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(54) CALCULATORS

(71) We, HEWLETT-PACKARD COMPANY, of 1501 Page Mill Road, Palo Alto, California 94304, United States of America, a corporation organized and existing under the laws of the State of California, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

This invention relates generally to calculators and improvements therein and more particularly to calculators which may be easily adapted to meet the specific needs of each user.

The present application has been divided out of our Application NO. 59038/73 which contains a more detailed description of the calculator hereinafter described, which is therefore incorporated herein by reference, and which claims features other than the features claimed herein.

The present invention is also closely related to that disclosed and claimed in the complete specifications of United Kingdom Patent Applications Nos. 50310/74 and 50312/74.

Calculators constructed according to the prior art have generally taken one or two approaches toward reducing the labor content of repetitious, routine computational tasks. The first is by means of programmability. The programmable machine has the inherent advantage of program versatility in that it can be programmed to solve problems encountered in nearly all disciplines including mathematics, science, engineering, business, finance, statistics, etc. Unfortunately, this versatility has added significantly to cost. The user is, therefore, paying for considerably more calculating capability and versatility than is required, for instance, in solving repetitive problems related to the same discipline. The approach which has recently been taken to solve this problem is that of a "dedicated" calculator. Such a machine generally has built-in, fixed programming which allows it to handle only a narrow range of problems. Even though these dedicated calculators are less expensive than programmable types, they have a serious short-coming in that their programs cannot be changed.

In the complete specification of the aforesaid application No. 59038/73 there is disclosed and claimed and electronic calculator comprising: a keyboard input unit for providing the user with a plurality of keyboard functions and for entering into the calculator information used to initiate selected ones of those keyboard functions and data used in making selected calculations to perform the selected keyboard functions; a memory unit for storing routines and subroutines of instructions to be performed by the calculator in making the selected calculations to perform the selected keyboard functions; a modular keyboard section, including a read-only memory containing additional routines and subroutines of instructions, for providing the user with additional keyboard functions and for entering into the calculator information used to initiate selected ones of those additional keyboard functions; processing means responsive to information from the keyboard input unit and to operating states within the calculator itself for selectively performing one or more of the routines and subroutines stored in the memory unit to make the selected calculations employing data entered from the keyboard input unit; said processing means being responsive to information from the modular keyboard section and to operating states within the calculator itself for selectively performing one or more of the additional routines and subroutines of instructions contained in the read-only memory to make selected calculations em-

(12)

ploying data entered from at least one of the keyboard input unit and the modulator keyboard section; and output means for providing an output indication of the results of the calculations performed by the processing means.

In the complete specification of the aforesaid application No. 50310/74 there is disclosed and claimed an electronic calculator comprising: keyboard input means for entering information into the calculator, said keyboard input means including a plurality of command keys and a plurality of data keys, each command key and each data key being associated with a separate mnemonic code; main memory means for storing microprogrammed routines and subroutines performed by the calculator in executing selected keyboard commands; read-only memory means coupled to said main memory means for storing keyboard mnemonic codes representing one or more programs employing selected keyboard commands and data; processing means coupled to said keyboard input means, read-only memory means, and main memory means, said processing means being selectively responsive to actuation of a command key or to the mnemonic code associated with a command key, when that mnemonic code is encountered in processing a program stored in said read-only memory means, for executing the microprogrammed routines and subroutines stored in said main memory means that are associated with that command key or keyboard mnemonic code; and output means coupled to said processing means for providing an output indication of the results of selected commands executed by the calculator.

In the complete specification of the aforesaid application No. 50312/74 there is disclosed and claimed an electronic calculator comprising: keyboard input means for entering information into the calculator, said keyboard input means including a percent key for entering a percent operator into the calculator and a plurality of keys for entering data and arithmetic operators including an addition operator into the calculator; and processing means coupled to said keyboard input means and responsive to information entered into the calculator from said keyboard input means and to operating states within the calculator for selectively performing calculations and for providing an output indication of the results of those calculations, said processing means being responsive to entry of a first number followed by entry of the addition operator followed by entry of a second number followed by entry of the percent operator for calculating the sum of the first number and a percentage thereof as specified by the second number.

