Popular Electronics®

Special Focus on Digital Electronics

Digital techniques play a leading role in electronics today. Switching, coding and logic function methods are not difficult to grasp. And equally important, they make it possible to create many interesting electronics circuit designs. In this special supplement, many of these concepts are illustrated, including projects for a digital auto fuel gauge and a shirt-pocket digital stopwatch. In addition, the first article gives many helpful hints on how the electronics hobbyist should go about choosing a microcomputer from the many available today.

How to Select a Hobbyist Microcomputer

BY STEPHEN B. GRAY
Senior Editor

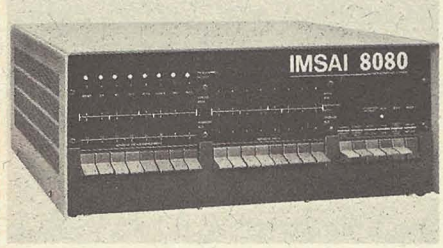
DECIDING which microcomputer to buy is quite a challenge. Not only are there several dozen on the market, but they're available in a wide range of prices, with a variety of features and peripherals, and with several different MPU's (microprocessor units), such as the 8080, 6800, 6502, F8 and 6100, among others.

One of the easiest ways to narrow down your choice of a microcomputer is to decide which basic type is best for your own use. To do this requires a breakdown of microcomputer types, as in the following paragraphs.

1. Box With. The best-known type of microcomputer looks very much like a minicomputer: a box with a bunch of switches and lights on the front panel. Two hobby computers of this type are the MITS Altair 8800b and the Imsai 8080. This microcomputer type is the most widely used among hobbyists, with the widest choice of peripherals and memory expansion boards.

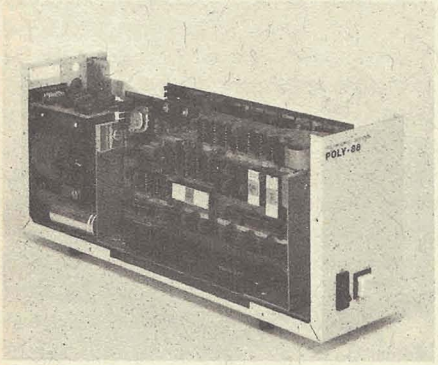
2. Box Without. The second type of computer is also a box, but with a bare

Type 1:
MITS Altair 8800b

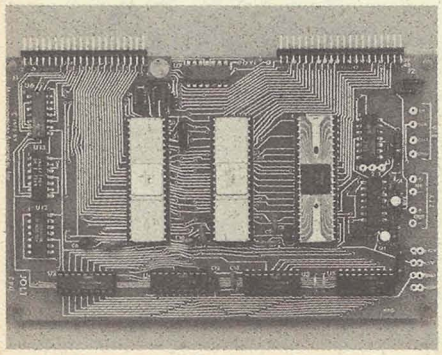


Type 1:
Imsai 8080

Type 2:
Southwest Technical 6800



Type 2:
PolyMorphic Poly-88



Type 3:
Microcomputer Assoc. JOLT

minimum of switches and lights. An example is Southwest Technical Products' 6800, which has only two switches, for power and reset. Only the power switch has a light.

There are two main differences between Type 1 and Type 2 computers. First, with a Type 1, you can load short programs and operate the computer manually, reading the results on the LED display. Obviously, you can't do this with a Type 2 machine. The second difference is in loaders. When you turn on any microcomputer, you can't put a program into memory until a bootstrap loader is inserted first. This acts as a set of signs to guide the program to the right places in memory. With most of the Type 1 computers, you have to load the bootstrap instructions by hand, using the front-panel switches. With most of the Type 2 computers, which have stored loaders, all you do is press RESET and the loader is inserted automatically.

However, just because a microcomputer has a full set of switches and lights isn't always a sign that the loader must be inserted by hand. The MITS 680b is a good example of a micro with switches, lights, *and* a bootstrap loader in permanent memory which doesn't "drop out" when the power is turned off.

