CALCULATOR STOPWATCH

eti project 534

An inexpensive calculator modified to provide one-hundredth of a second timing.

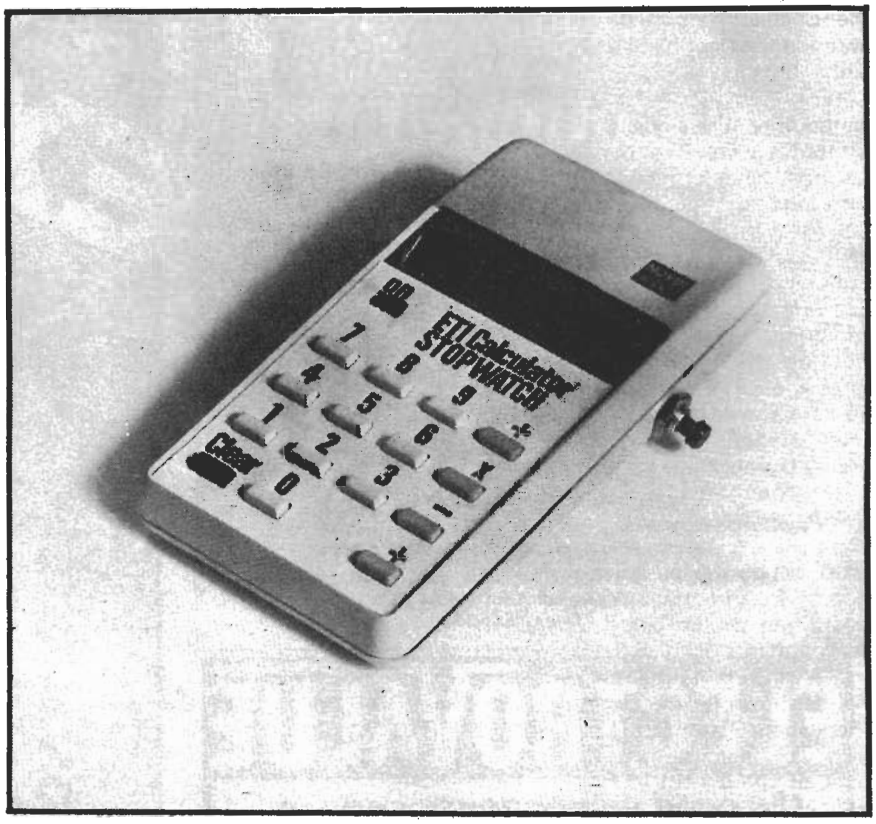
FOUR-FUNCTION calculators are now available for as little as £5.00. At those prices, it is cheaper to buy a calculator and throw away the parts that you don't need, than it is to buy a keyboard, display, or calculator chip separately.

Having this in mind we were very interested to receive an application note from National Semiconductor which detailed how to modify one of their calculators for use as a stopwatch. We therefore decided to develop this idea to a full project for a calculator/stopwatch which provides timing with one-hundredth of a second resolution for a cost as low as £10.00 (including the calculator).

The NOVUS 650 calculator is a simple four-function machine which has a fixed decimal point between the second and third (RH) digits. The calculator does not have floating point, and only works in whole numbers, the decimal point being an indicator only. These features however, whilst detracting from the usefulness of the machine as a calculator, make it ideal for modification, without difficulty, for use as a stopwatch.

Stopwatch operation is made possible by the fact that if '1' is entered into the calculator and the '+' key is continually pressed, the calculator will add '1' to the number displayed each time the '+' key is pressed. Thus, as a stopwatch, the '+' key must be 'pressed' electronically 100 times per second. (If a floating-point calculator were to be used, 0.01 would have to be added each time the key was pressed and this of course is much more difficult to do).

The 100 Hz timebase, required for the key-pressing function, needs to be supplied by means of a crystal and a divider chain or, by some other simple but stable oscillator such as a PUT. For most applications the PUT (programmable unijunction transistor) is quite accurate enough and this, coupled with the fact that the crystal and its dividers are bulky and relatively expensive, led to us choosing the PUT oscillator.



The additional electronics for the stopwatch is all mounted on a separate printed-circuit board which is a very tight fit in the calculator. Soldering to the pins of the calculator IC is also required and unless you have previous constructional experience, especially with soldering, do not attempt this project.

CONSTRUCTION

Due to the unusual nature of this project the constructional procedure given is much more detailed than usual. The constructor is well advised to follow the following steps carefully.

