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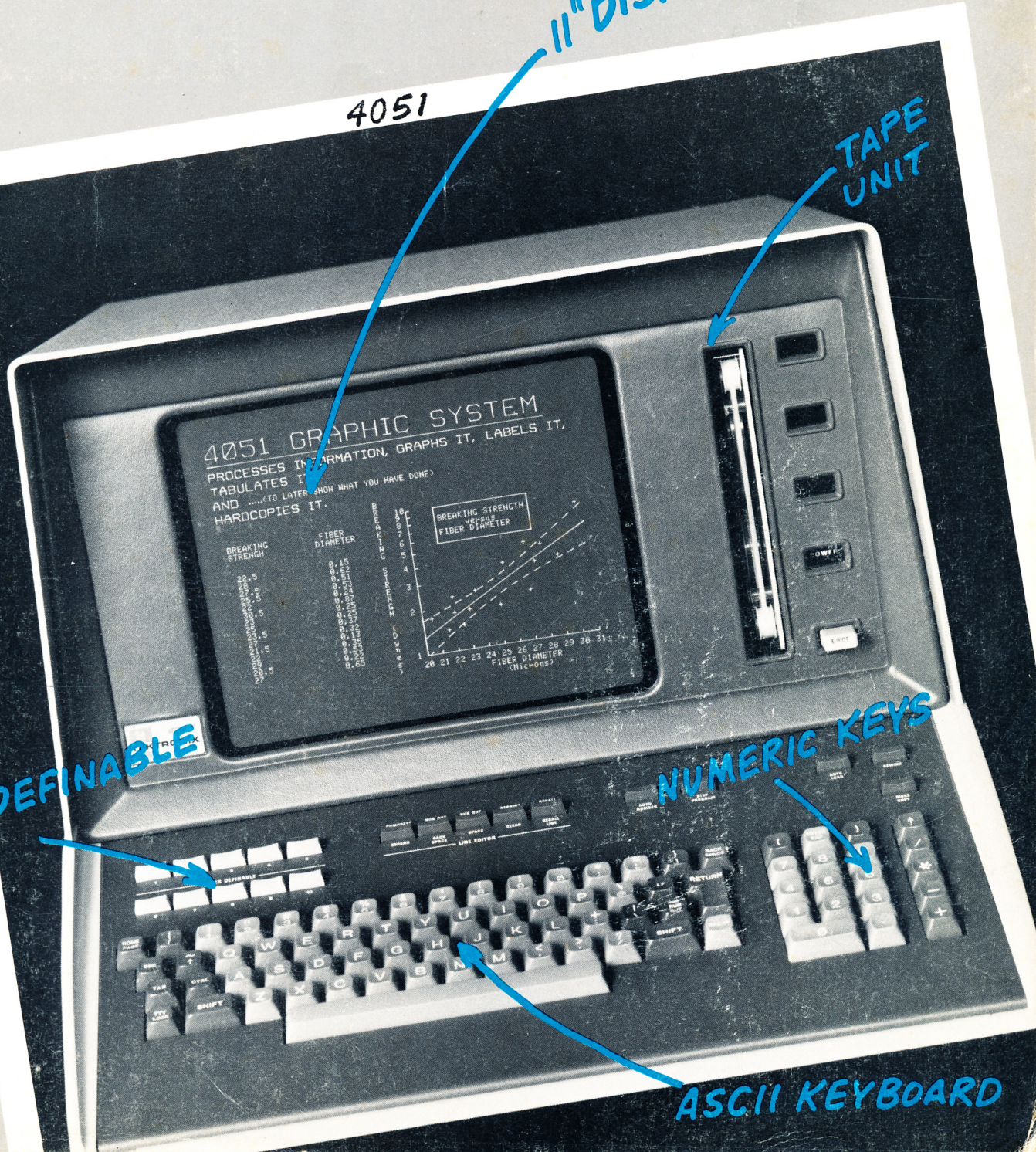
11" DISPLAY

TAPE UNIT

USER DEFINABLE KEYS

NUMERIC KEYS

ASCII KEYBOARD



TEKSCOPE



Colin Barton



Customer Information from Tektronix, Inc.,
Beaverton, Oregon 97077

Editor: Gordon Allison
Ass't. Editor: John Mulvey

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A desk-top graphic computing system

With the cost of memories and processors on the decline, the economies of scale of big computers are slowly diminishing. Communications costs are high. There are often long waits for results, and the system can take as much as 40% of its time trying to figure out what to do next. Like big cities, big computers are fraught with problems. In the future, more and more computing will be done locally at the desk of engineers, business analysts, scientists, etc.

