Interdisciplinary Automated Manufacturing Laboratory

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Abstract

There is a need in industry for technology graduates who can use a combination of electrical and mechanical concepts in the design, installation, and service of products and production systems. Preparing Associate Degree graduates for this role is difficult because four semesters is too short for extensive education in both disciplines. Penn State Altoona Campus addressed this problem by: 1) modifying three courses offered at the Associate Degree level to include concepts that bridge the two technologies; and 2) introducing a new four-year degree program, Bachelor of Science in Electro-Mechanical Engineering Technology (BSEMET), in the Fall, 1994, semester.

The solution to the training problem created two major pedagogical problems. The first problem was to properly deliver the interdisciplinary content in the three modified courses. While the courses covered both product design and production system design and had a mix of electrical and mechanical concepts, there was no effort to use the same product examples in all three courses. The second problem was teaching standard 16 student laboratory sections with single production machines and integrated manufacturing systems.

This paper proposes two initiatives that would overcome the instructional delivery problems associated with cross training in electro-mechanical concepts and the use of large automated manufacturing systems in traditional laboratory sections. These initiatives involve: 1) the integration of a product design problem into manufacturing courses; 2) the development of a laboratory environment that permits standard laboratory class sizes of 16 students to effectively use single production machines and integrated manufacturing systems. The second problem is significant because many colleges add manufacturing systems to laboratories but few address the training issues associated with integrated manufacturing systems hardware in standard laboratory sections.

Introduction

The Penn State Altoona Campus offers the first two years of 180 baccalaureate programs, two ABET accredited Associate of Science (AS) degree programs in Mechanical and Electrical Engineering Technology (MET/EET), and a new Bachelor of Science degree in Electro-mechanical Engineering Technology (BSEMET).

In April, 1996, the Altoona Campus begins construction of an Advanced Technology Center (ATC) for the two- and four-year technology programs plus first- and second-year courses for the pre-engineering students. The new facility will have two state of the art classrooms and five additional laboratories for advanced CAD, CAD/CAM, CAE, instrumentation and control, automated manufacturing, materials processing, machine shop and a project laboratory.

The initiation of the BSEMET program and the development of the ATC began with the industries the university serves. These central Pennsylvania industries have experienced the following changes in their manufacturing operations.

- *New production systems include a high degree of distributed control and information integration*[1].
- *Distributed control of discrete processes using programmable logic controllers (PLC) is increasing*[2].
- *Electrical and mechanical disciplines are merging in the design, manufacture, and service of products for the home and office*[3].

The changes in product and production design suggests that the traditional Associate Degree programs in EET and MET need to provide a broader education[1]. However, the number of courses required to produce a competent electrical and mechanical engineering technology (EET/MET) graduate in just four semesters does not provide much leeway for cross training. The Penn State Altoona Campus with the support of Penn State's School of Engineering Technology and Commonwealth Engineering (SETCE), regional industries, and the technical advisory committee, addressed this interdisciplinary instructional problem with the following two initiatives.

1. *Three courses offered at the Associate Degree level were revised to include concepts that bridge the two technologies.*

Three courses taken by second semester MET students, IET 215 Production Design, IET 216 Production Design Laboratory, and MET 210w Product Design were modified to include electro-mechanical concepts and activities critical for the design and implementation of products and production machines.

2. *A new Bachelor of Science degree program in Electro-Mechanical Engineering Technology (BSEMET), was implemented Fall 1994.*

The BSEMET program is designed to give students who complete a traditional two-year MET or EET program two additional years of study focused on concepts that bridge the disciplines. The technical courses in the final two years of the BSEMET program fall into two categories: 1) courses addressing interdisciplinary concepts, and 2) courses that address advanced system issues. For example, the junior year for EET students includes several interdisciplinary courses that broaden mechanical concepts for the EET group. Three of these courses are IET 215 Production Design, IET 216 Production Design Laboratory, and MET 210 Product Design. In the same year, the MET students take several interdisciplinary courses to broaden their background in electrical concepts. Then, courses directed at advanced system concepts, EMET 430 Automated Machine Control Technology and EMET 440 Electro-mechanical Project Design are taken. These two senior level courses in the BSEMET program focus on concepts critical to the design and control of electro-mechanical systems.

