THE S-100 & OTHER MICRO BUSES

SECOND EDITION

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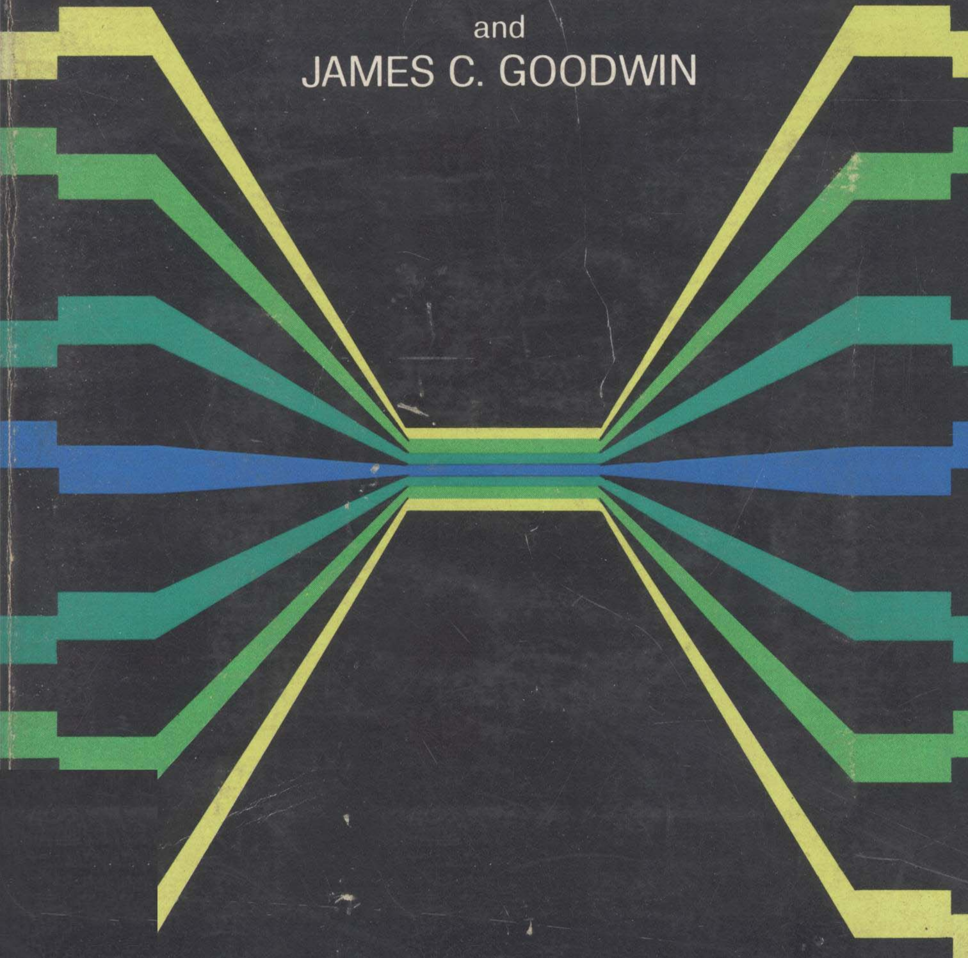
and
JAMES C. GOODWIN



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Preface

Everyone's computer seems to shrink with age. This shrinkage is usually first apparent in the memory as what was, initially, an enormous memory becomes very confining. The addition of another memory board or two temporarily solves the problem. Also, at first, the lack of hardcopy seems almost a blessing but, with every passing clock cycle, the need for a written record becomes more important. A printer interface board is added in hopes that it will do the trick. However, there are a host of expansion boards available for expansion and the present system always seems to be wanting and waiting for more and more. The key to system expansion is the *bus* through which the processor communicates with the present and future system components.

This book is about buses. A general discussion in Chapter 1 is used to acquaint the reader with bus basics. Then, the mechanical data, pinout designations, and bus signal definitions of the 21 most widely used bus systems are listed and explained in the following chapters so that the reader may better understand the bus of his or her system, or evaluate the bus of another system, or plan the interface of one bus to another. Expansion and interface boards are described and explained so that a greater use of the bus system can be obtained. Many photographs and pinout drawings are shown so that a better understanding of microcomputers, interface boards, and *buses* can be realized.