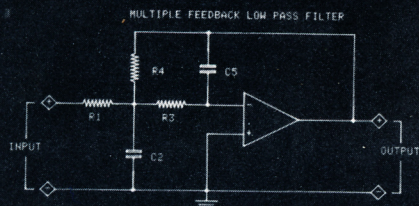
As society progresses technologically the problems faced in all fields increase in complexity. People need to devote all their energy to whatever is facing them. Having to understand the problems of putting together a computer system should not be one of their tasks. So the 4051 is not a collection of hardware and paper tape for a user to get along with somehow. Instead, it is designed so all of its facilities are easy to use. It avoids user perceived complexity. A desktop system should be an extension of a user's mind. The 4051 does this in four ways:

1. It is a machine using a people-oriented higher-level language . . . extended BASIC.
2. It uses graphics to help a user perceive a problem more naturally, see a solution in perspective.
3. The acquisition of data by and from instrumentation can be handled using the same language . . . extended BASIC.
4. The 4051 can efficiently access host computer files.

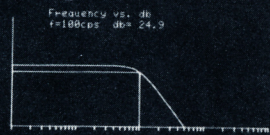
The language

For those who already know BASIC as a programming language little needs to be said about its simplicity and conversational character. A lot of very careful, capable thinking went into the development of the language to make it simple to learn as well as suitable for a wide range of disciplines. Today it is widely used. Only a few hours with a self-study book gives you a feel for the language. A few days of study will make you an apprentice programmer.

The main thing experienced programmers question is whether BASIC is adequate to solve their toughest programs. When you already know a more complicated language and have access to machines that use it, there may be little opportunity or reason to learn about the limits of BASIC. That



FREQUENCY 100KHZ
 GAIN 20
 R1 = 450.2 Ohms
 R2 = 5.20 uf
 R3 = 492.8 Ohms
 R4 = 11254.0 Ohms
 C5 = 0.10 uf



4051 GRAPHIC SYSTEM

4051
 TEKTRONIX

POWER

RESET



factor will probably retard wide-spread understanding of its great power. However, counterbalancing that factor will be people who recognize the comparatively small investment necessary to develop the expertise with BASIC to know, instead of guess at, its limitations. For people who already know a language like FORTRAN, learning BASIC is a snap. There is even a tutorial tape cartridge for the 4051 that is like a programmed instruction course. It is good for beginners as well as experienced programmers.

There probably is no "pure" form of BASIC in practical use. Most equipment uses extended forms that differ somewhat from one manufacturer to the next, and even from one kind of equipment to the next from the same manufacturer. But these differences typically don't cause big problems. Many programs already written in BASIC can be used with little or no alteration in the 4051. And alterations are simple to make right from the keyboard, using the edit facilities.

