early 1990s. Believing that SMT would have a major impact on both the topics that should be taught in BS EE and EET programs, as well as on all lab-oriented courses, he proposed and was granted a sabbatical for the 1992-93 school year. During that time he was employed as a senior project engineer at Delco Electronics Corp. (now Delphi Delco) and worked in the Electronics Manufacturing Development (EMD) department. At that time, Delco was using approximately 20 million surface mount components daily. The EMD department was charged with looking 3-5 years ahead and developing ways Delco could stay current with the component packages and speeds that were being developed in that time frame.

During the sabbatical period, the author submitted a grant proposal to the Instrumentation and Laboratory Initiative (ILI) division at NSF. This grant was awarded, allowing the EET department to purchase a number of devices specific to the assembly and test of SMT components. Additionally, Delco had sent the author to the National Electronics Production and Productivity Conference (NEPCON) and as a result of contacts made at that conference, an automated SMT placement machine was donated to the department. Matching monies from a General Motors grant allowed the purchase of an automated solder paste dispensing system and a conveyorized reflow oven.

Figure 2. Purdue ECET SMT automated assembly equipment

Subsequently, in 2000 the author submitted a follow-up grant proposal, which was also funded. This allowed the purchase of more sophisticated analysis and test tools.

Several contract electronic manufacturers have donated many of the passive parts necessary for use in the various courses. When a design is changed or a production run is terminated prior to the contract production amount, the contract manufacturers are left with numerous components. They can donate these parts rather than consign them to scrap.

new course development

A further effect of the sabbatical at Delco Electronics was to speed the development of an undergraduate course on designing with SMT and SMT assembly automation. This course was first taught in 1994 with 22 students and in the fall of 2003 64 students were enrolled in the course. Topics in the lecture portion of the course include:

Intro. to Surface Mount Technology (SMT)
IC Fabrication issues re SMT
SMT Devices/Packages
Substrates; Thermal Transfer in SMT boards
Concurrent Engineering in PCB design and production
Substrate Design for use with SMD's
Solder Characteristics, Solder Ball Prevention
Reflow; Thermal Profiling;
Design for Test; Project Assignments and Definitions
Proposal Presentations for student reports
DFT: Boundary scan
DFT: ICT, MDA,
Burn-in; ESS
Design for Manufacturability
HDI, BGAs, CSPs
PCB layout re BGAs (SMD, NSMD), x-ray inspection, testing
SMD Placement Techniques
Placement machines - styles
Inspection Techniques: manual, automated, vision
AOI
Student Presentations and Reports
Functional Testing of Assembled Boards
Functional test implementation
Cleaning? Yes, No, with what?
Alternative Packaging Styles: MCM, COB,
PCB Packaging, Student Presentations of SMT Articles

In addition to courses specifically in SMT, both lower division and upper division courses have become involved in the use of SMT. In lower division courses, SMT has been introduced so that the students have some knowledge of the technology. In upper division courses, the labs cannot make use of the latest ICs in their circuits without the use of SMT since many newer design ICs are only available in SMT packages. In the senior design project design courses, the seniors find that many of their designs must include SMT packages for the same reason. The ECET department has focused on manual soldering operations that can be accomplished with standard techniques used by industry (4). Pace and Metcal are manufacturers of SMT repair and rework equipment that have numerous techniques for soldering and desoldering surface mount components on their web sites (5,6), while Silicon Laboratories (formerly Cygnal) is one of the several IC manufacturers that include rework information on their web site (7). While it is true that specialized soldering equipment makes the use of SMT easier, standard high-quality soldering irons along with magnified inspection lights and robust soldering practices will allow introduction of SMT soldering in all programs. Basic information on SMT soldering is available from a wide variety of sources, including Pace, Metcal, and Silicon Laboratories. For low-cost reflow soldering, one reference is "Have you seen my new soldering iron (8), which describes reflow soldering in a toaster oven! A student project to add a feedback control system could create an inexpensive reflow oven.

In addition to the required SMT knowledge and tools, all lab-oriented courses must consider how to make the transition from through hole technology (THT) devices, such as DIP ICs, to SMT devices. Since they cannot be directly placed on a breadboard like DIP ICs, their implementation must be planned for ahead of their expected use.

As might be imagined, most of the up-to-date information available on both basic and advanced SMT is available on the worldwide web. The author has found these web-based handbooks to be particularly valuable in the courses he teaches:

- Intel Packaging Databook, http://www.intel.com/design/packtech/packbook.htm
- National Semiconductor packaging information, http://www.national.com/packaging/
- Philips Semiconductor IC packages data handbook, http://www.philipslogic.com/packaging/handbook/
- Xilinx packaging and thermal characteristics, http://www.xilinx.com/publications/products/packaging/index.htm

The ECAD package the Purdue ECET department uses, Cadence, with its Capture circuit design and analysis tool and its Layout PCB design tool, adequately supports design with SMT packages. The footprints available in the Layout libraries support all but bleeding-edge SMT component packages. The use of older ECAD software or ECAD software with only limited SMT libraries does a great disservice to the students. While the Cadence package is very comprehensive and therefore relatively non-intuitive to use, it is representative of the software packages the graduates of our program will be expected to use in industry.

recommendations

The author believes that all EE/EET/ECE/ECET programs will ultimately make the transition to the design with and use of SMT-packaged devices. Whether they make that transition in a planned manner or are forced into making it remains to be seen. The author believes that programs that have not yet implemented SMT must:

1. Consider the impact SMT is having in industrial designs
2. Consider how they can begin to incorporate SMT concepts in their design courses
3. Consider how they can begin to transition from THT-packaged devices to SMT-packaged devices in their labs
4. Begin the implementation now.

references

1. ------, “Flip Chip Packaging Services”. http://www-306.ibm.com/chips/products/interconnect/products/flipchip.html.
2. ------, “Ceramic Chip Carriers”. http://www-3.ibm.com/chips/technology/makechip/interconnect/4.html.
3. Holloman, J.K.: “Benefits and limitations of surface-mount technology”. Chapter 1 in Surface Mount Technology for PC Boards. Prompt Publications, Indianapolis, 1995.
4. ------, “Circuittech Guidebook for rework and repair. http://www.circuittechctr.com/guides/guides.shtml
5. Pace, Inc., www.paceusa.com
6. Metcal Inc., www.metcal.com
7. -------, “Hand soldering tutorial for fine pitch QFP devices”. Application note AN114 at http://www.silabs.com/products/docfinder.asp
8. Maxon, K: “Have you seen my new soldering iron?” At http://www.seattlerobotics.org/encoder/200006/oven_art.htm .

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Glenn Blackwell currently is teaching in the areas of project courses, surface mount technology (SMT), and electronic manufacturing. To increase his knowledge in the areas of Surface Mount Technology (SMT) and electronics manufacturing , he spent the 92-93 school year on sabbatical leave at Delco Electronics, Kokomo, IN, as a Senior Project Engineer in their Powertrain Electronics Manufacturing Development Group. To increase his knowledge in controls techniques and automation software, he spent the calendar year 2000 on sabbatical leave to work with several contractors in the automation field. He supervises EET design projects in the sophomore year and previously has done so for project courses in the freshman, junior, and senior years. He is a registered Professional Engineer in Ohio and Indiana, and consults in the areas of SMT and UL compliance.