# Microprocessor and Microcomputer Data Digest

by W. H. Buchsbaum, Sc. D.
and
Gina Weissenberg, W.E.E.

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We want to express our special appreciation to those manufacturers who granted us permission to reproduce specific logic or block diagrams, or the pertinent portions of the appendix. These companies are listed alphabetically below:

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# ABOUT THIS BOOK

The continuing growth of the microprocessor field and the many varieties already in use make it extremely difficult to keep a full set of technical data for each type number. Anyone involved in the maintenance, repair, troubleshooting, kit building, experimenting and electronics education field is bound to run into microprocessors at some time or other, because these key integrated circuits (ICs) are now used in anything from a TV receiver, an electronic game or toy, or a microwave oven to the dashboard of an automobile and a supermarket cash register. The detailed technical data for a particular microprocessor is essential only to the engineer involved in the original design of the device in which that IC is used. All other electronics personnel really need only a selected portion of the fullscale technical data sheets.

This book provides all of the essential technical data for each microprocessor IC that is currently listed as an off-the-shelf, "standard" item. This does not include those special ICs made only on a custom order and not listed in the manufacturer's manuals. This book does include microcomputers, considered a microprocessor which contains all of the other "on-board" functions to make it a complete computer. We also include slice microprocessors, ICs that contain only a portion of a complete central processing unit (CPU) and that require additional ICs to perform as a CPU. A new version, the microcontroller, is basically a CPU microprocessor, which has only a limited range of function. These ICs are also included in this book.

To enable even those readers not familiar with microprocessors to use the technical data provided in this book, the first chapter covers the fundamentals of microprocessors, explains the functions by means of detailed block diagrams and describes all of the classifications and categories. The use of auxiliary ICs, such as special interface ICs, random access memory (RAM) ICs and various controllers is discussed briefly. All of the key electrical parameters are defined and the principles of the "IN-CIRCUIT QUICK-TEST" are explained.

Each of the different categories of microprocessors is covered in numerical sequence, allowing the reader to look up any microprocessor IC and find all necessary information on two opposing pages. Each IC entry contains a pin connection diagram, a description of each pin connection and a brief functional description of that particular microprocessor, together with any references to similar ICs and special features. A functional block diagram is included to illustrate the IC's operation. The unique feature, however, is the "IN-CIRCUIT QUICK-TEST." This information enables the reader to test the IC in the actual circuit, with a minimum of test equipment. We present tests for two levels of confidence, wherever practical. The first "IN-CIRCUIT QUICK-TEST" provides a 75% confidence level that the test will show whether the IC is defective or not. The second test, usually more complex, provides a 90% confidence level. This information is not available in any manufacturer's manual, but offers the reader of this book the great advantage of being able to troubleshoot microprocessors without unsoldering leads or removing a complex and costly IC from the printed circuit board.

Troubleshooting electronic equipment that contains microprocessors can be quite difficult. With the *Microprocessor Data Digest* much of the difficulty is removed and anyone with a basic knowledge of electronics can use this book along with his test equipment to save time and unneccessary replacement ICs. A single repair job more than pays for the price of this book and once the reader has used it he will never want to start on a microprocessor troubleshooting job without his copy of *Microprocessor Data Digest* on the bench.

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G. Weissenberg, M.E.E.

# HOW TO USE THIS BOOK

As its title indicates, this book is a digest of the technical data supplied by the manufacturers for their various types of microprocessor integrated circuits. The tab arrangement at the edge tells you immediately that there are four classes of microprocessors: *Slice Microprocessors (µP), Central Processing Units (CPU), Microcomputers (µC)* and *Microcontrollers (µController).* An explanation and detailed description of these four classes is contained in Chapter 1, but for now we can define the Slice µP as an integrated circuit (IC) that contains less than a full CPU IC would. The CPU itself is the "original" µP, an IC that contains all of the elements and can function as central processing unit in a computer. A microcomputer (µC) is defined as a CPU plus both a random access memory (RAM) and a read-only memory (ROM), on a single IC, capable of performing actual computer functions. The µController is really a µC that is limited to perform controlling functions, but cannot really act as computer. There is no "standard" industry-wide definition for these four classes, but the majority of manufacturer's technical manuals and catalogs uses these definitions.