Course Weaknesses

In developing the lectures and laboratories for the five courses, three major implementation problems were identified.

1. *It is difficult to effectively teach a laboratory class of 16 students on single production machines and integrated manufacturing systems.*
2. *The existing production hardware is not integrated into a production system suitable for teaching the distributed control found in flexible manufacturing cells and systems.*

3. *Courses that teach production system design (IET 215/216) and product design (MET 210) are taught in isolation.*

Concurrent engineering, design for manufacture and assembly, fixturing, part feeders, automated assembly, CNC programming, robot programming, and fundamental sequential machine control are taught in IET 215/216 and MET 210w; however, the concepts are taught using different product and production examples. Student learning would be enhanced if the product and the production system design used the same product example throughout the sequence. After a thorough study of the three problems by department faculty, the following solutions were recommended:

1. *Use a common product design problem throughout the IET 215 to EMET 430 course sequence*[4].
2. *Develop a Student Programming Laboratory Bench (SPLB) that supports programming of all automation laboratory systems by classes of 16 students working in teams of two.*
3. *Develop an integrated automated manufacturing laboratory which includes existing robots, a new conveyor, existing CNC machines, and a new automated assembly station with automated storage and retrieval*[5].

The Implementation Process

A three step development plan is necessary to implement the three recommendations.

Step One: Product Development

The first step in the plan is to develop product specifications that define the type of product for use in the IET 215 to EMET 440 course sequence[6]. Characteristics of the product family include:

- *The ability to represent the initial design with violations of good design rules.*
- *The opportunity for students to change the product to comply with design for manufacture and assembly standards.*
- *The flexibility to allow each student design team the opportunity to make their redesign unique.*
- *The ability to use the same parts feeders and production/assembly fixtures for the product from each student group.*

A ball bearing maze game is an example of the type of product family that would be used at the beginning of the course sequence. Starting with a bolted maze, the students in MET 210 will explore alternative designs that eliminate fasteners and make automated assembly possible. One solution for the problem would be to use a press fit assembly. Each team can develop a unique maze and lettering, but the overall dimensions will permit each design to use the same fixturing and tooling. In the Production Design course and laboratory (IET 215/216), student teams work on production problems like CNC machining codes, fixturing, part feeders, etc. that support the manufacturing of the product. The common features of the design permit the product from each team to be used in the Automated Machine Control Technology (EMET 430) course as a product that the automated manufacturing system must produce and assemble. The EMET 440 course gives students an opportunity to develop improved fixturing or fixed automation machines for assembly of the entire product or subassemblies of the product[7]. The current course content and laboratory exercises will be changed to include the common product design throughout the sequence. In addition, a new product will be introduced each year so that each class has a unique design problem.

Step Two: Training System

The training system includes programming stations called Student Programming Laboratory Benches (SPLB) and an advanced integrated manufacturing system. These two major components are necessary because teaching students to work on the complex systems used in automated manufacturing is a two step process. First, students must master the operation of the hardware and programming of the software for the individual automation machines, and second, they must learn how to integrate the machines into a production system. The eight SPLBs are designed to teach concepts that include: interfacing devices with programmable logic controllers (PLC), programming PLCs, robot programming, CNC machine programming, and sequential machine control[8]. Each SPLB has an Allen Bradley PLC, a micro-computer, and a sampling of the devices that are used on the larger automation system including: sensors, a bar code reader, lamps, switches, a robot, and small conveyor. The robot and conveyor are shared between two SPLBs through a quick disconnect interface. The shared connection to the training devices will not create a problem because experience indicates that the program development time exceeds the testing time by a large factor. The interface is a patch panel to wire the PLC input/output (I/O) modules to the conveyor and robot I/O. Connectors on the PLC side of the interface permit either SPLB to connect to the trainers. The wire jumpers on the panel permit students to wire the PLC interface and permit the introduction of faults.

