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A CP/M* PROCESSOR EXTENSION FOR THE iAPX 86, 88 FAMILY

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The CP/M chip (80150) from Intel breaks new ground in operating system software-on-silicon components. It is unique because it is the first time that an industry-standard personal/small business computer operating system is being put in silicon. The CP/M chip contains Digital Research's CP/M-86 operating system, which is designed for Intel's full line of software-compatible iAPX 86, 88, and 186 microprocessors. Since the entire CP/M-86 operating system is contained on the chip, it is now possible to design a diskless computer that runs proven and commonly-available applications software. The CP/M chip is a true operating system extension to the host microprocessor, since it also integrates key operating system-related peripheral functions onto the chip.

Last year, Intel took a giant step forward in operating systems on silicon with its 80130, which contains the kernel of the iRMX-86(TM) operating system. The iRMX-86 operating system is a full-featured multi-tasking real-time executive. From the kernel in the 80130, either a custom operating system or a full iRMX-86 system can be built.

The 80130 and the CP/M chip contain not only the 16 kilobytes of the iRMX-86 kernel, they also integrate some essential operating system hardware on the same chip. Included are a programmable interrupt controller and timers for baud rate generation, system timing, and delay timing. The integration of the operating system and the peripheral devices make the 80130 a true operating system extension for the microprocessor.

WHAT IS CP/M-86?

CP/M-86 is a general purpose control program for microcomputers that are based on the Intel 8086, 8088, or 80186 microprocessors. This control program, also known as an operating system, manages the microcomputer's resources so that standard languages and applications programs can be run on the microcomputer. The resources managed include disk files, the user interface device (such as a console, teletype, or CRT and keyboard), the printer, and auxiliary serial or parallel communication lines.

CP/M got its start on the 8080, 8085, and Z80* microprocessors, where CP/M-80* became the microcomputer industry standard operating system. CP/M-80 and the 8080 family of microprocessors rode to success together as the core of most of the first generation of microcomputers. Hundreds of applications programs, including trend-setters such as MicroPro's Wordstar* word-processing package, Peachtree's business applications (such as general ledger and accounts receivable), and VisiCorp's VisiCalc* electronic spreadsheet turned these microcomputers into useful tools for business, engineering and home use.

With Intel's introduction of the software-compatible 16-bit 8086 and high-performance 8-bit 8088 microprocessors, the design of the second generation of microcomputers began. Digital Research redesigned CP/M and produced CP/M-86 to run on these new microcomputers.

CP/M-86 offers two unique benefits because of its CP/M-80 origins. The first benefit is that CP/M-86 ASCII and data files are completely compatible with CP/M-80 files. This simplifies conversion of CP/M-80 programs to run on 8086 or 8088-based microcomputers. In general, programs written in high-level languages will simply need to be re-compiled with the appropriate 8086-based compiler, and programs written in assembly language can be converted to 8086 assembly language with code converters such as Digital Research's XLT-86* or Intel's CONV-86. The second benefit of CP/M-86 is that it is easy for the end-user of the microcomputer to learn. If he has used CP/M-80, he will find no significant differences in CP/M-86. Programmers will also find that the program interface is unchanged; all CP/M-80 system calls are unchanged in CP/M-86.

The results of the compatibility of CP/M-86 and CP/M-80 are:

1. All popular programming languages are now available to users of CP/M-86 based systems, including BASIC, FORTRAN, PASCAL, COBOL, FORTH and C.

2. The successful CP/M-80 applications packages, along with many new ones which take advantage of the enhanced capabilities of the iAPX86, 88, are commercially available, including VisiCalc and Wordstar.

3. Personal and business computers running CP/M-86 on the 8086 and 8088 are taking the market by storm, with offerings from manufacturers such as IBM* (Personal Computer and Displaywriter), Digital Equipment Corp. (Rainbow 100), Zenith Data Systems, Victor Business Machines, Altos, Vector Graphic, Northstar Computers, Mitsubishi and Hitachi.