Since the first edition of this book was published, personal microcomputers have changed. Most are now offered as a complete package that contains everything necessary for immediate use in BASIC. Although many do not contain the traditional motherboards, the bus is still important for expansion. In these systems the expansion bus is generally brought out to an edge connector.

The industrial microcomputer still contains a motherboard which must be populated with selected boards to do the particular job at hand. Such boards, which include CPU, memory, and i/o boards, have to be interconnected through a system bus.

We would like to express our appreciation to the many manufacturers who participated in the preparation of this book by sharing their schematics and system descriptions. Thus they have helped the reader to better understand and use their products. We also want to give special thanks to Debbie for her meritorious service in preparing the manuscript.

ELMER C. POE
JAMES C. GOODWIN II

To our wives, Debbie and Sue

Contents

CHAPTER 16

CHAPTER 17

CHAPTER 18

CHAPTER 19

CHAPTER 20

CHAPTER 21

CHAPTER 22

CHAPTER 23

CHAPTER 24

CHAPTER 25

APPENDIX

CHAPTER 1

Bus Structures

After the introduction of the Altair 8800 in early 1975, interest in microcomputers by hobbyists began to grow rapidly. In those early days, getting a system set up and running was often a formidable challenge. Yet, even then, the need for system expansion was quickly felt. Companies producing Altair-compatible memory boards soon appeared and flourished. By the end of the year the Altair had become a leader with over 50 companies producing plug-compatible boards for the "Altair" or S-100 bus. During this period several other successful systems, including the SWTP 6800, KIM-1, and IMSAI, were introduced. Some of these systems used the Altair bus but many did not. Since then, many systems and buses have appeared. Memory, serial and parallel i/o, video and graphics display, analog i/o, voice systems and recognition, music synthesis, and a host of other boards are available for these systems. Figs. 1-1 through 1-9 show some typical systems and plug-in boards.

The Commodore PET shown in Fig. 1-1 is a complete microcomputer system in one unit. It has its own bus. The Atari 800 illustrated in Fig. 1-2 is also a complete microcomputer system with its own bus. The AIM 65 computer shown in Fig. 1-3 is a complete system that can be expanded via the bus connector at the rear of the board. The Heathkit H8 uses Heath's Benton Harbor Bus. It is complete as shown in Fig. 1-4 using keypad and octal displays or it is usable with other i/o devices.

Fig. 1-5 shows the Vector 1, an S-100-based system that relies entirely on external i/o devices. An S-100 serial communications board is illustrated in Fig. 1-6, while a Heath H8-2 parallel interface board is shown in Fig. 1-7. Notice the bus connector on the right side of the H8-2 board. Fig. 1-8 shows the Percom floppy disk and controller for SS-50 systems, while Fig. 1-9 illustrates the video digitizer board. It is using the SS-30 connector in an SS-50 system.

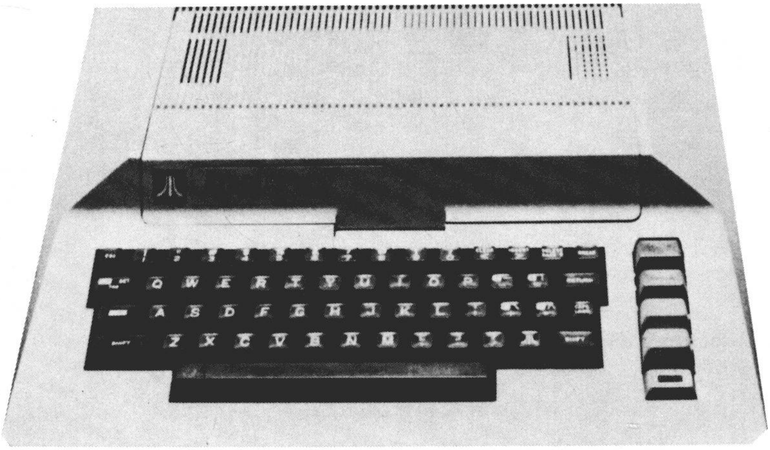
Courtesy Commodore Business Machines, Inc.

