The NEC PC-8001: A New Japanese Personal Computer

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One of the products attracting a lot of attention at the 1980 NCC (National Computer Conference) in Anaheim, California was the PC-8001 personal computer produced by NEC (Nippon Electric Company). Because this well-made little machine has been selling briskly in Japan, NEC was trying to gauge consumer reactions to the PC-8001 that would aid them in deciding whether or not to sell it in the US.

This article is based on our evaluation of a PC-8001 that some colleagues purchased in Japan. When we first received it, we were bewildered because all the instructions and documentation were in Japanese (with only the BASIC commands in English). After several months of poking, playing, and progamming, some syllable-by-syllable transliterations of the katakana (a Japanese syllabary) instruction manual, and a few puzzled visits to Hiro, a Japanese-American co-worker, we believe that we have a good understanding of the PC-8001's most important features, its strong points, and its limitations.

Photo 1 shows the basic components of the computer. It consists of two units: a keyboard (including both the processor and memory) and a color monitor, and it features a 24 K-byte version of Microsoft BASIC in ROM (read-only memory). The dollar equivalent prices of the keyboard unit and monitor are $700 and $910, respectively. *[These prices, however, may be only distantly related to the final price of the American version of this microcomputer....GW]*

The processor is an NEC version of the Z80 running at 4 MHz.

Keyboard

The eighty-two-key keyboard has a high-quality standard English alphabet keyboard, five user-definable function keys, and a separate numeric keypad. In the normal mode, the user can enter uppercase and lowercase Roman characters; if he presses a locking shift key, he can enter characters in the Japanese katakana syllabary as well. Pressing a letter key and the nonlocking "graph" key causes one of a set of graphic characters to be displayed; this set includes bars, arcs, crosses, hearts, spades, clubs, and diamonds. (Although the katakana character set may appear useless to most American users, the characters are visually interesting and nicely augment the set of graphics characters.) All the characters available are shown in photo 2. There is also a reset button on the back of the console, so it can't be hit accidentally.

Inside the keyboard unit, the most noticeable feature is the switching power supply, which is mounted in a long, thin metal cage (approximately 38 by 6.35 by 3.175 cm [15 by 2½ by 1¼ inches]) extending along the entire rear of the keyboard enclosure. (See photo 3.) The elongated shape allows the entire power supply to be suspended over the printed-circuit board under the only portion of the cabinet that can be vented. During operation, however, the power supply remains cool.

The 22.9 by 38.1 cm (9 by 15 inch) printed-circuit board has three layers, but the center layer does not appear to be nearly as extensive as the other two layers. There are at least sixteen test-point posts staked into the board.

Most of the integrated circuits are mounted directly on the board, but the circuits that are either expensive or might have to be replaced (the

memory, central processor, DMA [direct-memory access] controller, USART [universal synchronous/asynchronous receiver-transmitter], video display device, and font memory) are all in sockets. The board is easy to remove because all connections to it—power, keyboard, beeper—are made with plugs and sockets; there are no external connections or even jumpers soldered to the board.

The processor is an NEC version of the Z80 running at 4 MHz. The BASIC ROM occupies the 24 K bytes of memory from hexadecimal 0000 to 5FFF, and hexadecimal locations 6000 to 7FFF are available for an expansion ROM. Standard programmable memory extends from hexadecimal locations C000 to FFFF, with locations 8000 to BFFFF available for expansion. The board has empty sockets available for both expansion ROM and programmable memory. A time-of-day clock is included on the board (see figure 1).

The video controller is a custom NEC integrated circuit. There are two separate video output connectors on the back of the keyboard unit. A 5-pin DIN (Deutsche Industrie Norm) connector provides a baseband video signal for a black and white monitor and a similar 8-pin connector provides red-green-blue signals for a color monitor. With a black and white display, colors appear as different shades of gray.

In addition to a video-out signal and ground, the 5-pin connector provides V_{DD} (+12 V) and horizontal and vertical sync signals. The 8-pin connector provides V_{DD}, ground, color-clock signal, horizontal and vertical sync signals, and red, green, and blue signals. Although the color monitor has an audio amplifier and speaker, the processor does not use them. The only sound made by the PC-8001 is provided by a 2-inch speaker mounted on the power supply. The user can only control the duty cycle of a fixed-frequency beeper.

Another DIN connector and an adapter cable provide an interface to any standard cassette recorder for program loading and storage. The encoding scheme is 600 bps (bits per second) FSK (frequency shift keyed) Kansas City format (which uses 1200 and 2400 Hz frequencies). This encoding scheme is very robust—unlike many computers, almost any volume setting on the tape recorder is okay. A relay inside the console controls the tape recorder motor (or any other motor for that matter—a MOTOR command in BASIC allows a user to toggle this relay).