The laboratory exercises first concentrate on PLC programming using switches, lamps, and sensors[9]. As a node on the Allen Bradley (AB) data highway, the microcomputer serves as a programming device for the AB PLCs through AB software. Using the QBASIC language and the serial ports, the same computers are used to learn robot programming. In addition, the SPLBs support the programming of the lathe, mill, and laser engraver using the MasterCAM CNC programming software with the laboratory LAN as the link to the CNC machines. Figures 1 and 3 illustrate the layout of the hardware in the automation laboratory and the interface between the SPLBs and the automated manufacturing system.

An integrated manufacturing system is the second major component of the training system. The layout of the automation system is shown in Figure 1

Step Three: Implement the Distributed Control System

The distributed control system links the eight Student Programming Laboratory Benches (SPLBs) to the automated manufacturing system. The detailed interface for the programmable logic controller (PLC) cell controllers and the system computer is illustrated in Figure 2. Three PLCs perform cell control functions for the following hardware: CNC machines(mill, lathe, and laser), conveyor, and assembly cell. As the diagram in Figure 3 shows, the PLCs use sensors, limit switches, bar code readers, and cell data to manage the sequential operation in each area. The management and transfer of robot and CNC program files is accomplished by the system computer using cell controller software like Dmax from Intellution Corporation. The system computer is part of the Allen Bradley data highway and the laboratory LAN. This architecture gives the training laboratory flexibility in how manufacturing hardware is used in the exercises and permits direct numerical control because the production machines have the capability to be nodes on the LAN.

The Operational Laboratory

In operation, the SPLBs and automation system will function as follows:

- Each team of two students uses the computer and the Allen Bradley PLC at the SPLB to develop a program for the control of one element in the automated manufacturing system (i.e. the movement of pallets on the conveyor).

- When the program is ready, the team transfers the code file over the AB data highway to the PLC on the automated manufacturing system.
- The team tests the code on the manufacturing system (i.e. conveyor).
- If the solution works, they move back to the SPLB to work on the next part of the system control problem. If bugs are identified, they return to the SPLB and correct the problem.
- Another team moves their solution to the automated system and the process is repeated.
- Again, the program development time is greater than the verification time so one automated manufacturing system will support the eight SPLBs.

A similar technique is used to teach the programming of the CNC lathe, mill, and laser and the material handling robots. Students create programs for the robots using QBASIC and create CNC machine code using MasterCAM software on the SPLB computers. In addition, the generation and testing of programs for the robots and CNC machines in the manufacturing system from each of the SPLBs is supported by the laboratory LAN and the cell control software. The LAN permits the program to be transferred from the SPLB to the cell controller, and cell controller acts as a direct numerical control (DNC) system for the CNC machines and robots.

Conclusion

A strategy for effectively delivering a multidisciplinary program has been presented. Manufacturing was chosen as a program emphasis because of the needs of industry and because of the wide variety of electromechanical applications. An extensive amount of time will be devoted to developing product families that enhance design for manufacture concepts and integrated manufacturing activities.

Bibliographic Information

James Rehg has Bachelor and Masters degrees in Electrical Engineering from St. Louis University and has been teaching and consulting in manufacturing automation for the last fifteen years. His robotics text is in the third edition and his most recent text is titled Computer-Integrated Manufacturing.

Bruce Muller graduated from Rutgers University in 1978 with a bachelors degree in Mechanical Engineering. Following three years of turbine design experience at Westinghouse Electric, he attended graduate school at Penn State completing a Masters degree in both Mechanical Engineering and Industrial Engineering by 1986. He currently teaches at the Penn State Altoona Campus with specialties in design, manufacturing, automation, and computer-aided drafting.

