THE HP-41C

From Hewlett-Packard

BY TUDOR JONES

The HP-41C Alpha numeric Programmable Scientific Calculator is a product of Hewlett - Packard Co., of Corvallis, Oregon. It is the most powerful personal calculator Hewlett - Packard has ever designed.

It is 5¾" long, 3⅛" wide, 1⅜" high and weighs in at 7½ ounces. The instrument is available through a variety of stores, and costs about $500.

Following are descriptions and comments on some of the features of this very remarkable calculating engine.

In its basic configuration, the standard HP-41C has sixty-three registers that can be allocated to data storage or program memory in any combination. It is fully programmable, and can be expanded to contain over 2000 lines of program memory, or up to 319 registers for data storage.

A complementary metal-oxide-semiconductor technology, together with a liquid crystal display, result in a calculator with very meagre power requirements. The battery pack included with the instrument should last from nine to twelve months, depending upon the freshness of the batteries installed, and on how much the calculator is used.

In order to conserve battery power, the HP-41C will automatically turn itself off after ten minutes of inactivity. It can be turned on again by pressing the "ON" switch. This turn-off feature can be disabled through the keyboard so that the "ON" function will stay in effect until it is turned off manually.

A continuous memory saves all programs and data for later use when the machine is switched off.

The liquid crystal display is equipped with a complete system of status annunciators, which appear in a special area of display. A wide variety of comprehensive messages pinpoint calculation errors, prompt for data, label results, and supply reminders to absent-minded operators, for example, as when a printer is attached: -

PRINTER OFF
OUT OF PAPER, etc. etc.

It uses the "Reverse Polish Notation" logic for solving problems as opposed to the algebraic operating system used by most others. The R.P.N. logic system is most apparent during chain calculations. The automatic memory stack stores up to four intermediate results inside the calculator until needed, then inserts them into the calculation.

Conditional and unconditional branching, six levels of sub-routines, flexible addressing and complete program editing are standard features. Magnetic cards for recording custom programs and data register contents, and a peripheral printer are some of the options.

The HP-41C is equipped with two functions that produce audible tones. These can be used to signal the end of a computation that may have taken a few minutes to run. The pitch of the control can be controlled from the keyboard or a programmed instruction. Short tunes may be composed and played for the amusement of yourself and the amazement of your friends.

Flags

The calculator has 30 "user" flags that may be used in custom programs, and 26 "system" flags that have a more limited use in programs. The annunciator in the display indicates when Flags 0 through 5 are set.

Flag 21, for example, is set by the calculator and is used to enable and disable printing from programs. This flag can be tested like any other, so that programs may be constructed to print results if an optional peripheral printer is plugged in, or to stop and display results if no printer is connected.

Flags 28 and 29 are interesting, and are used to control how numbers appear in the display.

The decimal point flag, number 28, controls the radix mark and the separator mark in a number. The radix mark is the divider between the integer portion of a number and the fractional portion of a number. The separator mark is the separator between groups of digits (usually three digits per group) in a large number.

In some countries of the world, the radix mark is the comma and the separator mark is the period. In this country, the radix mark is the decimal point, or period, and the separator mark is the comma. Flag 28 allows the operator to use the radix mark and separator mark with which he is most familiar.

The second flag that controls how numbers appear in the display is the digit grouping flag, number 29. It controls whether or not a separator is used. If the operator preference is for separators, he can specify them. If the preference is no separators, then they can be turned off.

Functions

Over 130 separate operations comprise the total function library of the HP-41C. These can be accessed from the keyboard in several ways. The fifty-eight most used, or popular, functions are shown right on the keyboard. In the "normal" mode of operation, a simple keystroke will cause the function to execute.

The keyboard has four modes of operation - normal, user, alpha and program. The status annunciator in the display indicates which mode the machine is in at any time.

The instrument must be in "program" mode, of course, for an operator to key in the instructions of his own custom program.

When the HP-41C is placed in the "alpha" mode, a special alphanumeric keyboard becomes active. The characters printed on the lower front face of each key appear on the display when the keys are pressed. The functions printed on the top face of each key and above each key are no longer active.