WHY PUT CP/M-86 IN SILICON?

At first glance, users appear to be perfectly content with the standard diskette-based CP/M-86. Why is there all the interest in CP/M-86 on-a-chip?

1. CP/M-86 on-a-chip reduces the software development required by the system designer. It can change the implementation of the operating system into the simple inclusion of the CP/M chip on the CPU board. As described later, the designer can either simply incorporate the Intel chip without the need for writing even a single line of additional code, or he can add additional device drivers by writing only the small amount of additional code required.

2. The CP/M chip is the most cost-effective way to implement CP/M-86 in a microcomputer. The integration of CP/M-86 with the 16K bytes of system memory it requires, the two boot ROMs required in a diskette-based CP/M-86, and the on-chip peripherals (interrupt controller and timers) lead to savings in parts cost, board space, and interconnect wiring.

3. The reliability of the microcomputer is increased significantly. Since CP/M-86 is now always in the system as a standard hardware operating system, a properly functioning system diskette is not required. CP/M-86 in hardware can no longer be accidentally overwritten by a runaway program. System reliability is enhanced by the decreased dependence on floppy disks and fewer chip interconnetions required by the highly-integrated CP/M chip.

4. The microcomputer system boots up CP/M-86 on power-on, rather than requiring the user to go through a complicated boot sequence, thus lowering the user expertise required. This is an important ease-of-use

