United States Patent [19]

McLaughlin et al.

[11] **3,941,989**

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[54] **REDUCING POWER CONSUMPTION IN CALCULATORS**

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[73] Assignee: **MOS Technology, Inc.**, Norristown, Pa.

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[52] **U.S. Cl.**..... **235/156;** 340/172.5; 340/324 R

[51] **Int. Cl.**[2]..... **G06F 7/38;** G06F 1/04

[58] **Field of Search** ..... 235/156; 340/324 R; 445/1

[56] **References Cited**

UNITED STATES PATENTS

3,453,601	7/1969	Bogert et al.	340/172.5
3,781,852	12/1973	White et al.	340/324 R
3,812,489	5/1974	Hirano et al.	340/324 R

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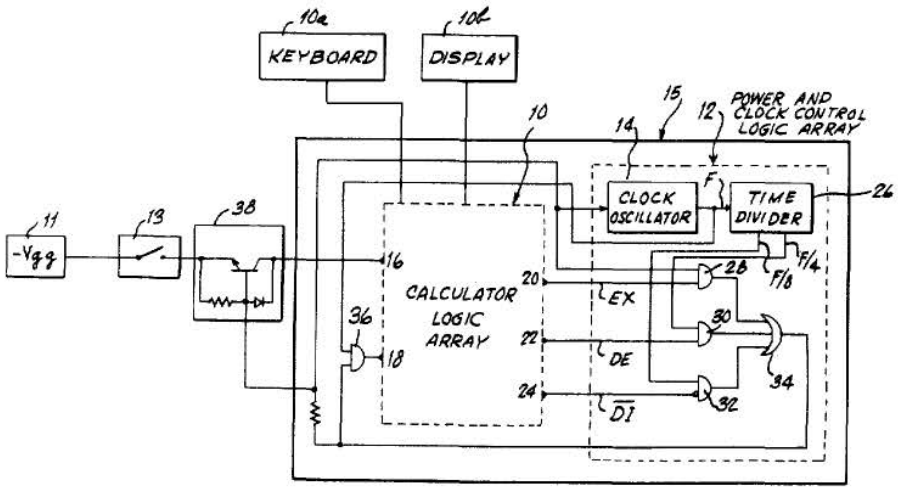
Attorney, Agent, or Firm—Cooper, Dunham, Clark, Griffin & Moran

[57] **ABSTRACT**

Continuous power and a high rate clock are supplied to a calculator while it is in an execute mode and is actually decoding and processing input information, but lower duty cycle power and lower duty cycle clock pulses are supplied during the subsequent display mode, when the only requirement is to maintain and display selected information resulting from the execute cycle, so as to reduce the power consumption rate as compared to the rate during the execute mode. If there is no new execute mode within a selected time interval, the display is turned off and the duty cycle of the power and the clock supplied to the calculator are lowered still further so as to maintain (without displaying) selected stored information but to further reduce the rate of power consumption.