Fig. 1-1. PET, a complete microcomputer system.

The bus of a system is the selection and arrangement of its signal and power lines on a connector for distribution to other boards. Bus structure becomes important when system expansion is considered, since the needed signals must be available. Careful examination of the bus of a system should be made before a system is purchased. The most popular buses will be discussed in detail.

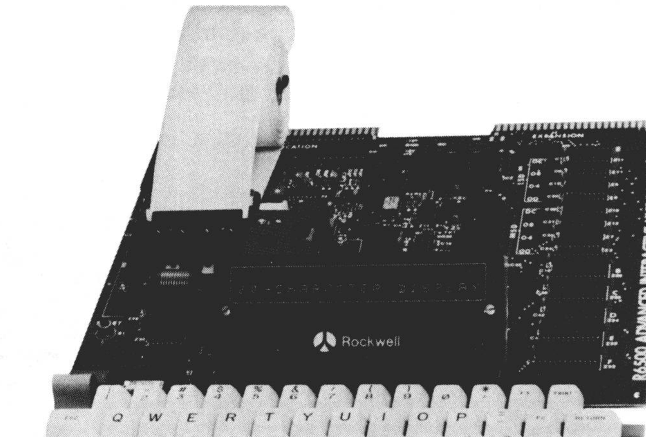
ADDRESS LINES

Regardless of the microprocessor used in a system or the number of lines on its bus, the address, data, and control signals must be available. The address lines are used by the processor to indicate to memory and other peripherals the location with which it wants



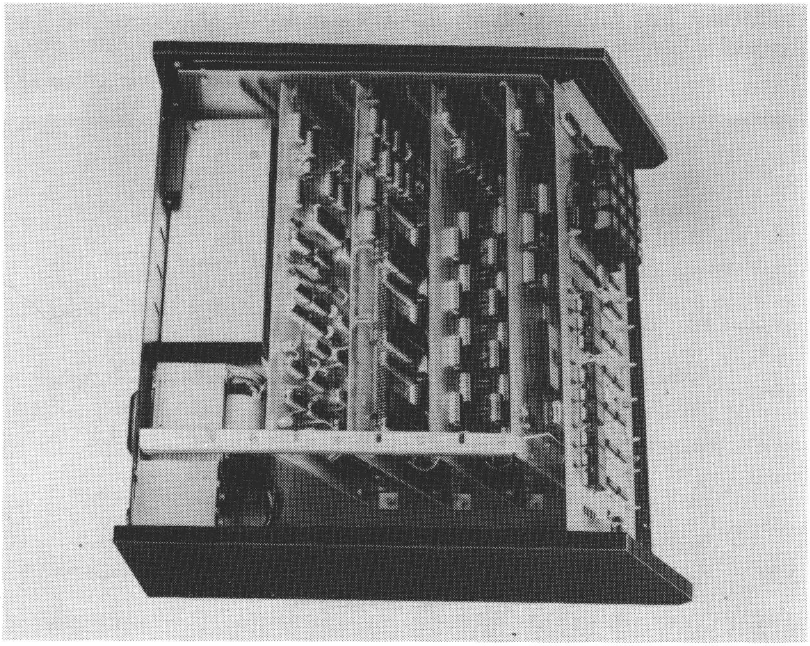
Courtesy Atari, Inc.

Fig. 1-2. Atari 800 computer.



