# Designing with Microprocessors
# A Course for Electrical Engineering Students at NDSU

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## ABSTRACT

A new course, "Designing with Microprocessors", for Electrical Engineering majors has been developed and introduced at North Dakota State University, Fargo. This paper discusses the rationale behind the design of the course, describes the course contents and the list of experiments and shares the experiences of its first offering during the spring of 1981.

## 1. INTRODUCTION

Microprocessors along with their associated hardware and software are relatively new and unique devices. Due to the great advances made in VLSI technology, these devices have become available at low cost and with high capabilities. They are used in a wide spectrum of applications ranging from automobiles to space shuttles, from children's toys to home computers and from household appliances to more sophisticated industrial controllers. New applications for microprocessors are found every day. In addition, the rapid development of microprocessors has brought forth a dramatic change in design philosophy associated with control and computing systems. No longer does one deal with a large number of discrete components, as many of their jobs are carried

out using simple software. When the software becomes too complex, special purpose hardware may be required. To aid in the design of these systems, a new crop of development tools have emerged.

All the above developments have opened up new areas for the engineers to learn and to pursue. This has placed new responsibilities on engineering institutions. They must educate the future engineers in the proper and effective use of these new devices and to motivate them to carry out innovations in this field. The use of microprocessors has become so widespread that engineers of every discipline find it necessary to learn something about them. As the needs of each category are understandably different, no one course will be satisfactory and hence a number of course proposals have been suggested and implemented at many institutions [1, 2].

In contrast to other groups of engineers, who may be interested only in the application of microprocessors, electrical engineers are expected to know all aspects of microprocessors, namely, hardware, software and applications. They should understand the theory as well as the practice of microprocessor engineering. At least one course should be included in existing electrical engineering curricula to cover the above topics. This poses a difficult problem for electrical engineering departments. They must develop a suitable place in electrical engineering curricula where the course(s) will cover the necessary material to the required depth at the right time. A new course, "Designing with Microprocessors", developed by the EEE department at NDSU to achieve the above objectives is described in this paper. It is a modification of earlier offerings on microprocessors taught under the heading Special Topics.

## 2. COURSE SETTING AT NDSU

A successful course in microprocessors for electrical engineering majors should cover hardware, programming and applications and at the same time avoid undue emphasis in any one aspect leading to either a technician's course or a programmer's course. Laboratory work involving microprocessors should form an integral part of the students' training. In addition to exposing the students to various development tools, the philosophies of their operation and design should be taught. The following decisions were made in order to establish an appropriate setting for the course.

(1) A course on digital system principles would be made a pre-requisite and another course on digital electronics would be made a pre- or co-requisite.

(2) The course would be a 4-credit course, consisting of three one-hour lectures and one two-hour laboratory per week.
(3) The course would be offered to juniors so that they would have an opportunity to use microprocessors in their senior design course.
(4) The course would be a required course for EEE majors.

Based on the above decisions, the contents of the lecture and laboratory portions of the course were designed. They are discussed in the next two sections.

## 3. LECTURE PART OF THE COURSE

The goals of the lecture part of the course are:
(1) to describe the characteristics and capabilities of microprocessors,
(2) to provide an insight into the principles of operation, the philosophy of design and the engineering involved in various applications of microprocessors and their support devices, and
(3) to prepare the students for the various experiments in the laboratory.

A syllabus for the course, as shown in Table 1, was designed to satisfy the above goals. Topics 1, 2, and 3 enable us to achieve the first goal and topics 4 through 6 the second goal. The discussion of development tools and interfacing is interspersed throughout the term providing the students with the necessary background to perform the laboratory experiments. Presently, the book by Leventhal [3] is used as the text for the course.

TABLE 1

Syllabus for "Designing with Microprocessors"

| | Topic | Number of Periods |
|---|---|---|
| 1. | Introduction to Microprocessors | 1 |
| 2. | Structure of Microprocessors<br>General Microprocessor Architecture<br>Registers<br>Arithmetic Units<br>Instruction Execution<br>Stacks | 2 |
| 3. | Microprocessor Instruction Sets<br>Formats<br>Addressing Methods<br>Instruction Categories | 6 |
| 4. | Development Tools<br>Assemblers/Cross Assemblers<br>Editors, Compilers and Loaders<br>Emulators<br>Development Systems<br>Logic Analyzers | 5 |
| 5. | Interfacing<br>Memory<br>Support Chips, viz., PIA's & ACIA's<br>Conventional I/O Devices<br>Interrupt Handling<br>Input Transducers<br>Output Actuators<br>ADC's and DAC's | 8 |
| 6. | Design of Systems<br>Specifications<br>Evaluation of Different Microprocessors<br>Selection of Interfacing and I/O Devices<br>Software Development<br>System Implementation & Testing | 5 |

## 4. LABORATORY PART OF THE COURSE

An important objective in the design of the experiments for this course was to expose the students to a variety of hardware and software development facilities; they include time shared general purpose computer and microprocessor development systems for cross assembling and emulation. Further, extensive experiences with hardware aspects and prototype testing are provided. To facilitate the development of originality and initiative in the use of microprocessors two laboratory sessions are allotted for a miniproject. Providing laboratory experiences based primarily on a set of projects, as has been suggested elsewhere [4], is not practical with our facilities and the academic load of our students. Hence, it was decided to have a sequence of predesigned experiments followed by the miniproject. The list of experiments follows.

