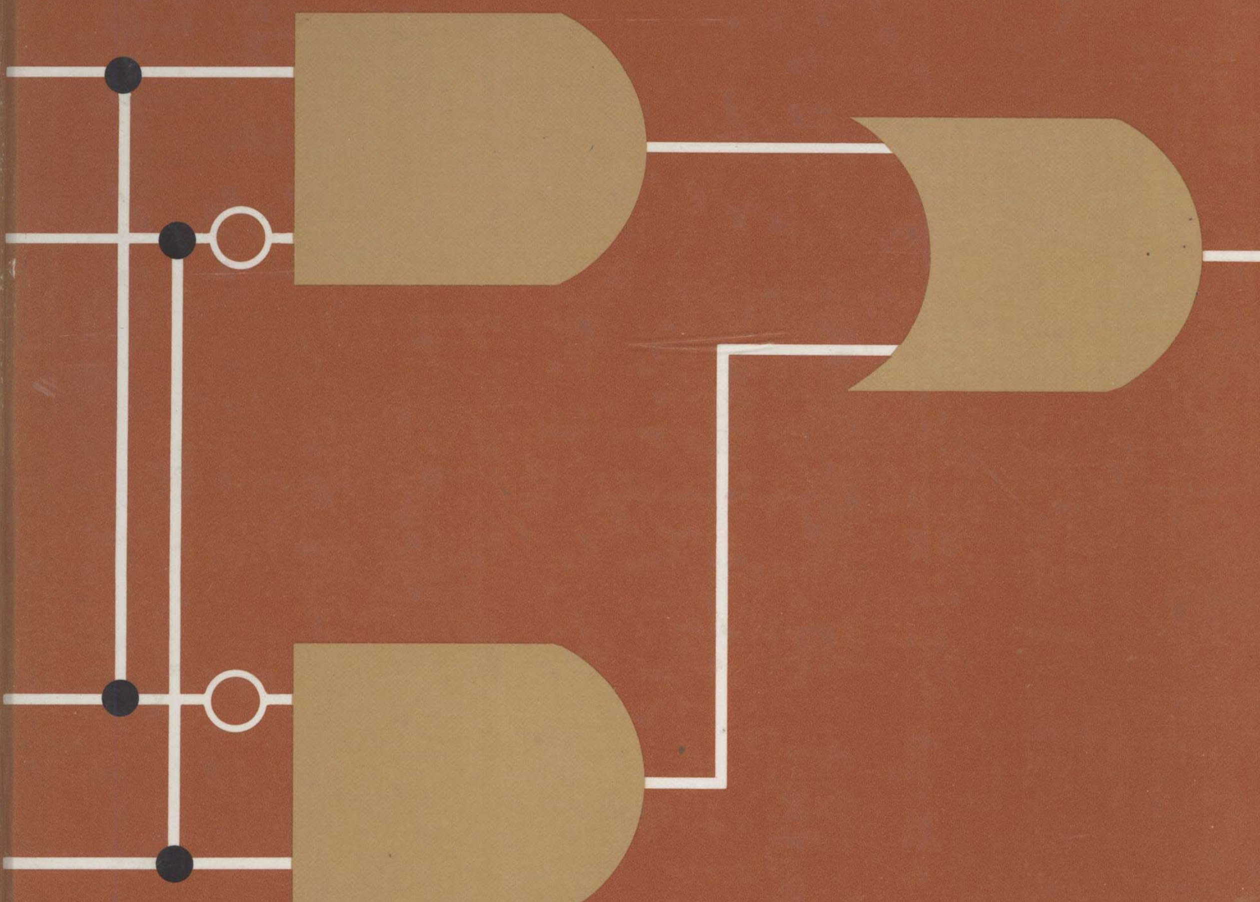
MICROPROCESSORS IN INDUSTRIAL CONTROL

by Robert J. Bibbero



An Independent Learning Module from the Instrument Society of America

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In loving memory of my wife, Lillian, 1982.

Preface

ISA's Independent Learning Modules

This is an Independent Learning Module (ILM) on *Microprocessors in Industrial Control;* it is part of the Series on Fundamental Instruments and Techniques.