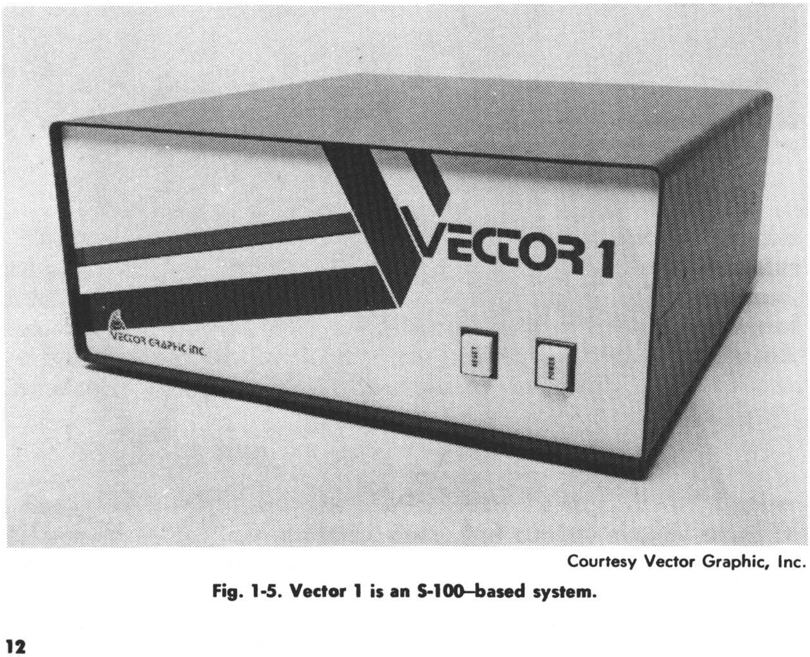
Courtesy Rockwell International

Fig. 1-3. S-100 extender board.



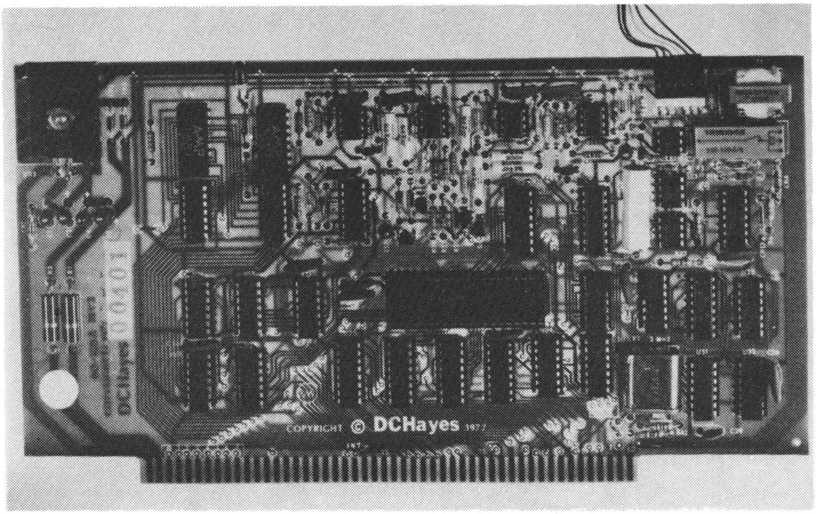
Courtesy Heath Co.

Fig. 1-4. Heathkit H8 digital computer mainframe.



Courtesy Vector Graphic, Inc.

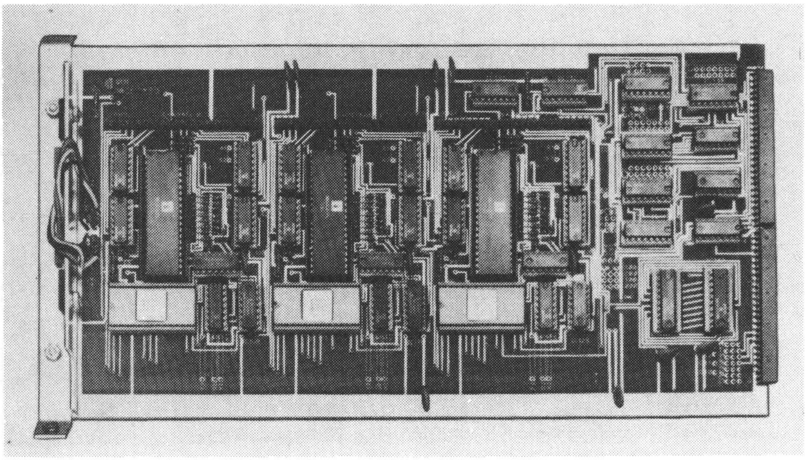
Fig. 1-5. Vector 1 is an S-100–based system.



