4-digit universal timer & stopwatch

This project should prove really popular. It's a versatile "Universal Timer" that can be built as a stopwatch, an event timer or a countdown timer. Features include two independent counters that can time two different events at once, a bright 4-digit LED readout and switch-selectable timing rates from .01 to 1 second. We have no doubt that it will find many applications in sporting events such as athletics, yachting and rallying.

by GERALD COHN & GREG SWAIN

Here at last is a project that you can tailor to your own requirements. It's based on a single timer IC that's so versatile one could easily become confused just wading through all the various options.

Essentially, you have the choice of wiring the unit to operate in one of seven different modes, or functions. Sufficient information is presented here so that you can choose the function that's best suited to your particular application and, to this end, we have designed a "universal" printed circuit board to make the job as easy as possible.

We elected to wire our unit to produce a versatile stopwatch with optional event counter. As shown in the photograph, the circuit is built into a low-cost plastic zippy box fitted with three momentary-contact pushbutton switches on a 4-position rotary "Rate Select" switch. The latter sets the timer resolution to either .01s, 0.1s or 1s.

Alternatively, the Rate Select switch can be set to "EXT" so that timer counts external clock pulses (ie. operates as an event counter).

The maximum interval that can be timed and the display format both depend on the position of the Rate Select switch. In the low resolution 1s mode, for example, the unit displays elapsed time in minutes and seconds for a maximum count of 99hrs 59s. The other two modes display the results in seconds only (plus tenths and hundredths of seconds as appropriate), with maximum times of 999.9s and 99.99s for the 0.1s and .01s modes respectively.

In practice, if a maximum count is reached, the unit resets to zero and recommences timing. Leading zeros are automatically blanked during counting.

The three momentary-contact switches control the basic stopwatch functions and are labelled Start/Stop, Final Event and Reset. The Start/Stop button initiates timing by two independent counters and can subsequently stop and restart one of the counters while the other continues counting. The Final Event button stops both counters simultaneously, while the Reset button resets them to zero ready for the next event.

Once the Final Event button has been pressed, the contents of each counter are alternatively displayed by pressing the Start/Stop button. The function of the Reset button is self-explanatory – it simply resets both counters to zero.

We'll have more to say about the way the unit operates a little later on.

THE TIMER IC

At the heart of the circuit is an MM5865 "Universal Timer" IC from National Semiconductor. This 40-pin PMOS device contains all the logic necessary to control two 4-digit counters, to blank leading zeros and to cascade to another MM5865 device. Signals to various control pins start, stop and reset the counters, determine which of seven operating functions is performed, and set the resolution of the display (.01s, 0.1s, 1s or external clock).

Other features of the chip include up/down counting and selectable 6 or 10 modulo for digits 2, 3 and 4.

Block and Connection Diagrams

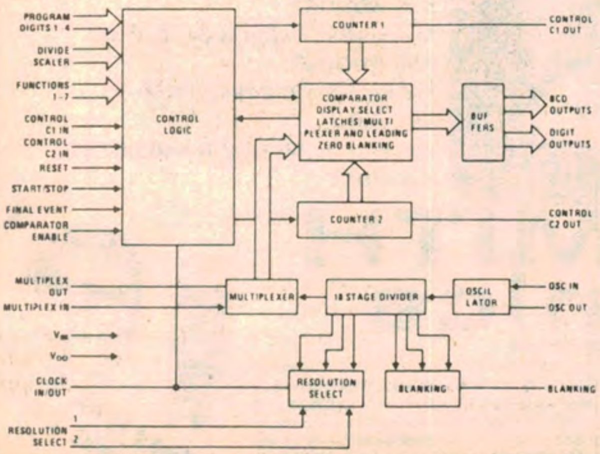


FIGURE 1.

