THE MICROCOMPUTER BUILDER'S BIBLE

BY CHRIS JOHNSTON

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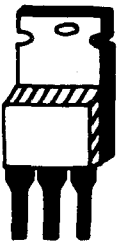
Introduction



Building your own computer can be a very rewarding experience. You can certainly save a lot of money by "doing it yourself," but there are even greater benefits than lower cost.

One of the greatest advantages to building your own system is that it allows you to combine the best features of several different products into a computer that will serve *your* needs better than a commercial one. You can expand your system as your interests grow and as finances become available. You can add more memory, for example, or a printer or disk drive.

All along the line there are decisions to be made such as should you build from scratch or from a kit, or should you purchase an addition already assembled and tested? That is part of the reason why I have written so much about the various products on the market—their capabilities and the differences between similar boards.

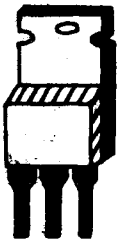
Building a computer is something that should be thought out carefully before you start. I have tried to provide enough information to allow you to make reasonable choices.

My first system was built about six years ago and I have continually expanded it, adding memory, a printer, etc. At the present time I am interested in graphics hardware and software and am adding such equipment to my system.

Some of the schematic diagrams in this book are taken directly from equipment in use in my machine. Some circuits were recently designed and are just now being tested.

There is a great feeling of accomplishment when you look at and use a computer that you have built yourself, something that will do what you want because you planned it that way.

This book is dedicated to my parents, who typed, photocopied, trimmed, criticized, and generally made the whole thing possible.



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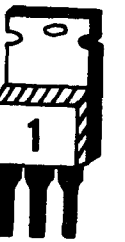

Whether you are a businessman who wants to keep inventory records, an engineer who needs to do repetitive calculations, or a hobbyist looking for a home computer, you have to decide how much computing equipment you will need and what kind will best fulfill your requirements. You will also have to decide whether you would be better off building or buying your computer equipment. In order to help you decide, I will discuss several different types of computers in this chapter. The build/buy decision is put off until the next chapter.

To determine what equipment you will need you must first evaluate what "minimums" you require. That is really asking the question "What do I *have* to have to let me do what I want?" You want to avoid, of course, getting equipment that either will not fulfill your needs or has more capability than you can use. In either case you would be unhappy with your computer system.

For example, a business that has to keep track of 10,000 customer accounts, payroll for fifty people, and a 5000-item inventory will hardly be happy with a personal computer that has one 5¼-inch disk drive! On the other hand, a person who purchases a $50,000 minicomputer to handle the inventory of a small store with a staff of three would be spending a lot more than necessary.

This disparity is common in the construction or purchase of home (hobbyist) computers. An individual who wants a small computer because he enjoys playing with his friend's $5,000 home-built system will be disappointed if he buys a $200 computer and discov-

ers that it cannot be expanded to do all the "neat" things he has seen. Similarly, it would be a waste of money to spend $5,000 on a computer and use it only to play games.

It *is* important to have a computer that can be expanded later if your needs and interests change. Once you have your own computer, it will be very easy to find things to do with it that you hadn't even thought of at the time you obtained it. Expandability is therefore, of prime importance.

Acquiring a computer for the rather vague reason that "the kids will have to know something about them" really *does* make good sense. People once received their first computer experience (if they ever got any) in college. As computers became more common in high schools, students began entering college with some (sometimes quite extensive) computer experience. As the home (appliance) computer field expands (and the systems drop in price), younger children are being exposed to the computer in their homes. A child that has had exposure to a small, friendly computer since he was two or three years old, will *enter* school with a firm footing in the basics of computer science.

In my experience I've found that a good many older people who have never been exposed to computers are afraid of them. The computer, to many of them, is the machine that makes mistakes in their monthly bills. This unfortunate, if understandable, attitude has prevented many from understanding the strengths as well as the weaknesses of computers. Until recently computers *were* big nasty machines and the people who used them tended never to speak English when they talked about them.

How many times have you heard "computer error" used to explain a problem? Many people do not realize that most of the time this error was committed by a *person* entering wrong data or a program—developed by a *person*—that wasn't properly tested. (The computer merely does what it's told to do!)

A small computer can also be a powerful creative tool. Obvious areas are computer-generated art and music. However, writing and testing a computer program is an equally great opportunity to create something that is the unique product of your own mind. Many people enjoy small computers for this reason. Writing a program is the ultimate crossword puzzle and rivals any conventional game. Before you start to play the game, however, you need the tools.