Each of the four classes is arranged according to the "size" of the microprocessors in it. Size means the number of binary bits that the device can operate on simultaneously. As explained in Chapter One, µPs are designed to handle 4,8,16, and 32 bits in parallel and are therefore referred to as "4-bit Slice µP," "8-bit CPU," "16-bit µC," or "4-bit µController." Within each sub-class (bit-size), the microprocessors are listed in numerical sequence.

The number assigned to a particular µP often appears arbitrary, particularly when a "family" or a series of µPs is considered. Usually a manufacturer designs a new µP for a particular application. If that IC is successful and finds other applications, a series of variations is developed. Typical of this is the use of letters, added to the original design number which indicate, for example, an industrial version (I), a military version (M), a low power version, a higher clock speed version, etc. Different manufacturers use different letter symbols, or, to make matters more confusing, they even introduce different type numbers.

In many instances a series is indicated by the first two or three numbers, with the remainder denoting variations of the basic μP design. In the 6500 series, for example, the basic 8-bit CPU (6500) is available with 1.0 MHz clock speed. The "A" version accepts up to 2.0 MHz clock signals. There are also the 6502, 6503, 6504, 6505, 6506, 6507, 6512, and 6513, each available in the 1.0 MHz or the 2.0 MHz ("A") version. All of these μPs are software compatible, but vary in their input/output capabilities and have different packages and pin configurations. All are listed, in numerical order, after the description and block diagram of the 6500, which is the "original" 8-bit CPU of this series.

Most μP ICs are made by more than one manufacturer and the manufacturer listed on the title page for each μP is either the one who originated this particular device or the one who supplied us with technical data first. We have, in almost every instance, been able to list other manufacturers making the same device, but occasionally the "second source" has not been announced at the time we went to press. In addition to the actual type number, there are letters preceding the number which indicate the manufacturer's own coding. The 6800 8-bit CPU is listed as MC 6800 if bought from Motorola, F 6800 from Fairchild, S 6800 from AMI, HD 6800 from Hitachi, and MBM 6800 from Fujitsu. To avoid confusion, we have omitted these manufacturers designations on the margin labels and on the illustrations. To look up a μP by type, simply omit any letters preceding the type number and scan through the numerical listing in the table of contents.

Each μP type is introduced by a brief description that covers its essential features. Next there is a list of every signal or voltage with a brief description and an indication whether it is an input (I) or output (O). This list corresponds to the pin configuration diagram appearing on the same page. As standard practice, all pin configurations are shown as viewed from the top of the IC, and the key slot which is between the lowest and highest pin numbers as well as the dot identifying the number one pin are included. A few manufacturers do not provide the dot identifyer, but all include the slot.

Special features of each μP as well as notes and other manufacturers who make the same μP are included in the specific data digest. The block diagram illustrates how the various features and functions are implemented. Unfortunately, there are great variations in the way different manufacturers show these features. Some provide very detailed diagrams while others rely on the reader's technical knowledge to fill in a fairly general block diagram. We have tried to select the most detailed diagrams available in each case.

Probably the most unique and useful feature of this book is the IN-CIRCUIT QUICK-TEST section provided for each μP. It gives the reader a means to test the μP without disconnecting anything, without disturbing the operation of any part of the device in which the μP works, and it can be done with standard test equipment. A good voltmeter and an oscilloscope that can handle the clock signal of the μP under test are necessary. For the 75% confidence level tests any oscilloscope used for color TV servicing (4 to 5 MHz) will be satisfactory. In order to perform the 90% confidence level tests a dual trace oscilloscope is really necessary, but it is possible, though time consuming, to use a single trace oscilloscope and record the first signal on the screen with a grease pencil and then compare that tracing with the signal that would appear on the second trace.

