1

System Overview

Before attempting any troubleshooting analysis on a system, you must first understand the system configuration and how the system works. In this chapter, you will approach the IBM PC from the systems level and become acquainted with each functional element in the microcomputer. From your introductory computer instruction, you learned that every computer system has five basic parts (Fig. 1-1):

- An arithmetic logic unit
- A control unit
- A memory unit
- An input unit
- An output unit

The arithmetic logic unit (ALU) does the adding, subtracting, multiplying, dividing, comparing, and logic operations. A control unit regulates the operation of the complete machine. It fetches and interprets instructions, and it causes certain parts of the circuitry to respond according to those instructions. The ALU and control unit can be considered the nerve elements of the computer's brain. Important to the computer is adequate power and a good system clock.

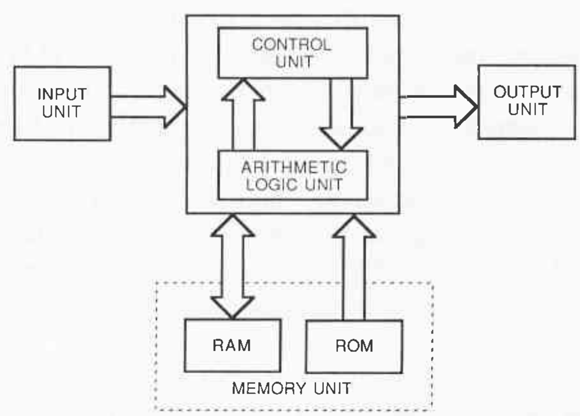

Fig. 1-1. Basic parts of the IBM PC computer.

The memory unit is the remembering part of the machine. It stores programs, data, calculations, and results. Two types of memory are included in the PC: temporary memory called random-access memory (RAM) and permanent memory called read-only memory (ROM). The ROM chips are permanently programmed or written into during manufacture with computer instructions and special data. Since one of the

IBM ROMs has an operating system program permanently stored in it (hardware), we call it "firmware."

RAM is sometimes called "main memory." Information stored in RAM exists only as long as power is applied to the computer. When power is removed, the programs and data stored in the RAM are lost unless transferred (copied) to external permanent memory. External memory can be attached to the PC by connecting floppy disk drives or hard disk drives.

Communication with the computer occurs through the input and output units. These person-machine interfaces are called "peripherals." A peripheral can be just about any type of device connected to the basic PC.

An input unit allows commands, programs, and data to enter the computer–It's how the user "talks" to the computer. Keyboards, joysticks, game paddles, graphics tablets, light pens, microphones, and analog-to-digital converters (ADCs) are examples of input devices.

The computer communicates with our environment and us via an output unit. Monochrome and color displays, printers, plotters, a speaker, and digital-to-analog converters (DACs) are examples of output devices.

Some devices are used for both input and output. These include the mass storage devices (the floppy disk drives, the hard disk drives, and archival storage tape systems) and MOdulator-DEModulators (MODEMs) which enable computer to computer communications over long distances.

The arithmetic logic unit and control unit can be combined into a single integrated circuit called a "central processing unit" as shown in Fig. 1-2. Microprocessors are also called central processing units (CPUs) because they can be designed to do the same functions as the central processing unit in a large computer. In the IBM PC, an 8088 integrated circuit (IC) is the systems central processing unit. It accesses memory (fetches an instruction), interprets what the instruction means, and does the actions required by the instruction, and then fetches the next instruction in the program and repeats the sequence. This sequential process was described by mathematician John Von Neumann in the late 1940s. Today, every desktop or laptop personal computer operates as a sequential "Von Neumann" machine. In the future, microcomputer systems will include multiple processors and operate on many instructions at the same time in a parallel "non Von Neumann" architecture.

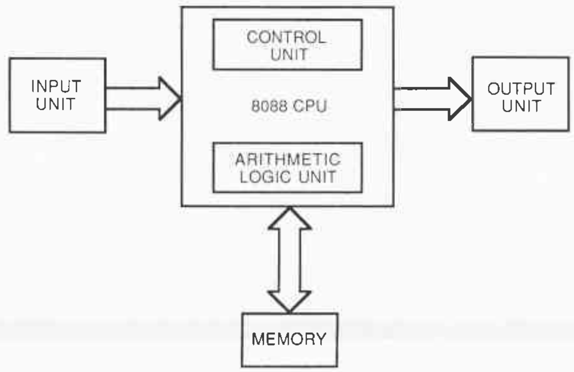

Fig. 1-2. The control unit and arithmetic unit together form the central processing unit CPU.

THE BASIC IBM PC INTEGRATED INTO A SYSTEM

Taken as a whole, an IBM PC system could look like the configuration shown in Fig. 1-3.

A typical PC system is comprised of the system unit with keyboard, a display unit, two disk drives, and a printer. The next few pages will describe each of these units.

System Unit

The system unit shown in Fig. 1-4 is the main component of the computer. It houses the system board (motherboard) with its expansion slots for external interface peripheral devices, the switching power supply, and two standard-height, double-density disk drives. On the right side, near the back of the system unit, is the on-off power switch.