Bibliography

1. Tomovic, Mileta "A Manufacturing Laboratory to Prepare Technology Students for the 21st Century" Proceeding of 1994 ASEE Annual Conference PP 300-301
2. Fabiano, Phil "An Engineering Technology Course Responsive to the Needs of Industry" Proceeding of 1994 ASEE Annual Conference PP 2087-2091

3. Nagle, Edward “What a Graduate of an Associate Degree in Manufacturing Engineering Technology Program Should Know” Proceeding of 1994 ASEE Annual Conference PP 2393-2395
4. Wilczynski, V “Integrating Engineering Design Across the Curriculum: Results from the Trenches” Proceeding of 1994 ASEE Annual Conference PP 1877-1881
5. Brice, C. W., “Design of a New Electromechanical Systems Instructional Laboratory”, IEEE, May 1, 1991, v6, n2, pg 872
6. Tillman, Tracy “A Two Course Sequence for Teaching Concurrent Engineering and Lean Production Manufacturing” Proceeding of 1994 ASEE Annual Conference PP 271-273
7. Tavora, Carlos J. “A Laboratory Design Project on Equipment Automation” Proceeding of 1994 ASEE Annual Conference PP 1944-1946
8. Beaini, J. E., “Integrated Electromechanical Controls Laboratory using Programmable Logic Controllers”, American Controls Conference, 1993, pp2036-2040
9. Kittaneh, Omar “Preparing a Course in Programmable Logic Controllers for Electrical/Mechanical Engineering Departments” Journal of Engineering Education, January 1993, PP 1583-1585