15 Claims, 3 Drawing Figures



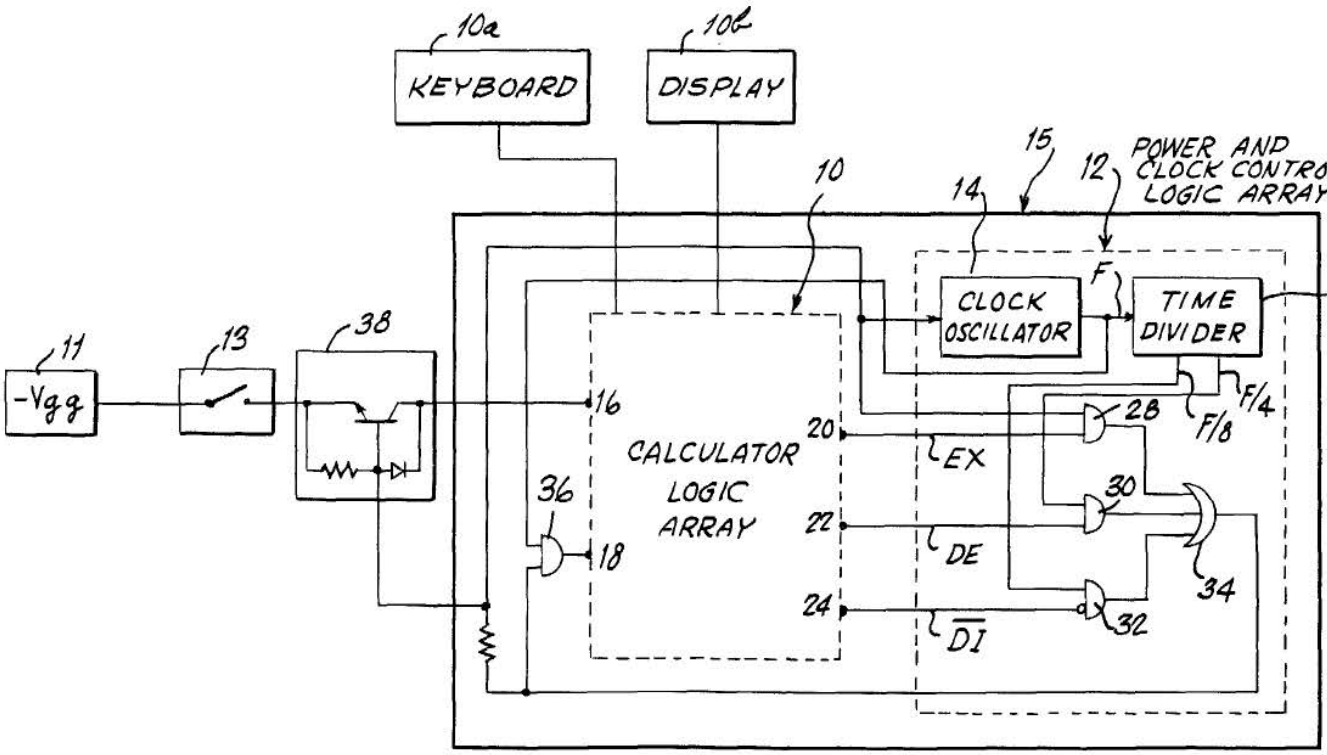
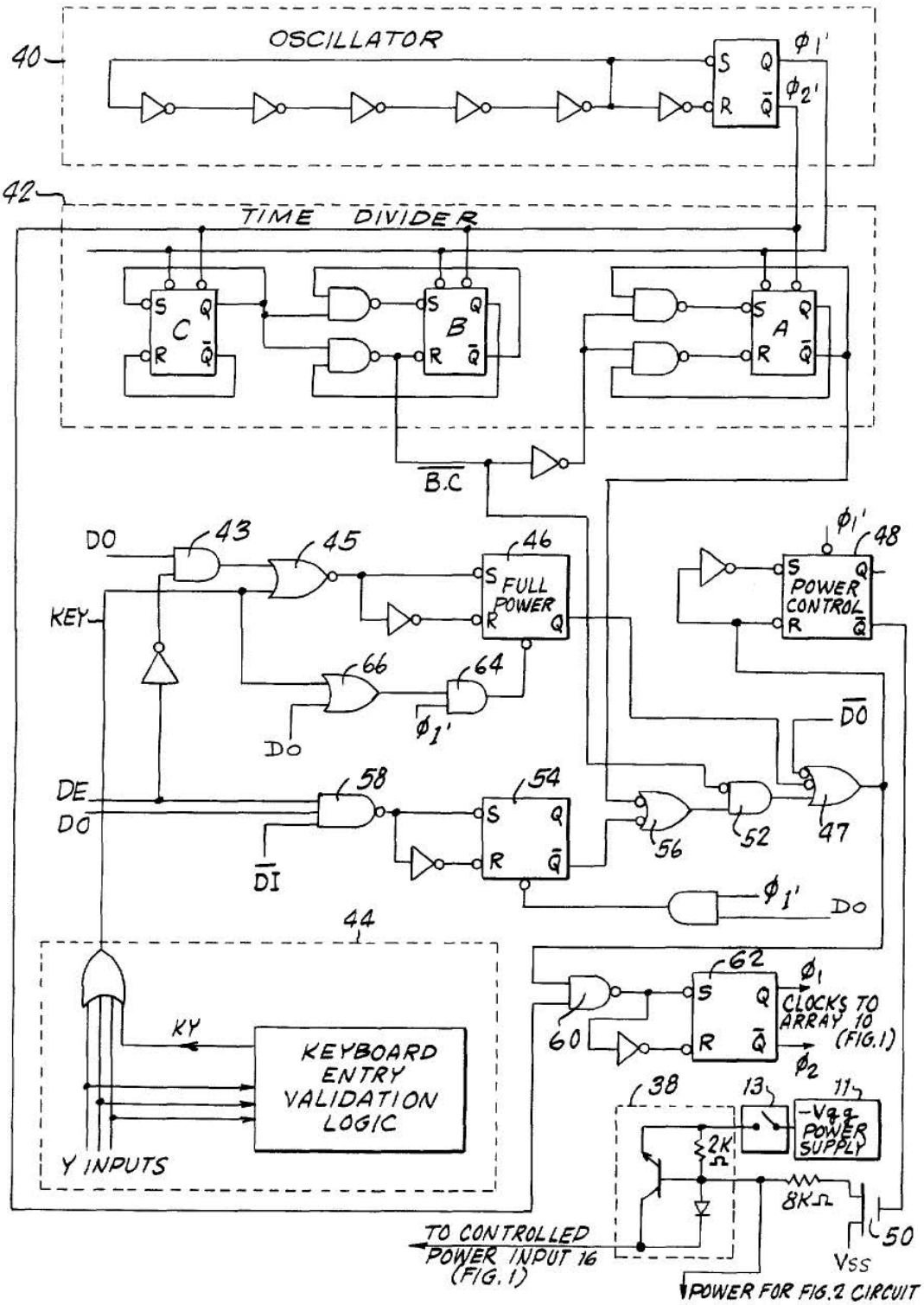


Fig. 1.