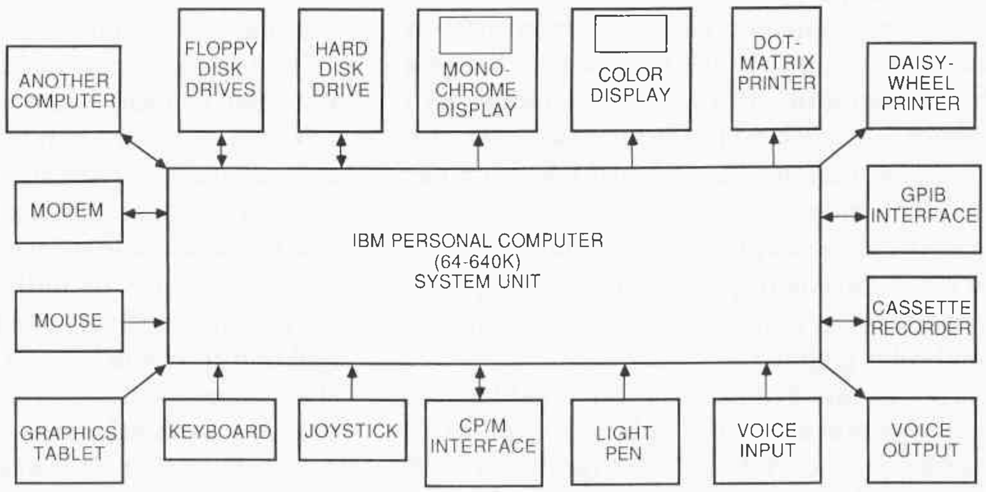

Fig. 1-3. Example of an IBM PC system.

Fig. 1-4. The system unit sits behind a detachable keyboard.

Keyboard

The detachable keyboard has 83 keys that can generate all 128 American Standard Code for Information Interchange (ASCII) characters. It can also generate special symbols and graphic shapes. In all, the keyboard can cause the machine to generate and display (or print) 256 characters, shapes, or symbols.

The numeric keypad on the right side of the keyboard has some keys that double as cursor-control keys. Ten programmable function keys are mounted on the left side of the keyboard to execute specific programs or to initiate special software routines. The functions can be programmed by the software designer. Many special keys are provided including Shift, Up-Down-Right-Left arrow keys, Caps Lock, Number Lock, Scroll Lock, Backspace, Enter (or Return), Home, Page Down, Page Up, End, Delete, Insert, Print Screen, Tab, Control, and Alternate. The functions of these keys and key combinations are described in the *IBM Guide to Operations* manual.

All 83 keys have automatic repeat and a 10-character type-ahead buffer to let you type at rapid speed without getting ahead of the computer processing of each key stroke.

Each of the 83 concave keys have a tactile feel with an audible click to provide positive feedback that key action has been completed. Inside the keyboard are electronic circuits that enhance key operation and permit keys to be redefined for increased programming flexibility.

On the bottom side of the keyboard are two plastic feet that allow the keyboard to be tilted in two positions for best typing comfort. A plastic ridge above the top row of keys can hold a book or report between the keyboard and the display screen. It can also hold templates for special application software. A 6-foot coiled cable connects the keyboard to the rear of the system unit.

Output Unit

Two output units that make the computer system complete are the display unit and a printer.

Many display units can connect to the IBM including monochrome and color monitors. A display unit connects to the computer at the rear of the system unit. If a radio frequency (RF) modulator is connected to the video adapter card inside the system unit, a standard television can be used for a monitor.

Two video adapters are available for the PC: a monochrome display adapter that supports text, and a color/graphics adapter that supports text and color graphics.

The monochrome adapter enables the system to generate and display 25 rows of 80 characters each in white on black (green on black with the IBM monochrome monitor), black on white (or black on green), blinking, in high intensity, or underlined. This adapter card also has a connection for the IBM dot-matrix printer.

Color is available using the color-graphics adapter card. This interface provides options for two types of text (25 rows of 40 characters, or 25 rows of 80 characters) and three types of graphics (low resolution, medium resolution, and high resolution). Only medium resolution and high resolution are supported by the ROM. The 6845 CRT controller IC on the adapter board must be directly addressed by custom software to enable low-resolution graphics.

Low-resolution graphics refers to 100 rows of 160 pixels (picture elements) or dots each, in any of 16 standard colors. Medium-resolution graphics can produce 200 rows of 320 pixels per row in any of four colors. Additional colors can be generated when dots of different colors are juxtaposed. High-resolution graphics produces 200 rows of 640 pixels per row in black and white (or black and green). Text can be positioned within graphic shapes enabling window operations.

Many types of printers can connect and function with the PC. Both dot-matrix and full character printers are commonly connected to this machine. The recent introduction of consumer laser printers has given very high quality hard copy output capability to PC users. All of these interconnections are achieved using a special expansion slot adapter board as the interface. Some users have both types of printers connected at the same time–dot-matrix for drafts and working copies, and letter quality for documents.