The present invention provides an electronic calculator comprising keyboard input means for entering information into the calculator; memory means for storing information entered into the calculator; processing means responsive to information entered from the keyboard input means and to operating states within the calculator for selectively performing calculations and for providing an output indication of the results of those calculations; and logic means responsive to designation of an automatic decimal point mode for automatically placing a decimal point at any predetermined one of a plurality of positions in noninteger data subsequently entered into the calculator from the keyboard input means without the necessity of manual entry of the decimal point in the noninteger data by the user.

In a calculator as set forth in the last preceding paragraph preferably the keyboard input means includes decimal point control means for designating placement of the decimal point at any one of the aforementioned plurality of positions, and automatic decimal point mode control means for designating the automatic decimal point mode and causing the logic means to automatically place the decimal point at the one of the aforementioned plurality of positions designated by the decimal point control means in noninteger data subsequently entered into the calculator.

There now follows a detailed description which is to be read with reference to the accompanying drawings of an electronic calculator according to the invention. It is to be clearly understood that this calculator has been selected for description to illustrate the invention by way of example and not by way of limitation.

In the drawings:—

Figure 1 is a front perspective view of an adaptable calculator according to the preferred embodiment of this invention; and

Figure 2 is a block diagram of the calculator of Figure 1.

CALCULATOR ARCHITECTURE

Referring to Figures 1 and 2, there is shown a desk top electronic calculator 10 including a keyboard input unit 12 for entering data and instructions into the calculator, an optional plug-in seven-segment fifteen-digit LED output display unit 14 for displaying each data entry and the results of calculations performed by the calculator, and a plug-in read-only memory (ROM) or programmable read-only memory (PROM) 22 tailored to the requirements of the user and removably plugged into the calculator by means of a hinged top cover 24. The calculator also includes an eighteen-column built-in output printer unit 16 for printing intermediate and final results of calculations, entered data, arithmetic operators, and diagnostic notes.

Keyboard input unit 12 includes a group of data keys for entering numeric data into the calculator, a group of control keys for controlling the various modes of the calculator and the operations of the output printer, a group of operand keys for designating the mathematical operations to be performed on various items of data, and a group of program keys for controlling the execution of library programs stored within the plug-in ROM or PROM. The keyboard input unit also includes a covered blank section 18 which will accommodate a plug-in function block 20 containing fifteen keys and associated read-only memory. Various function blocks 20 may be dedicated to different disciplines and problem solving areas for expanding the capabilities of the calculator. The keys of each such function block 20 represent functions which are useful in making calculations relating to the discipline to which that function block is dedicated. For example, a dedicated function block oriented toward statistics includes keys whose representative functions would be helpful in solving statistical problems. Likewise, a mathematics function block would include various mathematical functions available as the result of key actuations. Alternatively, the function block 20 may comprise a user-definable function block containing fifteen keys, each having a transparent cap which the user may remove for the purpose of inserting a function label. Each of these keys is associated with a particular function or program contained within the plug-in ROM or PROM 22 employed with the calculator. Thus, each such function or program may be executed by simply actuating the associated key of the user-definable function block. The calculator may employ a ROM or PROM 22 without also employing a plug-in function block 20. In such a case, the ROM or PROM contains one or more programs which the user may execute from the main keyboard.

As shown in the block diagram of Figure 2, the calculator also includes an MOS/LSI control and timing circuit 30, an MOS/LSI arithmetic and register circuit 32, eight MOS/LSI ROM circuits Ø-7 comprising a ROM group 34, an MOS/LSI data storage circuit contained within a data storage assembly 36, and an MOS/LSI input/output circuit contained within an input/output processor 38. The MOS/LSI circuits are two-phase dynamic types with low thresholds for assuring compatibility with standard TTL bipolar circuits and for operation at very low power levels. They are organized to process fourteen-digit BSD words in a digit-serial, bit-serial manner. They are also capable of bit-serially processing fifty-six bit binary words. The maximum bit rate or clock frequency is two hundred kilohertz, which gives a word time of two hundred eighty microseconds. This means that a floating point addition may be accompalished in sixty milliseconds.