The principle behind the IN-CIRCUIT QUICK-TEST is that first one determines that the correct DC voltages appear, and then considers certain key signals. For the 75% confidence level tests it is necessary to "see" the clock signal. As described in Chapter One, all of the μP functions depend on the clock signal. If that signal cannot be seen on the oscilloscope, the μP cannot be considered to function properly. The next test involves an output signal that is a submultiple of the clock signal. If the μP has a functioning clock and at least one output signal, it indicates that at least some key portions in the μP must be operating. An output signal that is the result of a number of internal operations, such as a "data ready", "valid address enable," or "start fetch cycle" signal is usually used.

The 90% confidence level is obtained by adding two more tests to those that must have been passed for the 75% confidence level. For these two tests output signals that are synchronized with the clock are usually used. By observing them on a dual trace oscilloscope it is possible to ensure that their amplitudes are essentially the same, and that rise and fall times are also alike. Logic signal amplitudes and timing characteristics are usually standardized for a particular μP. When all of these tests are performed correctly there is at least 90% certainty that the μP is operating correctly.

Replacing defective μPs usually requires an exact replacement. In a few instances it is possible to use a variation of the same type as replacement and this is indicated at the end of the IN-CIRCUIT QUICK-TEST section. Microcomputers include a ROM and when replacing a defective μC it is essential that the replacement contains the same information in its ROM. This usually means that it is necessary to obtain the replacement μC from the manufacturer of the device in which the μC is used, rather than from the μC manufacturer. The same applies to μControllers.

ICs are generally quite reliable and the likelihood of a defect in the μP is relatively small. Before attempting to test the μP, be sure that the defect is not in some other portion of device in which the μP is used. Capacitors, resistors, connectors, and the printed circuit board itself are more likely trouble sources than the μP. For a detailed guide to troubleshooting electronic devices we refer the reader to *Tested Electronics Troubleshooting Methods*, 2nd Edition, Prentice-Hall, '83, by W. H. Buchsbaum.

# SUMMARY

Tabs indicate microprocessor slice (μP), central processing units (CPU), microcomputers (μC), and microcontrollers (μController). Within each tab section μPs are listed by "bit size" and within each "bit size" they are listed numerically.

To find a function and "bit size"—an 8-bit μC, for example—use the table of contents to find the page where that sub-class starts.

If you are looking for a particular μP by number, look it up in the numerical listing which is included in the table of contents.

If more information than is contained on the pages describing that μP is needed, try the appendix. Appendix A contains a list of all μP manufacturers, including phone number and the address of their main office. Appendix B contains dimensioned drawings of all standard DIPs (dual in-line package). Appendix C contains electrical characteristics for eight IC technologies as exemplified by typical μPs. This includes TTL, CMOS, HMOS, NMOS, PMOS, $P^2MOS$, $I^2L$ and $I^3L$ integrated circuits.

Before suspecting a defective μP, try troubleshooting the components and circuits associated with it. Then, if you are certain that the external circuitry is not defective, apply the IN-CIRCUIT QUICK-TEST method to determine if the μP is the source of the trouble.

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# CHAPTER 1

# MICROPROCESSOR FUNDAMENTALS

In the area of electronics and computers, the word "microprocessor" has become the popular buzz word and an expression for everything that is new, small, powerful, and magical. This book contains the essential technical data needed by anyone working with microprocessors and in this chapter we cover some of the terminology, operations, and functions of this electronic miracle.

The term microprocessor is usually applied to any kind of integrated circuit (IC) that performs the key functions of a central processing unit, the center of the action in any computer. Microprocessors ($\mu$P), however, are available in a variety of versions, each incorporating specific features or attributes and, in some cases, the word microprocessor is incorrectly applied to what is, in effect, a microcomputer ($\mu$C).