A final output device that is part of the PC is a small (2-inch) 8-ohm speaker mounted at the left side of the system board inside the system unit chassis. This device can produce the familiar beep, arcade, and music sounds. It can also produce crude speech.

Two types of bidirectional data storage devices are used with the IBM PC: tape cassette and minifloppy drives. While cassette storage is slow, magnetic tapes provide an excellent way to provide archival and storage for the large amounts of data that are generated every day. Many more files or pages of information can be stored on a good audio cassette tape than can be stored on a 5 1/2 inch floppy disk. In fact, one form of tape archival storage uses video tape for long term computer-generated data.

The typical system uses minifloppy disks that operate in a disk drive unit as the mass storage medium for the PC. Up to six disk drives can be connected to the PC using non-IBM hardware.

Each 40-track disk can be single- or double-sided, double-density depending on the drive used. The disks are magnetically sectored during formatting into 512-byte sectors providing 163,840 bytes of storage for single-sided, double-density disks (184,320 bytes with PC-DOS 2.x) or 327,680 bytes of storage for double-sided, double-density disk drives systems (368,640 bytes for PC-DOS 2.x).

Connections

Figure 1-5 shows the connections on the rear of the PC. A female connector provides power to an external monochrome display. The male connector to the right is for the power cord. To the right of the round fan air exhaust port is a 5-pin circular connector for the keyboard cable. Next is a 5-pin circular connector for cassette data input/output. The five slots align with five expansion sockets on the system board inside. These slots are for connecting other display outputs, disk drives, plotters, printers, and other peripherals.

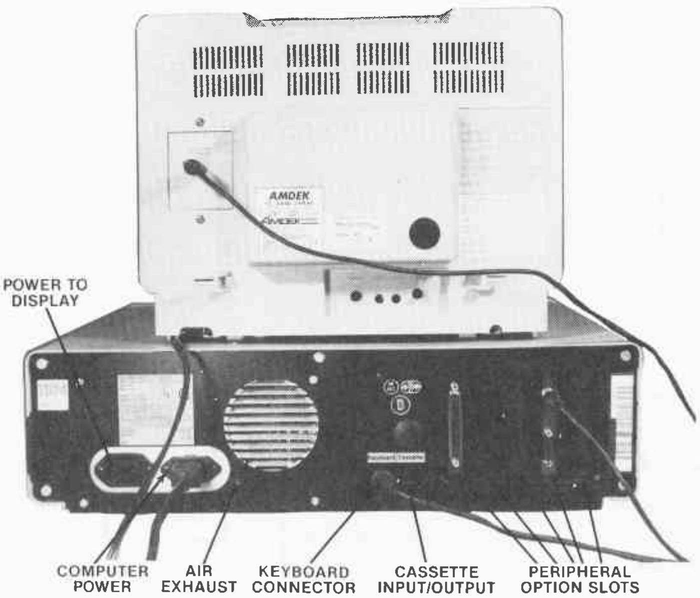

Fig. 1-5. The connections found on the back of the PC system unit.

Internal Components

Figure 1-6 shows the position of subsystems inside the 5.5 inch by 19.6 inch by 16.1 inch system unit. On the left is the system board, or motherboard. At the top of this board are the five expansion slots to connect peripheral devices. On the lower left of the system board are the memory chips.

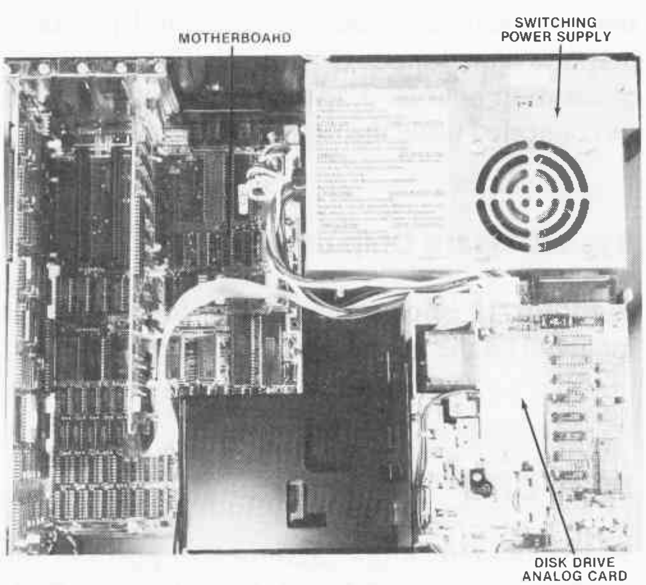

Fig. 1-6. Inside view of system unit

The top right portion of the system unit is the switching power supply. The lower two-thirds of the system unit houses two floppy disk drives.

Figure 1-7 is a block diagram of the IBM PC system. Dashed lines allocate the system elements into the basic parts of any computer.

Each part of this diagram will be covered in detail in the next chapter.

System Board

The most important part of the computer is the CPU and the circuitry surrounding the CPU. On the PC, the CPU and its associated circuitry are mounted on a densely packed printed-circuit board called the system board, or motherboard. Two system boards have been produced for the IBM PC. The board shown in Fig. 1-8 was designed for systems that contained between 16k and 64K of RAM.