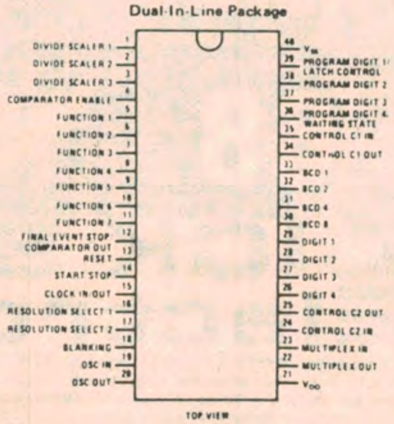
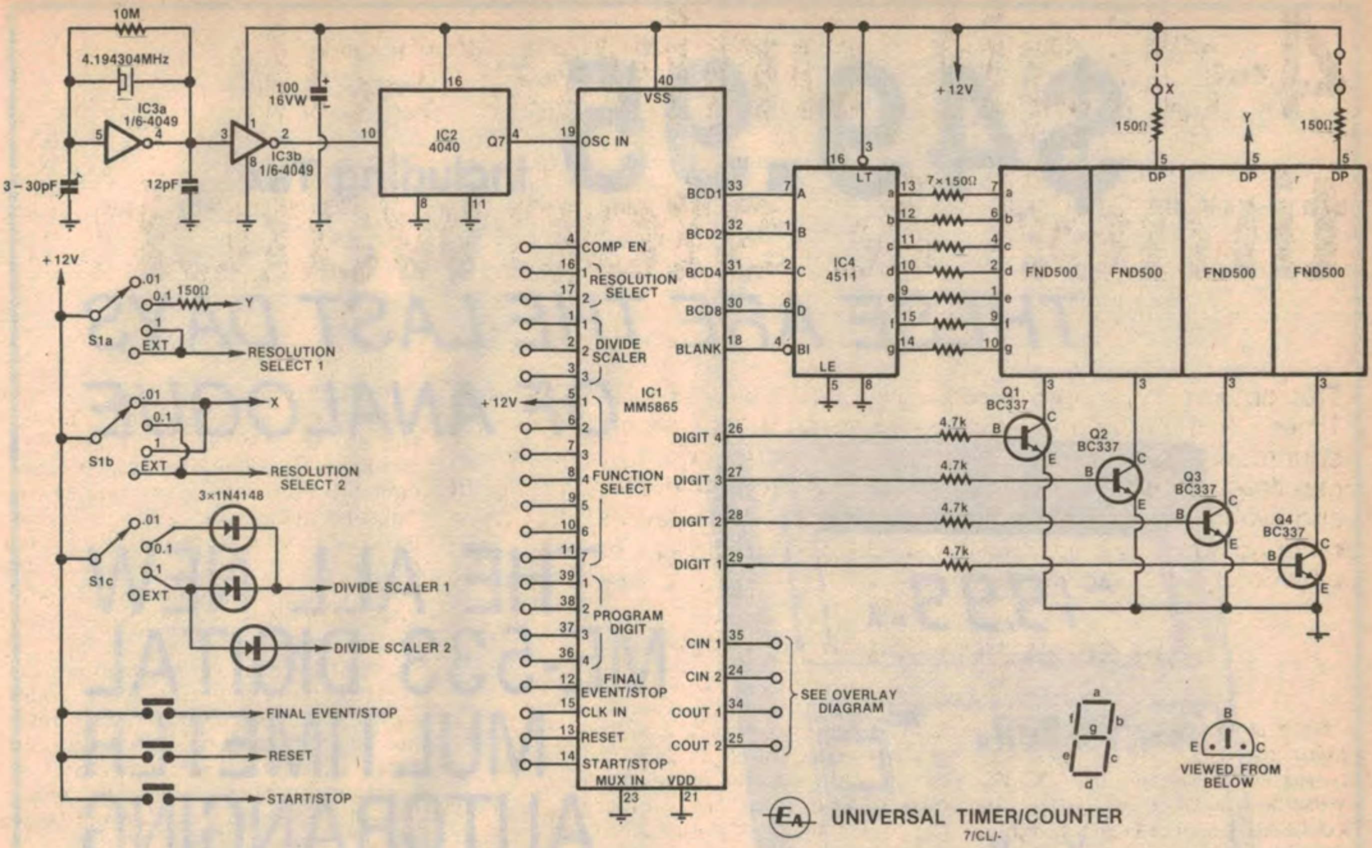


FIGURE 2.

Figs 1 & 2: these block and pin connection diagrams for the MM5865 will enable you to wire the circuit to your own requirements.



The circuit (above) can be broadly divided into three sections: a CMOS clock (IC3a), the MM5865 timer IC, and the display circuitry.

It's really very simple to use the MM5865 in a circuit that will perform a specific function. To change from one function to another, all you have to do is wire the appropriate function select pin (5-11) to the Vss (+12V) line and either add or delete logic switching to a few control pins.

The main thing to remember is that the Vss rail (+12V) represents logic high, while the Vdd rail represents logic low. A control pin is enabled simply by connecting it to logic high (usually via a switch), and disabled when left floating. Since the control pins are all tied to the Vdd rail by internal resistors, no external pulldown resistors are required.

Let's take a closer look at each of the seven chip functions and see what they have to offer. They are:

- Function 1: standard start/stop with total elapsed time memory;
- Function 2: standard start/stop with total accumulative event time;
- Function 3: sequential with total elapsed time memory;
- Function 4: standard split;
- Function 5: rally with total elapsed time memory;
- Function 6: programmable up count, repeatable upon command;
- Function 7: programmable down count.