(a) Dissassemble the calculator by removing the battery and the four screws that hold the case together.

(b) Remove the external power socket and disconnect the leads from it to printed-circuit board. Take note

SPECIFICATION

Maximum Reading	9999.99 sec (2 hours 46 mins 39.99 secs)
Resolution	0.01 secs
Accuracy (typ)	± 0.2%

Mode – accumulating type, single button start/stop, separate button for clear.

Calculator.

Six digits, four functions, reverse Polish fixed point.

of the position of these leads as they must be replaced later.

(c) The new pushbutton for the stopwatch must now be mounted into the back cover. The photograph shows the approximate location of this button. Note that the web of plastic, between the battery compartment and the calculator housing, must be cut away on the right-hand side so that the push button may be fitted. To determine the correct position, temporarily reassemble the calculator, without screws. The correct location can now be determined as the button goes between the display board, the calculator board and the battery (yes there is space!)

(d) Due to the curved case of the calculator we did not use the normal mounting method for the push button, but just drilled and filed a hole just large enough to allow the push button to cut its own thread in the plastic. It may also be necessary, however, to epoxy the button into position.

(e) Assemble the printed-circuit board, ETI 534, as shown in the component overlay. The components must be positioned as shown, as the board fits between the calculator board and the keyboard and space is very limited

(f) Attach thin insulated wires to the points shown on the overlay and leave them about 75 mm long.

(g) To obtain a little more space, trim all component leads on the back of the calculator board, including those of the calculator IC, as close to the board as possible. Now cut the printed-circuit track on both sides of pin 1 of the MM5736 calculator IC (pin 1 is the pin next to the • mark) Using a single strand of flexible wire rejoin the tracks on both sides of pin 1, leaving pin 1 isolated.

(h) Position the control board, ETI 534, alongside the calculator board (see photo). Due to space limitations the wires from the control board have to soldered directly onto the pins of the calculator ICs.

(j) Check very carefully the point to which each wire must be connected, cut it to length (not too long), and solder it directly to the specified pin. The ICs are numbered anticlockwise from the '•' mark.

(k) Reconnect the power wiring from the external socket.

(l) Connect the push-button switch.

(m) Check the calculator before final assembly as follows:-

Connect the battery and switch on. Clear the display and check all keys and calculator functions.

