Introducing a Microprocessor Laboratory Experience for Entering Freshmen

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Abstract

As part of a new freshman course in Electrical and Computer Engineering at the University of Minnesota, Duluth, each faculty member in the department was asked to introduce the students entering the program to an area of speciality in his or her field. This paper reports the approach, methods, hardware, and results involved in introducing new students to a microprocessor laboratory experience. Included is a description of the microprocessor system used by the students, software experiments performed in class and in homework exercises, and feedback from students regarding the microprocessor portion of the course. In short, teaching entering students how to use a microprocessor system was rewarding and enlightening both for the students and for the author.

Background

Students entering an engineering program are faced with a daunting sequence of math and physics courses that must be completed before traditional engineering topics can be addressed properly. Most engineering topics require some skills in calculus and differential equations and some knowledge of basic physical phenomena to use as foundations for developing material. Microprocessor programming and interfacing is one area that does not require sophisticated preparation, and with today's technology, significant microprocessor-based systems can be described and used in introductory classes without exceeding the preparation level of beginning engineering students. Furthermore, particularly in a department called Electrical and *Computer* Engineering, introducing microprocessors very early in the students' technical careers incites interest and inspires excitement in the topic and in the program.

Because other faculty in the department also were eager to present their own special areas of expertise in this new quarter-long freshman course, very limited time was available for devoting to a single topic such as microprocessor systems. Consequently, the choice of processor and of topics to be included was critical to success. The processor selected is a microcontroller in Motorola's 6805 family line. This family is well-established and still popular. In fact, during 1995 Motorola ran a design contest based on a member of that same processor family. The processor offers manageable simplicity while exposing students to all basic techniques of memory addressing, data manipulation, and input/output. The topics for discussion in class focussed on arithmetic, including software techniques for multiplication and division, and interfacing to a keypad and multi-digit display.

Hardware

The hardware implementing the microprocessor laboratory stations for this course had to be absolutely minimal in all respects. Virtually no time was available in class for describing more than just rudimentary connections between the processor and necessary input and output devices, and any extraneous components had to be avoided. The resulting lab station hardware is based around the Motorola 68705P3 microcontroller, and is built into an old telephone handset. The 68705P3 is a full-featured microcomputer on one chip, including clock generation with no external components and input/output ports that are designed to interact directly with conventional LED displays and switches. The telephone handset includes a standard twelve-key keypad for use as an input device, and also provides familiarity for the students, to reduce the intimidation felt by many students when faced with a computer that they can hold in their hands.

This hardware was used in Fall, 1995, in a class of almost one hundred students. The size of the class prohibited holding class meetings in our existing microprocessor lab. Instead, a dozen of the telephone-handset-based computers described above were constructed, and passed through the large class to establish groups of eight or so students per station, and the stations were powered by six-volt lantern batteries to make them entirely self-contained. Figure 1 shows the schematic for the lab stations. As the figure shows, there are almost no components other than the microcontroller chip itself. The electrical characteristics of ports B and C on the 68705P3 allow direct connection to the four-digit calculator-type LED display for use as an output device. Port A includes internal pull-up resistors so that no external components are required to connect to the telephone's standard twelve-key matrix keypad. The clock generator in the microcontroller can operate without an external crystal by shorting the two crystal pins together as shown. The only additional external electronic components are the power-on reset capacitor and the diode shown in the schematic, which serves both to reduce the six-volt battery voltage to an acceptable 5.3 volts and to protect the circuit from accidental reversed battery connections. The circuit is wire-wrapped on a small perforated board built into the earpiece of the telephone handset, and is connected to the keypad included in the handset to complete the system. Monitor software programmed into the internal EPROM in the 68705P3 allows the user to examine and modify memory and to execute programs stored in memory, using the keypad as an input device and the'LED display as an output device. Figure 2 is a photograph of one of the lab stations, showing how the station circuits are visible to students. With the quartz window in the 68705P3 package, even the silicon chip implementing the microcontroller itself can be examined and discussed.