Although microprocessors do not of themselves measure or control, they have become the principal tools spearheading the advance of digital techniques to all types of instrumentation and control systems. Microprocessors are small and cheap enough to be used in the most fundamental instruments, yet have sufficient power and capability to take on the job of controlling entire process units.

In order to understand and apply microprocessors, it is not necessary to know advanced mathematics, but it is necessary to look at our everyday arithmetic and logical processes with sufficient understanding to learn the new way of thinking — binary logic — that actuates digital machines. While a prior exposure to logical processes, such as relay design, would be helpful, it is not required as this module supplies all the necessary background. Computer programming exposure is also unnecessary; however it would be useful to have access to a small personal or single-board computer when applying the exercises and examples of this course.

This course is intended to teach the groundwork of digital instrumentation and the application of microprocessors to control systems engineers, process operators, and technicians. A basic understanding of electrical or electronic devices is assumed; otherwise the course is entirely self-contained. By following the steps outlined in this module, the engineer or technician with no prior digital or computer experience will acquire the ability to understand, evaluate, and choose microprocessors for specific tasks and to select and apply the most common microprocessor programming languages.

The basic thrust of the applications and examples described are from the control instrumentation field, however any technically oriented person should find this module useful in acquiring fundamental digital- and microprocessor-application skills.

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UNIT 1

Introduction and Overview

You are about to embark on a tour with ISA's Independent Learning Module *Microprocessors in Industrial Control*. This self-study program will introduce you to the world of digital control and to microprocessors. This is different in many respects from the analog control world with which you may be familiar. The learning module is divided into units: each unit has a set of learning objectives, an explanatory section, and questions to assure that you have reached the objectives. This first unit tells you what you must know to take the course.

Learning Objectives — When you have completed this unit you should:

A. Understand how the course is organized.

B. Know the course objectives.

C. Know how to proceed through the course.

1-1. Course Coverage

Microprocessors and microprocessor industrial-control systems are parts of the rapidly evolving field of very large-scale integrated circuit (VLSI) electronics. Since important improvements to microprocessors are still being made, it is wise to learn basic principles rather than the details of specific devices. The basic elements of digital mathematics and control are common to all microprocessor systems, but individual microprocessor types vary widely in capability and features, and there is yet little standardization. Furthermore, the applications and industries in which microprocessor control is used are quite diverse. Microprocessors can operate on a unit of information, called a "word," as small as 4 bits or as large as 32 bits, where a bit is a binary digit or number to the base 2. This is a 300 million-to-one range. The computation power of microprocessor ranges from that needed for a simple four-function calculator to the equivalent of a large main-frame computer, such as the IBM 360. Applications for microprocessors are found in many different industrial situations, such as the control of heat treating furnaces, process-control systems for large chemical plants and refineries, robot automation of machine tools and assembly processes, and general-purpose, programmable logic controllers (PLC's) replacing electrical relays and controllers in many plants.

This course will focus on the basic digital principles underlying all present microprocessors and on the application and programming methods common to all systems. It will not cover the complete range of microprocessor designs (architecture) and integrated-circuit technologies, since many of these are applied to large computers rather than control systems for industry. Examples of microprocessor operations will be given, but not the complete analysis of digital control applications, such as a commercial process controller or a robot arm. As an introductory course, the purpose of this module is to give the student the necessary background to proceed further with specific applications.

1-2. Purpose

The purpose of this ILM is to show how the principles of modern digital systems embodied in the programmable microprocessor can be applied to industrial control. To achieve this purpose, it is necessary to teach binary arithmetic and the logical methods by which the microprocessor accomplishes its elementary operations. These operations can be combined or "programmed" to achieve control objectives of any desired degree of complexity. Fundamentally, the process of applying a microprocessor to a given task requires the creation of a list of instructions, the "program," in a language that can be understood by the microprocessor. Ultimately, this language is the language of binary logic and mathematics, but there may be several stages of translation intervening between the user and the device. This course aims to teach an understanding of how the microprocessor receives and responds to instructions and to teach how to perform elementary programming tasks. This is a practical and useful skill not requiring advanced mathematical or electronic knowledge, but instead, a good knowledge of the control task that the device is to perform. Therefore, instead of being an esoteric form of knowledge, the ability to use and program microprocessors is a skill that anyone in the control and instrument field is able to learn.