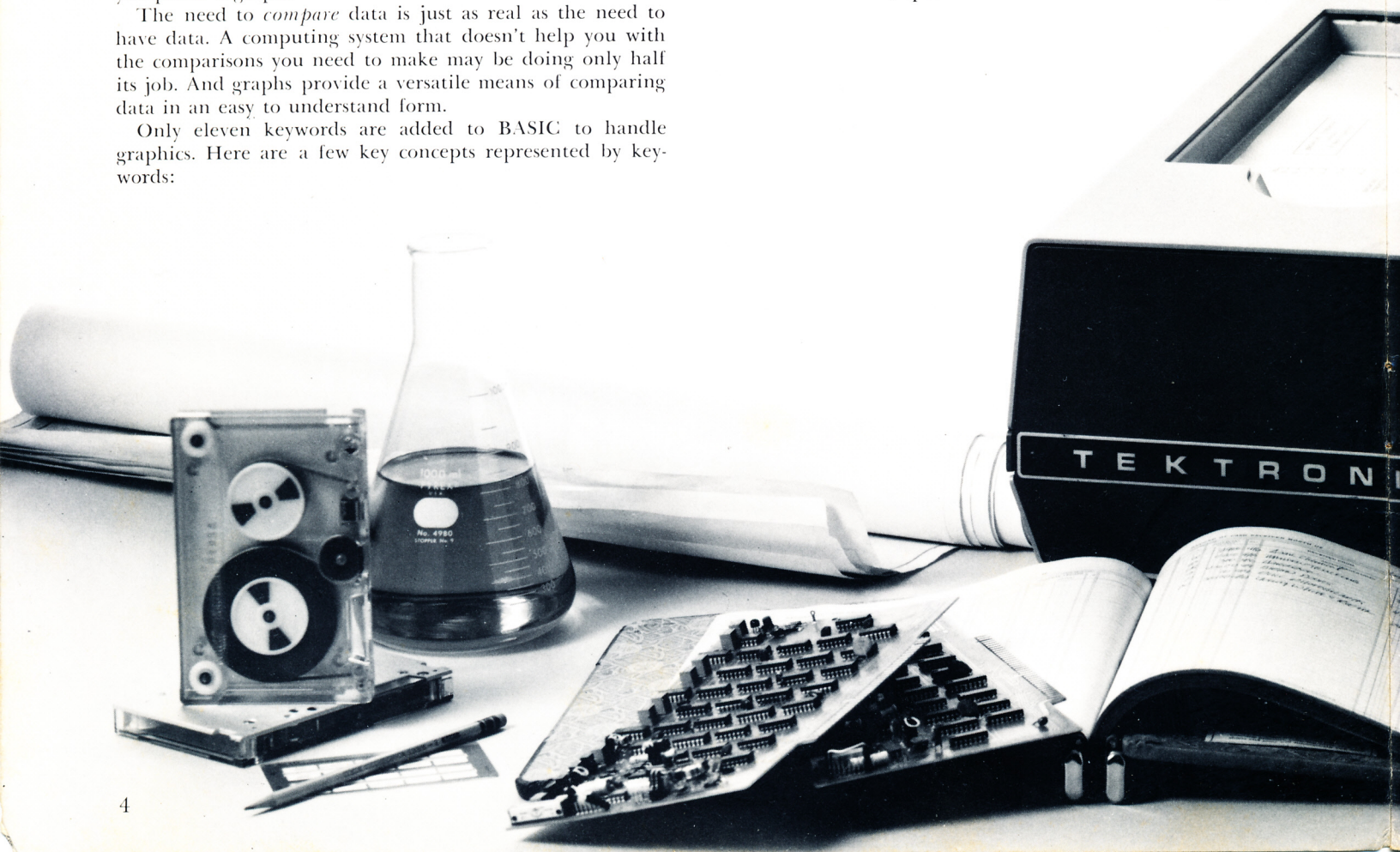
Language extensions for graphics

The ability of the 4051 to depict information in graphic form, as distinguished from simply displaying alphanumeric characters and a few straight lines, may be its most valuable feature. But many who need computer data in graphic form may not even know it. You need to think about it a little to know. And if you have always expected computer output in the form of letters and numbers, because that is all you have seen you haven't seen enough. When it comes to your pay check, for example, characters you call take-home pay may be clear enough. But how does your take-home pay over the past 120 months compare to the cost of living? You might be shocked but if this were a scientific business statistic, it would be far better to know than to guess. Would you like that information in a column of 120 figures, or would you prefer a graph?

The need to *compare* data is just as real as the need to have data. A computing system that doesn't help you with the comparisons you need to make may be doing only half its job. And graphs provide a versatile means of comparing data in an easy to understand form.

Only eleven keywords are added to BASIC to handle graphics. Here are a few key concepts represented by keywords:

- VIEWPORT: Controls how much of the output surface is used for a graph and where the boundaries will be.
- WINDOW: Controls what portion of the available X-Y coordinate data will be placed in the viewport.
- SCALE: Divides the X-Y coordinates of the viewport into segments corresponding to the proper numeric values for the graph.
- POINTER: Causes the machine to display an arrow positionable with the optional Joystick.
- DRAW: Draws a straight line between the present position of the cursor and a specified point in the WINDOW.
- RDRAW: (Relative draw) Draws a straight line between the present position of the cursor and a point in the WINDOW specified relative to the position of the cursor.
- MOVE: Like DRAW except no line is produced.
- RMOVE: Relative move. Like RDRAW except no line is produced.
- AXIS: X and Y axis lines are drawn and scale tic marks located.
- GIN: Graphic Input. Records the location of the graphic point; either the point of the arrow or the lower left corner of the normal 5 x 8 dot matrix rectangular cursor.
- ROTATE: Causes relative draw or relative move to follow a path that departs from the normal by a specified number of radians or degrees.