A 16-pin socket on the printed-circuit board serves as an RS-232C connector, while cutouts at the back of the cabinet give access to a pair of edge connectors on the board. One is for a printer and one is a DMA channel. An expansion unit is available to interface the DMA channel to up to four disk drives, two RS-232C serial

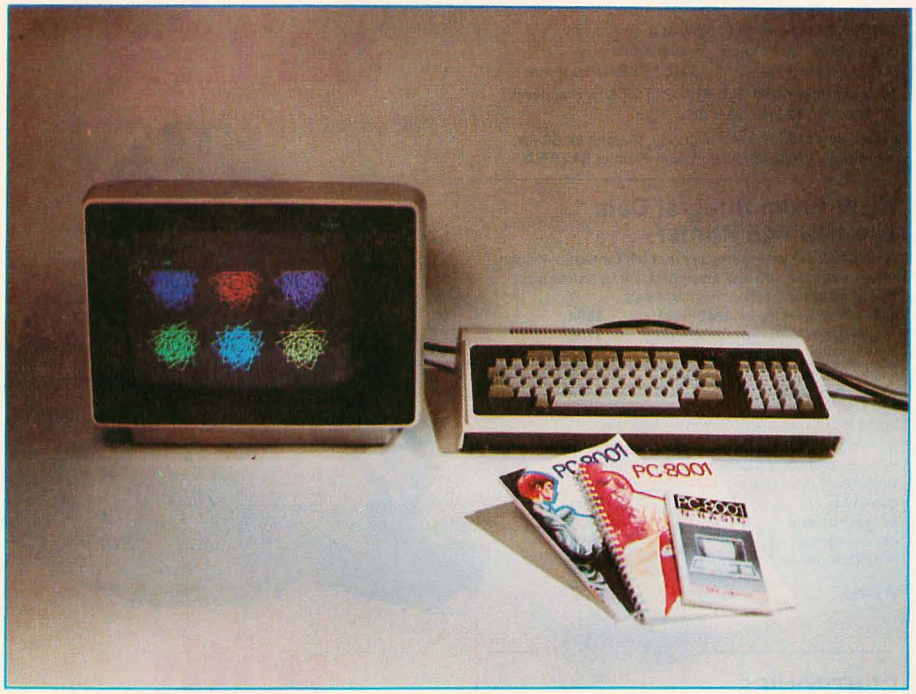

Photo 1: *The NEC PC-8001 personal computer system. Shown here is the basic system: high-resolution color monitor, keyboard unit, and documentation (reference manual, BASIC manual, and BASIC reference card).*

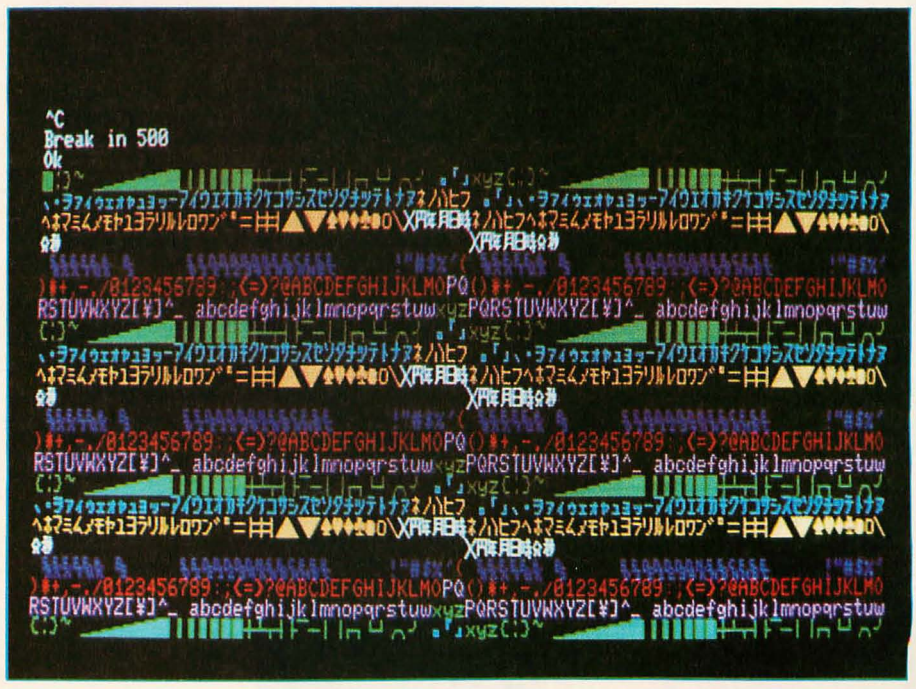

Photo 2: *A display illustrating the colors and the character set on the PC-8001. In addition to complete ASCII, there are various graphics characters, control characters, and katakana characters.*