A photograph of the system board used in newer 64K to 256K RAM systems is shown in Fig. 1-9. These parameters define the amount of RAM that can be installed in the system board before expansion memories can be used. COMPUTERFACTS pages 27 and 34 provide another view of the newer PC system board. The trace side is shown on CF pages 26 and 35.

As noted, most of the ICs on these boards are mounted in a common direction with pin 1 of each chip facing the same direction. This is important when these boards are repaired because it helps to prevent you from mounting the chip backwards. Chips are marked with the package positioned in the same way. If you inadvertently solder a replacement IC into the board with pin 1 facing the wrong way, you can quickly tell by the upside down lettering and numbering that it's mounted incorrectly.

Each component IC has a corresponding code (U23, U36, and so forth) stamped on the system board. In addition, the chip locations are marked in increasing order from top to bottom and right to left. This is helpful in quickly locating ICs.

In Chapter 2, all system board chips will be discussed in detail. For consistency, only the

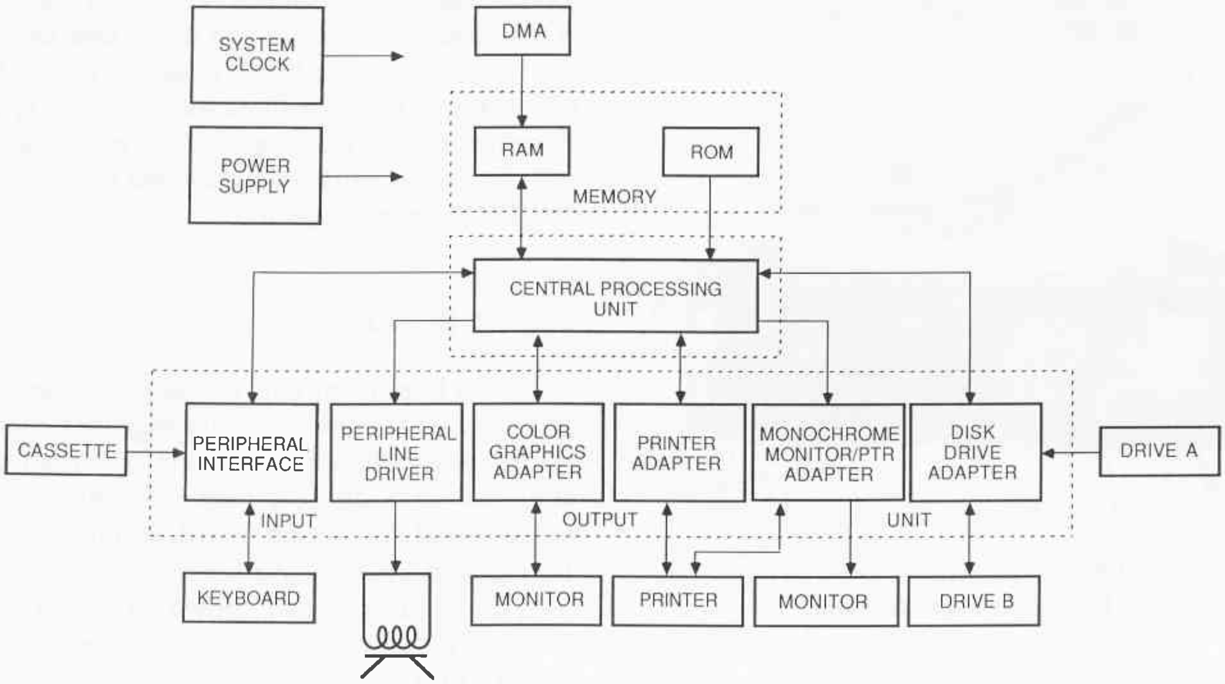

Fig. 1-7. IBM PC system block diagram.

64K-256K board will be described. The 8088 CPU is plainly visible on the lower right side of the board. In all, 99 chips are mounted on the system board. These chips comprise the CPU, memory, timer, controllers, and input/output (I/O).

I/O Interfaces

Five 62-contact expansion slots are mounted at the upper right in Fig. 1-9. These slots connect peripheral devices to the system board. Besides the address and data buses, an extensive selection of control, power, and ground signals available on each slot allow PC system interfacing with many external devices. Each peripheral except the keyboard connects to the system board via an adapter board that plugs into one of the expansion slots. These slots are numbered J1 (slot 1) to J5 (slot 5) from left to right.

Slot 1 is allocated for the disk controller interface board. Up to four disk drives (two internal and two external) can be connected to the PC. Third party hardware can expand the mass storage to six double-sided, double-density drives.

Slot 2 is used for the display adapter card. Slot 3 is allocated to the asynchronous/synchronous communication card. Other interface devices include modems, additional printers, graphics tablets, and voice-recognition and voice-generation boards. Expanded memory can also be connected using the expansion slots.

System Board Chip Layout

Figure 1-10 shows the layout for the chips mounted on the newer IBM PC system board.

