Development System for Undergraduate Microprocessor Courses

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ABSTRACT

This paper describes a two-semester sequence of microprocessor courses based on the Intel 8086 microprocessor and its associated microprocessor lab. The first course in the sequence focuses on assembly language programming while the second course places an emphasis onmicroprocessor-based hardware design. This adequately covers both software and hardware fundamentals of a 16-bit microprocessor. In the lab for the second course, each student designs and implements a complete 8086-based microcomputer board. Once this prototype board is implemented, the student can use it for various microprocessor-based applications. A microprocessor development system designed to provide up-to-date development tools for the lab is also described. This development system is implemented as a network consisting of six stations, each equipped with a PC, an emulator, a logic analyzer and an EPROM programmer.

INTRODUCTION

For many microprocessor courses, laboratory projects are often limited to assembly language programming. A main reason is that software development tools such as cross assemblers, linkers, and simulators [1] for various microprocessors that run in PCs are readily available to create executable modules. In addition, students can execute and test their programs by using PCs and low-cost single-board, microcomputers specifically designed as a teaching tool. However, it is important for engineering students, especially those majoring in Electrical or Computer Engineering, to receive hands-on training on microprocessor interface and hardware design [2], [3], as well as assembly language programming. Also' equally important, is for students to learn the usage of modern development tools in designing their projects.

MICROPROCESSOR COURSE SEQUENCE

Due to the complexity of 16-bit microprocessors, a one-semester course is no longer sufficient to adequately cover both software and hardware fundamentals of a typical microprocessor. For this reason, at The University of Texas at El Paso the Electrical and Computer Engineering Department offers a two-semester sequence of microprocessor courses based on the Intel 8086 microprocessor. Such sequences and courses based on 16/32 bit microprocessors have also been developed at other universities [3]-[5]. The first part of the sequence is EE 3376 Microprocessor Systems I and EE 1376 Laboratory for EE 3376. In EE 3376 and EE 1376, students learn the architecture and instruction set of the 8086, assembly language programming, and macro assemblers. They use PCs and Borland Turbo Debugger to design, implement and debug their assembly language programs.

The second part of the sequence consists of EE 3478 Microprocessor Systems II and EE 1478

Laboratory for EE 3478. The emphasis in EE 3478 is placed on the hardware aspect of the 8086 microprocessor family. This course discusses the concept and principle of system bus and LSI system supporting devices, and the design of various system components, such as bus control circuits, I/O interfaces, and memory modules. To acquire a working knowledge of microprocessor-based design, a student must enroll in EE 1478 currently with EE 3478. In the laboratory, students implement and test their assigned design projects.

MICROPROCESSOR DEVELOPMENT SYSTEM

The department has recently implemented a microprocessor development system to provide necessary development tools mainly to support EE 1478. A block diagram of the system is shown in Figure 1. This system is configured as a network consisting of six stations, each equipped with a PC as the host, an HP 64700 emulator for the Intel 8086/8087 microprocessor, an HP 1660 logic analyzer, and a universal IC programmer. The HP 64700 emulator includes a LAN interface and is hosted by a PC running under Window 3.1. Each emulator includes a built-in 8087 coprocessor, 128 KB emulator memory, and a 48-channel emulator bus analyzer. The HP 1660 logic analyzer provides 136 channels and a flexible disk drive to store data. The six stations are connected together through Ethernet to share files and a printer.

Emulators and logic analyzers facilitate the design and debugging of microprocessor-based circuits, thus significantly reducing the time required and enhancing the student's chance of completing the project implementation. Once a prototype board, such as the one described previously, has been implemented, the student can use it for various interface design projects by redesigning control programs and modifying 1/0 devices. However, the program must be integrated with the target system for testing and debugging. The software/hardware integration for testing can be accomplished by: 1) Programming EPROM's and installing them on the target system; and 2) Using a microprocessor emulator connected to the target system.

Using EPROMs provides an inexpensive means to test a program on the prototype board. However, content modifications of an EPROM is very time-consuming due to its lack of in-circuit programming capability. Whenever changes need to be made to the stored program, the EPROM must be removed from the target system, erased by UV light, reprogrammed, and then inserted in the target system. This is particularly true in our case, where once the minimum microprocessor board is developed, a student needs to use it to design and test different programs for various applications, thus requiring frequent reprogramming of EPROMs.

A microprocessor emulator in conjunction with a host development system is a very effective debugging tool. In debugging a prototype system, the microprocessor on the target system is removed from its socket and is substituted with a connector attached to the emulator. The emulator then executes the: program being tested in the environment of the prototype system under the control of the host. Programs can' be executed with breakpoints and can be stepped through while the status is being displayed. Since the emulator is connected to the target system during the entire debugging process, several emulators are necessary to adequately support several students in each laboratory session, Once the code is fully debugged, **it can** be stored into EPROM via a universal IC programmer. By inserting the EPROM into the target board, it can operate as a stand alone circuit.

EE 1478 LABORATORY EXERCISES AND PROJECTS

For the first two weeks, students do lab exercises designed to become familiar with the usage of logic analyzers and emulators. Students use logic analyzers to monitor timing signals, address lines, data lines, and handshaking bus signals to understand various bus cycle timing of 8086-based boards. They also use emulators to trace and execute programs, and exercise various control commands to configure memory mapping, set breakpoints, display and modify registers and memory locations, and display trace information.