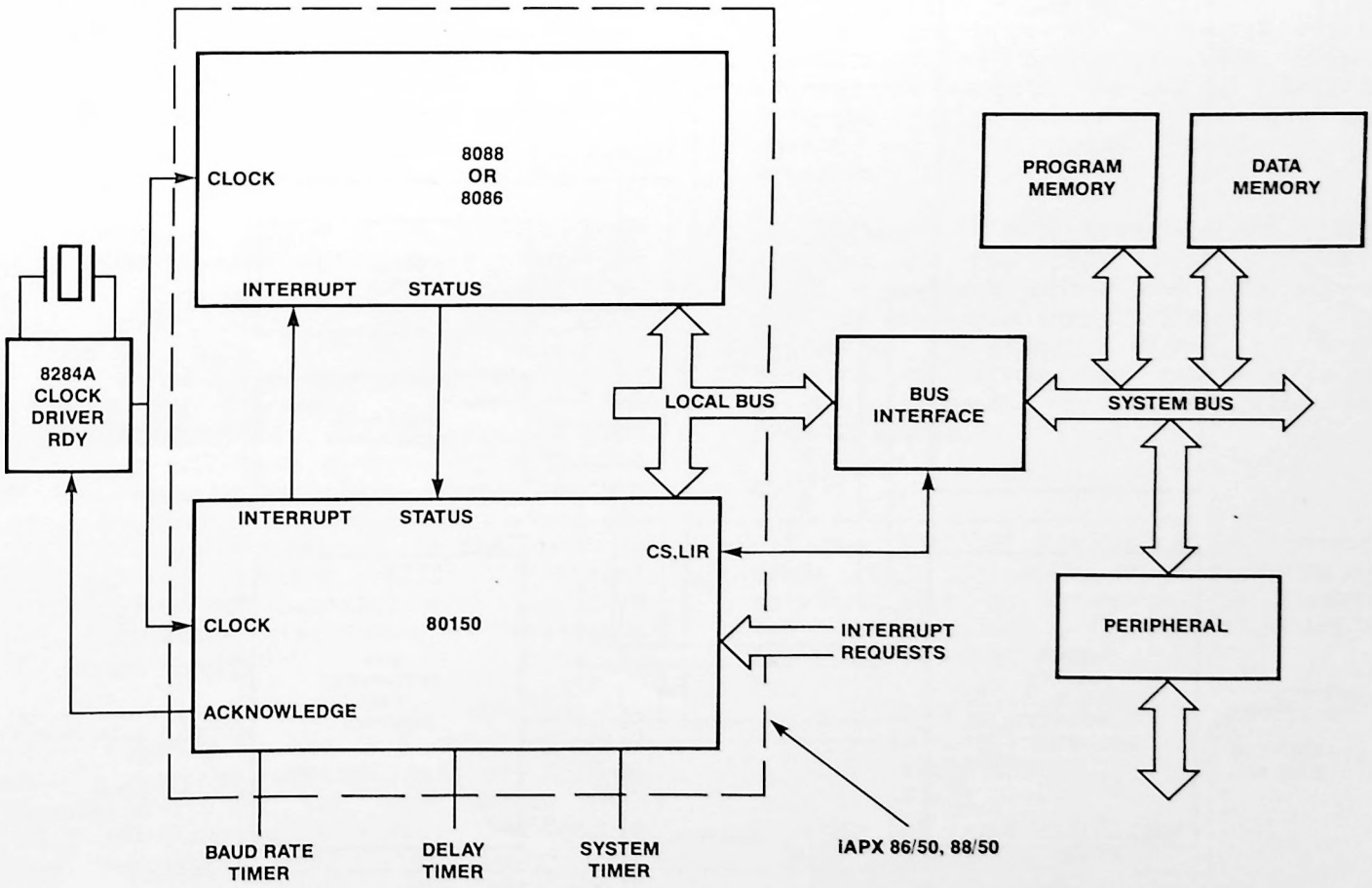

Figure 1. iAPX 86/50, 88/50 Block Diagram

consideration as microcomputers enter wider and wider use.

5. Diskless CP/M-based systems are now easy to design. Since CP/M is already in the microcomputer hardware, there is no need for a disk drive in the system if it is not desired. Without a disk drive, a system becomes more portable, simpler to use, less costly, and more reliable. The CP/M chip substitutes a Memory Disk for the disk drive. The Memory Disk is system random-access memory (RAM) that the CP/M chip treats as a disk, maintaining program files there exactly as if it were a disk. Application programs can be loaded and stored from communication links, bubble memories, other system ROMs, cassette recorders, or directly through the keyboard.

6. The administrative costs associated with distributing CP/M-86 are eliminated. Since CP/M-86 is now resident on the CP/M chip in the microcomputer system, there is no end-user licensing required nor is there any serialization requirement on the CP/M diskette (because no CP/M diskette is used!).

7. End users will value having their CP/M operating system resident in their computer rather than on a diskette. They will no longer have to back up the operating system or have a diskette working properly to bring the system up in CP/M, increasing their confidence in the integrity, reliability and useability of the system.