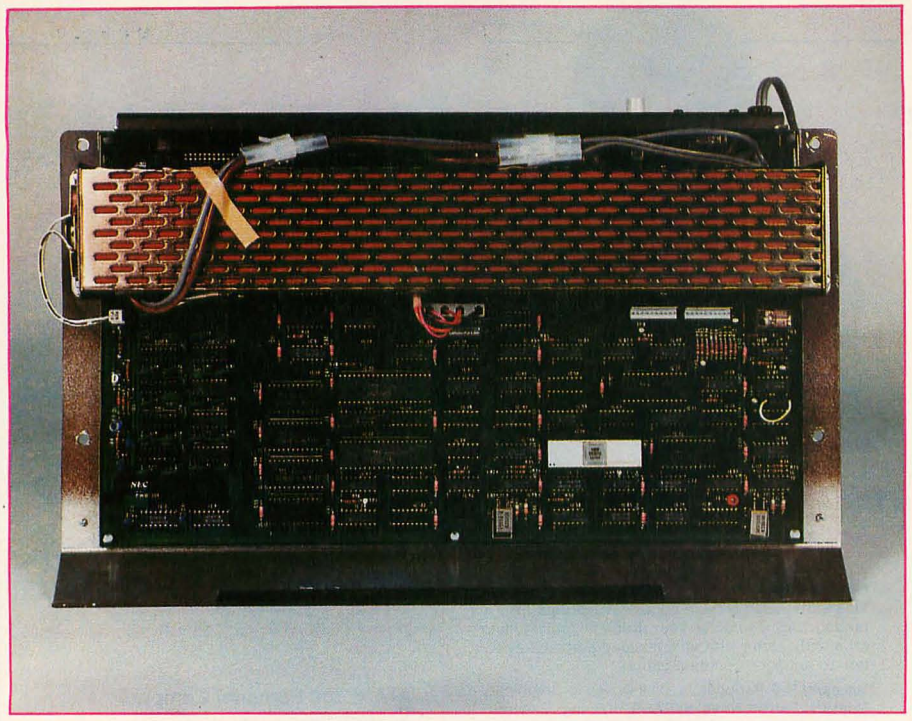

Photo 3: *Inside the keyboard unit. The bottom of this photo corresponds to the front of the keyboard. Along the top edge is the power supply and, below it, the main printed-circuit board. The reset button can be seen at the rear of the keyboard near the power cord.*

N-BASIC, written by Microsoft, is a floating-point BASIC capable of operating in either single or double precision.

ports, a parallel port, and an IEEE (Institute of Electrical and Electronics Engineers)-488 bus (see figure 2).

Monitor

Everyone who has seen the NEC color monitor has commented favorably on its convergence and overall quality of construction. The CRT (cathode-ray tube) is a 30.48 cm (12-inch) diagonal tube and has an in-line gun structure and dot screen face with 12-mil (0.012-inch) dot spacing. The deflection yoke is the precision wound torodial type. Convergence is excellent: during construction, wedges were inserted between the yoke and the neck of the tube to shim the yoke into correct alignment.

The chassis is transformer powered. Almost all the electronics are mounted on one large single-sided printed-circuit board. The horizontal scan frequency is 15,974.4 Hz, and the vertical scan frequency is 60 Hz. The monitor uses an RGB (red-green-blue) signal interface with separate horizontal and vertical sync signals. All signals are at TTL (transistor-transistor logic) levels. Although the monitor has an audio amplifier and speaker, the audio line on the connector is tied to V_{DD} on the Z80 microprocessor. The computer generates a format of up to 80 characters per line and 25 lines, noninterlaced. The image quality is excellent, as can be seen from photo 2.

The monitor power supply apparently has some sort of time delay element, either intentionally or unintentionally, that prevents the user from turning on a set that is still warm. If you turn the monitor off and then try to turn it back on again without waiting a minute or so, the screen remains dark.

Software

As mentioned previously, the BASIC by Microsoft, called N-BASIC, is contained in three 8 K-byte ROMs. Contained within these 24 K

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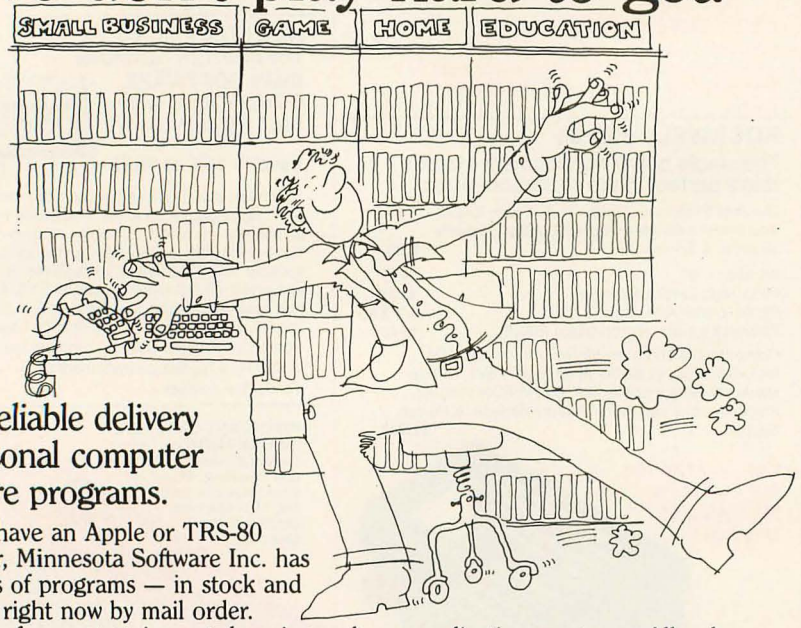

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bytes of ROM is a very complete BASIC, as well as a system monitor program. Advertisements in the Japanese computer magazine *ASCII* indicate that a number of user programs (including a color version of the ever-popular Space Invaders) are readily available on tape.