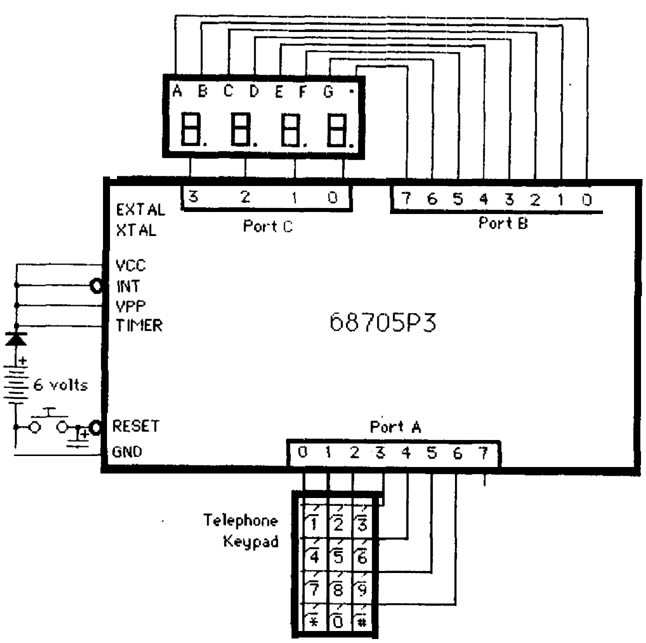

Figure 1. 68705P3 system schematic

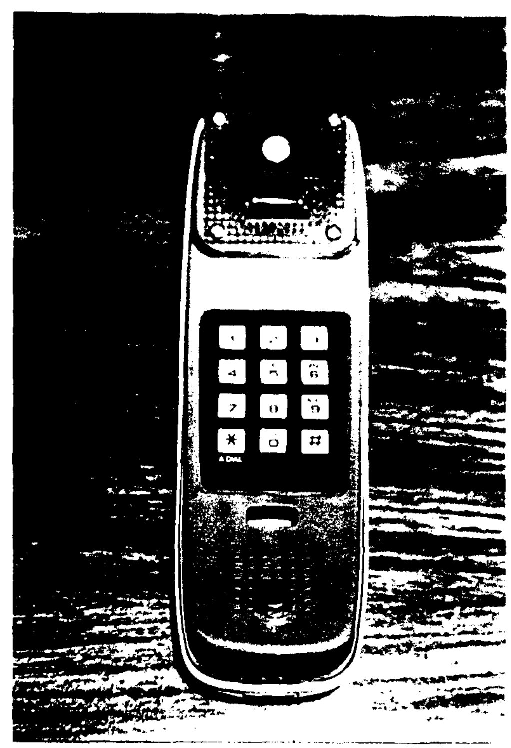

Figure 2. Photograph of lab station

Course Content

Because of the need to squeeze introductions to many Electrical and Computer Engineering topics into this one quarter-long course, only two lectures were devoted to discussing microprocessor systems in general, and the lab station described above in particular. Packaging enough material into two lectures to make it possible for students to get a feel for microprocessors ystems was a challenge. Some topics were abbreviated, with only part of the story being told, while other topics were omitted entirely. Nevertheless, the content of the two lectures did expose students to enough material to make their experience with the lab stations memorable.

In the first lecture, no previous knowledge of digital systems or programming was assumed. The first topic was hexadecimal numbers and arithmetic in base sixteen, including definitions of bit and byte, etc. Then a brief introduction to the 68705P3 processor introduced the accumulator, the carry, negative, and zero flags, and a description of the RAM and EPROM memory built into the microcontroller. No mention of other registers such as the index register or stack pointer was made, and only the zero-page memory addressing mode was discussed. Since the 68705P3 includes only 112 bytes of RAM starting at address 16, limiting addressing to page zero was not a restriction for student programs. Only a selected portion of the 68705P3 instruction set was presented, including instructions that modified the accumulator and instructions that involved immediate operands and memory operands in page zero. Unconditional branches and simple conditional branches that depended only on the Carry, Negative, or Zero flags were included. The service routine for the software interrupt instruction was used to scan the keypad, and the "swi" instruction was described to students as a “customized’ instruction named “key,” which collected keystrokes from the keypad. Not described for the students was the timer interrupt service routine, which interrupted student programs every millisecond or so behind the scenes to scan the four-digit LED display and keep its contents alive while the student software executed.