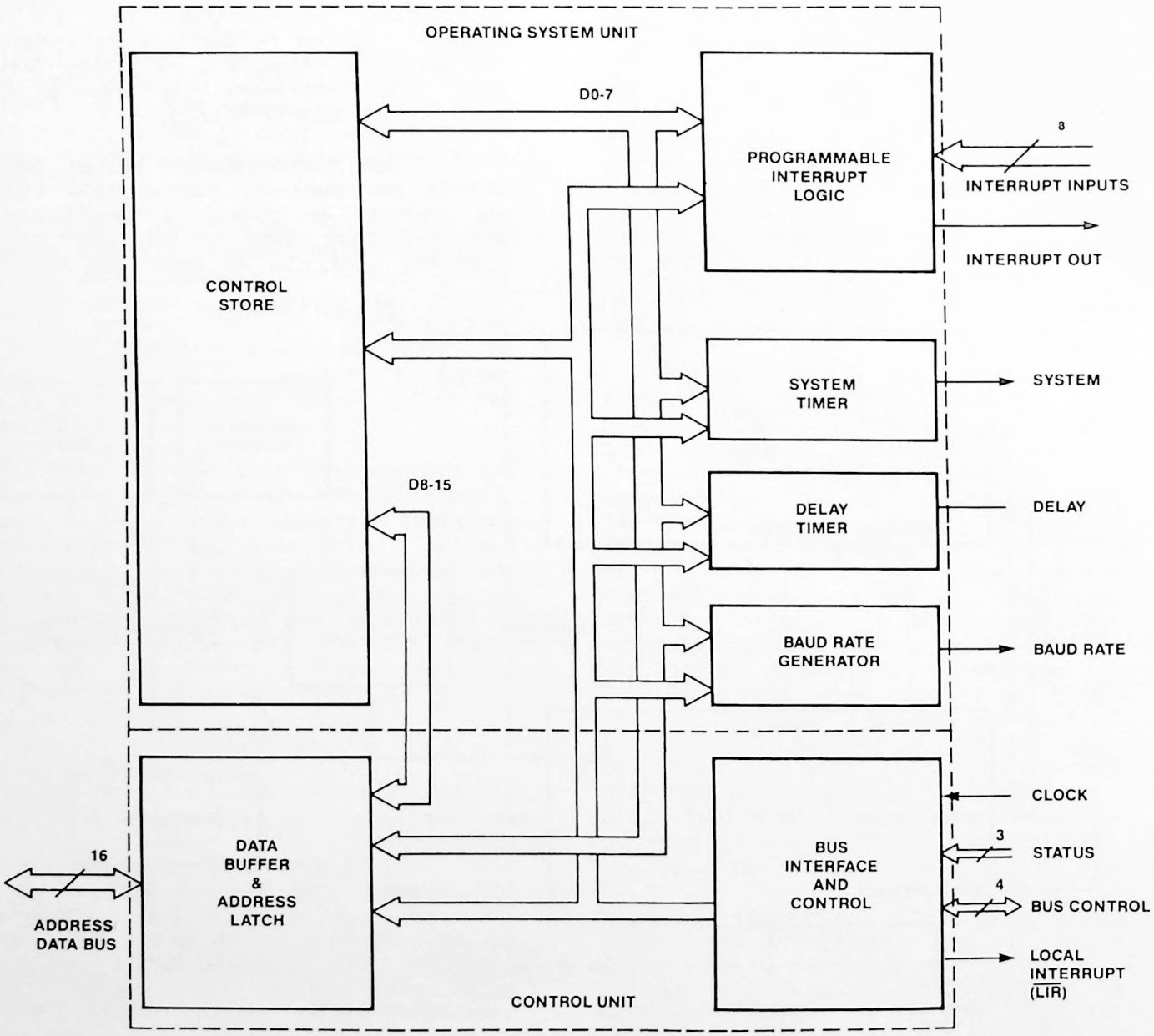

Figure 2. CP/M* Chip Internal Block Diagram

WHAT IS THIS CP/M CHIP?

The CP/M chip (Intel part number 80150) is a processor extension for the 8086, 8088, and 80186 microprocessors. When the CP/M chip is combined with the microprocessor, the two-chip set is called an Operating Systems Processor, and is denoted as the iAPX 86/50, 88/50, or 186/50. The basic system configuration is shown in Figure 1. The CP/M chip connects directly to the multiplexed address/data bus and runs up to 8 MHz with no wait states.