Courtesy DCHayes Associates

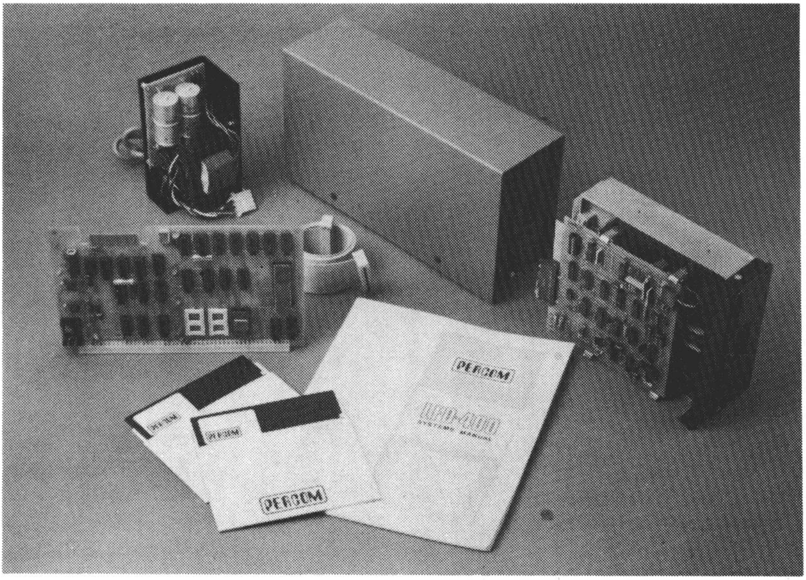
Fig. 1-6. An S-100 serial communications board.

to communicate. The 8080, 8088, Z-80, 6800, 6809, and 6502 have 16 address lines, generally labeled A0–A15, that are divided into two 8-bit bytes. Lines A0–A7 comprise the low-address byte and lines A8–A15 comprise the high-address byte. Not all address lines may be used by any one board. The 8086, 68000, Z-8000, LSI-11, and TI9900 are 16-bit processors that may contain up to 24 address lines.



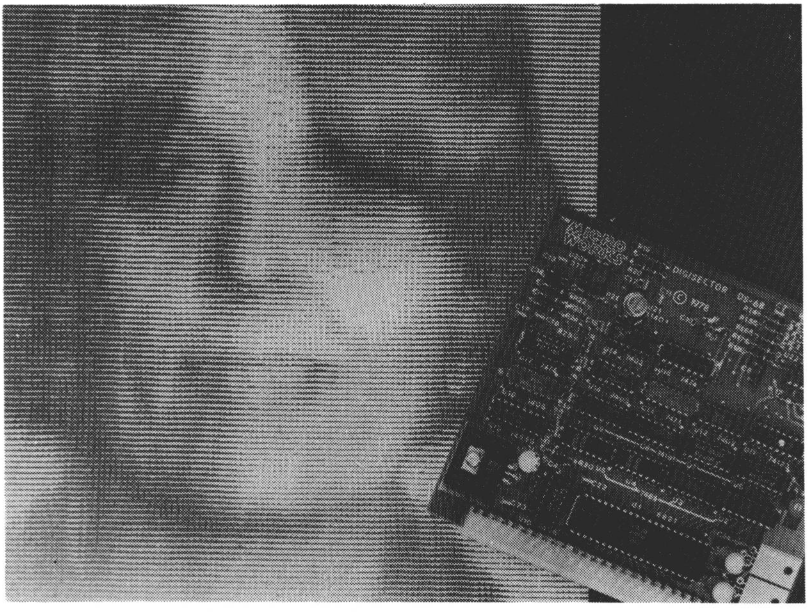
Courtesy Heath Co.

Fig. 1-7. Heath H8-2 parallel interface board.



Courtesy Percom Data, Inc.

Fig. 1-8. Percom floppy disk and controller for SS-50 systems.



Courtesy The Micro Works

Fig. 1-9. Video digitizer board using the SS-30 connector in an SS-50 system.