N-BASIC is a floating-point BASIC capable of operating in either single or double precision. All the features of standard BASIC are present, along with a few interesting extensions, such as:

- SWAP: exchanges value of two variables;
- BEEP, MOTOR: toggles beeper or motor relay;
- HEX$: decimal to hexadecimal conversion;
- STRING$ (X,Y): string equal to X copies of the character with ASCII (American Standard Code for Information Interchange) code Y.

The PC-8001 has one feature that ought to be included in all personal computers: a single BASIC command that changes it from a computer to a terminal.

In addition, there is a whole set of graphics and display commands that will be described further.

There is also a monitor program which gives the user direct access to the Z80 machine code. After entering the monitor by typing MON, the user can test, manipulate, load or store bytes of blocks of memory using the commands in table 1.

Another useful feature of N-BASIC is the use of the ESC (escape) key on the keyboard as a pause function. It

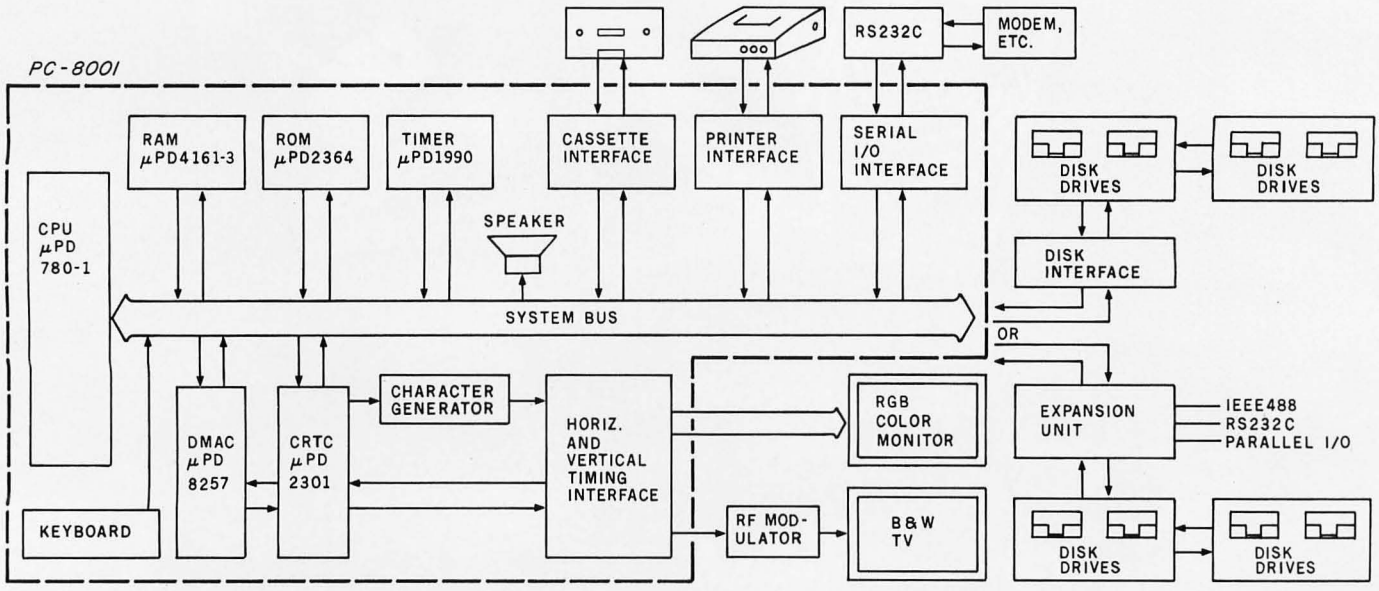

Figure 1: *Block diagram of the NEC PC-8001 system. The modules within the dotted lines are contained in the PC-8001 keyboard unit.*

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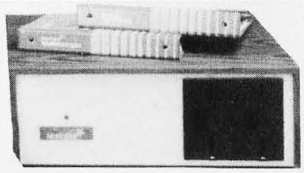

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can be used to pause in the middle of a program execution, program listing, monitor dump, and just about any other process. Pressing ESC again resumes the program or listing. This is very handy for debugging or for reading parts of a long program listing.

Finally, the PC-8001 has one feature that ought to be included in all personal computers: a single BASIC command that changes it from a computer to a terminal. The TERM command allows the user to select either ASCII or JIS (Japanese Industry Standard) coding, parity, and clocking options. A jumper inside the keyboard unit selects data

Command	Meaning
S xxxx	displays the byte whose address is xxxx and changes it to the value to be entered
D xxxx, yyyy	displays the hexadecimal values stored in locations xxxx to yyyy
G xxxx	goes to byte xxxx and starts executing
W xxxx, yyyy	writes to tape the block from xxxx to yyyy
L	loads a stored block from tape back to memory
LV	loads a stored block from tape and verifies that it has been correctly loaded
TM	tests memory and returns to BASIC
control-B	returns to BASIC

Table 1: *Monitor commands within the NEC PC-8001. These commands are available to the user for work in machine-language programming.*