Listener, talker, controller

The 4051 is designed to control the operation of instruments in the same sort of way as larger computer-based systems. Whether you want to simply monitor and analyze processes, or control processes, the capability is built in. Perhaps top on the list of the advantages the 4051 offers over former test and process controllers is that it has a new standardized, general-purpose, interfacing system (GPIB). This system, now standard in the U.S., is close to being an international standard. Peripheral instruments under control of the 4051 may be classified as Talkers, Listeners, or both. The 4051 may talk, listen, or control, according to its program and signals on the GPIB. The way in which it goes about this is what has been standardized. Commercially available Talkers or Listeners are already compatible. Future designs will be. The 4051 is at the forefront of a new era of instrument test, measurement, and process control. The U.S. Standard is called IEEE Std 488-1975. It was adopted this year. This standard was sponsored by the IEEE Instrumentation and Measurement Group and is based on work initiated by Working Group 3 of Technical Committee 66 of the International Electrotechnical Commission (IEC). The full title is IEEE Standard Digital Interface for Programmable Instrumentation.

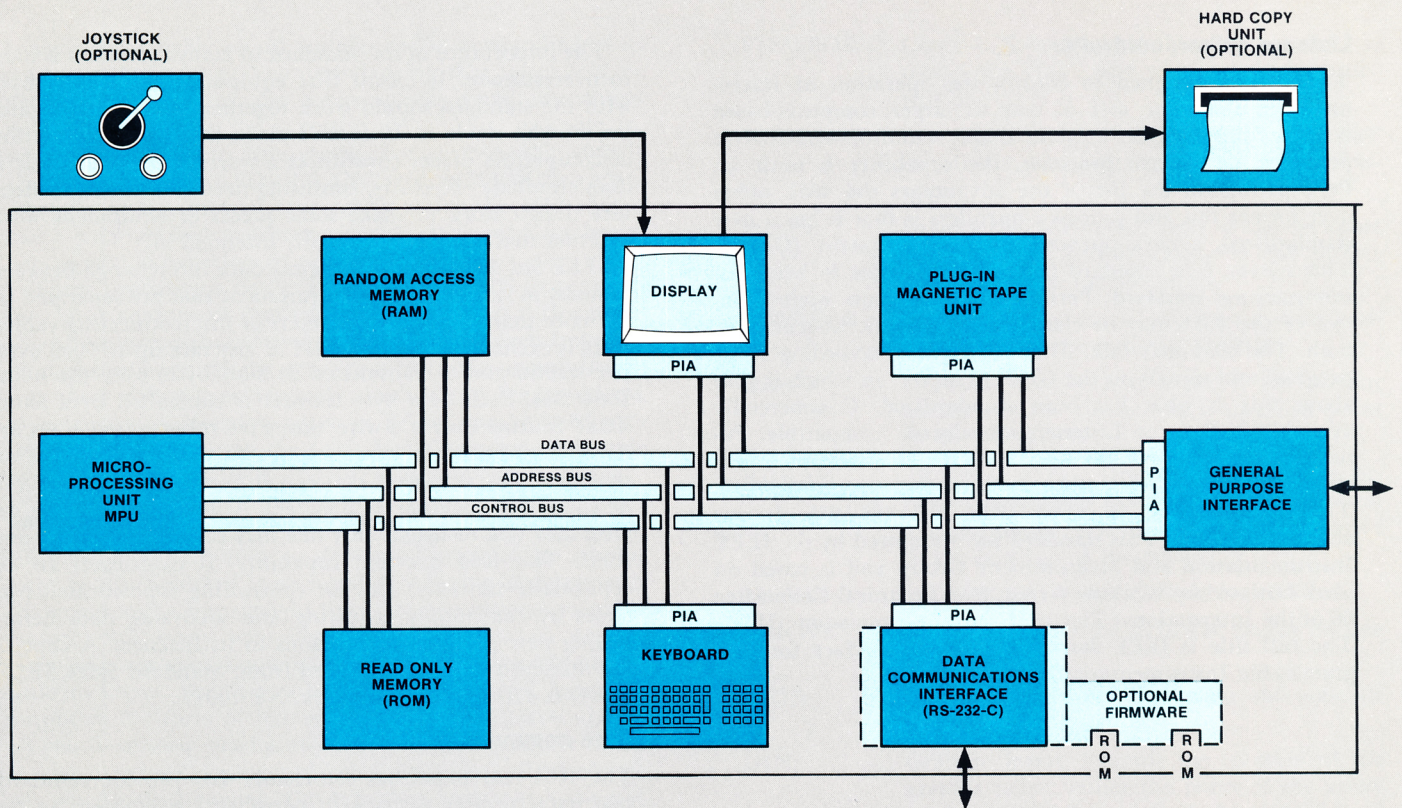
The importance of the standard to many customers is hard to overestimate. It means that equipment built to comply with the standard should work together as a system regardless of who made it. It doesn't mean that any combination of compatible pieces constitutes a worthwhile entity, but it does eliminate the costly, confusing need to do custom interface design work to make some pieces of equipment work together that were not originally intended to.