These alpha strings can be up to 24 characters long, but only twelve can be displayed at any one time. Any time the HP-41C must display a single line of information which exceeds the 12-character display, the calculator automatically "scrolls" the line through the display to the left so that the complete line can be seen.

As mentioned, 58 functions can be addressed directly from the keyboard in "normal" mode, whereas over 130 operations are available. Any of these functions can be assigned by the operator to almost any key on the keyboard.

In "user" mode, each key can have a new function, as assigned by the operator. As many functions as necessary can be assigned. When a function is assigned to a key location, it remains there until it is cancelled or changed by assigning a new function to that location.

Key assignments of standard 41C functions are stored in program memory and use registers allocated to program memory. Two key assignments require one storage register, ten require five registers, fifteen require eight, and so on.

Four peripheral devices can be connected to the HP-41C by plugging them into one of four input/output ports provided on the top of the calculator. The standard features of the calculator can be supplemented with memory modules for increased program and data storage capacity, a magnetic card reader and writer, a printer output, and special application modules.

Memory

Each memory module contains 64 storage registers, which can be reallocated to up to 400 program instructions.

Some program instructions, or operations, require more program memory for storage than others. For example, a "clear X" instruction requires one byte of memory, while an "execute (numeric)" requires three bytes. Therefore it is impossible to predict how many instructions can be stored in a given segment of memory. It depends on the instructions to be stored.

The program memory in the HP-41C appears to be a very flexible and true random access memory. The position of programmed instructions within the memory is taken care of by the calculator.

Most calculator memories begin at step 00 for the first instruction, and proceed upwards step by step until the limit of the memory is reached. Individual programs within the memory are labelled, and these labels occur at various step numbers or line numbers, or what have you.

Not so in the memory of the 41C.

All programs are labelled as usual, but they all begin at line 00.

As new programs are keyed in, the instructions within the memory are "packed" by the calculator, and then the display announces how much memory is left for additional instructions.

Because these instructions are shunted about within the memory at the discretion of the calculator, the instruction

"Go To" followed by a line number cannot be recorded in a program. Any instructions to branch to another part of the program or to a subroutine must use labels as an address.

Generally, this is a slower process than going to a specified line number, because the calculator has to search through memory to find the label specified. This is the case with the HP-41C, but only for the first execution of that program, because the calculator can remember the location of most labels in program memory. Subsequent branches to a label are usually much faster because the calculator does not need to search for it again.

If four modules are plugged into the ports, a total of 319 data storage registers or up to 2000 lines of program memory become available.

The memory modules have continuous memory as does the calculator itself. A module removed from the calculator loses its contents, of course.

If a card reader, for example, is plugged into one of the ports, then a memory module will first have to be removed so that it can be accommodated.

Printer

A 5 x 7 dot matrix thermal printer connects to one of the 41C's ports. It prints out numeric characters, of course, as well as upper and lower case alpha, double-wide characters, and character plotting on the 2¼" wide paper tape. It has an intensity control for optimum contrast and readability.

6-character lines print out at 120 lines per minute. The maximum line width of 24 characters outputs at 70 lines a minute.

The printer has a special set of registers that allows it to control printing when required. These registers are collectively known as the print buffer. Specific characters and data may be placed in the buffer without being printed. When all of the desired characters have been loaded into the buffer, then the system can be instructed to print the contents of the buffer in one burst.

A typical configuration of the HP-41C for a land survey office would see a survey application module in one port, and a printer in another. It would not be necessary to include memory modules in the other two ports, because unfortunately the Hewlett-Packard survey programs do not store survey co-ordinates or other data.

If it was decided to prepare custom programs in lieu of the application module, two memory modules, a card reader and a printer would be appropriate options. Such a configuration would pro-

vide a total of 191 registers in the memory, and including the calculator would cost about $1400.

Comparisons

To see how this compares with the Texas Instruments T. I. 59 calculator, which incidentally is a less expensive instrument, a map-check, or closure and area, program written for the T. I. 59 was re-written for the 41C. The original program contained 473 program steps, and from keyed in bearings and distances calculated a closure or missing course, and from stored latitudes and departures, computed the D.M.D.'s and the enclosed area.