The control and timing circuit 30, the ROM group 34, the arithmetic and register circuit 32, the data storage assembly 36, and the input/output processor 38 are tied together by a six-line bus 40. This bus comprises a SYNC line, an instruction (I_s) line, a word select (WS) line, an instruction address (I_a) line, a START line, and a BCD line. All operations occur on a fifty-six bit (b_0 - b_{55}) word cycle (fourteen four-bit BCD digits).

The SYNC line carries synchronization signals from the control and timing circuit 30 to ROM circuits Ø-7 in the ROM group 34 and to the arithmetic and register circuit 32 to synchronize the calculator system. It provides one output each word time. This output also functions as a ten-bit wide window (b_{45} - b_{54}) during which the instruction line I_s is active.

The instruction line I_s carries ten-bit instructions from the active ROM circuit of the ROM group 34 to the other ROM circuits within the ROM group 34, to the control and timing circuit 30, to the data storage assembly 36, and to the input/output processor 38, each of which decodes the instructions locally and responds to or acts upon them if they pertain thereto and ignores them if they do not. In order to free instruction bit patterns normally associated with the aritmetic and register circuit and the control and timing circuit, the I_s line is gated prior to being examined by these circuits. For example, an ADD instruction affects the arithmetic and register circuit 32 but is ignored by all other circuits. Similarly, a SET STATUS BIT 5 instruction sets status flip-flop 5 in control and timing circuit 30 but is ignored by all other circuits.

The actual implementation of an instruction is delayed one word time from its receipt. For instance, an instruction may require the addition of digit 2 in two of the registers in the arithmetic and register circuit 32. The ADD instruction would be received by the arithmetic and register circuit 32 during bit times b_{45} - b_{54} of word time N+1. Thus, while one instruction is being executed, the next instruction is being fetched.

The WS line carries an enable signal from the control and timing circuit 30 or one of the ROM circuits in the ROM group 34 to the arithmetic and register circuit 32 to enable the instruction being executed thereby. Thus, in the example of the previous paragraph, addition occurs only during digit 2 since the adder in the arithmetic and

register circuit 32 is enabled by the WS line only during this portion of the word. When the WS line is low the contents of the registers in the arithmetic and register circuit 32 are recirculated unchanged.

The I_s line serially carries the addresses of the instructions to be read from the ROM circuits Ø-7 of the ROM group 34. These addresses originate from the control and timing circuit 30, which contains an instruction address register that is incremented each word time unless a JUMP SUBROUTINE or a BRANCH instruction is being executed. Each address is transferred to the ROM circuits Ø-7 during bit times b_{19} - b_{28} and is stored in an address register of each ROM circuit. However, only one ROM circuit is active at any given point in time, and only the active ROM circuit responds to an address by outputting an instruction on the I_s line. Control is transferred between the ROM circuits Ø-7 by a ROM SELECT instruction. This technique allows a single eight-bit address, plus eight special instructions, to address up to eight ROM circuits of two hundred and fifty-six words each.

The START line carries a one-bit pulse which occurs during bit time b_0 and is used to synchronize operations of the data storage assembly 36 and the input/output processor 38 with those of the arithmetic and register circuit 32.

The BCD line carries numerical data between the arithmetic and register circuit 32, the input/output processor 38, and any basic or optional units containing data storage circuits. The format of the data carried on this line is illustrated in Figure 4.

A CARRY line 42 transmits the status of the carry outputs of the adder in the arithmetic and register circuit 32 to the control and timing circuit 30. The control and timing circuit 30 uses this information to make conditional branches, dependent upon the numerical value of the contents of the registers in the arithmetic and register circuit 32.