Note too, that not all micros have the same internal expansion capability. This sometimes accounts for differences in size and, naturally, influences price too.

3. PC Board. The third main type of microcomputer consists of a printed-circuit board without input or output. These were first introduced for use in commercial products, or for engineering evaluation, and many are still sold for such purposes. Several recent ones are being sold mainly to hobbyists. The best-known of Type 3 are the Jolt and SC/MP.

All the computers described up to this point have neither separate input nor output. So unless you enjoy loading programs via front-panel switches (if your microcomputer has them) and reading out the program results from the front-panel lights, you'll need some more hardware. This means a keyboard for putting data into the computer, and a more sophisticated readout for checking that the program is correct and for reading the results. There is already a wide variety of keyboard terminals available, and the most common readout today is a TV screen.

4. All-On-One-Board. For those who want a complete computer with less sophisticated inputs and outputs than teletypewriter and video monitor, there are many everything-on-one-board microcomputers. This type includes a small keyboard and some form of readout. The readout is sometimes individual LED's, but is usually segmented alphanumeric display. The KIM-1 is the best known of these, although several others are coming up fast. Two units come with a case, the Infinite UC 1800 and the Hamilton/Avnet Pacer. They have built-in power supplies, whereas most of the others don't.

Just about the least expensive Type 4 microcomputer for the hobbyist who wants to learn the basics is the Elf, featured as a construction project in the August and September 1976 issues of POPULAR ELECTRONICS. This hardware and software trainer, with RCA COSMAC MPU, toggle-switch input, hex LED display, 256 bytes of RAM, four input lines, and a latched output line, costs about $80 to build. Memory is expandable at minimum cost.

Nearly all the computers of this type are on a single pc board; two exceptions are the Mike 3 and Mike 8, from Martin Research. Each is a stack of several boards, separated by spacers, with the keyboard and display on the console board at the top, CPU on a second board, memory on a third, etc. This modular approach permits using different CPU boards, either for the 8080A MPU, Z-80, or 8008.

The keyboard almost always has 16 hex keys for entering programs in machine language plus various control keys. These boards are popular among people who want to learn what computers are all about, at minimum cost. For those who want to go further, more memory can be added, as can be peripherals such as a full keyboard and/or a printer, to start with.

5. All-In-One Box. Another type of computer that doesn't require buying a keyboard or TV set has a built-in keyboard and CRT, such as the various models of the Sphere. Although this type of computer is expensive, it does have everything you'd need for almost any type of programming. However, you are locked into the integrated input/output system much as you are for an FM tuner when it's built into an FM receiver. A printed output can be added on, as it can to almost any hobby computer. The cost of a simple printer has decreased substantially. For example, Southwest Technical offers one in kit form for $250, and Electronic Products Associates has an assembled printer for $450.

Among the computers of this type, the Intecolor 8001, with an 8-color CRT, is unique. This adds an extra dimension to graphics and to just about anything you want to put on the screen.

Intelligent Terminals. A step up from most hobby terminals, which can be used only as input/output devices, is the intelligent terminal. With one of these, you can write, edit and store programs for transmission to a larger computer directly, or to a time-sharing computer over a telephone line (using a modem device).

Any hobby computer with a keyboard, RS-232 or 20-mA current-loop interface, and enough memory can be used as an intelligent terminal, of course. All you need are the right programs. The SOL terminal from Processor Technology provides these programs in the form of pre-programmed PROM's, called "Personality Modules," at three levels.

One module allows simple terminal operations. A second-level module makes SOL an editing terminal. The top-level module transforms it into an intelligent terminal as well as a stand-alone computer.

Programming. An important factor in choosing a hobby micro is to decide at which level you want to program. How much memory your computer has will determine its price and also what kind of programming language you can use.

With only a few hundred bytes of memory, you'll usually be restricted to programming in machine language, or to short programs in assembly language. Some people enjoy working in machine language, down at the bit level, using instructions such as 00111010, which is the 8080 code for "load the accumulator with the contents of the specified memory address."