PROGRAMMABLE CALCULATORS

The programmable calculator links the world of hand-held

calculators to the world of computers. If you need a pocket-sized portable computer, this is really your only choice. Example of modern programmable calculations are the Texas Instruments TI-59 and the Hewlett-Packard HP-41C (Fig. 1-1). THe HP-41C calculator, with an LCD alphanumeric display, has options including memory modules, a card reader, printer, cassette program recorder, and bar code scanner.

Programmable calculators are designed for high precision mathematical calculations. Because they can be programmed, they are good for repetitive calculations. Very few small computers can handle mathematics with the facility of a calculator. Programmable calculators normally have built-in capability to do trigonometric calculations, summations, coordinate conversions, and similar functions that are often not found in small computers. They are also small and light, making them usable anywhere when on their internal battery pack.

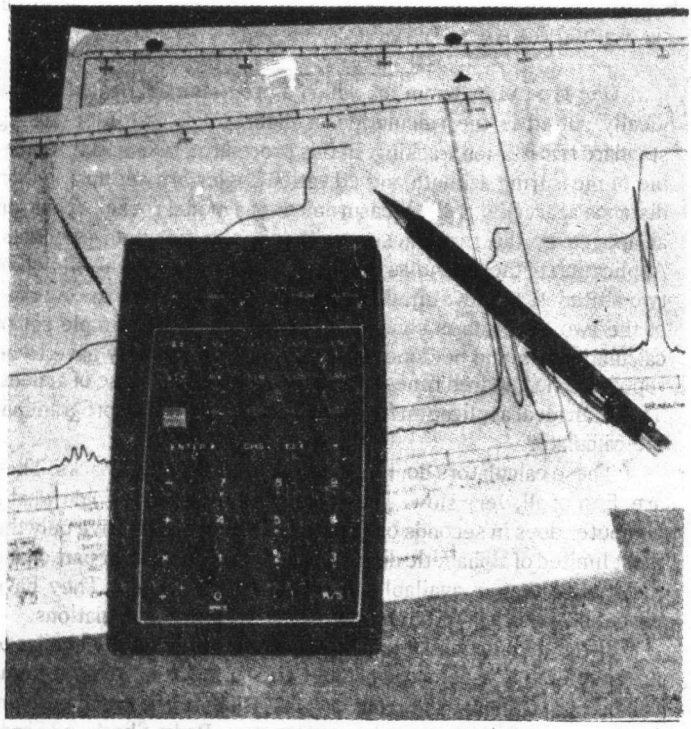

Fig. 1-1. Hewlett Packard HP-41C Programmable Calculator.

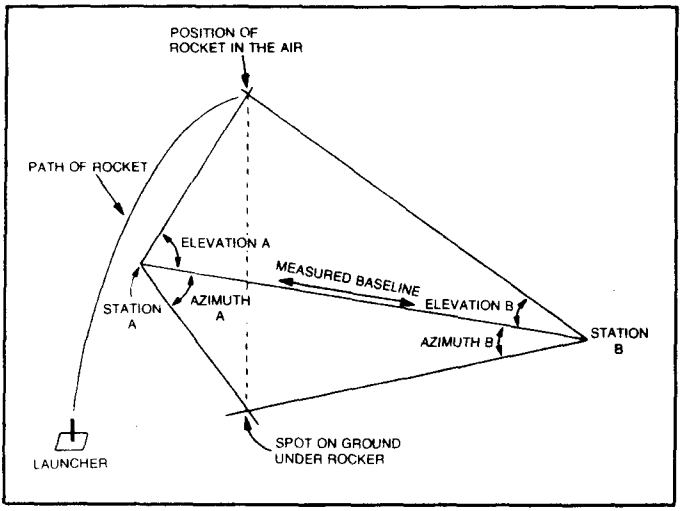

Fig. 1-2. Tracking triangle for two-station tracking.

One type of program for which a programmable calculator is ideally suited is the calculation of model rocket altitudes using standard two-station tracking. In this procedure, two trackers capable of measuring azimuth and elevation angles are set up a known distance apart (Fig. 1-2). Measurement of a model rocket's position at apogee by the two trackers will result in two sets of angles. Application of the formulas in Fig. 1-3 will allow the calculation of two altitudes. If both altitudes are within 10 percent of the average of the two, the data is considered good. This fairly simple set of calculations should be done on the flying field and may have to be repeated one hundred times in an afternoon in the course of a meet. This is an ideal application for a small battery-powered programmable calculator.

These calculators do, however, have several drawbacks. They are, first of all, very slow. They take minutes or hours to do what a computer does in seconds or minutes. Generally they have only the most limited of alphabetic display capability. One line (or part of one line) is all that is available for display at any time. They have essentially no capability outside of mathematical calculations.