The control and timing circuit 30 is organized to scan a five-by-eight matrix of switches in search of an interconnection that designates actuation of a key. Any type of metal-to-metal contact may be used as a key. Bounce problems associated with keyboard switch contact are overcome by programmed lockouts in a key entry routine. Each key has an associated six-bit code. To accommodate more than the forty-key maximum represented by the five-by-eight matrix scanner included in the control and timing circuit, an additional keyboard multiplexer circuit is provided. The control and timing circuit is also employed for retaining status information relating to the condition of the calculator or of a particular subroutine and for generating a next address in read-only memory.

The arithmetic and register circuit contains an adder, a group of working registers, a group of data storage registers forming a stack, and a constant storage register for storing microprogramming level flags associated with various subroutines.

The eight ROM circuits Ø-7 of ROM group 34 have subroutines stored therein for performing various functions. These ROM circuits also supervise program execution and serve to control any peripheral input/output units which may be connected to the calculator. The eight individual ROM circuits are identical in structure and differ only in the way in which they are programmed.

The calculator employs a standard power supply containing a power-on circuit which supplies a signal for forcing the calculator to start up in a known condition when power is supplied thereto. A line switch on the calculator keyboard controls the application of operating power.

The data storage circuit provides ten data storage registers, five of which are used for parentheses nesting, three of which are used for performing various internal system housekeeping functions at the microprogram level, one of which is a grand total register which may be interrogated by the user, and the last of which is accessible to the user for storing a single item of data.

The input/output circuit enables the calculator to communicate with various input/output peripheral units such as a typewriter or an X-Y plotter and determines whether the proper peripheral configuration for running a particular program is present. It also includes a binary arithmetic logic unit for performing binary arithmetic, a program address counter used in running programs, and the necessary logic circuit for driving the output printer unit 16.

The calculator may be operated manually from the keyboard input unit utilizing functions available as keys on the basic keyboard, on a dedicated plug-in function block, or on a user-definable plug-in function block. The calculator may also be operated automatically from a program comprising user-level language instructions and stored in a plug-in ROM, a plug-in PROM or a read/write memory unit associated with a plug-in magnetic card reading and recording unit.

CALCULATOR OPERATION

The basic calculator contains three register locations into which numbers are either entered for immediate use or are stored for later use. These are the X-register in the arithmetic and register circuit 32, and the C-register and RT-register in the data storage assembly 36.

Each number which the user enters from the keyboard is placed in the X-register. If

the calculator is configured with the plug-in LED display unit, the number is displayed as it is entered. The X-register also receives the result of each mathematical operation. Each time the EQUALS key is actuated, a result is generated, which is placed in the X-register and also added to the contents of the RT-register for accumulating the result total.

The C-register may be used for storing any constant for later use in making calculations. Whenever the STORE key is actuated, the contents of the X-register are duplicated (stored) in the C-register. Any constant stored in the C-register remains unaltered until either another constant is stored therein or the calculator is switched off. The RECALL key is used to bring the contents of the C-register back into the X-register.

Actuating the CLEAR key erases the contents of the X and RT registers and causes the word CLEAR to be printed on the output printer. CLEAR operations leave the contents of the C-register unaltered. Actuating the CANCEL ENTRY key erases the X-register but leaves the C and RT registers unaltered. When operating power to the calculator is removed all storage registers are erased.

In addition to printing CLEAR and tallying keyboard operations, the calculator informs the user of his operating errors by printing diagnostic notes when an error has been made. Some errors may be readily corrected, while others may require that the CLEAR key be actuated and the problem begun again.

The four basic arithmetic operations comprising addition, subtraction, multiplication, and division may be easily accomplished with the calculator. The first operand is entered; the desired operation key is actuated; the second operand is entered; and then the EQUALS key is actuated to execute the calculation. The result is placed in the X-register. When performing calculations involving more than one operator, each successive operation uses the result of the previous operation.