But working with machine language may be boring to all but real "computer freaks." Also, you can easily make mistakes that aren't at all quickly apparent when working with only zeroes and ones. With a little more memory, though, you can program in assembly language. In order to do this, you must load an assembler into your computer's memory. This is a program that translates the assembly-language instructions, such as LDA, into machine language; in this case, 00111010.

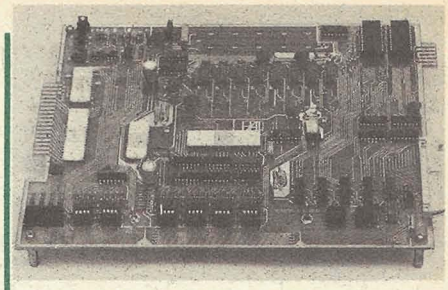
In assembly language, you use *mnemonic* names for program instructions; these are easy-to-remember abbreviations, such as LDA for "load accumulator" and MOV for "move the contents of the accumulator to register B." To add one number to another in 8080 assembly language takes eleven steps, including five mnemonics and three pairs of address codes. Address codes are in pairs because addresses take up two *bytes*; that is, groups of 8 bits. (An 8080 machine can address 2^{16} memory locations.)

The program for adding two numbers consists of these steps: load the accumulator with the number to be found at, say, memory address 128. Then take what's in the accumulator and move it to register B. Next, load the accumulator with the number to be found at address 129, and add the contents of register B to what's in the accumulator. Take the sum that's now in the accumulator, and store it at address 130. If you've previously stored numbers at addresses 128 and 129, this program will add them together and put the sum in 130. Actually, you can use any memory addresses you want, instead of 128, 129 and 130, as long as you don't select an address that's higher than the maximum address in your system.

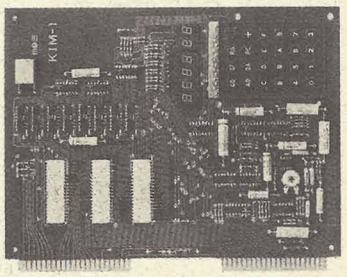
If you'd rather write programs with mnemonics such as LDA, MOV and STA, then you need, as previously noted, an assembler program, which is also stored in memory along with your own program. For example, the MITS Altair 8800b assembler takes up 5500 bytes of memory, so if you're going to be writing programs of any real length, you'll need at least 8k bytes of memory.

But suppose you're not really interested in programming for programming's sake, but rather in what the program will do for you. If so, then you might prefer BASIC, a high-level language that will do in a single instruction, LET C = A +B, what requires eleven assembly-language instructions to do. That single BASIC instruction will store the sum of A and B in memory location C, which is determined by the BASIC interpreter all by itself, thus taking care of much housekeeping. Should you want to show the answer on your TV screen, or print it out, simply write PRINT C. Or you can combine both steps by writing a single BASIC instruction, PRINT A+B.

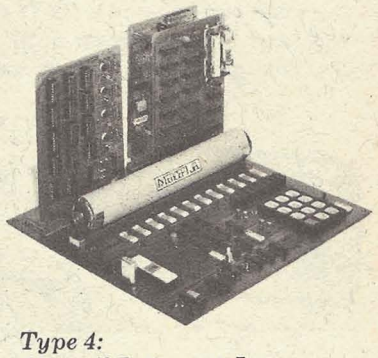
Just about all high-level-language programs written for hobby computers are in BASIC (there are several varieties of BASIC, each with minor differences). You can get several BASIC interpreters for some computers, requiring 4k, 8k or 12k bytes of memory. The 8k and 12k versions offer more features than the 4k BASIC. The 8k BASIC interpreter, which turns LET C = A+B into machine language, takes up 5.7k bytes of memory in