During the next seven weeks, each student designs and constructs a complete minimum 8086-based board.- This minimum configuration has 4K EPROM, 4K RAM, a push-button reset logic, a bus interface of the 8086, and simple parallel input/output devices using switches and LEDs. In order to verify the hardware implementation, a demonstration routine is required to be programmed into the two 2K x 8 EPROMs so that the system starts executing this routine when the power is turned on. This routine will simply input a byte from the switches and store it into the RAM as the initial data byte, and repeatedly rotate the data byte in the RAM by one bit and display it on the LEDs after a short delay.

The entire project is divided into the following schedule:

WEEK #1 - clock circuit and reset logic.
WEEK #2 and #3 - address latches, interface of 8255 to 8086 and EPROMs to 8086, and connections of LEDs and switches.
WEEK #4 - EPROM programming and debugging.
WEEK #5 - Debugging and schematic diagram.
WEEK #6 - Adding 4K RAM and modifying the test routine and schematic diagram accordingly.
WEEK #7 - Project report.

Once implemented, this minimum microprocessor board is used for laboratory exercises to gain hands-on experiences on designing various interface circuits in the remaining semester. Some design projects chosen by students are:

Serial interface to CRT terminal or modem.
Interface and control of 8-bit A/D converter.
Traffic light controller.
Programmable security system with sensors.
Programmable clock and time measurement controller.
Programmable temperature sensor and controller.

These laboratory projects contain significant programming as well as additional hardware design and interface components. Some similar design exercises have been reported in [2]-[5]. With the development system, students are able to develop their programs, test the code, design and debug 8086-based hardware projects, emulate and test their wire-wrapped circuits, and integrate software and prototype boards, all by using this microprocessor development system.

The students in EE 3442/1442 Digital Design II also benefit from the availability of logic analyzers and IC programmers for their design projects. This development system also allows some students in EE 1412/EE 2412 Senior Project to design more significant senior projects involving microprocessors. These projects could be applications of microprocessors to various industrial problems such as automatic controller design, real-time monitor design, data acquisition and processing, and display terminal implementation.

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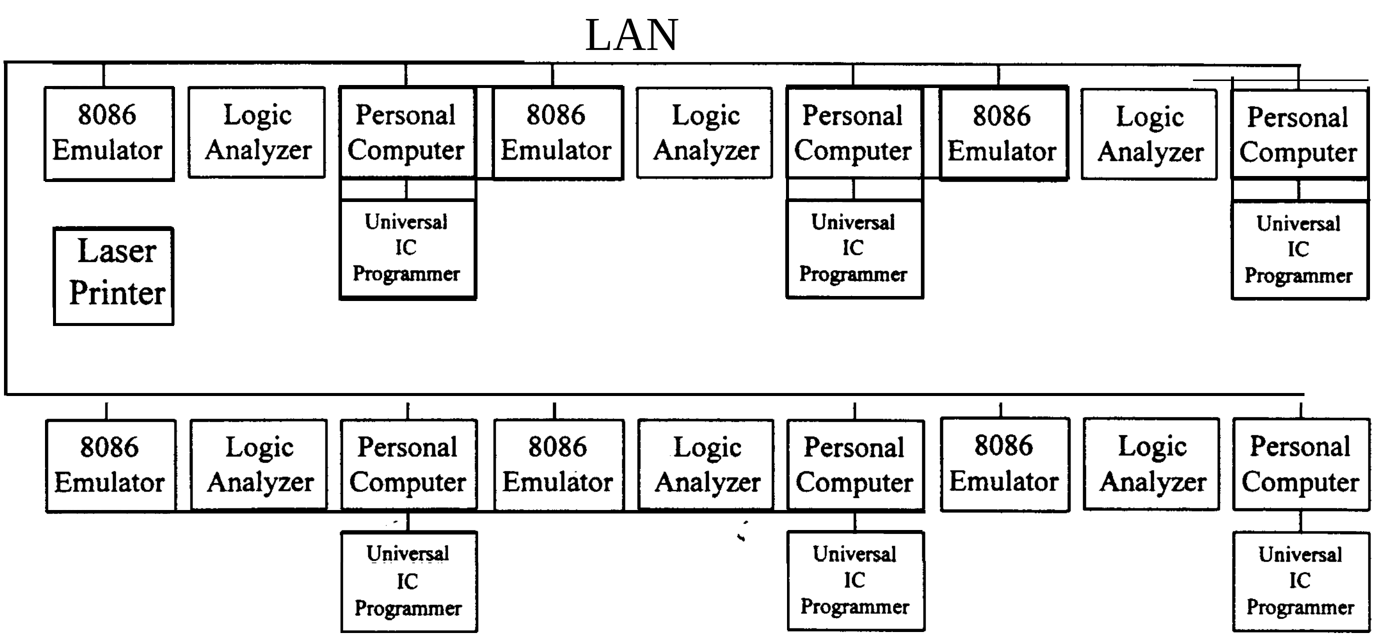

Figure 1 Overall organization of the microprocessor development system.