A red busy light on the keyboard flashes whenever the calculator is performing a function and cannot accept key actuations. When the calculator is executing a library program stored in a plug-in ROM or PROM, the busy light may remain on for several seconds. This light simply serves to remind the operator that the calculator will ignore any key actuations which occur during the time it is busy.

Negative numbers are entered by first keying in the number and then changing its sign. The sign is changed by successively actuating the SHIFT key and the LEFT PARENTHESIS key. Negative numbers are printed in red on the output printer 16.

As discussed above, the calculator performs successive mathematical operations by using the result of the previous operation. By using the LEFT PARENTHESIS and RIGHT PARENTHESIS keys, operations may be grouped together just as is done in standard mathematical notation involving parentheses. Use of parentheses in expressions eliminates the need for storing the recalling intermediate results. The output printer prints the result of each operation within parentheses at the time each right parenthesis is entered. Parentheses may be nested up to and including five levels.

The EXPONENT (↑) key is used to raise any number to any power. The number to be raised is entered, followed by the EXPONENT key, followed by the power.

The PERCENT key may be used in conjunction with all four arithmetic operators to calculate, for example, a percentage of a number in the X-register or to further use a percentage of a number in the X-register within a calculation. For example, if it is desired to calculate 6% of 39.95, the user would enter 39.95, followed by the MULTIPLY key, followed by 6, followed by the PERCENT key, terminated by the EQUALS key, to give a result of 2.40. As a further example, if the user wishes to discount or subtract 20% from 80, he would first enter 80, followed by the SUBTRACT key, followed by 20, followed by the PERCENT key, terminated by the EQUALS key, to give a result of 64. As a final example, if it is desired to calculate the simple interest for a term of 2 years on $500 at 7%, the user would first enter 500, followed by the MULTIPLY key, followed by 7, followed by the PERCENT key, followed by the MULTIPLY key, followed by 2, terminated by the EQUALS key, to give a result of $70.

The output printer unit is associated with several keys which control its operation. The PRINT OFF (PRT OFF) key suppresses tallying of keyboard operations on the printer, but allows printing of the diagnostic notes plus CLEAR. Actuation of the PRINT key prints the current contents of the X-register, regardless of whether the PRINT OFF mode is in effect. The symbol # accompanies each number printed by actuating the PRINT key. The PAPER key is used to quickly advance the printer paper. When the calculator is turned on, the display and print format is automatically set to ROUND 2. This means that each number displayed and/or printed is shown with two digits to the right of the decimal point. This format can be altered to indicate from zero to six decimal point digits by actuating the ROUND [RND( )] key followed by the appropriate number. Printed and displayed numbers may be shown in floating point, or scientific notation by actuating the ROUND

key followed by the DECIMAL POINT key.

Some of the calculator keys represent dual functions distinguished by whether actuation has been preceded by actuation of the SHIFT key. Actuation of the SHIFT key followed by the EXPONENT key operates to calculate the reciprocal of the contents of the X-register. Actuation of the SHIFT key followed by the DIVIDE key results in calculating the common logarithm of the number in the X-register. Actuation of the SHIFT key followed by the MULTIPLY key is used to calculate the natural logarithm of the contents of the X-register.

Actuation of the SHIFT key followed by the ADD key operates to raise the Naperian logarithm base *e* to the power indicated by the contents of the X-register. Actuation of the SHIFT key followed by the SUBTRACT key acts to divide the number in the X-register by 12.

When solving problems involving the entry of many numbers in the same form, such as dollars and cents, the AUTO DECIMAL POINT (AUTO .) key may be used to automatically place the decimal point at a specified position in each number entry. This eliminates physically depressing the DECIMAL POINT key at the proper point during entry of each number. The place at which the decimal point is automatically located is specified by the current rounding format. For instance, if the calculator is operating in ROUND 2 format and the automatic decimal point feature is being used, the decimal point will be placed so that two digits will be indicated to the right thereof.