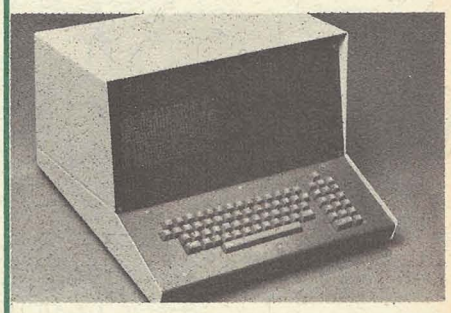
Type 3:
HAL MCEM-8080



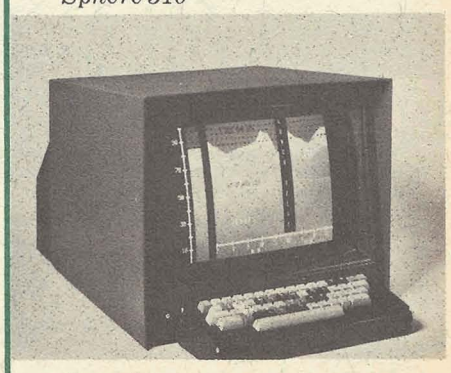
Type 4:
MOS Technology KIM-1



Type 4:
Intersil Intercept Jr.



Type 5:
Sphere 310



Type 5:
Intelligent Sys. Intecolor 8001

the Altair 8800b, for example. MITS specifies it as requiring 8k bytes of memory so that you'll have 2.3k bytes for your own use in writing programs. Incidentally, although many serious computer hobbyists will be satisfied with 8k or 16k of memory, many hobby computers can be expanded to 65k.

Hobbyist Bus. The MITS Altair 8800 microcomputer was the first to be sold in large volume, and set a bus standard that some other micro manufacturers have followed. This standard is based on the 100-pin bus, to which all the Altair 8800 boards are connected in common. Consequently, many other manufacturers of CPU boards, memory boards, and peripheral boards have tailored their designs so they will plug into the Altair 8800, and also into the busses of several other computers that use the Altair bus structure, including the Imsai 8080, the PolyMorphic Poly-88 and Processor Technology's SOL. As a result, there are more boards for CPU and memory, and for peripherals such as printers, disk drives, graphics devices, cassette memory, etc., available to owners of computers using this bus.

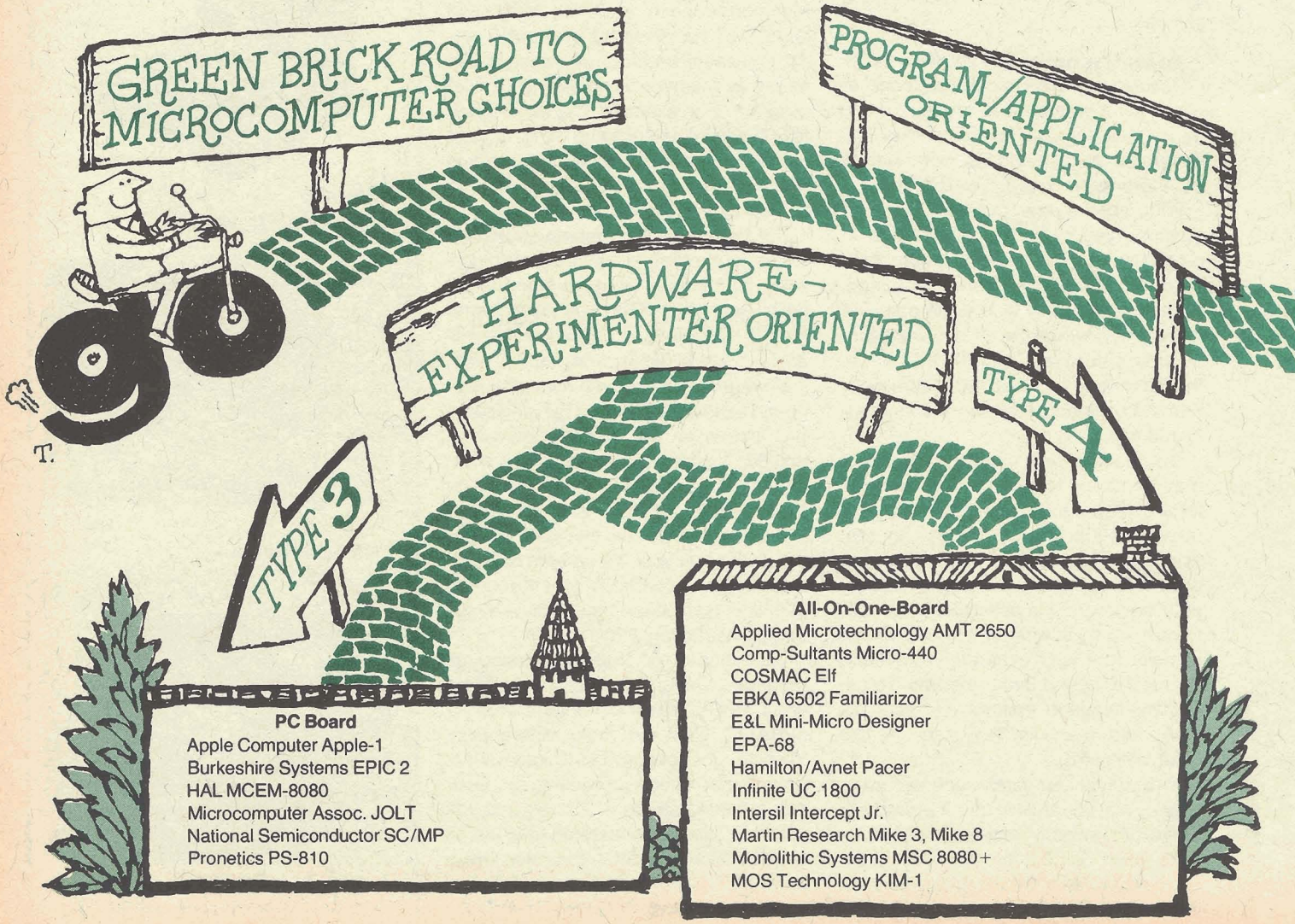
There are other bus lines, of course. For example, the Southwest Technical 6800 computer utilizes a different bus, with a growing number of boards for it.