Programming mathematical calculators is generally similar to programming in assembly language on a computer—the programs can be very complex and quite cryptic. This programming problem has been attacked by several manufacturers. Radio Shack and Sharp

have produced "pocket computers." These are slightly larger than a normal calculator and programmed in BASIC, but they have a limited amount of internal memory.

If your computing requirements are limited to a lot of mathematical calculations (especially repetitive calculation) a small portable device, then you should look seriously at a programmable calculator.

MICROCOMPUTERS

The microcomputer is really at the heart of the computer revolution." The development of the inexpensive, single-chip microprocessor, and the simultaneous development of high capacity and inexpensive memory chips, has made computers affordable by the average person.

The current microcomputer industry is an outgrowth of interest shown by electronic hobbyists in the new (at that time) microprocessor chips. The first real microcomputers were developed by hobbyists, and small businesses (often operated by these computer hobbyists) sprang up to service the growing market.

The hobby market was distributed among a small group of systems. The first (and oldest) were built around the 100-pin bus defined by MITS, Inc. for their Altair 8800. The major event that shaped the future of the microcomputer was the IMS Associates' decision to use the same system in their IMSAI 8080 computer. As

$$A = \frac{\text{Baseline}}{\text{Sin } 180 - (\text{Azimuth A} + \text{Azimuth B})}$$

$$\text{Alt 1} = \text{A Sin (Azimuth B) Tan (Elevation A)}$$
$$\text{Alt 2} = \text{A Sin (Azimuth A) Tan (Elevation B)}$$

$$\text{Avg Alt} = \frac{(\text{Alt 1}) + (\text{Alt 2})}{2}$$

If Alt 1 and Alt 2 are both within ± 10% of Avg Alt:
Then track closes; Else tracking error.

Fig. 1-3. Tracking equation.

more and more manufacturers jumped to this design, the Standard 100 (S-100) bus was born.

At the same time, Southwest Technical Products introduced their SWTPC 6800. This computer, built around the Motorola 6800 microprocessor, used a 50-pin bus for memory and a small one for peripherals. This became known as the SS-50 bus. The Digital Group, Inc. also brought out a line of very nice computers based on their own bus design. A large number of single-board computers were introduced, some of which (like the KIM-1) became very popular.

Several interesting things happened at this point. Some of the older, original manufacturers left the scene. MITS was bought by Pertec, and the IMSAI slowly faded away. There were enough new companies building products for the S-100 bus that the absence of the original manufacturers had little effect. The Digital Group also went out of business, killing the Digital Group bus as a result since they were essentially the only ones supporting it.

Several new microcomputer giants developed. Apple Computer Company, riding the phenomenal success of their APPLE II computer, became one of the industry leaders. Radio Shack and its TRS-80 surprised everyone (especially themselves) with their popularity. Radio Shack is now, in fact, the most popular manufacturer in terms of units sold. Texas Instruments, Heath, and Atari have all entered the market. In the recent past the "real" computer corporations also have entered the micro market—DEC, IBM, and Xerox.

Much of this expansion is a result of the discovery that small businesses could put these computers to work. There was initial disappointment for some of these smaller businesses when they discovered how small their computers were and how large their small businesses!

The microcomputer is a good answer to nearly any small computing project, but there are major difficulties in their use. While much faster than programmable calculators, microprocessors tend to be much slower than minicomputers and larger systems.

Their total amount of disk storage is also more limited than that in larger computers. One inventory management system advertised for a microcomputer requires six 5¼-inch disk drives for storage of about 4800 items in inventory. Six disk drives is a lot for any small system (probably over $3000 just for disk drives!). This is really pushing the capabilities of a small computer. If, then, you needed to keep inventory records on 7000 items, you wouldn't want

to try it on a small computer using 5¼-inch diskettes! This case would require a hard disk or multiple double density 8-inch diskette drives, all of which are discussed and explained in Chapter 9.

If you need to do a lot of high speed numerical calculations, then a microcomputer isn't right for you either.

But, there are many cases where a microcomputer *is* the right choice. If you want a small computer because you are interested in learning how to write programs, then having a micro at home is ideal. There is a great advantage in being able to use the computer whenever it is convenient for you, and for as long as you want. Once the computer is complete all that is required is to keep it in electricity and diskettes or cassettes!