8088 CPU

Just to the left of the cassette I/O port (J6) on the far right side of Fig. 1-10 is the 8088 CPU

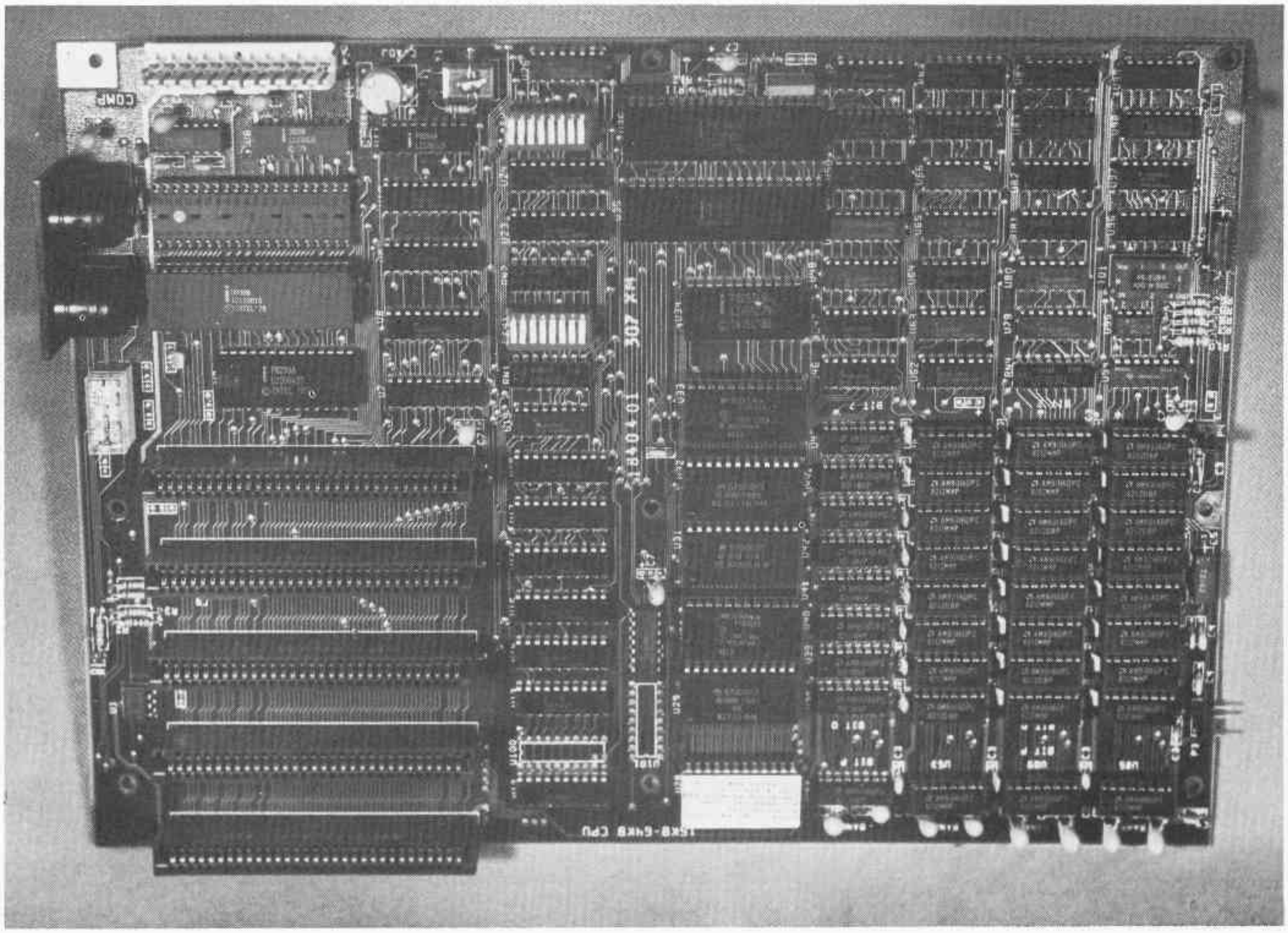

Fig. 1-8. Photo of the 16K-64K IBM PC system board.

(socket U3). A closer view is provided in Fig. 1-11. The 8088 is an Intel designed microprocessor that operates on a 4.77 MHz clock as a 16-bit machine internally, using the same instruction set as the 16-bit Intel 8086 microprocessor, but with an 8-bit data bus. It supports 16-bit operations including multiply and divide and has a 20-bit address bus so it can access over a million memory locations.

Internally, the 8088 handles 16-bit formats so the CPU expands its internal address word to 20 bits at its output using a segmentation scheme. Memory addresses are logically subdivided into special segments of 64K bytes each. Each segment can be allocated to special registers in the 8088. Then bytes within a segment are addressed using a 16-bit offset address which is added to a 16-bit segment address to generate a physical address. This addressing scheme will be described in detail in Chapter 2.