Price. Of the five basic types of hobby computers, the cheapest is the pc-board-only, with which you need a power supply, an input, and an output. The complete-computer-on-a-board follows, and usually requires the addition of only a power supply. Next is a box-type computer with which you'll need input and output peripherals. With a box-with-CRT type, which gives you the most equipment at a minimum cost, on a one-shot basis, you already have the peripherals, unless you also want a printed output.

Let's look at what it costs to buy a microcomputer with enough memory for the various levels of programming, taking into consideration several of the best-selling micros. The basic computer, without memory can range from $212 to $840 in kit form, $500 to $1100 assembled. These wide ranges are due to some of the computers being full-featured models, others being "bare-bones" types. Not many 1k memory boards are being offered any more; they used to be about $120 kit, $160 assembled. Using just a basic 8-bit computer and 1k of memory, you could write programs containing up to about 500 instructions, if you don't mind flipping switches for hours and hours.

Stepping up to assembly language, you'll need two 4k memory boards, each of which run from $125 to $167 kit, $279 to $325 assembled. If you buy the Altair 8800b and the two 4k boards at the same time, you get a "software package" for $75, which includes the assembler and several other programs. The Southwest Technical 6800 editor/assembler package is $14.95.

You'll need some sort of input/output, of course. To connect your computer to your TV set requires an interface that can cost from $40 to $148 kit, $60 to $180 assembled. For keyboard input, you may be able to use the same interface if it can handle two serial I/O devices. You'll also need a keyboard termi-



nal, such as a Model 33 Teletype. This, however, is expensive, costing between $769 and $1500 new, depending on what features you select. With an ASR33, you can enter a program from either the keyboard or punched paper tape. Or you could get a hobby unit, such as Southwest Technical's CT-1024 terminal. With this, the program is entered via the keyboard. The CT-1024 kit, less cabinet and power supply, is $175; there are various options available.