CONSOLE <T>, <N>, <K>, <M>
Sets the following display parameters:

T = top line of scrolling window
N = number of lines in scrolling window
K = key list flag; if 1, displays identity of programmable function keys
M = color mode: 1 = color, 0 = black and white

COLOR <C>, <B>, <M>
Sets the following parameters:
C = color (or attribute in black and white mode):

In Color Mode:	In Black and White Mode:
0 = black	Bit 0 = visibility (0 = visible)
1 = blue	Bit 1 = flashing (1 = flash)
2 = red	Bit 2 = reverse video (1 = reverse)
3 = magenta	
4 = green	
5 = cyan	For example, color 6 in black and white mode would pro-
6 = yellow	duce flashing, reverse-video characters.
7 = white	

B = background character; fills the background with the character whose ASCII code is B.
M = mode flag, 1 = graphics mode, 0 = text mode

WIDTH <H>, <V>
sets screen format (H by V); (H = 80, 72, 40, or 36; V = 25 or 20)

LOCATE <X>, <Y>
moves cursor to character position (X,Y)

PSET (<X>, <Y>, <C>)
draws a graphics dot at graphics coordinate X,Y in color C

PRESET (<X>, <Y>)
erases a graphics dot at X,Y

LINE (<X1>, <Y1>)-(<X2>, <Y2>), "<char>", <C>, [B [F]]
Draws a line from (X1,Y1) to (X2,Y2). The line is a line of text characters "char". If "char" = PSET or PRESET, the line is a graphics line and X and Y are interpreted as graphics coordinates. <C> is the color of the line. If present, B causes a rectangle (block) to be drawn with (X1,Y1) and (X2,Y2) as opposite corners, and F causes the rectangle to be filled.

GET @ (<X1>, <Y1>)-(<X2>, <Y2>), X
stores characters from the specified rectangular area of the screen into array X

PUT @ (<X1>, <Y17>)-(<X2>, <Y2>), X
puts characters from array X to the display

Table 2: *Commands for color-graphics display from within N-BASIC.*

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transfer rates of either 4800, 2400, 1200, 600 or 300 baud; the function keys on the keyboard determine whether the terminal operates in half- or full-duplex modes. The only apparent deficiency is the lack of a shift lock key for the terminal mode.

Graphic and Display Features

The display features of the PC-8001 include:

- eight-color display (both text and graphics);
- 248-symbol character set (complete ASCII, katakana, and graphics characters—lines, arcs, card symbols);
- variable screen format: (80, 72, 40, or 36 characters by 25 or 20 lines);
- two display modes: text and medium-resolution (160 by 100 pixels) graphics (these two modes can be intermixed on the same display);
- flashing, reverse video, and underlined text.

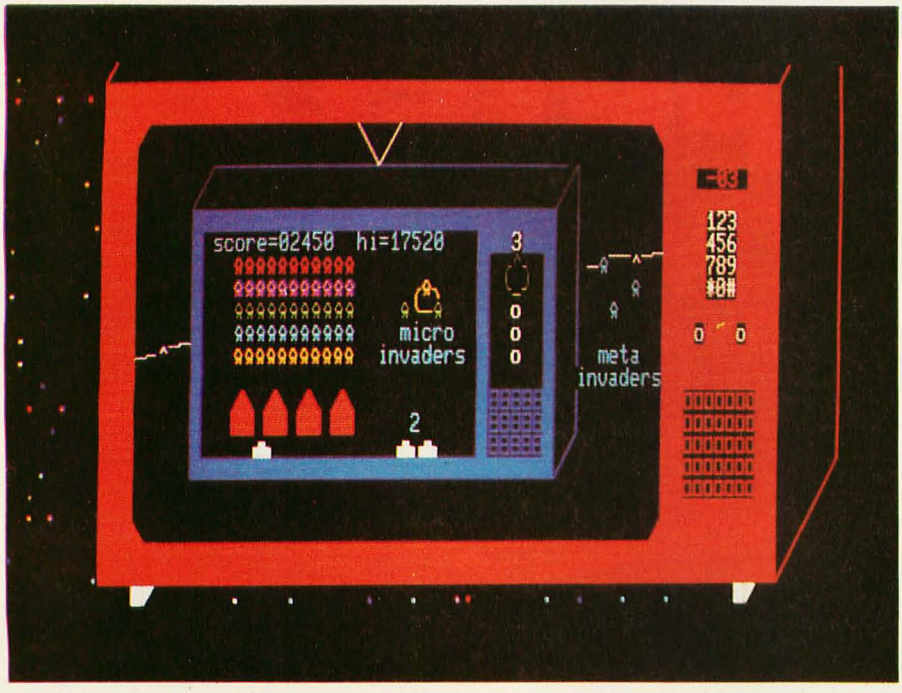

Photo 4: *Sample display created on the PC-8001 by the authors. Note the use of the Japanese characters for graphics—the little invaders are actually the Japanese characters for the word "minute."*