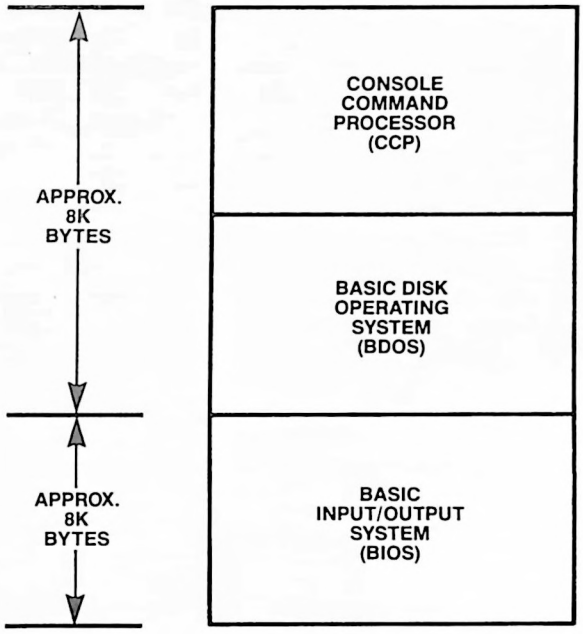

Figure 3. Software Blocks in the CP/M* Chip

A. Hardware. Figure 2 is a functional diagram of the CP/M chip itself. The 16K Bytes of program storage represent the largest commercially-available ROM. Intel has combined this leading-edge technology with the random-logic technology required by the timers and interrupt controller. The timers are compatible with the standard 8254 timer. The interrupt controller, with its eight programmable interrupt inputs and one interrupt output, is compatible with the 8259A Programmable Interrupt Controller. In fact, external slave 8259A interrupt controllers can be cascaded with the CP/M chip to expand the total number of interrupts to 57.

B. Software. The CP/M software is obviously the key to the CP/M chip. Digital Research's current version 1.1 of CP/M-86 forms the basis of the CP/M chip. CP/M consists of three major parts: the Console Command Processor (CCP), the Basic Disk Operating System (BDOS), and the Basic Input/Output System (BIOS), as shown in Figure 3. ** The CCP and BDOS code come directly from Digital Research's CP/M-86; the BIOS was developed by Intel.

CCP

The CCP is the human interface of the operating system that parses and executes the user's commands. The command lines execute either commands built-in to the CP/M chip or transient programs from the system's mass storage (typically floppy disk or memory disk). Built-in system commands include standard CP/M commands such as:

DIR	Displays the filenames from a disk directory.
ERA	Erases a filename from the directory and releases the storage space occupied by the file.
TYPE	Writes the content of a character file to the console.
USER	Allows change in user number.

Built-in commands in the CP/M chip have been expanded to include capabilities normally included as transient utilities on the Digital Research CP/M-86 diskette. Commands are provided to format diskettes, transfer files betwen devices (based on Digital Research's Peripheral Interchange Program, PIP), and alter and display I/O device and file status (based on Digital Research's STAT).

Standard CP/M-86 transient utilities not included in the CP/M chip, such as the Digital Research editor and 8086 assembler, will be available through Intel on a utility diskette. The standard CP/M-86 CCP has been enhanced to allow the user to add new built-in commands to further customize his CP/M-86 system.

BDOS

Once the CCP has parsed a command, it sends it to the BDOS, which performs system services such as managing disk directories and files. Some of the standard BDOS functions provide:

Console Status
Console Input and Output
List Output
Select Drive
Set Track and Sector
Read/Write Sector
Load Program

The BDOS in the CP/M chip provides the same functions as the standard Digital Research CP/M-86 BDOS. This, along with the CCP user interface, allows microcomputers designed with the CP/M chip to execute any CP/M-86 based languages or applications packages which utilize standard CP/M functions; the applications program cannot tell whether the system uses the CP/M chip or a diskette-based CP/M-86.

BIOS

The BIOS contains the system-dependent I/O drivers. The BIOS on the CP/M chip offers two fundamental configuration options:

1. A predefined configuration which supports the minimum cost CP/M-86 microcomputer system and which requires no operating system development by the system designer.

2. An OEM-configurable mode, where the designer can choose among several drivers offered on the CP/M chip or substitute or add any additional device drivers of his choice.

These two options negate the potential software-on-silicon pitfall of inflexibility in system design. The OEM can customize his system as desired.

The predefined configuration assumes a minimum peripheral set of an 8251A USART (Universal Synchronous/Asynchronous Receiver/Transmitter) for the CONSOLE device, an 8272 Floppy Disk Controller, and an 8255 PPI (Programmable Parallel Interface) for the LIST device and mini-floppy motor control (see Figure 4).