8087 NUMERIC DATA PROCESSOR (COPROCESSOR)

The 8088 can also operate in maximum mode with an optional 8087 numeric data processor functioning as a coprocessor. This configuration greatly increases computational speed. The socket just below U3 is for the 8087 (U4). The 8087 is a high-speed, two-channel I/O controller/coprocessor that extends the 8088 instruction set to include arithmetic and logic operations. It doesn't change the way the system operates, but

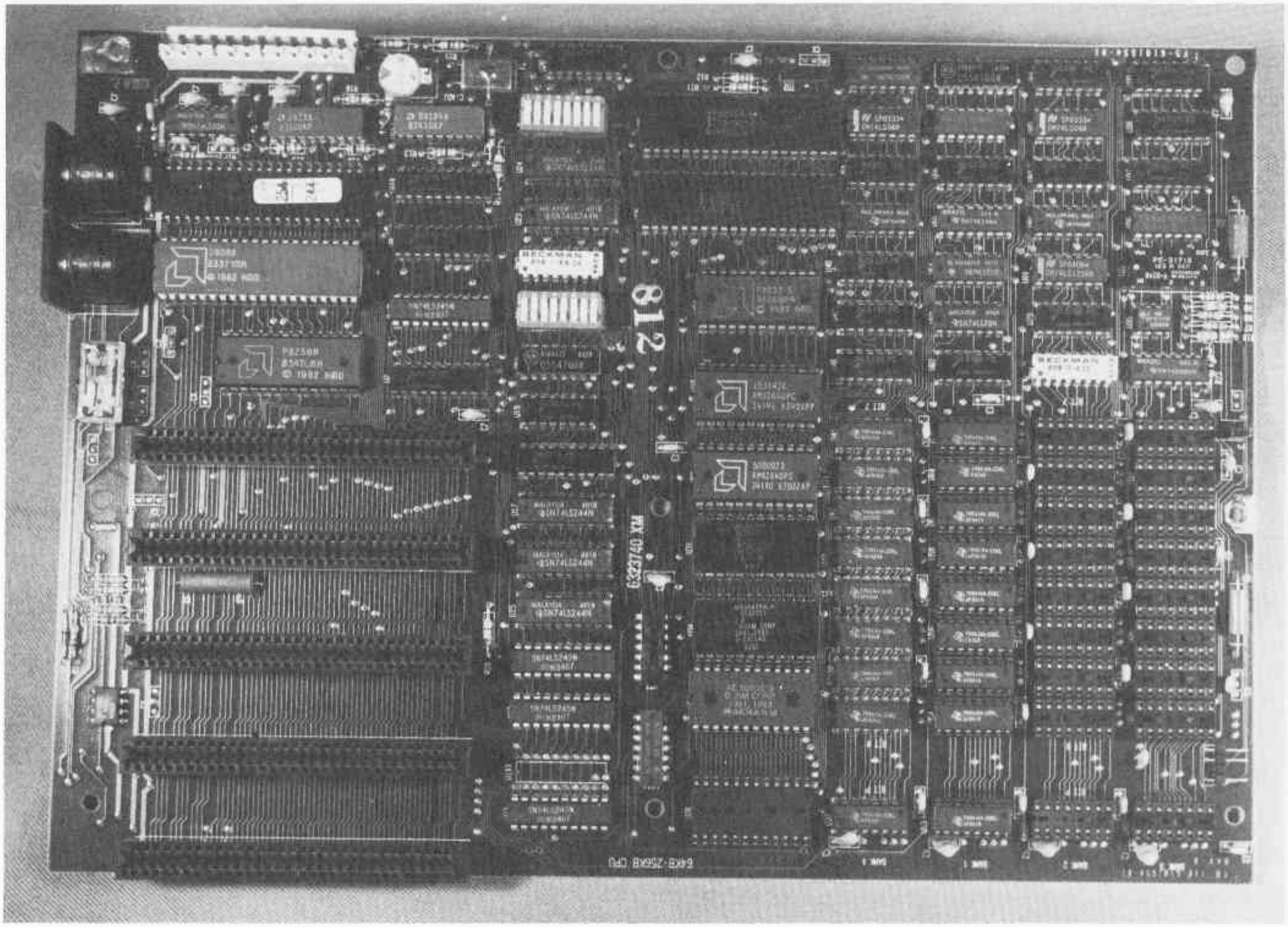

Fig. 1-9. Photo of the 64K-256K IBM PC system board.

it does greatly reduce the time required for certain mathematical functions. This IC can operate on floating point and multiple digit BCD numbers up to 18 digits in length.

The 8087 numeric data processor handles the data transfers between it and the 8088. Permanently stored in the 8087 are micro instructions for add, subtract, multiply, divide, absolute value, arctangent, tangent, square root, and other operations. Its unique "number-crunching" architecture enables calculations 100 times faster than the 8088. When installed, a switch on the system board enables the 8087 CPU to quickly download mathematic operations to its 8088 coprocessor, dramatically reducing execution times of these algorithms.

8259 PROGRAMMABLE INTERRUPT CONTROLLER (PIC)

Just above the 8088 shown in the layout diagram of Fig. 1-11 is the 8259 PIC (U2) that produces special signals that are used for external device communication with the CPU. The PC is an interrupt driven machine in which peripheral devices communicate with the CPU by interrupt signals that cause the CPU to stop what it was doing and service their request. Up to eight external devices can request PIC U2 to produce a CPU interrupt signal. By knowing which device is requesting the interrupt, U2 puts a special code out on the data bus for CPU recognition and action.