Clear the display

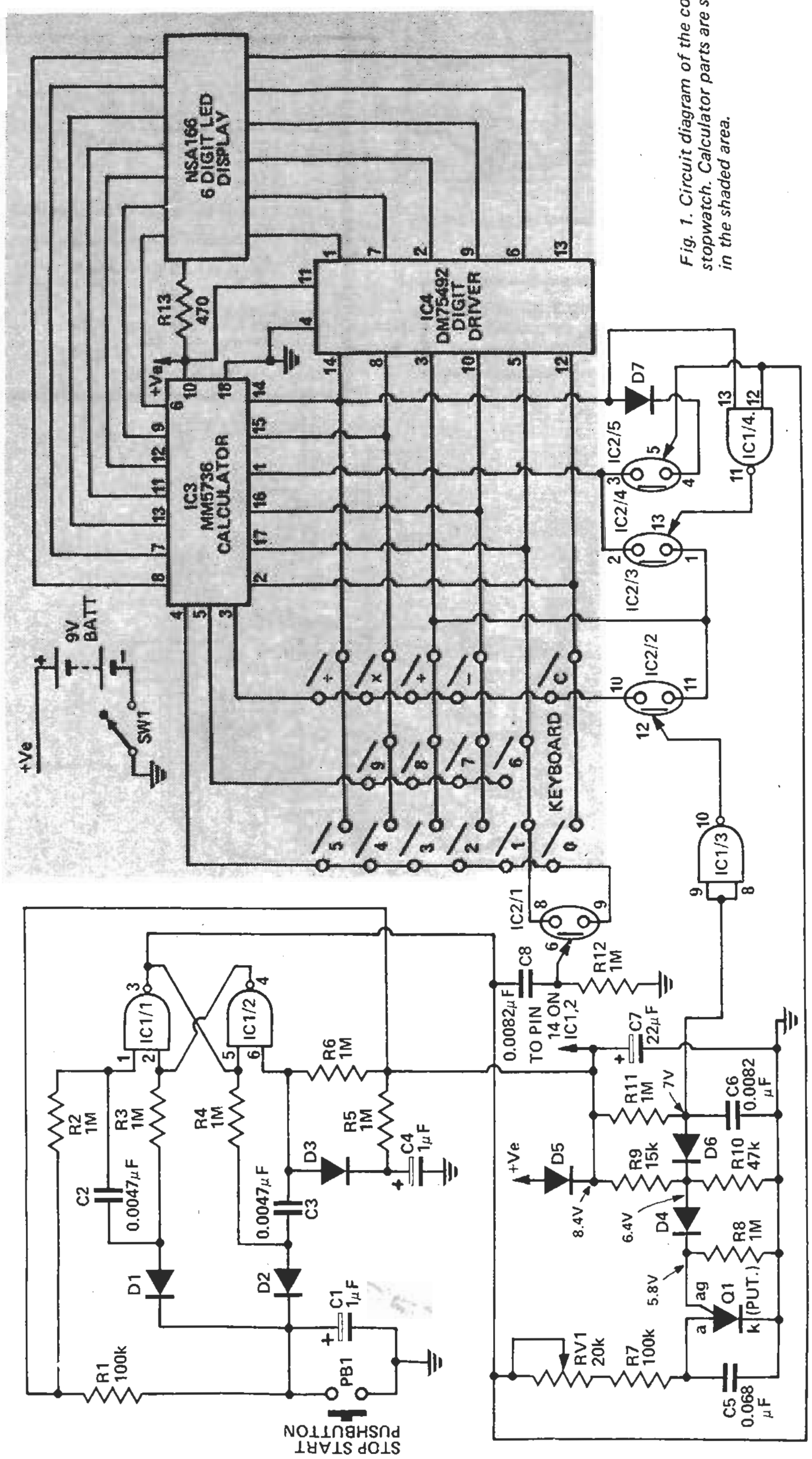


Fig. 1. Circuit diagram of the complete stopwatch. Calculator parts are shown in the shaded area.

CALCULATOR STOPWATCH

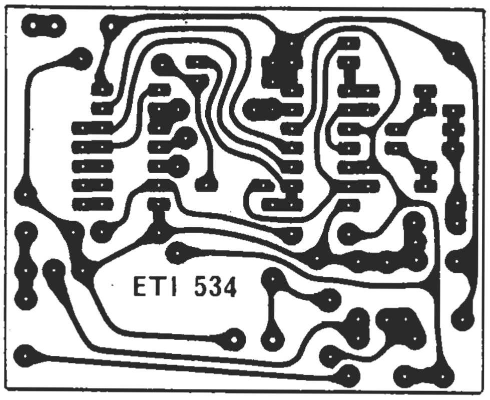


Fig. 2. Printed circuit board layout. Full size 64 x 52mm.

Marshalls are supplying a kit of parts for this project (less calculator and PCB) at a price of £2.50 + VAT.

PARTS LIST — ETI 534

R9	Resistor	15 k ¼ W 5%
R10	"	47 k " "
R1,7	"	100 k " "
R2,3,4,5	"	1M " "
R6,8,11,12	"	1M " "
R13* part of calculator		
RV1	Trim potentiometer	20 k 20 Turn type 84 (Morganite)
C2,3	Capacitor	0.0047 μF polyester
C6,8	"	0.0082 μF "
C5	"	0.068 μF "
C1,4	"	1 μF Tag tantalum
C7	"	22 μF 16 V Tag tantalum
D1-D7	Diode	IN914 BA318 or similar
Q1	Transistor	2N6027 or similar
IC1	Integrated Circuit	4011 (CMOS)
IC2	"	" 4016 (CMOS)

Small push button
PC Board ETI 534
Calculator NOVUS 650

PCB from Ramar at 68p inc.