Even in the predefined configuration, the system designer (or end user, if the system designer desires) may select parameters such as the baud rates for the console and printer, the floppy disk size (standard 8" or 5 1/4" mini-floppy), and format (FM single density or MFM double density, single-sided or double-sided).

Since all microcomputer configurations cannot be anticipated, the OEM-configurable mode allows the system designer to use any set of peripheral chips that he wants.

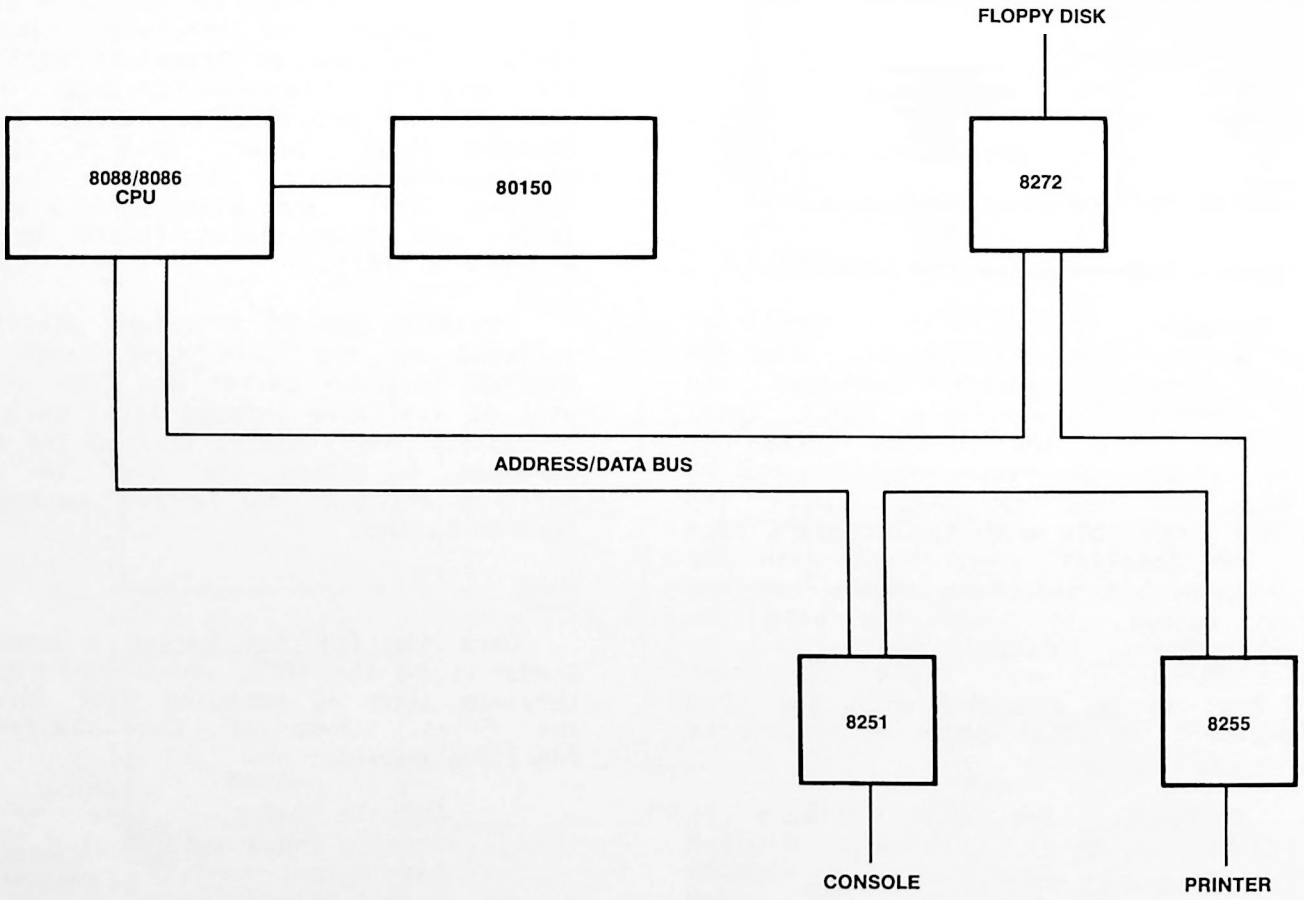

Figure 4. Predefined Configuration

Drivers for the following chips are included in the BIOS of the CP/M chip:

8251A	Universal Synchronous/Asynchronous Receiver/Transmitter (USART)
8274	Multi-Protocal Serial Controller (MPSC)
8255A	Programmable Parallel Interface (PPI)
8275	CRT Controller
8272	Floppy Disk Controller
8237A	DMA Controller

Drivers for the on-chip timers and interrupt controller are also included in the BIOS. This configuration is shown in Figure 5. For example, some of the designer's choices for his CONSOLE are:

a. 8251A USART connected to a terminal.
b. 8274 MPSC connected to a terminal.
c. 8275 CRT plus 8255A keyboard.

By simply changing the jump addresses in a configuration table, the designer can also gain the flexibility of adding his own BIOS drivers for other peripheral chips, such as bubble memories or more complex CRT controllers. These drivers would be stored in memory external to the CP/M chip itself. By providing the configurability option, the CP/M chip is applicable to a far broader range of designs than it would be with an inflexible BIOS.

Memory Disk

A unique capability offered by the CP/M chip is the Memory Disk. The Memory Disk consists of a block of RAM whose size can be selected by the designer. The Memory Disk is treated by the BDOS as any standard floppy disk, and is one of the 16 disks that CP/M can address. Thus files can be opened and closed, programs stored in it, and statistics gathered on the amount of Memory-Disk space left.