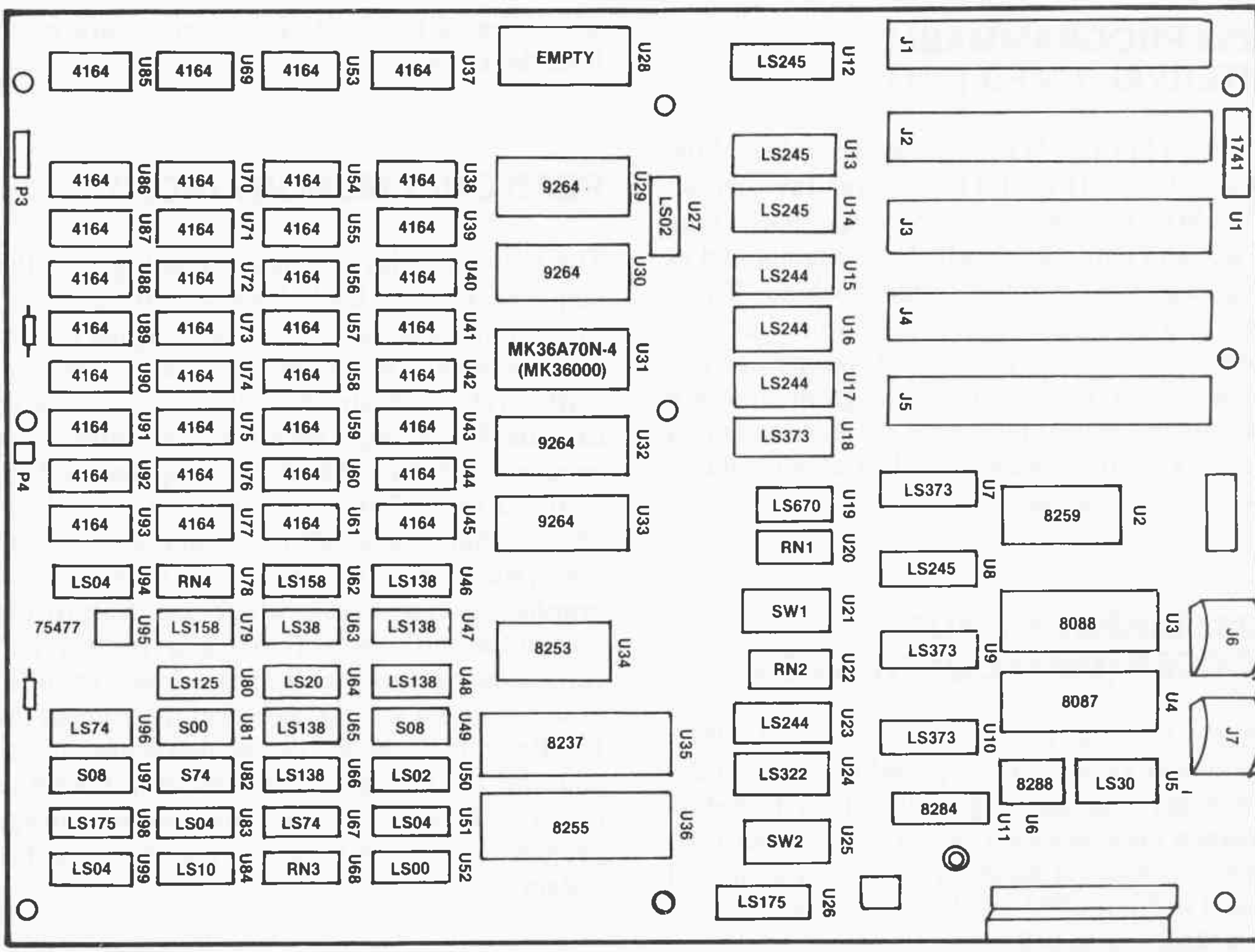

Fig. 1-10. The system board chip layout

8288 CLOCK GENERATOR

In the lower right of Fig. 1-10 is an 8288 clock generator (U11) that receives a power good signal from the power supply and a 14.31818 MHz signal from an attached crystal and produces the *reset* pulse and clock signals to start the CPU operating and awaken the circuitry of the system board into electronic life.

Once powered, this IC continuously produces several clock signals that pulse throughout the PC. A 4.772727 MHz signal is passed to the 8088 CPU and out onto the system board as the system clock. The clock generator also produces a 2.386 MHz signal that is divided by two and used to refresh the dynamic RAM on the system board, and to update the time-of-day internal PC clock. It also is used to activate the speaker.