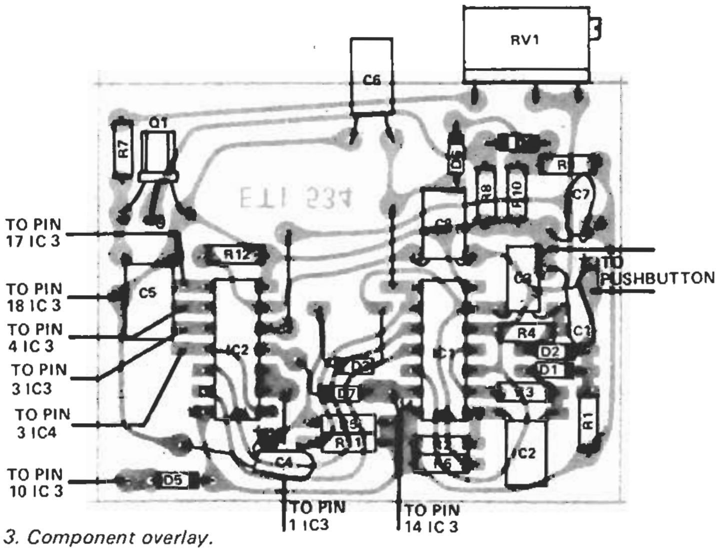


Fig. 3. Component overlay.

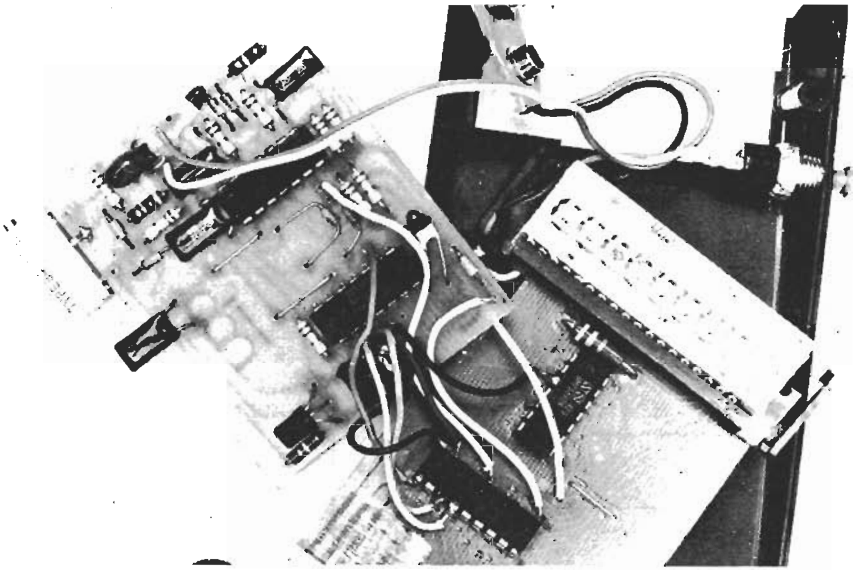


Fig. 4. The calculator as modified and before final assembly.

Press the push button once. The calculator should now count up by ones at 100 times per second.

(n) If a frequency counter or an oscilloscope is available connect to the junction of R11 and C6 and adjust for 100 Hz. If an oscilloscope is used sync the cro from the mains and beat the 100 Hz against that.

(p) Fold the control board on top of the calculator board making sure that none of the leads is on top of any of the ICs thus preventing the board from going right down.

(q) Cut a small hole in the side of the case to allow access to RV1.

(r) Assemble the calculator completely again making sure that the leads do not foul anything and that the calculator fits together without needing to be forced.

(s) Check the accuracy of the stopwatch by timing, over a long period, using a known accurate source (eg telephone time service) and make successive adjustments of RV1 to give correct results.

USING THE STOPWATCH

The conventional stopwatch has a single button which starts, stops, and resets, the timing. The ETI stopwatch, on the other hand, uses the side button for start/stop and the existing CE/C key for reset.

This configuration allows the stopwatch to be used for applications where accumulative timing is required. For example where three separate runs must be timed for a total time, the stopwatch is not reset between runs but merely started and stopped for each run.

A further advantage is that timing may be commenced from a reading preset by the keyboard. This is done by first clearing the display and then entering the starting time in one-hundredths of a second. If the '+' button is now pressed before starting, the stopwatch will count up from the entered time, whereas if the '–' button is pressed the stopwatch will count down from the previously entered time to zero.

When using the stopwatch be careful to hold it in such a way that accidental pressing of keys is avoided, as spurious keyboard entries will result in an erroneous reading.

As a service to readers having difficulties obtaining the Novus 650 calculator used as our stopwatch, we have decided to supply direct. The price is £5.00 inc, and orders should be sent to ETI Novus 650 Sales, 36 Ebury Street, London SW1W OLW. Please allow 21 days for delivery.