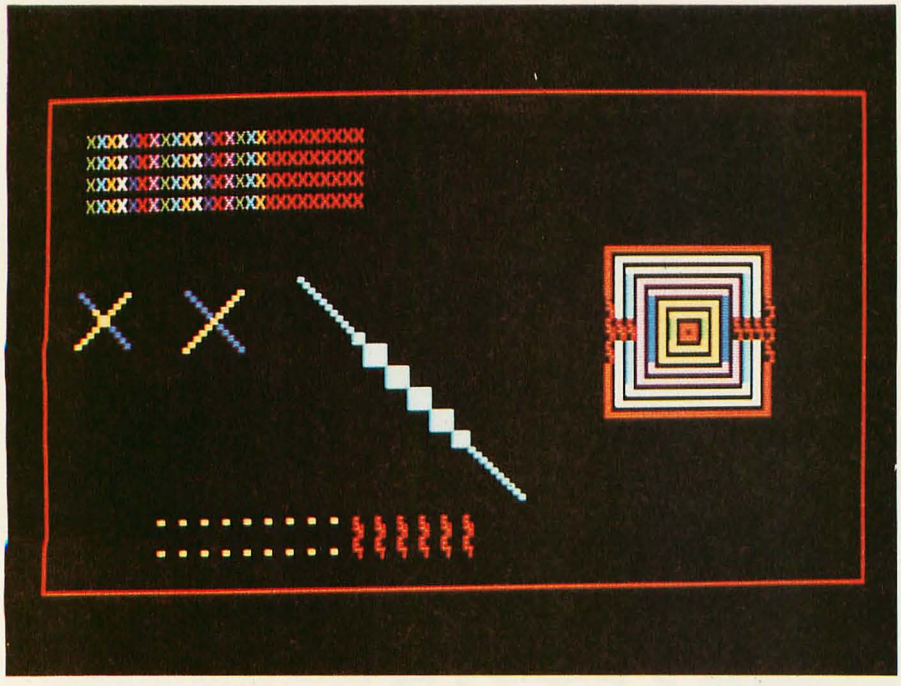

Photo 5: *Illustration of some of the display restrictions of the PC-8001. See text for explanation.*

Table 2 lists the graphics and display-related extensions in the PC-8001 dialect of BASIC. These include commands for cursor positioning, changing various display parameters, and plotting points and drawing lines in gaphics mode. Two particularly worthwhile instructions are GET and PUT. GET allows the user to store the image in a specified rectangular area of the screen in an array, which can then be PUT at another location on the screen. This allows the user to define complex shapes that can then be drawn on the screen with a single instruction. Repetitive erasure and redrawing of a shape also provides a simple method of animation.

Photo 4 is a sample of what can be done with the PC-8001 graphics. This display uses most of the commands in table 2 and, in addition, illustrates the use of some of the Japanese characters for graphics purposes (the invader figures and the television speakers are made from these characters).

Problems with Video Displays

Upon further experimentation with the computer, we discovered that certain graphics operations can sometimes produce strange and unexpected results. A sampling of some of the display anomalies which can occur is shown in photo 5. The following unexpected things happen in this display:

1. Each column of Xs in the upper-left corner should be a different color, but after eighteen columns, the display remains in one color.
2. The two pairs of intersecting lines should be the same, but in the one on the left, extra areas are colored in near the intersection.
3. The width of the white diagonal line should stay constant, but it becomes much thicker in the middle.
4. The two rows at the bottom left should be all dots, but some of the dots are printed as text characters.
5. The figure on the right of the

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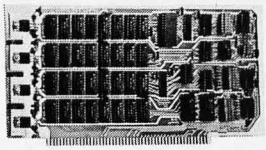

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display should be a ring of concentric squares, each a different color, but the line thickness varies and some dots are replaced by text characters.

The explanation for all these anomalies lies in the way the text and graphic information is represented in memory. For example, consider the full 80-character by 25-line screen format. To represent a screen of information in memory requires storage space for 2000 characters and their attributes (color, flashing, etc). At 1 byte for the character and 1 byte for its attributes this would require about 4 K bytes of memory. However, only 3 K bytes are allocated for screen storage (addresses F300 to FEB8). The way these 3 K bytes of memory are organized explains all these display anomalies and also provides insight into a useful feature that makes the PC-8001 unique.

As shown in figure 3, each row of characters on the screen is represented by 120 bytes in memory. The first 80 of these 120 bytes contain the ASCII codes for the 80 characters in the row. The remaining 40 bytes are organized into twenty pairs. We have not determined the use of the first pair, but the remaining nineteen pairs are used to encode up to nineteen attribute fields for that row. Each pair P_i points to the beginning of the field, which runs to position $P_{i+1}-1$ (the P_i are always ordered so that $P_1<P_2<$...etc) and contains characters with attributes a_i (where a_i is the 1-byte attribute within pair P_i).