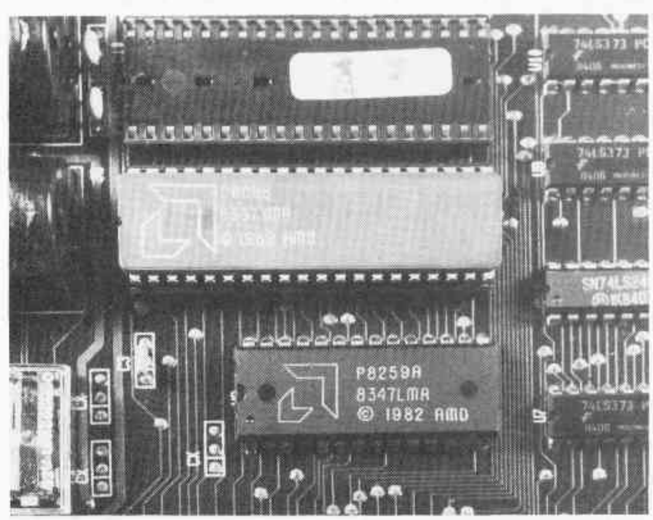

Fig 1-11. The 8088 central processing unit.

8253 PROGRAMMABLE INTERVAL TIMER (PIT)

The 8253 PIT (U34) near the lower middle of the system board (Fig. 1-11) receives the divided 2.386 MHz clock signal and develops special time of day and date signals which are maintained as long as power is applied to the machine. These time and date signals can also be stored in mass memory with a file you have developed so you know which version of a program you are accessing when you reload the file into temporary memory on the system board. It also produces speaker pulses for generating sound.

8237 DIRECT MEMORY ACCESS (DMA) CONTROLLER

Below U34 in Fig. 1-11 is an 8237 DMA Controller (U35). This special purpose microprocessor enables large data block transfers between mass storage (disk drives or other I/O) and the internal memory on the system unit board without CPU involvement. It can handle data blocks up to 64K bytes in length.

One of the four DMA channels of U35 combines with one of the three counter/timer channels of U34 to produce a refresh signal for the temporary memory chips and any additional memory mounted on expansion boards and plugged into one of the five expansion sockets.

8255 PROGRAMMABLE PERIPHERAL INTERFACE (PPI)

The IC below U35 in Fig. 1-11 is the 8255 PPI (U36). This smart peripheral device allows external communication with the CPU. It is a parallel I/O chip with three ports that can be configured by a software command to function as either input or output. The PPI is used to read the system board configuration switches to determine how much memory is installed, the number of disk drives, and the type of display screen being used. It also accepts data input from the keyboard.

READ ONLY MEMORY (ROM)

The column of large chips beginning with the empty socket for U28 holds 40K bytes of ROM. The empty socket was originally designed to hold cassette BASIC but wasn't required in the final configuration. Four 8K ROMs contain a large cassette BASIC high level language interpreter program. A fifth 8K ROM chip below U28 contains the ROM basic input/output system (BIOS) that enables CPU communication with the system circuitry. It handles video display graphics, a time-of-day clock, printing to the screen cassette operations, and printer and asynchronous device communications. Included in this chip is a self-test program that checks the functionality of the PC during power-up. It also contains a minifloppy disk bootstrap loader to cause a floppy drive to load mass storage programs onto the temporary memory on the system board.

RANDOM ACCESS MEMORY (RAM)

The temporary memory is the RAM mounted in four columns of nine chips each at the far left top of Fig. 1-11. Eight chips in each column make up the 8-bit data word. Early versions of the PC contained four columns of 16K x 1-bit ICs with a single column of chips providing the minimum 16K system and four columns of chips providing the maximum configuration of 64K RAM. After late spring of 1983, each PC was designed to hold 64K x 1-bit RAM chips providing working memory of between 64K and 256K.

In both cases, the ninth chip in each column is a special RAM used to store the parity value for each byte of stored data. During storage, parity circuitry determines the number of logic 1s in the word and adds enough (1 or 0) to make the number of 1s an even number. Thus 10010001 in the stored word would cause the circuitry to store a 1 in the parity RAM thus ensuring that the total number of 1s is even. When a word is read from RAM memory, parity check circuitry computes what the parity should be and compares its value (1 or 0) with the value stored in the parity RAM. If the two values are not the same, a non-maskable interrupt called parity error occurs causing the CPU to produce a display that reads PARITY CHECK and then halts system operation.

POWER SUPPLY

The switching power supply inside the system unit provides up to 64 watts of energy to operate the computer, its internal disk drives, and the adapter cards plugged into the system board expansion slots. It can also pass 120 VAC through to a socket on the rear of the system unit for powering a monochrome display.

The supply receives 120 VAC at 50/60 Hz through the line cord and generates +5, -5, +12, and -12 volts as output. It is fused and includes a power sensing device that automatically cuts off power to the PC if too much or too little voltage is detected. It also shuts down if an overvoltage or overcurrent condition occurs because of a short on the system board, on an expansion board, or in the disk drives.

Two 6-pin connectors provide power to the system board, and two connectors provide power to each internal disk drive assembly.

In the next chapter, you will read about the role of each of the previously described chips in the PC system and gain an in-depth understanding of how the IBM personal computer system operates. Chapter 2 takes you deep into the circuitry to gain a detailed understanding of the system you are about to repair and maintain.