Programs can be entered into the computer much faster by using a cassette. To enter the 8k BASIC interpreter into the Altair 8800b takes 12 minutes from paper tape, 4 minutes from cassette. Typical cassette interfaces range from $35 to $138 kit, $65 to $195 wired. You can buy a 4k BASIC interpreter for $4 to $60 depending on manufacturer. The 8k BASIC interpreter ranges in price from $8 to $75.

Which to Pick? A major question to answer is: will you be satisfied with programming in assembly language, or do you want to program in BASIC? If you're sure you'll be happy with assembly language, you have two types of computers to choose from. The least expensive is the all-on-one-board computer, Type 4, such as the KIM-1 or 6502 Familiarizor, where the only extra to buy is a power supply except for a couple that have it built in. The other choice is Type 3, the pc board with no I/O, such as the SC/MP. To use one of these, you'll need a power supply, keyboard, and some sort of output, either a printer or a TV receiver or video monitor.

If you're more interested in programs than in computers, and want BASIC, you have three choices. The Type 1 computers, including the Altair 8800b and Imsai 8080, require interfaces and peripherals for input and output, as do the Type 2 machines, such as Southwest 6800 and Poly-88. You can add these at any time. You'll need no additional hardware if you buy a Type 5 computer, which has both CRT and keyboard.

Summarizing, you must decide what you plan to do with the microcomputer now and in the future, as well as what your bankbook can tolerate.

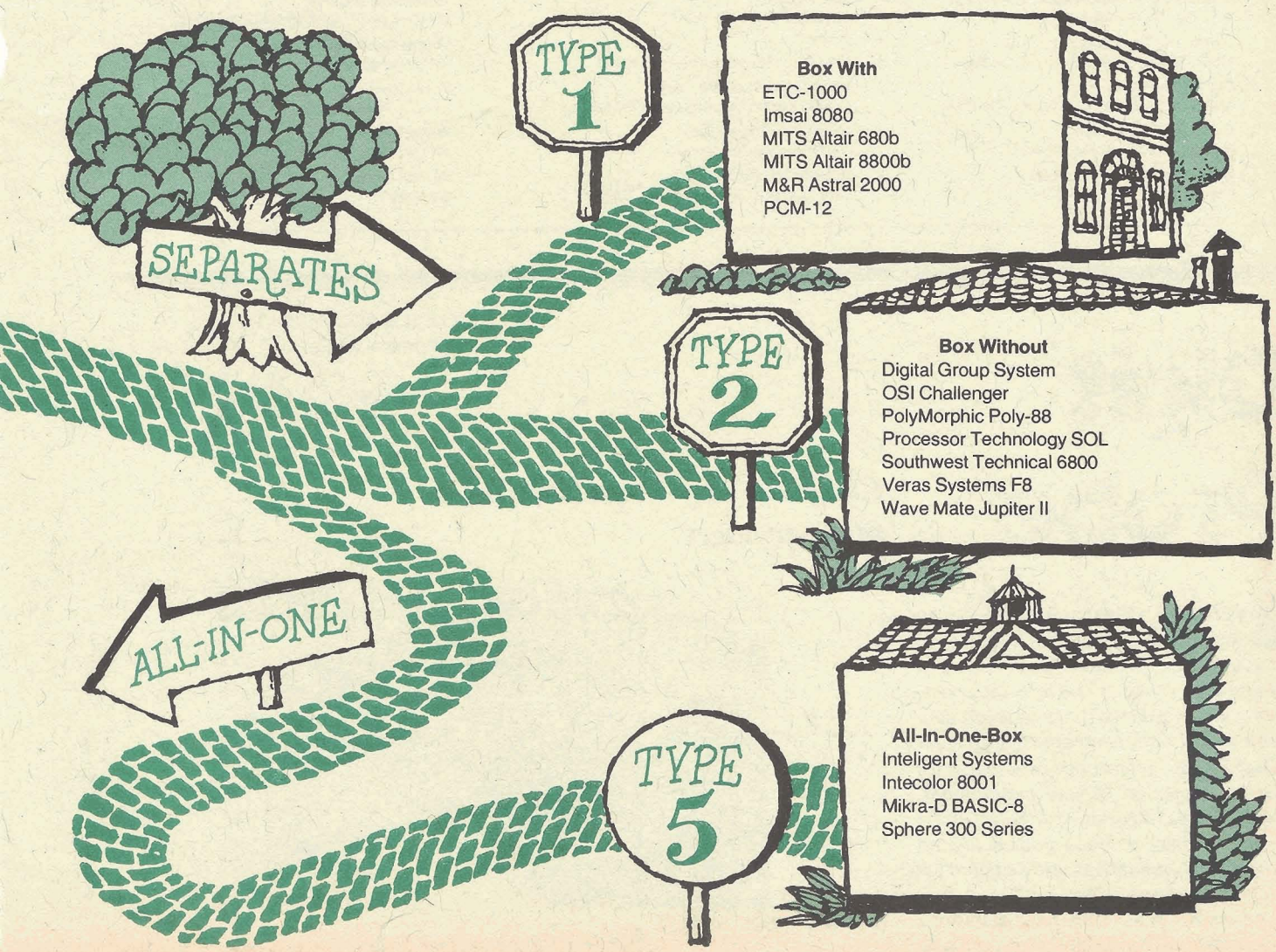
Are you determined to be an experimenter, more interested in hardware and/or learning the fundamentals of computers? If so, a Type 3 or 4 unit might be your best bet.