IEEE Std 488-1975 is for digital data interchange between as many as fifteen pieces of equipment that are separated by no more than a total of 20 meters of interconnecting cables. Data is exchanged with the 4051 at any rate up to 7000 bytes per second and is transmitted in 8-bit bytes over the 8-line Data Bus. Each data byte transfer is controlled by a handshake routine over a 3-wire bus. Five other signal lines are devoted to interface management. Figure 1 shows the bus structure that is shared between different devices that can be connected together in a system. Although any of the devices may talk or listen, only one may control the others and itself. The 4051 has that capability. It constitutes an exceptionally universal tool for controlling sophisticated processes by continually acquiring and analyzing data before issuing new program instructions to its listeners. A copy of the Standard may be purchased from: Standard Sales, IEEE, 345 East 47th Street, New York, NY 10017.

Data communications

The 4051 rear panel has connectors that provide standardized data transfer paths with peripheral equipment in the outside world in *two* standard ways. One is via IEEE Std





Functional description

Microprocessing unit (MPU): Directs systems operations. Solicits one instruction at a time from the ROM by placing a 16-bit address on the ADDRESS BUS. Decodes and executes the instruction received on the DATA BUS, then fetches the next instruction.

Read only memory (ROM): A semiconductor memory with 36K 8-bit byte capacity containing full permanent set of BASIC instructions for the microprocessing unit.

Random access memory (RAM): A semiconductor memory for temporary storage of intermediate results of arithmetic operations and BASIC instructions for the microprocessing unit. Contains 8K, 16K, 24K, or 32K 8 byte storage capacity.

Display: Rectangular, flat-faced, 11-inch diagonal, direct-view storage crt. Serves as the primary output device for alphanumeric characters, graphs, and line drawings.

Keyboard: Primary user input. Statements in BASIC are typed here and each alphanumeric character appears on the crt as it is typed. Appropriate calculations and other responses to each completed statement immediately follow the last key-stroke in each statement. Editing keys allow programs to be altered and typing errors to be corrected. User-definable keys make it simple and fast to execute any one of up to 20 pre-programmed sub-routines by pushing the right key.

Plug-in magnetic tape unit: A 3M® Data Cartridge with capacity of 300K 8-bit bytes. It allows the operator to make a permanent record of whatever may be stored in the RAM and allows data and programs to be placed in the RAM from the tape.

General purpose interface: Provides asynchronous communications with and control of instruments and other peripheral devices designed to be compatible with the IEEE Std 488-1975.

Data communication interface: Provides communications with data terminal equipment or data communication equipment designed to be compatible with EIA Standards RS-232-A, B, or C. A second RS232 output-only interface is available for control of printers. Both are optional.

Optional firmware: Another part of the Data Communications Interface. Contains receptacles for one or two specialty plug-in ROM's that may be bank-switched under program control to substitute for the internal ROM.

Peripheral interface adapters (PIA): IC's that are part of a family of components that includes the MPU, ROM, and RAM. Integral sections of the 4051, such as the Keyboard, Magnetic Tape Unit, GPIB Interface, and Display Unit, are connected to the DATA, ADDRESS, and CONTROL buses through these adapters. Although such sections are integral parts of the 4051 they are considered peripheral with respect to the MPU. Each adapter has unique 16-bit addresses that it responds to when the MPU wants to communicate with the peripheral at those addresses.

Joystick: A single handle control for arbitrarily positioning the axis of a graph to a particular point on the crt screen.

Hard copy unit: A unit for copying all the data displayed on the crt screen at any particular time.

488-1975, just discussed. The other is optional and is part of what is called a Data Communications Interface. It works with equipment that complies to EIA Standards RS-232 A, B, or C, transmitting data serially one binary bit at a time to such peripherals as line-printers, keyboard terminals, and to host computers.