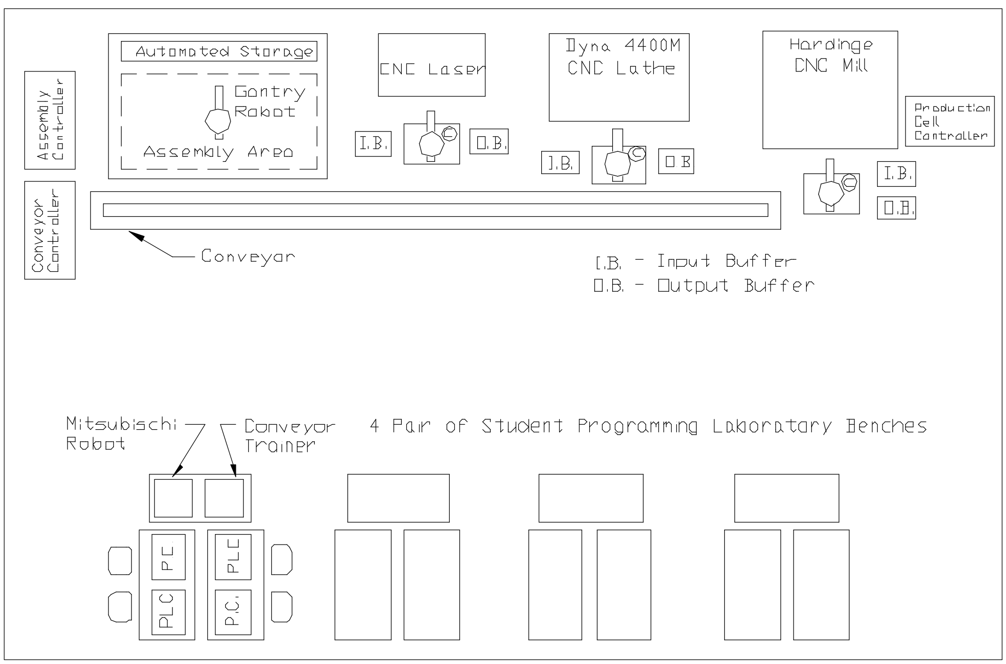

Figure 1

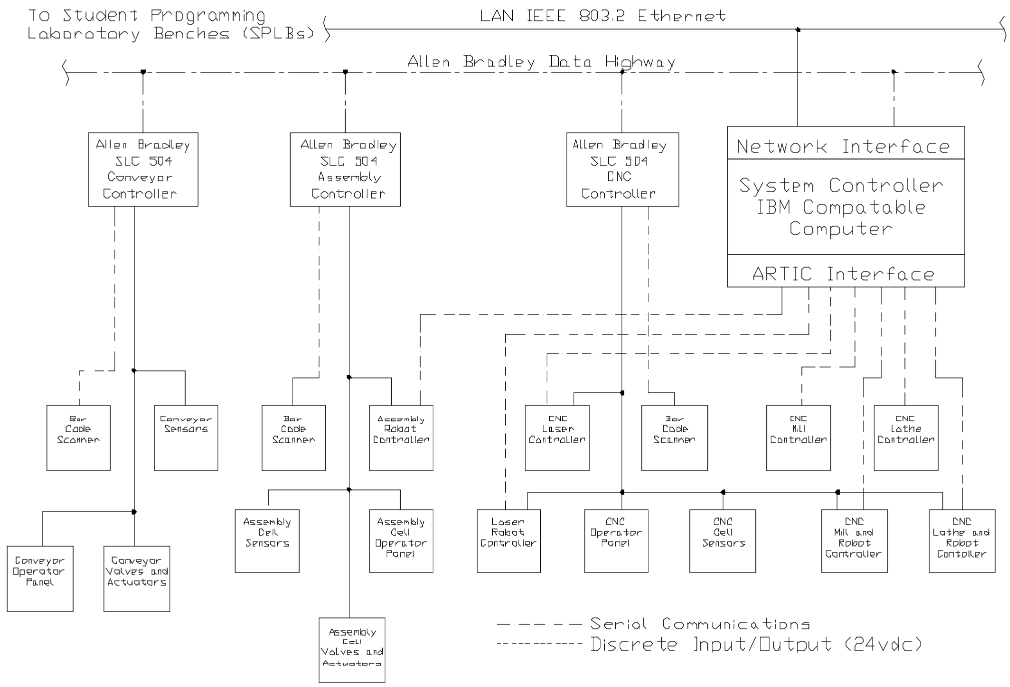

Figure 2

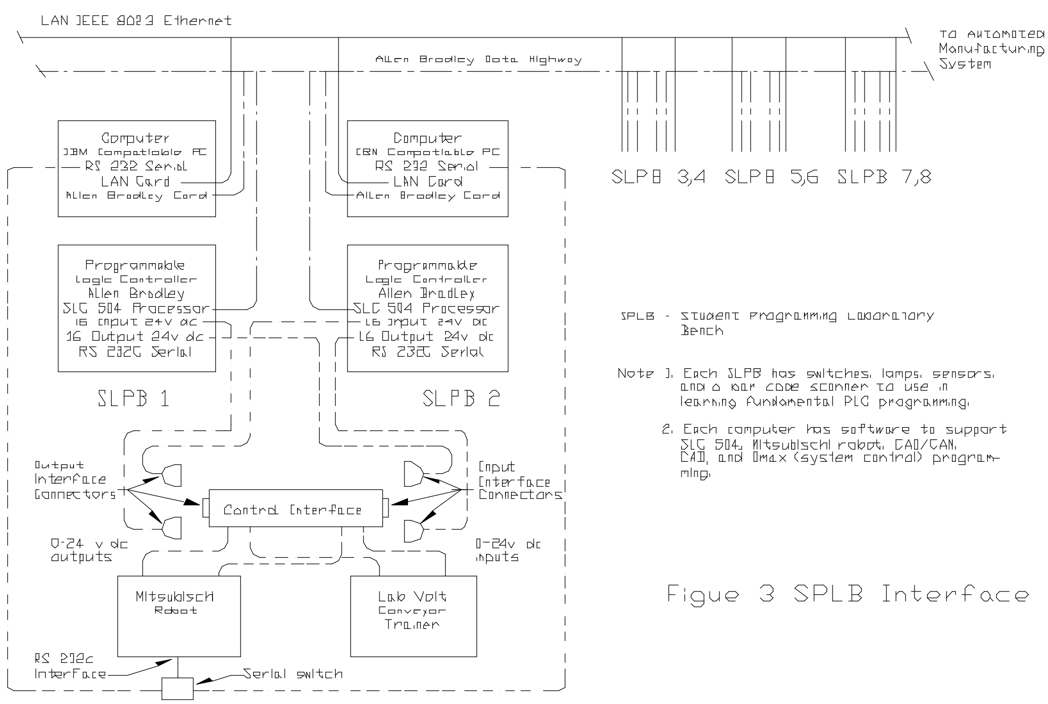

Figure 3