1-3. Audience and Prerequisites

This ILM is designed for those who want to work on their own to achieve an introductory understanding of microprocessors applied to industrial control. The material presented will be useful to engineers, first-line supervisors, senior technicians, and maintenance personnel who are concerned with the control applications of microprocessors. The course will be helpful to students in colleges, universities, and technical schools who wish to learn the theoretical and practical aspects of microprocessors in control systems.

No formal prerequisites are required to take this course. In particular, it is not necessary to have a special knowledge of mathematics, computers, or electronic-circuit theory. It is necessary to learn a new kind of arithmetic, but this requires more a reexamination of familiar elementary principles than learning new theory. Semiconductor theory is not a prerequisite, but an exposure to electronic/electrical fundamentals familiar to most in the control instrument field is assumed. Rather than elaborate preparations, the requirements for learning digital and microprocessor concepts are an open mind and a willingness to reexamine the familiar.

1-4. Study Material

No study material is needed other than this book. As promised by the title, this is an independent, stand-alone text designed specifically for this course. Some excerpts from data sheets for specific microprocessors are included in this book. In order to design or analyze specific applications, access to the complete data sheet sets furnished by various manufacturers might be required, but this is beyond the scope of this introductory course.

Sources for additional reading and data are found in Appendix A. It is suggested also that the student study other ILMs, such as *Fundamentals of Process Control Theory*, available from ISA, since these present a broad range of material applicable to the general field of instruments and control.

1-5. Organization and Sequence

This ILM is divided into eleven separate units. The next three units (2, 3, and 4) contain the elements of digital codes and binary arithmetic needed to understand any digital system. The two subsequent units (Unit 5 and Unit 6) describe the architectural principles and the basic hardware of microprocessor systems, including essential details and analysis of a few common microprocessor device types. Units 7 through 10 explain the methods of programming microprocessors to accomplish specific tasks. These programming methods range from the most basic binary machine code to some of the "high-level" languages it is now possible to use with microprocessors and which are more nearly like natural human languages. Assembly language, BASIC and FORTH, are covered in separate units. The final unit teaches a method of developing digital-control algorithms and computer programs suitable for microprocessor controllers used in industry.

The self-study method for which this module is written permits you to study at your own pace and to complete the module in a period of time convenient for you. It allows you to adjust the speed and timing of the course to best suit your own capabilities and opportunities.

The format of each unit is consistent. First, a set of specific learning objectives is stated. It is important to carefully read and understand these objectives since the remaining material will be directed toward teaching them. Each unit will contain example problems or illustrations of specific concepts. Included in each unit there are exercises to test your understanding of the material. In Appendix C you will find the solutions to these student exercises, which you should check against your own answers.

It is recommended that you make notes or underline significant portions of your text, since it is your individual property. Ample white space and margins are provided for this purpose.

1-6. Course Objectives

When you have completed this entire ILM you should:

A. Understand the basic concepts of digital coding and why it is used.

B. Know binary arithmetic and logic as the basis for elementary microprocessor operations.

C. Recognize the basic design and architectural features of microprocessors used in control.

D. Understand the features and instruction codes of specific common microprocessors including the 6500 and similar families.

E. Know the fundamentals of programming microprocessors both in machine and high-level languages.

F. Know some of the techniques of developing digital algorithms and programs for microprocessors used in industrial control.

These overall course objectives are in addition to the objectives for each unit. The unit objectives will help you focus on the study of the particular unit.

1-7. Course Length

The basic concept of the ILM is to allow the student to proceed at his own pace, that speed which will allow him to learn best. Consequently each student will complete this course at a rate different from other students. This speed will depend on his personal experience and capabilities. Most students should be able to complete this course within a period of 20 to 30 hours.

This completes the introductory material needed to begin the study of microprocessor fundamentals. Please turn now to Unit 2.