A Data Communication Interface is made optional to avoid having to charge all customers for both kinds of interface circuits. It is for two-way communications, full duplex, or half duplex, odd, even, or no parity. The baud rate can be either 110, 150, 300, 600, 1200, or 2400 selectable by the user under program control.

Intelligent graphic terminal

It is easy to see the value of the 4051 as an intelligent terminal. The lion's share of the charges for time-shared computers usually falls into three categories: the number of seconds the computer is working for you, the number of minutes you are connected to the computer, and the number of minutes you are using the phone lines. In most cases the connect charges are the most expensive part of the bill. You can reduce these charges by taking programs off the host or by using the plug-in 4051 tape to transfer data to the host. That saves accessing it through the keyboard at the slow typing speed of the operator. Reductions in connect charges alone will typically pay for a 4051 in less than a year.

When your desk-top machine has access to the vast amount of data that you may store in a large computer, it is a great convenience. That way the data doesn't have to be duplicated in other storage devices and may be updated as frequently as necessary. When you can conveniently give your computer only those problems too big for your desk-top machine you also save money. That becomes an inviting practical possibility if your local terminal has enough intelligence to communicate directly with a host computer. It lets an operator interact only when he needs to, instead of acting as interpreter between his local desk-top machine and a remote wall-to-wall computer.

The new technology

Several recent technological advancements have made it possible to reduce the size, cost, and complexity of the 4051. The 3M® Data Cartridge is a small, fast, inexpensive magnetic tape cartridge that plugs into the front, containing 300 feet of tape able to store up to 300K 8-bit bytes of data or program instructions. This tape reads from, or writes into, an integrated circuit random access memory that is part of a family of IC's that make up a commercially available micro-computer family. The microprocessing unit that is the head of the family, is also the workhorse of the 4051. The architecture of the whole system is based on it. A wired-in 36K byte read-only memory contains a full, permanent set of instructions that are responsive to BASIC language statements made from the keyboard or the program in progress. Part of that memory is reserved for bank-switching to one or more plug-in ROM's to expand on the primary set of instructions if needed. This feature makes it possible to add special-purpose functions to the machine in response to a particular application problems. 

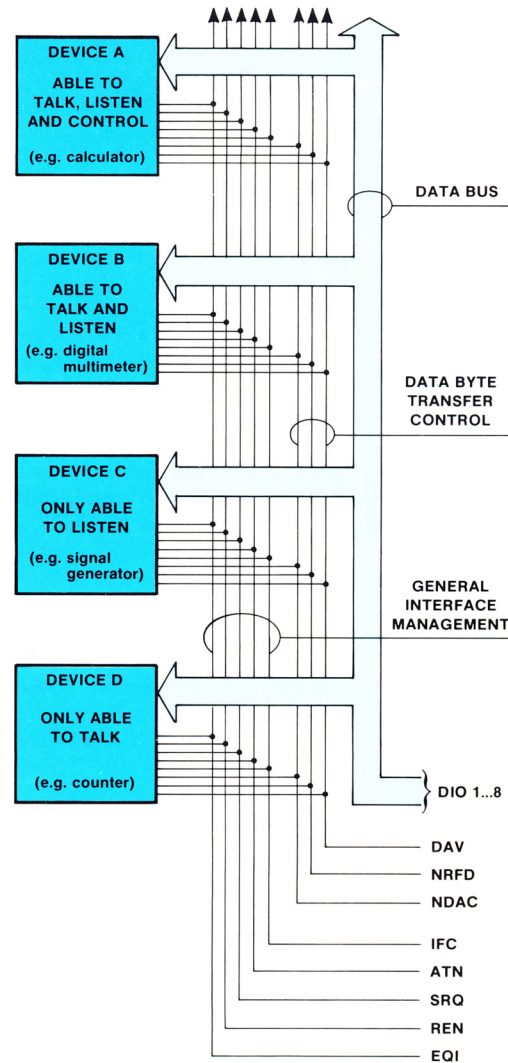


Fig. 1. The 4051 uses the IEEE Standard Digital Interface for Programmable Instrumentation portrayed here.



Tom Needham

Viewport Pointer
Axis Window Draw
Scale Redraw

Graphing with the 4051 graphic computing system

Until a few years ago the equipment necessary to make graphic displays with a computer was extremely expensive. Then the invention of the bi-stable storage crt at Tektronix led to the development of crt computer terminals and software that gave the world a simple, inexpensive graphic system. Until the 4051 came along, however, graphing required the help of a host computer or calculator. The 4051 has great computational power built-in. It can do computations and display the results graphically all on its own. And it can be made compatible with host computers through an optional RS-232-C standard interface, making it easy to use existing programs and the huge data-bases that some people have on tap at a host computer.