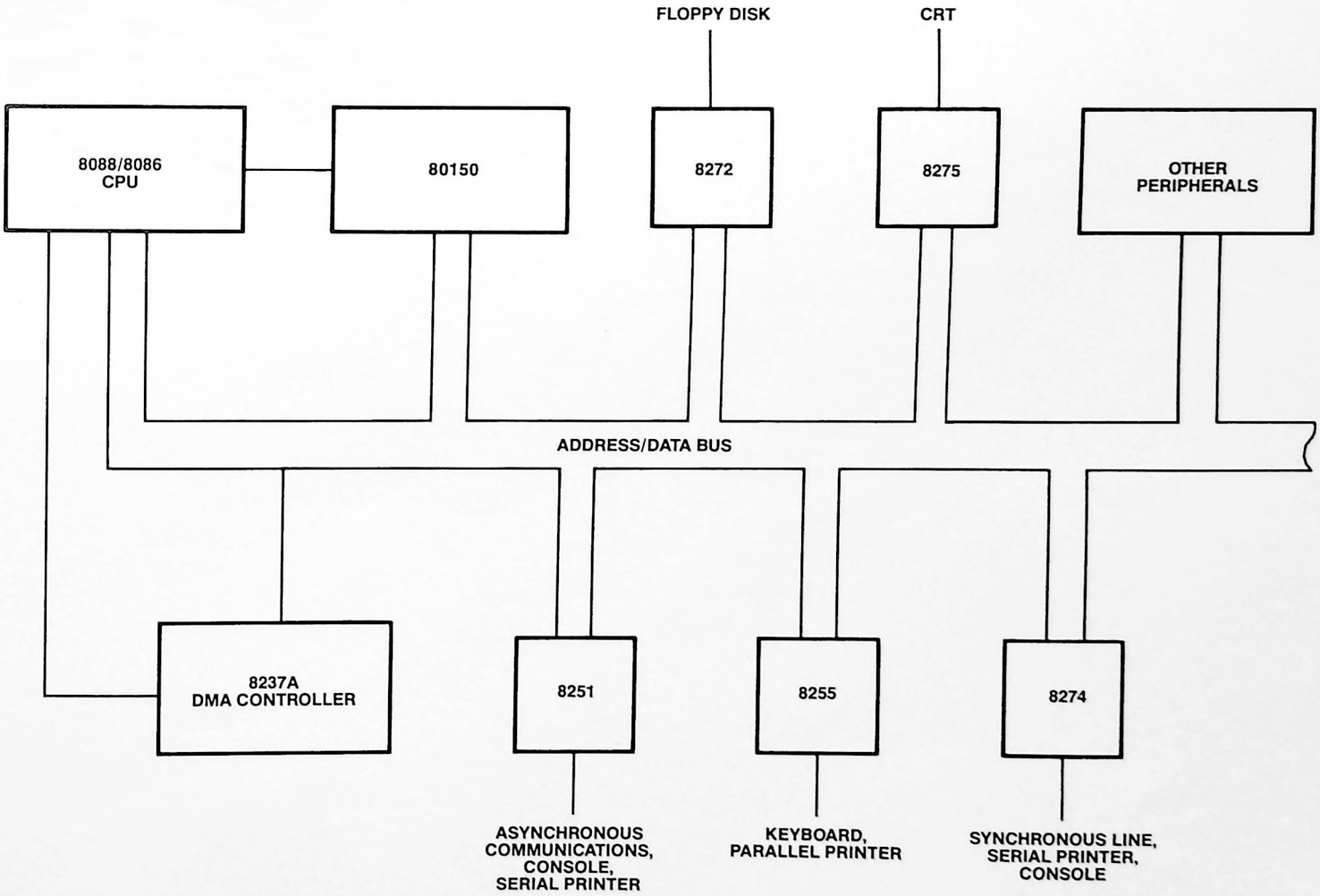

Figure 5. OEM Configurable System

The Memory Disk opens the possibility of a portable low-cost diskless microcomputer or network station. Applications software can be provided in a number of ways:

a. telephone lines via a modem.
b. ROM-based software.
c. a network.
d. bubble memory based software.
e. low-cost cassettes.

Software Updates

Even though Intel has put the CP/M chip through a rigorous set of software tests, any implementation of software-on-silicon must foresee the possibility of future updates. The CP/M chip takes care of this by its organization as a series of subroutines rather than one long monolithic piece of code. Subroutines can then be patched in memory external to the chip, if the change must be implemented before an updated chip is available. When the chip itself is updated by Intel, it will be fully compatible with the previous versions, due to the standard CP/M-86 calls and subroutine organization.

CONCLUSION

The CP/M chip contains all the elements for a successful implementation of software-on-silicon. First, the software must be proven by wide use in the market, so that updates to the code are required only infrequently. CP/M clearly meets this criterion since CP/M has been used for over five years and CP/M-86 for almost two years. This longevity leads to the second element, which is that for success in the market, the component must be readily usable. The wide market familiarity with CP/M and the breadth of applications packages that run under CP/M-86 make CP/M-86 an obvious candidate for implementation on silicon. The third requirement is that the manufacturer add value other than simply burning software on ROM. Intel adds value both in the CP/M software and the associated hardware. The CP/M software implementation includes a fully-tested BIOS to speed system integration significantly. CP/M is also fully integrated with the on-chip interrupt controller and timers, an appropriate marriage of closely-related hardware and software operating system functions. Finally, the solution is cost-effective, since several chips and software are combined, giving cost savings both in components and board space.

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Z80 is a registered trademark of Zilog.
IBM is a registered trademark of International Business Machines.

** This paper focuses on unique features of the CP/M chip. For further details on the capabilities of CP/M-86, consult the Digital Research CP/M-86 Operating System User's Guide, CP/M-86 Operating System System Guide, and CP/M-86 Operating System Programmer's Guide

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