If you are interested in computer hardware, then a microcomputer is for you also, especially since you may gain more pleasure and knowledge by building it yourself. The microcomputer really shines as a word processor. A microcomputer, two double-sided, double-density 8-inch diskettes and a letter-quality printer can be purchased for less than half the price of commercial word-processing systems. When you are not composing letters or documents, you have a general-purpose computer to work (and play) with. The decision-making power of a small computer is also of great value in many industrial, scientific, and home applications where control or monitoring is necessary.

Keep in mind, however, that there are operations better suited to a computer larger than a micro. It is as a home computer that the microprocessor is of greatest value. It is an affordable, understandable tool for use at home.

If you are considering the investment in a computer, get out and talk to people. Talk to sales representatives, people at the computer stores, and, especially, talk to other users. There is no better recommendation for any computer than a large group of satisfied users.

MINI AND LARGER COMPUTERS

The minicomputer—generally with a sixteen-bit word size—has been around much longer than the micro. Recent advances in microcomputer hardware now have somewhat blurred the traditional distinction between "minis" and "micros." The minicomputer tends, in general, to be built up out of many smaller circuits. While this greatly increases the computer's complexity, it also increases its speed. They are available with diskettes or hard-disk storage and are generally comparable to microcomputers in that respect.

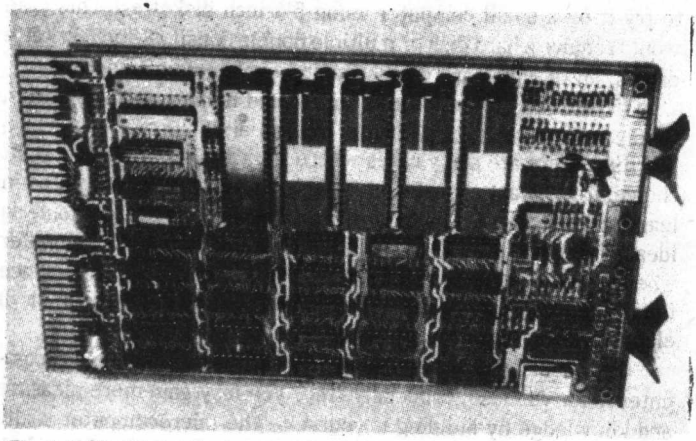

Fig. 1-4. The Digital Equipment LSI 11/2 processor card.

Digitial Equipment Corporation makes a line of computers that range from the LSI-11/2 computer (Fig. 1-4) to the large PDP 11/70. The instruction sets (the list of operations built into the computer) are upward compatible within the series. This means that programs written for the LSI-11/2 in principle, can be run on the PDP 11/70.

Because of their greater expense, most users of home computers will not consider purchasing minicomputers. The one exception is probably the DEC LSI-11. Heath sells their H-11 system, and LSI-11, in their own enclosure. Also, an experienced hobbyist can build up an "11" piece by piece, using equipment from a variety of manufacturers.

There are areas to which "large" computers will always be best suited. Handling huge address spaces and running extremely large complex programs will always be the territory of the large computer. One, the Cray Research Cray-I can perform ***one hundred million 64-bit floating point mathematical operations per second.*** It costs, by the way, between ten and fifteen million dollars, depending on options!

Microcomputers are encroaching on the larger ones in many situations where the prospective user needs some intermediate size computing facilities. Networks of small computers can often be used to replace one larger central computer. Determining the size of the computer that you need can be a complex problem.

For home use and for many small businesses the microcomputer provides the needed computing power at a reasonable cost.

Word processors are especially vulnerable to replacement by micro systems both because of cost and the utility of the system when it is not word processing. For businesses with several hundred to a couple of thousand items in inventory, or who need payroll for a fairly small number of employees, the microcomputer is often the right size.

Build or Buy?

Once you decide that you want a microcomputer, you must decide which one you want. No matter whose computer you might buy you are stuck with the choices that the designer made when the computer was originally planned. While you can never get completely away from having to make compromises, you can minimize them if you build your own system. Because you are providing the labor yourself you can also save money—or get more computer for your money.

If you don't want to build the entire computer, purchase one that will be expandable as your interest grows. Then do the expansion yourself. Many specialized uses require hardware that is not commercially available, at least not at an affordable price. There is also a satisfaction involved in building your own system that you just don't obtain by buying one already assembled. But even with all the advantages associated with building your own system there are sometimes circumstances that call for purchasing it instead.

DO COMMERCIAL COMPUTERS FILL YOUR NEEDS?

A strong argument for building your own microcomputer is that the computer to do exactly what you want is usually not available. If you do find a computer on the market that seems just right, then the advantages of purchasing it must be considered. A computer purchased fully assembled will generally work right the first time that