The vast majority of $\mu$Ps are either central processing units (CPU), or complete $\mu$C. Variations are the microprocessor slice, sometimes called slice-processor and the microcontroller ($\mu$ Controller). The microprocessor slice, as the name implies, provides only some of the microprocessor functions on a single IC. It usually requires several such microprocessor slices, together with auxilliary circuits, to make up a single CPU. Microprocessor slice arrangements are useful for special applications where high-speed performance of some of the elements of the CPU is more important than the smallest size possible when all functions are contained on a single IC. A typical example is the case where a high-speed arithmetic logic unit (ALU) is used together with ordinary speed operating functions in the CPU. For such applications it may be worthwhile to employ several microprocessor slices ICs, instead of a single microprocessor IC.

Microcontrollers are usually special purpose microcomputers which are preprogrammed to perform specific control tasks. These devices usually lack the flexibility of performing arithmetic and other functions as directed by a variety of programs but are solely designed to control some other electronic circuits and devices according to single, predetermined programs.

A microcomputer ($\mu$C) is generally defined as a single IC which contains a CPU, a read-only memory (ROM), a random-access memory (RAM), and all the interconnecting bus and port facilities that would make up a small, limited capacity computer. There are some microprocessors which can be used either as a CPU or a $\mu$C. These devices usually have a ROM and sometimes also a RAM and can be programmed to function either as a self-contained $\mu$C or as a very flexible, powerful CPU. In this book, any IC that contains both ROM and RAM, will be classified as a microcomputer ($\mu$C). If a microprocessor contains only a ROM, or only a RAM, it will be classified as a CPU since that will be its most frequent application.

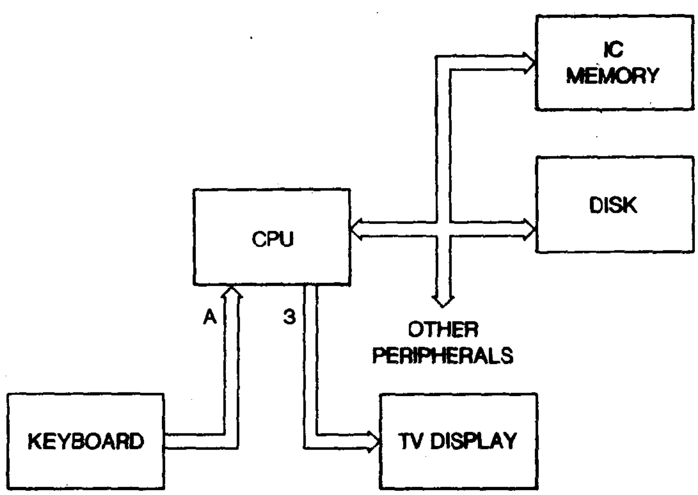
For those who are not familiar with computers, CPUs, ROMs, and RAMs, basic block diagrams and brief operational descriptions are included in this chapter. Individual textbooks could be written on all of these topics, but in the space available here, only the fundamental concepts of each of these essential computer elements is included.

# *HOW A COMPUTER WORKS*

The computer block diagram of Fig. 1-1 shows the essential elements that apply to any kind of computer, whether it be a small personal computer or a large main frame occupying an entire room. The main difference between the various computer sizes will be the number of keyboards, TV displays, disk, memory, and other peripherals connected to the CPU. This, of course, will require a different size and speed CPU, but the essential functions of each of the elements shown in the block diagram of Fig. 1 are always the same.

The CPU acts as the command center, the brain, of the entire system. It receives instructions from the human operator through the keyboard and provides information to the human operator on the TV display. The information that goes in and out of the CPU is generally divided into two categories: the program and the data. The program is in the form of coded instructions which tell the computer what functions to perform, while the data is the information on which the computer is asked to operate. The instruction "ADD" is part of the program, but the numbers that we want the computer to add, are considered data.

In Fig. 1-1, we have shown a separate IC memory and a disk which also serves as memory. The main difference between the two is that, while the IC memory operates faster than the disk, its contents are lost when power is turned off, while the magnetic information on the disk remains available until it is deliberately erased. In most systems, the IC memory is used as temporary storage and information from the disk is loaded into the




**Computer Block Diagram**
**Fig. 1-1**