The new program comprised 251 program lines which occupied 61 registers in the 41C memory. Of the 130 registers remaining, ten are required as work registers for counters and the temporary storage of data, etc. thus leaving 120 registers for the storage of 60 pairs of lats. and deps.

It is unlikely that a figure this big and requiring this much storage would be encountered very often, but if the calculation was to proceed into co-ordinate geometry, the capability of storing 60 pairs of co-ordinates would not be out of line at all.

The Texas Instruments T. I. 59 contains 120 storage registers. The above program occupies 60 registers, ten are required as work registers, leaving 50 registers to store 25 pairs of co-ordinates.

The T. I. 59 program records onto both sides of one magnetic card. The 41C program requires both sides of two cards.

The time taken by the 41C to compute the area of a twenty sided figure from latitudes and departures in storage was 75 seconds. You may recall that the T. I. 59 took 95 seconds and a desk top mini-computer with a solid core memory took less than 4 seconds to do the same amount of work.

The internal architecture of the micro-computers compared to that of the mini-computers is mainly responsible for the disparity in times. The semi-conductor memories are fast enough. The problem seems to be, for example, in getting the large memory addresses to the X and Y decoders, and the data moved between the memory and the processing unit.

Also, the operational codes in the micros can be extremely complicated. Sometimes the most seemingly simple function can use up hundreds of machine cycles.

Application Modules

Application packs are available from the Company for many specialties, including mathematics, real estate, games and surveying.

Up until now, my comments on both the Texas Instruments T. I. 59 calculator (Fall, 1979 issue) and the Hewlett-Packard 41C have been generally positive. It is truly unfortunate that the special programs put together by these two reputable firms for the surveying community leave so much to be desired.

The cost of these program packages are very reasonable, so I do not mean to infer that a purchaser does not get value for his money. However, a little extra effort on the part of the programmers, or a release of the purse strings by those who pay them, could so very easily increase their worth. The survey application modules as they are presently set up are in my opinion very poor.

A brief example will show what I mean.

Data on a field traverse has been entered into the 41C calculator, and a compass rule adjustment is about to be made.

Instructions to Step 5 read as follows:-

5. Beginning with the first point to be adjusted, input the unadjusted co-ordinates and obtain the adjusted co-ordinates.

6. Press R/S and repeat step 5 for the rest of the co-ordinates.

One of the reasons a person spends extra money to acquire a calculator such as a T. I. 59 or a 41C, is because it contains lots of storage space. In the HP-41C during the Traverse Adjustment program, up to 180 storage registers could be lying empty and unused, and the operator is required to re-enter a whole bunch of unadjusted sets of co-ordinates.

Back in about 1965, the pioneering Olivetti Programma 101, with only six storage registers, had virtually the same instructions. It is too bad that the advances we have welcomed in hardware over the past fifteen years, have not spilled into some worthwhile software.

The same conditions apply throughout the program packages. Starting and ending co-ordinates have to be keyed in for inverse routines, intersection routines (bearing - bearing, etc.), resections, traverse rotation, etc. etc. Has it not occurred to anyone to store these co-ordinates in memory and recall them when needed by point number? It really is not that difficult to do.

An alternative to the application pack is to prepare custom programs, and to record these on magnetic cards. To many people this is not a viable alternative, because they perhaps do not have the time nor the inclination to spend the

considerable time required to put together an operational set of routines.

Because a comprehensive survey program is so long, it has to be broken down into sections that will fit the magnetic cards and the available memory, and still leave as many registers as possible for data storage. Consequently, the constant reading of cards is frustrating for the operator, and hard on the equipment. No machine lasts for ever, and the more it has to be used, the quicker it will wear out.

In my opinion, a set of custom programs on magnetic cards is a poor substitute for a properly put together application module.

It occurs to me that these survey routines provided by Hewlett-Packard and Texas Instruments were written some time ago for earlier calculators with much smaller memories, and that they have not been upgraded sufficiently to take advantage of the tremendous capabilities of these newer instruments.