Fig. 2.



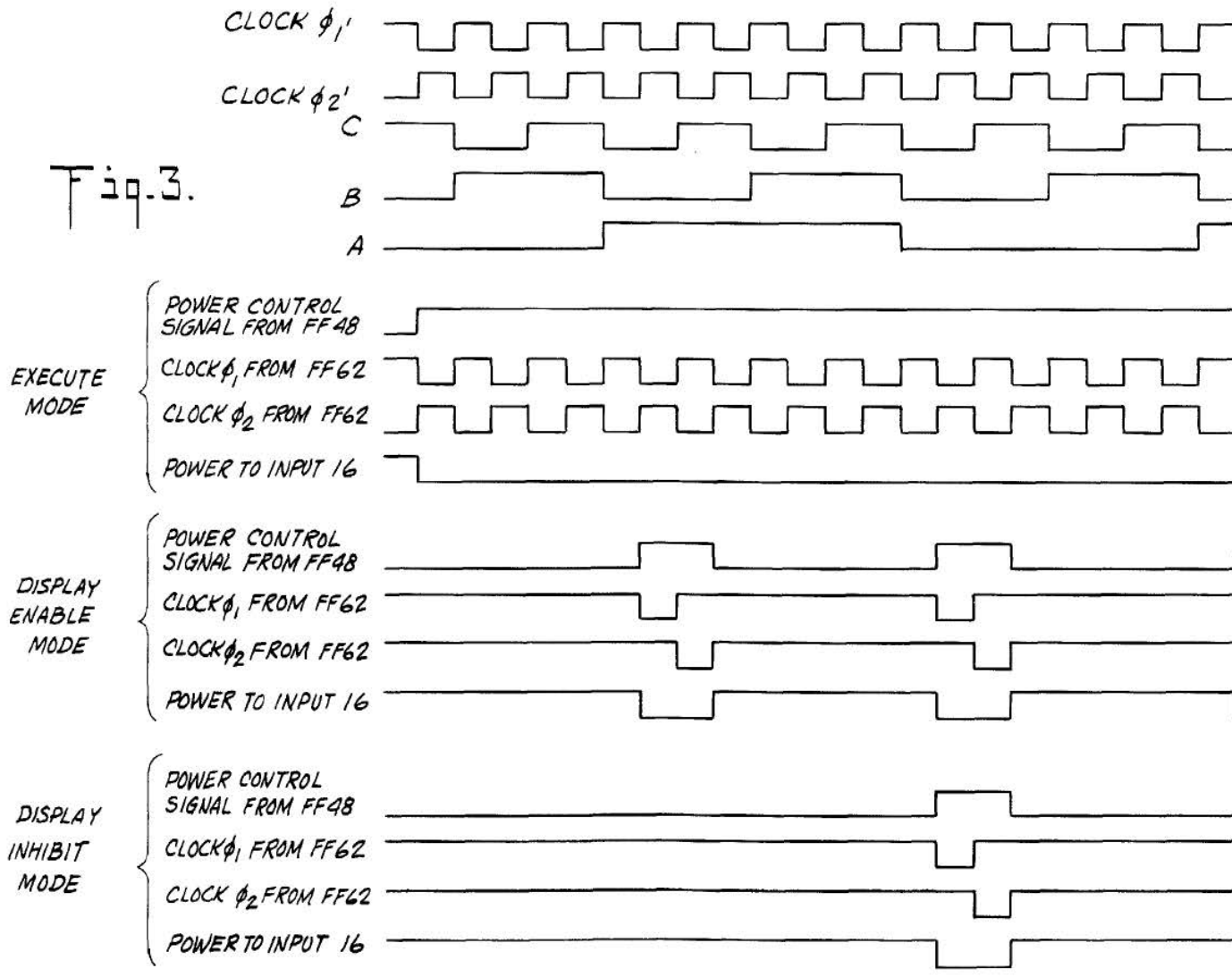


Fig. 3.