Whenever a program, in printing on the screen, uses up the first eighteen attribute fields for a row, all suc-

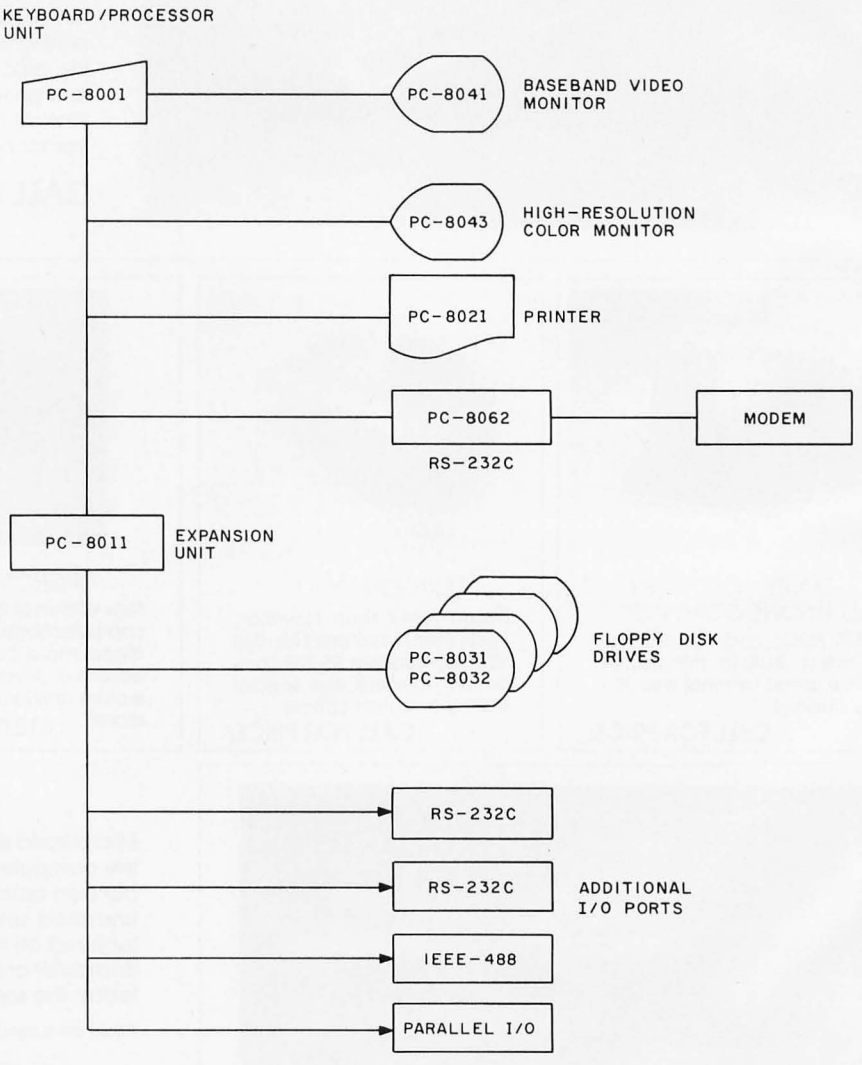

Figure 2: *Interconnection block diagram of the NEC PC-8001 system. While many peripherals can be directly connected to the PC-8001, disk drives and I/O ports must be connected through the PC-8011 expansion unit.*

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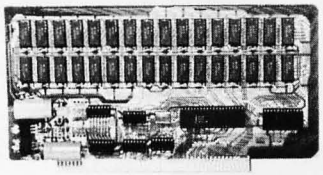

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cessive characters on the same line that occur after these fields are given the attribute a_{19}. This is the default attribute for that row that is set to the current attributes in effect whenever a clear-screen command is received.

This explains the first anomaly in photo 5. After eighteen different-colored columns, the computer "runs out of colors," and the remaining columns default to red. Red is not specified in the program; it just happened to be the color in effect when the program started.

Another problem occurs when plotting color graphics because the PC-8001 has character-oriented (not bit-mapped) graphics. (In this respect, it is closer to the Radio Shack TRS-80 than to the Apple II, for example.) Each character space is divided into a 4 by 2 array of cells, each of which can be "on" or "off." This provides an alternate character set consisting of the 256 possible arrays of on and off cells. When points, lines, or graphics shapes are drawn, the computer automatically converts the points to the required graphics characters and displays these, thus providing an effective graphics resolution of 160 by 100 cells.