DATA LINES

The data lines, usually designated D0–D7 on 8-bit buses and D0–D15 on 16-bit buses, carry instructions and data between the processor and all the peripherals, including the memory. All processors have bidirectional data lines which carry information both into and out of the processor. The direction of information flow on these lines is usually under processor control. All buses, except the S-100 and the Digital Group buses, maintain the bidirectional data lines. The S-100 splits the data lines into eight data-input and eight data-output lines. The Digital Group bus splits them into eight memory-data in, eight memory-data out, eight i/o in, and eight i/o out.

CONTROL LINES

The control lines coordinate the operation of all system components. Most buses include a master clock line, often $\phi 2$ on the processor, that indicates to peripherals that the address placed on the bus is settled and valid. The master clock line also indicates valid data is on the data lines during a write operation and that the processor can accept data placed on the data lines during a read operation. The 8080 and Z-80 buses may include an M1 line that signals the beginning of an op-code fetch and a sync line that signals the beginning of each machine cycle.

Direction of data flow on the data lines is determined by one or more processor outputs. The 6800 and 6502 systems use a single read/write line to control data direction. When the line is high a read operation is indicated, when low a write operation will occur. This 8080- and Z-80-based systems use separate read and write lines and they separate memory from other i/o with two sets of control lines. The memory-read and memory-write lines control direction of data flow during memory operations. The i/o read and write lines control data direction during i/o operations. Most buses include a ready line that can be used by slow memory or i/o to momentarily halt the processor until valid data can be accessed.

Most buses include reset lines. Although a few of these are connected directly to the processor's reset input, many are not. Some are outputs of a reset pulse generator that can be used to reset peripherals. Others are inputs to circuitry that reset the operating system, often through a nonmaskable interrupt input, without resetting the processor.

Interrupt inputs are common to all systems. These inputs allow infrequent or important peripherals to get the attention of the system. A maskable interrupt input line can be ignored by the processor on direction from the program. A nonmaskable input cannot be ignored;

it must be serviced by the processor. Vectored interrupt inputs feed an interrupt controller that assigns priority if more than one interrupt request should occur at one time. The number and type of interrupt inputs vary widely among buses. The 8080 and Z-80 buses may include status lines that indicate the condition of the maskable input or acknowledge the processor's recognition of an interrupt request.

Some micro buses are designed to allow more than one device to gain control of the bus lines. A system may have more than one processor or a variety of intelligent devices, i.e., disk controllers, arithmetic and i/o processors, etc., on the bus. Generally, any device that is capable of controlling bus operation is called a *bus master*. Devices that operate on the bus but cannot control it, i.e., memory, i/o ports, etc., are generally called *slaves*. A system will always have at least one master and one slave, and it may have several of each.

All processors require at least +5 volts dc. The 8080 also needs −5 and +12 volts dc. PROMs and communications devices may need −5, −9, or −12 volts. Most buses supply these voltages as filtered but unregulated +8 and ±16 volts, with regulation occurring on the individual boards.

SYSTEM EXPANSION

Expansion of some systems occurs via a motherboard, as shown in Fig. 1-10. A motherboard is a printed-circuit board that distributes bus signals to several connectors which mate with system boards. Motherboards are an integral part of some systems but single-board computers may require their addition to allow for expansion. Adding a board to a system is not as simple as just purchasing it and plugging it in. A space must be available on the motherboard; indeed, a motherboard must be present. The power supply of the system must produce the necessary voltages and be able to provide the extra current required by the new board. The power requirement may become critical in a system that is being expanded.

An extender board, shown in Fig. 1-11, is used to raise one system board above the remaining boards to facilitate testing and troubleshooting.

The microprocessor board of the system must be able electrically to drive the devices on the new board. The processor has very limited drive capabilities, so most systems pass the signals of the processor through buffer chips. These devices provide little load on the processor and are capable of driving up to 100 other devices. Without buffering, the processor can be fatally damaged. However, if a system does not buffer the signals of the processor, a buffer board may have to be added. Also, the speed of the new board must be compatible with the system. Memory and peripherals may not be