Experiment I: Cross Assembler and Emulator.

Using the interactive support on the University Computer Center's facility, the students run an existing program on the cross assembler and the emulator for the Motorola 6800 microprocessor. They learn that a microprocessor can execute only a machine level program and that this program can be generated from an assembly language program.

Experiment II: Assembly Language Programming.

The student writes a program for a specific problem and goes through the various steps learned in the previous experiment to test and debug his program. The student learns the principles of assembly language and error diagnostics.

Experiment III: Introduction to the MDL.

The student becomes familiar with the Microprocessor Development Lab (MDL). After becoming familiar with the various commands on the MDL, the student downloads his program of Experiment II into the MDL and emulates it. A part of this experiment involves connecting a microprocessor setup to the MDL and storing the object code on a cassette tape.

Experiment IV: Introduction to Interfacing.

This experiment is an exercise on interfacing with external components. This involves the simulation of a traffic control scheme, with LED lamps acting as traffic lights. The student learns the principles of the design of circuits needed to drive the LEDs, the timing loops using software, and interrupt service routines.

Experiment V: Application of PROM's.

In this experiment, the student learns the application of PROMs in microprocessor systems. He loads a previously tested program into a PROM and tests it for satisfactory operation in the microprocessor setup.

Experiment VI: Logic and Real Time Prototype Analyzers.

This experiment is devoted to the use of analyzers for debugging the hardware. The students learn the use of the Real Time Prototype Analyzer of the MDL. By studying the timing diagrams on a logic analyzer, the students are able to identify hardware malfunctions.

Experiments VII and VIII: Design Project.

These two experiments are devoted to a small design project. The project involves building a small external circuit on a protoboard and designing the software to accomplish a specific job. The projects may include a second order digital filter, a digital controller for a stepper motor, a Morse code generator, a Morse code interpretor, an advanced traffic controller, a music synthesizer, etc. Software and hardware debugging is done using the MDL and the logic analyzer. This project enables the students to develop an appreciation of the intricacies involved in the design of microprocessor based systems.

## 5. LABORATORY FACILITIES

The laboratory facilities required for the aforementioned experiments are:

(1) A suitable number of microprocessor work stations consisting of microprocessor modules with sufficient RAM, ROM, input-output devices, other interface devices and power supply. These stations should be able to function on a stand alone basis.
(2) A minimum of one microprocessor development system capable of assembling, emulating and prototype testing.
(3) Support devices such as a PROM programmer, a logic analyzer, etc.
(4) Access to an interactive computing facility.

Though microprocessors themselves are inexpensive many of their development facilities are very costly. The EEE Department Microprocessor Laboratory presently has five work stations as described above. These work stations are based on Motorola MEK6802D5 single board systems. The department also has a Tektronix Microprocessor Development Lab 8002A

with one emulator processor, 32K program memory, a real time prototype analyzer, a system console, and a 2704/2708 PROM programmer. The department also has three audio cassette recorders which can be used with the microprocesser setups for directly storing and retrieving object codes. The University Computer Center has an IBM 370/158 batch processor linked to an IBM 4341 running the VSPC timesharing system which are available to the students for cross assembling and emulation.

The above laboratory facilities would have to be expanded to cater to the needs of more than a nominal number of 20 students if the experiments were to be carried out on a fixed schedule; as most of the experiments require the use of the MDL, more than one group cannot be accommodated at the same time. Many other institutions are faced with this general difficulty. At NDSU this difficulty was overcome as in some other institutions [4, 5] using the concept of what is known as an "open laboratory". However, to ensure a time slot for each student, a modification of the open laboratory was introduced. In this scheme, students were given a week's time to finish an experiment and they scheduled the time for the experiment depending on availability of equipment.

## 6. EXPERIENCES

The course on microprocessors in the above described format was offered as an elective course in the spring of 1981 to 30 students. The students evinced interest and did not mind coming to the laboratory at odd hours. The free scheduling system worked well though it demanded a lot of time from the instructor. It is proposed to overcome this difficulty in the current term with the help of trained student volunteers. One problem arose when the single Tektronix MDL developed some bugs in it. However, with the assistance provided by the company, this problem was corrected in a week. started flowing as usual. To avoid this disruption in the future and to improve equipment availability, the department is making an effort to acquire another development unit. Having observed the response of the students and the success of the course, the EEE faculty is considering making it a required course for the BSEEE degree.

## 7. SUMMARY

A new course has been designed for electrical engineering majors by the EEE Department at NDSU, taking the advances made in the application of microprocessors into consideration. The various decisions made in the design of this course regarding the level of the course, relative emphasis between lecture and laboratory, required prerequisites, mode of instruction, etc. are discussed in this paper. The course contents and the list of experiments are also included. In addition, the required laboratory facilities and the experiences with the first offering of this course are described. This course will need many periodic revisions to keep abreast wih the advances of technology, but the goals as listed in this paper should be maintained.

## REFERENCES


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