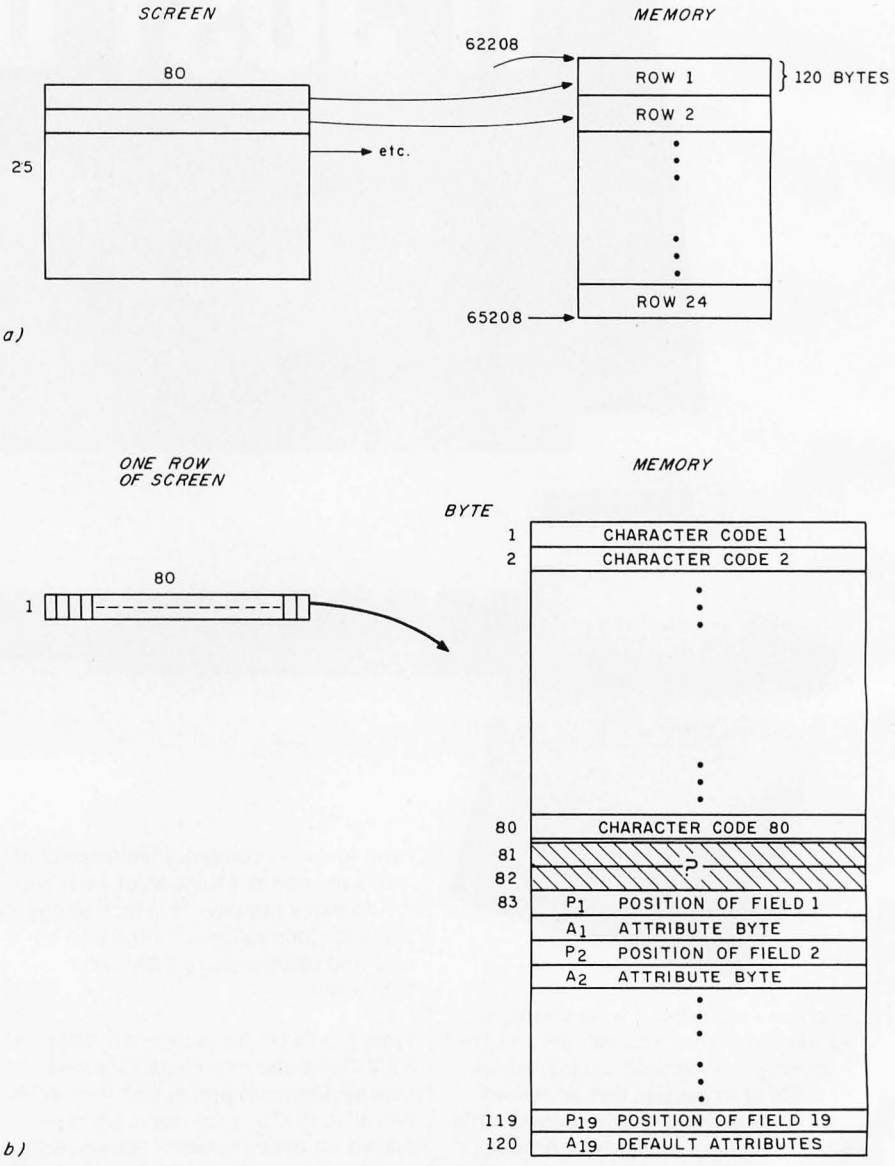

Figure 3: *Format of the NEC PC-8001 memory-mapped video display. Figure 3a shows how each row of the video display translates into a block of programmable memory. Figure 3b shows how each 80-character row is stored in memory. A row can be broken into a maximum of nineteen fields, the position and attributes of which are described in the last 38 bytes of the memory associated with one row. All numbers shown are in decimal. See the text for further details.*

However, a problem occurs when, for example, two lines of different colors intersect. Because a character cannot be two colors at the same time, the algorithm used by the computer gives the most recently plotted points precedence. Any cells within the same character space that are already "on" are changed to the new color. Thus, an adjacent pair of horizontal lines for which different colors are specified may be displayed in either the same or different colors, depending on whether or not they lie on opposite sides of a character cell boundary. We can show that this is a limitation of the software and not of the hardware video-controller device: the command OUT 63,41 (presumably an output to part of the video-controller device) fills the screen with adjacent horizontal lines of different colors.

This also explains anomalies 2 and 3 in photo 5. The two crosses look different because they intersect in different positions relative to cell boundaries. The white diagonal line changes width because it crosses a black graphics rectangle. Even though the black rectangle is invisible to the casual observer, it changes the appearance of the intersecting diagonal line: every cell in each character space changes to white.

This alternative graphics-character set is selected with one of the bits in the attribute byte. This implies that the user can also "run out of graphics" on a horizontal line. This is what happens in anomalies 4 and 5 (bottom and far right of photo 5). The default attribute byte happens to specify text mode. Hence the remaining characters on the line are displayed as their text equivalents.

It is unclear why the designers chose this display approach, particularly since a full character- and attribute-mapped display would have required only 4 K bytes of memory instead of 3 K bytes. But even though this implementation imposes some restrictions on the types of displays that can be generated, it also provides an interesting capability which, to our knowledge, is not found on any other personal computer.

This capability is a consequence of the fact that the attributes of a character on the screen are specified indirectly. That is, each character is identified with a field number which in turn is associated with an attribute byte. Thus, by a direct POKE into memory (a 1-byte change), the user can change an attribute (specifically, color) of a character or group of characters (up to an entire field) without altering the character or field codes. This allows a sophisticated method of animation called *color table animation* in which the user first prints a number of images in different fields on the screen, then changes the color of the fields to make each image appear in succession. As an example, we have written a BASIC program which animates a large flying saucer flying amidst a field of stars at 20 images per second. This is very fast for an interpretive BASIC animation.

Summary

The PC-8001 appears to be an attractive, well-planned, and well-made personal computer. The graphics, though somewhat rudimentary, are more than adequate for charting, graphing, and business applications, and they can do a creditable job on many games as well. Most people who have seen our PC-8001 feel that, if it were sold in this country, it would provide strong competition for any of the color-based home computers currently being sold. ■

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