To complete the first lecture, a sample program was developed that added two one-digit base-ten numbers entered from the telephone keypad and displayed the two-digit base-ten sum. The program was structured to collect and echo to the display the two single digit operands in the first 17 instructions, and then to produce and display the sum in the other 13 instructions, for a total program length of 30 instructions. This program was described and demonstrated to students during class. The homework assignment given at the end of that first lecture was to modify the last 13 instructions of the addition program to produce the difference of two one-digit base-ten numbers, and to display it, with sign if negative, on the LED display.

In the second lecture period, students used the lab stations to enter and execute the subtraction programs they wrote for the first homework assignment, using the monitor program in the 68705P3’s EPROM. The lecture content consisted of a description of loops, branches, and other programming forms. In order to do something non-numerical, a program that scrolled a message across the LED display was developed in class. The second class period ended with a second homework assignment consisting of modifying the last part of the addition and subtraction programs to accomplish multiplication and division of two one-digit base-ten numbers by performing iterative addition or subtraction, displaying the product or the quotient and remainder on the LED display as base-ten numbers. Unfortunately, there was no opportunity for students to test those programs, since after two lectures, the course moved onto topics other than microprocessor systems.

Results

The goal of this introductory freshman course was to expose incoming students to various topics in Electrical and Computer Engineering, and to inspire them and incite interest in the topics and in the program. The two lectures of the course devoted to microprocessor systems described in this paper were successful at that goal with many students. Microprocessor systems using today’s technology can do amazing things with very little hardware, and the lab station described above attempts to take advantage of that characteristic of technology to excite students about the topic. The material was fun to teach, and students enjoyed actually getting their hands on the lab stations

However, only two lectures is too short a time to exploit the features of a microprocessor system fully. A preceding lecture or two introducing the binary number system, hexadecimal representation, and binary arithmetic would have made the microprocessor topic much more approachable for the students, and an additional lecture or two of time following the two lectures allowed for this class would have permitted students to test their multiplication and division programs and to experiment with other features of the processor such as indexed addressing, etc. On course evaluations at the end of the quarter, some students complained that too little time was devoted to discussing the microprocessor system topic, which indicates that those students were interested enough in the discussions to want more. Well, getting students to "want more" is perhaps a good way to describe the goal of the course. If these students are indeed inspired enough to pursue the vigorous engineering program that lies ahead of them in order to gain more information on topics such as microprocessor systems, then this course has accomplished its mission.

Summary

Exposing beginning engineering students to a microprocessor laboratory experience was done successfully in only two lectures in our introductory freshman engineering class. Doing so required rigorous minimization of hardware complexity and careful selection of topics describing the processor and its software. Other departments considering attempts to attract or inspire students entering their programs using sophisticated technology should be encouraged by these results. What must be done is to dazzle the students without intimidating them. The microprocessor lab experience introduced using the hardware and techniques described in this paper did just that.

References

1. ***MC68(7)05P Series 8-Bit Microcomputers,*** Motorola, Inc., 1984.

Biography

CHRISTOPHER R. CARROLL received a Bachelor of Engineering Science degree from Georgia Tech, and M.S. and Ph.D. degrees from Caltech. After serving in the Electrical Engineering department at Duke University, he is now Associate. Professor. and Assistant. Head of Electrical and Computer Engineering at the University of Minnesota Duluth. His interests include special-purpose digital systems, VLSI, and microprocessor applications, especially in educational environments.