Operating the 4051 so it will display data graphically, as well as with alphanumeric characters, is much easier to learn than you would suppose. If you already know BASIC as a programming language, the task will be especially easy. There are only eleven additional keywords to learn. And once you understand their meaning and function, the whole process of plotting graphs will probably be clearer than it ever was before. If you have used TEKTRONIX PLOT-10 software with a Graphic Computer Terminal you will already be familiar with most of the words. For the 4051 they are:

VIEWPORT	DRAW	AXIS
WINDOW	RDRAW	GIN
SCALE	MOVE	ROTATE
POINTER	RMOVE	

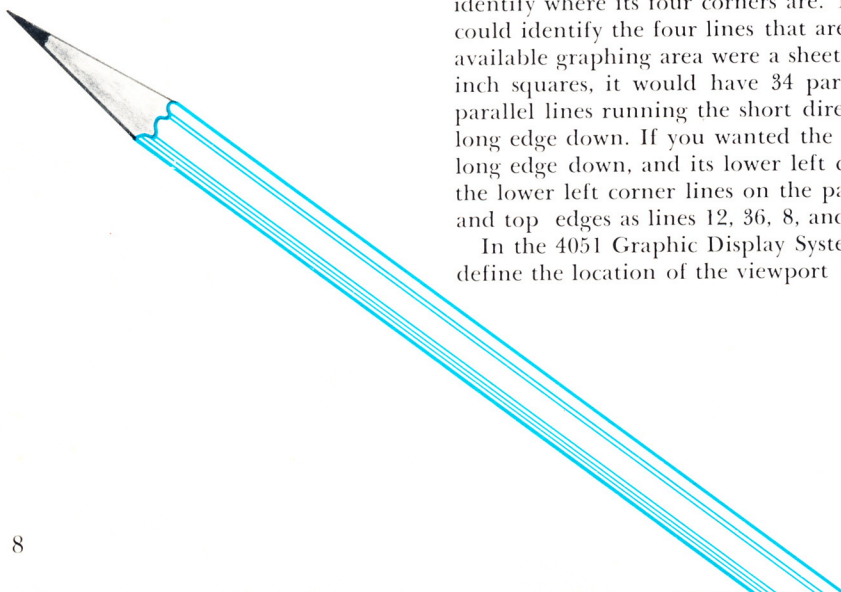
The Cartesian Coordinate system is a way of identifying the location of any point on a plane by first drawing and scaling two straight perpendicular lines in the plane. The lines are called axes. A unique pair of numbers corresponding to the scalar distance between any point and each line, will tell you where that point is.

After scaling the axes with appropriate numbers, the relationship between two variables, X and Y, can be shown graphically by calling one axis X, the other Y. (See Fig. 1)

The viewport

What things should you decide first when you proceed to make a graph of this kind? For one thing you decide what portion of the available graphing area you want to use. We call that portion the viewport. How would you describe it? You could identify where its four corners are. That would take four pairs of numbers. Or you could identify the four lines that are the sides of the rectangle. For example, if the available graphing area were a sheet of 8½ by 11 inch graph paper consisting of ¼ inch squares, it would have 34 parallel lines running the long direction, and 44 parallel lines running the short direction. Let us say the paper was placed with its long edge down. If you wanted the viewport to be a 5 by 6 inch rectangle with its long edge down, and its lower left corner 3 inches to the right and 2 inches above the lower left corner lines on the paper, you could describe the left, right, bottom, and top edges as lines 12, 36, 8, and 28 respectively.