REDUCING POWER CONSUMPTION IN CALCULATORS

BACKGROUND OF THE INVENTION

The invention is in the field of calculators employing dynamic storage of information and dynamic display of stored information, and specifically relates to calculators of this type in which the rate of power consumption is of concern, such as in hand-held calculators which are battery powered.

Calculators of this type typically have three alternate operating modes. There is an execute mode during which input information is decoded and is arithmetically and logically processed in accordance with either input or stored commands to provide selected processed information. The execute mode operation is typically followed automatically, without operator intervention, by a display mode in which selected processed information is displayed. When selected new information is entered, there is a new execute mode operation followed by a new display mode operation. If there is no new execute mode operation within a certain time interval, the calculator automatically goes into a display inhibit mode (alternately called blanking), in which the relevant information is no longer displayed, but is maintained in storage so that it can be again displayed if needed.

A typical calculator of this type (disclosed in White et al. U.S. Pat. No. 3,781,852) operates at full power during all three modes of operation, the only power reducing scheme being that the display is not driven during the display inhibit mode of operation. A somewhat different approach is disclosed in Bogert et al. U.S. Pat. No. 3,453,601 where a calculator is clocked at a high frequency during its arithmetic mode operation to ensure high calculating speed but is clocked at a lower frequency and low duty cycle during its subsequent display mode operation in order to reduce power consumption. However, the Bogert et al. system has no display inhibit mode of operation and has no special provisions for applying power to the calculator at different duty cycles during different modes of operation.

SUMMARY OF THE INVENTION

An object of the invention is to reduce the power consumption of calculators, and particularly of hand-held calculators which are battery powered, by supplying to the calculator only as much power as actually needed for each different mode of operation and by clocking the calculator at a rate which is only as high as actually needed for each different mode of operation.

The invention is applicable to calculators which have three different modes of operation: an execute mode in which input information is decoded and is processed to derive and dynamically store selected processed information, a display enable mode in which selected stored information is maintained in dynamic storage and is concurrently dynamically displayed, and a display inhibit mode during which selected information is maintained in dynamic storage but is not displayed. Each execute mode operation is typically initiated by information keyed by an operator through a keyboard and includes decoding the keyed information, any calculations such as addition, multiplication, etc. and storing of any resulting information in dynamic storage. Once the execute mode operation is completed, the calculator automatically goes into a display enable mode, without operator intervention. In accordance with the invention, the power supplied to the calculator during each execute mode operation is at a high duty cycle (e.g., continuous power) and the calculator is continuously clocked with a high rate clock, so as to minimize the duration of the execute mode operation and quicky provide the information sought by the operator.

During the display enable mode operation which follows each execute mode operation, the decoding or calculations results are displayed dynamically. If certain new information is keyed in during the display enable mode operation, the calculator goes into a new execute mode operation, which is followed by a new display enable mode operation. If no such new information is keyed in for a certain period of time during the display enable mode operation, the calculator automatically goes into a display inhibit mode operation, without any operator intervention. In accordance with the invention, the duty cycle of the power supplied to the calculator during each display enable mode operation is lower than the duty cycle of the power supplied during the execute mode operation, e.g., the calculator is supplied with a chopped voltage at a one-fourth duty cycle. Further, the duty cycle of the clock pulses supplied during the display enable mode is lower than the duty cycle of the clock pulses supplied during the execute mode, e.g., the same width clock pulses are supplied during the display enable mode operation, but only while power is being supplied to the calculator.

When the calculator goes into a display inhibit mode operation, the display is blanked out, but it is still necessary to preserve certain dynamically stored information. In accordance with the invention, during each display inhibit mode operation the calculator is supplied with power at a duty cycle which is lower than that supplied during the display enable mode operation, e.g., with a chopped voltage at one-eighth of the duty cycle of the voltage supplied during the execute mode operation. Further, the duty cycle of the clock supplied to the calculator is lower than that supplied during the display enable mode, e.g. the same width clock pulses are supplied but only while power is being applied to the calculator.

Typically, a calculator of this type is in an execute mode for only a small fraction of its operating time, and most of the operating time is spent in the display enable mode. The display inhibit mode occurs rarely (for example, when the operator forgets to turn off the calculator) but when it occurs, and no provisions are made to reduce power consumption, it is likely to continue for a substantial period of time and to drain a substantial amount of battery power.

In accordance with the invention, both the power supply duty cycle and the clock duty cycle are controlled to reduce power consumption without sacrificing speed or accuracy, since both are optimized for each of the three different operating modes of the calculator. Further in accordance with the invention, both the calculator logic array and the necessary logic and circuit elements for carrying out this invention are parts of the same integrated circuit, to thereby improve the reliability of the calculator, and to reduce the cost of implementing the invention as compared to implementing the invention in a circuit composed of discrete components or in a separate integrated circuit.

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