If you're more interested in "talking" to your computer and getting results easier and faster, but wish to add peripherals of your own choice at some future time, a Type 1 or 2 could be the way to go.

Should you want an all-in-one type of micro, with peripherals already incorporated, then perhaps a Type 5 should be considered.

There are other factors to weigh, of course, including language availability (do they have assembler or BASIC?), reputation of the computer manufacturer (how good are their computers and how long will they stay in business?), whether or not you plan to join a computer club for sharing ideas and trading information on software, and so on.

More Help. In addition to asking a manufacturer to send information on his microcomputer for performance details (see address listing), there are many



other ways to help you decide which to buy. There are over 90 computer clubs, many with membership in the hundreds, where you can talk with people who are using various hobby computers. Dozens of computer stores around the country will show you how their products work, and answer your questions in detail. Magazines and club newsletters devoted to the computer hobbyist are also excellent sources of information. And if you get to a hobby-computer convention, such as the ones that were held in New Jersey (Trenton and Atlantic City), you can check out dozens of computers and peripherals in a single day, as well as listen to talks about hardware, software and applications.

Whatever choice you make, you'll find yourself in a new, exciting field that will add to your knowledge and fun. ◇

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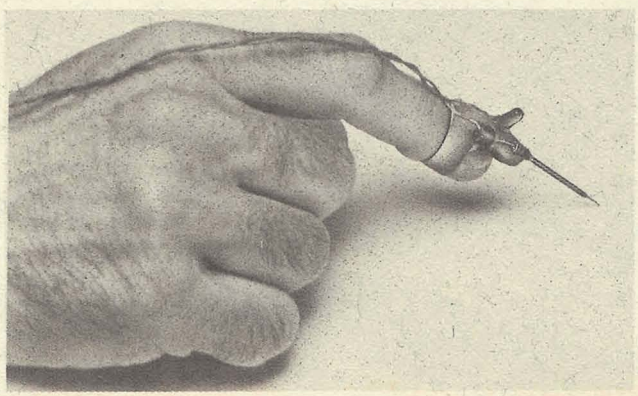
BY LESLIE SOLOMON
Technical Editor

Digit Probe

Compact, easy-to-use logic probe fits your finger.

EVER SEE a logic probe that was so compact that it could fit over the tip of your finger? Although there is such a device (see photo), don't look for it commercially—you have to make it yourself. We call this ultra-compact little gem the "Digit Probe," mainly because in use it's like an extension of your index finger. Used in this manner, the Digit Probe makes it easy to trace pulses around crowded IC assemblies and pc board foil traces that all look alike.

As shown in the schematic diagrams, the circuits for the Digit Probe are basic



The Digit Probe fits on finger.