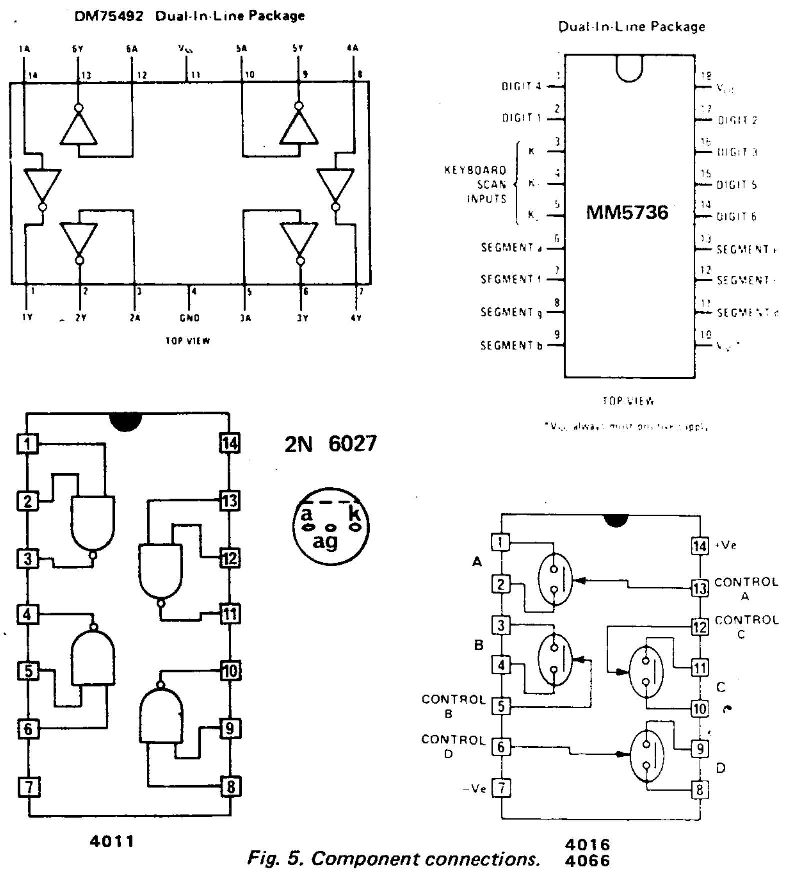


Fig. 5. Component connections.

HOW IT WORKS.

With the standard calculator the keyboard controls a three-line by six-line matrix, that is, a calculator key when pressed joins one of three pins, of IC3, to one of six other pins. This gives a maximum of 18 possible combinations of which only 15 are used. The 6 lines are both input and output of the IC, that is they drive the display via IC4 as well as passing keyboard commands to the calculator.

The stopwatch is controlled by an additional push button, which in effect stops and starts the calculator, whilst reset is performed by the front-panel 'clear' key. The push button operates a flip flop formed by IC1/1 and IC1/2. The capacitors around the flip flop change it from a normal RS type to a toggle type. Diode D3, capacitor C4 and resistor R5 set the flip flop into the stop condition on initial switch on. The output of IC1/1 is at zero volts in the 'stop' state and at +9 volts in the 'run' state.

When the output of IC 1/1 goes high capacitor C8, together with R12, provides a 10 ms pulse to the control input of IC 2/1. This is an analogue switch across the '1' key. Thus the closure of this switch is equivalent to pressing the '1' key. When the switch closes capacitor C5 begins to charge via R7. When it reaches about 6 volts (set by R9/R10) the PUT switches on, and C5 is discharged rapidly to a low voltage, the PUT turns off, allowing C5 to recharge. This action takes at place at 100 Hz. The diode D4 is used for temperature compensation. When the PUT fires, terminal 'ag' drops to a low voltage which discharges C6 via D4 and D6. And, although the PUT is on for only a short time, diode D6 isolates C6 allowing it to charge slowly (5 ms) via R11.

The pulse from the PUT is squared by IC 1/3 and is then used to control IC 2/2, which is across the '+' key. The pulse thus causes one to be added to the displayed number 100 times per second.

To operate the calculator, at the rate of 100 pulses per second, it is necessary to disable the calculator debounce circuitry. This is done by IC 2/3, IC 2/4, IC 1/4 and D7. The debounce is disabled only in the 'run' mode, and is still functional in normal calculator operation.

Diode D5 and capacitor C7 decouple the control circuitry from the calculator, as the high peak currents drawn can result in a two-volt ripple, on the nine-volt supply, which otherwise would upset the timing.