Hopefully, work is presently underway to do this, and that it will not be too many months before survey program packages worthy of the HP-41C and the T. I. 59 will be available from these companies.

The Incredible Shrinking Line

Following are a few brief words on silicon chip technology.

In laboratories and design centres around the world, integrated circuit designers have been busy shrinking line widths and lengths on current large scale integrated-circuit designs while creating incredibly finely detailed, dense semiconductor structures.

In the integrated-circuit era, chip densities have doubled every year, going from about 30 components on a chip in 1965 to approximately 30,000 in 1975. With the 64-K random access memory, the count in 1979 had reached about 135,000.

Since small transistors have relatively limited capability to drive loads, it becomes quite important to minimize the number of devices that must drive external connections. The large devices that are required to drive external connections consume a disproportionate amount of area on a small chip.

If complex functions are integrated, only a small percentage of the devices need drive any load other than the small capacitances of inter-connections and other devices on the same chip.

Apart from other benefits, such as low weight and volume, higher reliability and faster operating speeds, integrated

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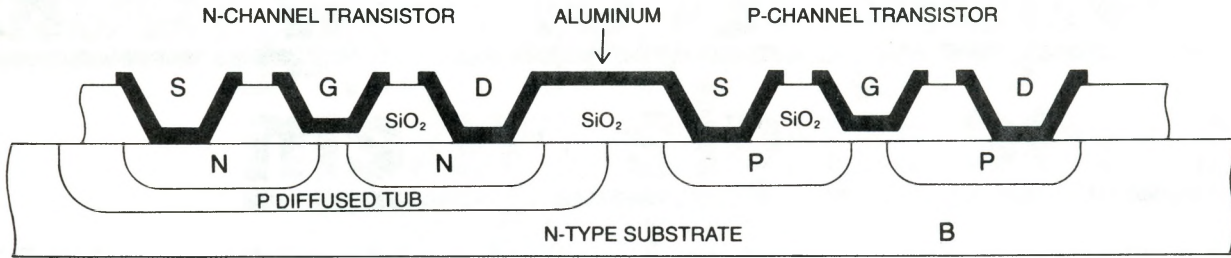
circuits have the potential of very low cost because the expense of each production step is shared by thousands of similar circuits.

The planar process is generally used for the production of silicon monolithic integrated circuits. In this method of fabrication, a silicon wafer from two to four inches in diameter and about 0.01 inches in thickness is sliced from a large single crystal of silicon. The electronic components are produced inside and on this slice by diffusing small amounts of impurities through windows in a layer of silicon dioxide (a kind of glass) grown on the silicon slice.

By heating the silicon wafer in an oxidizing atmosphere (oxygen or water vapour), a dense layer of silicon dioxide is formed on the surface of the slice. The oxide is then etched away in the areas where the regions required for transistors, diodes, or resistors are to be made.

A master drawing of the finished structure is first created showing how the several layers of impurities are superimposed. Typically, this might be done at 500 times final size, so that the art work for an integrated structure that was destined to occupy an area of silicon one tenth of an inch square would be 50 inches square. Separate, high precision drawings of the pattern for each layer are then prepared and reduced photographically to form a mask.

The impurities are deposited on the surface of the wafer, in a pattern indicated by the mask, by heating it to about 1200° C in an atmosphere containing a suitable impurity, usually phosphorus or boron. The impurity atoms diffuse into the silicon. The diffused layers are of the order of microns thick for diffusion times of hours. Thus the diffusion process is an accurately controlled way to introduce impurities in shallow layers into the existing crystal.

After several such patterning and diffusion steps, the various circuit components formed are interconnected with aluminum evaporated onto the surface of the slice. The resulting structure is a solid three-dimensional network of conductors and electronic devices.

The processing sequence is designed to make one complete integrated circuit correctly. This single structure occupies only a small portion of the water surface. By the batch processing nature of the technology, this complete circuit is repeated over the entire wafer surface so that large numbers are made at the same time.

To mount the chips in individual packages, break lines are inscribed between the circuits on the ceramic-type wafer with a diamond tool and the individual chips broken apart, or else the wafer is sawn apart or cut with a laser.