In the 4051 Graphic Display System we use the Graphic Display Unit concept to define the location of the viewport (see Fig. 3). A Graphic Display Unit is defined



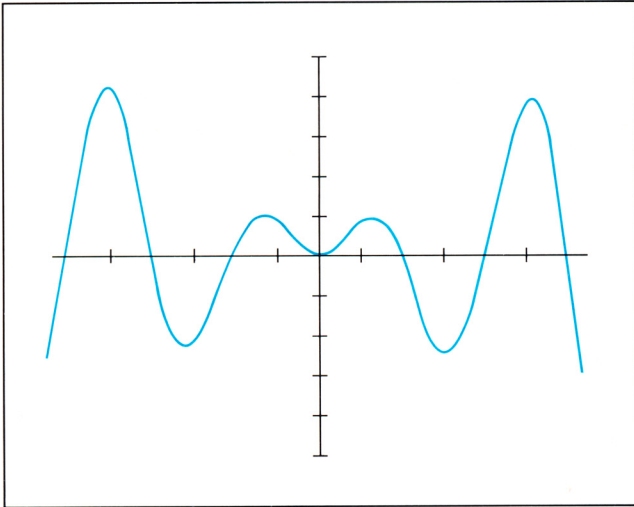


Fig. 4. The ease with which graphics can be generated on the 4051 is illustrated by this graph which was drawn using just seven program steps.

tion and receives the `AXIS` statement. Tic marks on one or both axes will be added automatically if the `AXIS` statement is followed by numbers for the desired size of the increment. The tic marks are automatically spaced and located on each axis to correspond with the user's units for each axis. Numbers can be added adjacent to the tic marks later if desired. Logarithmic axes, however, require a different technique.

Absolute and relative moves and draws

In one sense you draw a graph with the 4051 very much the same way as you would by hand, with a piece of chalk on a blackboard. The chalk can be moved from one point to another without drawing a line, if you lift it. On the 4051, the crt beam is turned off for `MOVE` statements and turned on for `DRAW` statements. The same is true for relative move (`RMOVE`) and relative draw (`RDRAW`) statements. The difference between absolute and relative moves is that absolute moves are stated with respect to the last point the beam was moved to. The same is true about the difference between absolute and relative draws.

A line is drawn each time a simple `DRAW` command is executed. From that, it is easy to make the assumption that the 4051 takes a lot of time to draw a complex curve. But not so. By storing data points in two matrices, even a long series of draws is executed very rapidly. The array variables representing the two matrices are specified in the `DRAW` statement.

How really simple it is to draw a complex graph on the 4051 is best illustrated by considering the graph in Fig. 4. It took just seven program steps to construct the graph:

```
100 VIEWPORT 10, 120, 10, 90
110 WINDOW -10, 10, -10, 10
120 AXIS PI/2,2
130 MOVE -10, 10*SIN (10)
140 FOR I=10 to 10 STEP 0.2
150 DRAW I, I*SIN (I)
160 NEXT I
```

The `VIEWPORT` statement was used to reduce the size of the graph on the display. If we had wanted the graph to fill the screen, the `VIEWPORT` statement could have been

omitted as the viewport parameters are automatically set to 0, 130, 0, 100 by default on system power up and after the execution of an `INIT` statement.

Dot matrix, pointer, gin

When the 4051 crt is producing an alphanumeric or graphic readout, the position of the last character or point is identified by a blinking marker. The marker is a small 5 by 8 dot matrix the same size as the outer limits of an alphanumeric character. The `POINTER` command places a small arrow on-screen. The position of the arrow can be controlled by an optional Joystick, or selected by the user definable keys. Using the `GIN` command, the X-Y coordinates of the point selected by the arrow are assigned to two variables and can be used by a program to keep track of its position.

About speed

Everyone wants to know how fast his computer or calculator is. It is a natural, important question that is very difficult to answer satisfactorily. The same question applies to the 4051, and is even a little harder to answer. If the 4051 is controlling peripheral instruments and is waiting for data from one of them before finishing a computation, it would be misleading to talk about how fast or how slow the 4051 was. On the other hand, if it is merely calculating 50 factorial, or doing a similar bench mark computation, you would like to know how the time it takes to perform this function compares with other similar equipment. But what are you to conclude when some of the bench marks are met better by equipment A than by equipment B, but other bench marks are met better by B than by A? You can start by being selective about which bench marks are more typical of your work. That is not a bad way. It leads you to the conclusion that the speed question may be answered satisfactorily by comparisons on each job. The main thing we want to know is whether a machine is fast enough for our job. If, on the average, it is slower than what we are used to, it follows that it should be more economical to be worthy of consideration. If, on the other hand, it does the things you want it to do, as fast as you expect, and has the price and advantages you can't equal elsewhere, it is fast enough.

For most jobs, the 4051 speed is comparable to a mini-computer executing a BASIC program. The graphic capability, ease of programming, and low cost of the 4051 Graphic Computing System can be important factors in solving your application problems in a more effective and productive way. It certainly bears looking into. 