The RT-register accumulates results that are placed in the X-register each time the EQUALS key is actuated. To recall the contents of the RT-register to the X-register, and at the same time display and print the new contents of the X-register, the user simply actuates the SHIFT key followed by the EQUALS key.

The user may plug into the calculator optional data storage units. This option is available to expand the single C-register of the basic calculator in increments of 30 or 100 registers. The extra registers are numbered zero through twenty-nine or zero through ninety-nine. To store the data currently in the X-register into one of the registers of the data storage option, the SHIFT key is first actuated, followed by the STORE key, followed by the desired register number, terminated by the EQUALS key. To recall a number from optional data storage into the X-register, the same key sequence is followed except that the RECALL key is actuated instead of the STORE key. It is possible to obtain a printed listing of all the data stored in the optional registers by means of the following key sequence: SHIFT, START PROGRAM (START PRGM), PRINT, EQUALS. The register contents are printed in blocks of ten, beginning at register zero. To erase all of the optional data storage registers, the following key sequence is observed: SHIFT, START PROGRAM, ZERO, EQUALS. The optional data storage registers may be incremented or decremented, respectively, by actuating the SHIFT key, followed by the START PROGRAM key, followed by either the ADD key or the SUBTRACT key.

It will also be appreciated that with the described calculator the user may designate an automatic decimal point mode for automatically placing the decimal point in entered data at a preselected position.

WHAT WE CLAIM IS:

1. An electronic calculator comprising: keyboard input means for entering information into the calculator; memory means for storing information entered into the calculator; processing means responsive to information entered from said keyboard input means and to operating states within the calculator for selectively performing calculations and for providing an output indication of the results of those calculations; and logic means responsive to designation of an automatic decimal point mode for automatically placing a decimal point at any predetermined one of a plurality of positions in noninteger data subsequently entered into the calculator from said keyboard input means without the necessity of manual entry of the decimal point in the noninteger data by the user.

2. An electronic calculator as in claim 1 wherein said keyboard input means includes decimal point control means for designating placement of the decimal point at any one of said plurality of positions, and automatic decimal point mode control means for designating the automatic decimal point mode and causing said logic means to automatically place the decimal point at the one of said plurality of positions designated by said decimal point control means in noninteger data subsequently entered into the calculator.

3. An electronic calculator according to claim 1 substantially hereinbefore described with reference to the accompanying drawings.

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When solving problems involving the entry of many numbers in the same form, such as dollars and cents, the AUTO DECIMAL POINT (AUTO .) key may be used to automatically place the decimal point at a specified position in each number entry. This eliminates physically depressing the DECIMAL POINT key at the proper point during entry of each number. The place at which the decimal point is automatically located is specified by the current rounding format. For instance, if the calculator is operating in ROUND 2 format and the automatic decimal point feature is being used, the decimal point will be placed so that two digits will be indicated to the right thereof.

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It will also be appreciated that with the described calculator the user may designate an automatic decimal point mode for automatically placing the decimal point in entered data at a preselected position.

WHAT WE CLAIM IS:

1. An electronic calculator comprising: keyboard input means for entering information into the calculator; memory means for storing information entered into the calculator; processing means responsive to information entered from said keyboard input means and to operating states within the calculator for selectively performing calculations and for providing an output indication of the results of those calculations; and logic means responsive to designation of an automatic decimal point mode for automatically placing a decimal point at any predetermined one of a plurality of positions in noninteger data subsequently entered into the calculator from said keyboard input means without the necessity of manual entry of the decimal point in the noninteger data by the user.

2. An electronic calculator as in claim 1 wherein said keyboard input means includes decimal point control means for designating placement of the decimal point at any one of said plurality of positions, and automatic decimal point mode control means for designating the automatic decimal point mode and causing said logic means to automatically place the decimal point at the one of said plurality of positions designated by said decimal point control means in noninteger data subsequently entered into the calculator.

3. An electronic calculator according to claim 1 substantially hereinbefore described with reference to the accompanying drawings.

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