The prototype was built into a low-cost plastic zippy box. Unit is powered either from a 12V car battery or from a 9-12V plugpack supply.

FUNCTION 1: this is the function we used for our timer. Counters 1 and 2 start counting up when the start/stop pin is momentarily taken high, but only counter 2's contents are displayed. A second pulse on the start/stop input stops the clock pulses to counter 2 and displays its contents, while counter 1 continues to count. A third pulse on the start/stop input resets counter 2, and starts a new count from zero. Subsequent pulses at the start/stop input repeat this sequence.

Counter 1 continues to count while counter 2 is being stopped and restarted. When a logic high is applied to the final event/stop input, both counters stop counting and the contents of counter 2 are displayed. The contents of counter 1 can now be examined by applying another pulse to the start/stop input. Further pulses at the start/stop input cause the display to alternately show the contents of the two counters.

How to use the various chip functions:

RESET: resets all logic and counters in functions 1 to 5 and function 7. In function 6, all logic and counter 2 are reset, the contents of counter 1 remaining intact. For a reset to occur, this line must be taken to a logic high.
START-STOP: used to control the counters as explained in the text describing each of the seven functions. For START-STOP to have any effect on the counters, it must be taken to a logic high.
FINAL EVENT/STOP/COMPARATOR OUTPUT: used to indicate to the circuit that no more events are to be counted or timed. Final event/stop affects the counters when it is taken to a logic high. This pin also serves as an output for the comparator. When a valid comparison has been made between the two counters (this requires the comparator to be enabled), the output will go to a logic high and can be used to control external devices if required.
DIVIDE SCALE INPUTS: used to determine whether the counters will count in modulo 6 or modulo 10. The table that follows shows the codes required to set the counter modulus. (Note: 1 denotes logic high; 0 denotes logic low).

DIVIDE SCALER			COUNTER 1				COUNTER 2			
1	2	3	D4	D3	D2	D1	D4	D3	D2	D1
0	0	0	10	10	10	10	10	10	10	10
1	0	0	6	10	10	10	6	10	10	10
0	1	0	10	6	10	10	10	6	10	10
1	1	0	10	10	6	10	10	10	6	10
0	0	1	10	10	10	10	10	10	10	10
1	0	1	10	10	10	10	6	10	10	10
0	1	1	10	10	10	10	10	6	10	10
1	1	1	10	10	10	10	10	10	6	10

COMPARATOR ENABLE: To enable the comparator, pin 4 is taken high and held there. To disable, leave the pin floating or tie it to Vdd.
RESOLUTION SELECT INPUTS: used to select the frequency of the clock pulses to the counters. The table that follows shows the codes required for the different values of prescaling.

RESOLUTION SELECT 1	RESOLUTION SELECT 2	FREQUENCY OF CLOCK TO COUNTERS	DISPLAY RESOLUTION
0	0	100Hz	0.01 sec
0	1	10Hz	0.1 sec
1	0	1Hz	1 sec
1	1	External	

CLOCK IN/OUT: functions as either an input or an output depending on the code applied to the resolution select inputs. The first three codes in the table for the resolution select inputs use this pin as an output, while the last code in the table turns this pin into an input. When the last code is selected, this pin is used to supply the clock pulses to the counters.
BLANKING OUTPUT: used to blank the display at the beginning and end of each digit time to allow for internal delays between two cascaded chips (see Fig. 2). The display is blanked when the blanking output is at Vdd (logic low).
OSCILLATOR IN/OUT: These two pins are the input and output respectively of an inverting amplifier. Normally a 32.768kHz crystal is connected across these two pins together with a resistor and two capacitors to form a single inverter oscillator (not used here).
MULTIPLEX INPUT AND OUTPUT: not used in this design, allows an external multiplex rate to be used with the chip. The multiplex rate inside the chip is one fourth the multiplex input and multiplex output rate. For normal use, the multiplex input pin is tied to Vdd.
CONTROL C1, C2 IN and C1, C2 OUT: used to cascade two chips together. When the control C1 input is floating (or tied to Vdd), clock pulses to counter 1 are inhibited. When control C1 is at Vss, counter 1 is enabled. Control C1 out is at Vss when counter 1 is at maximum count and is floating at all other times. The control C1 input must be floating while digit programming is taking place in function 7. Control C2 pins operate on counter 2 in a similar way.
PROGRAM DIGITS 1-4: used to program or set any desired count into counter 1 (functions 6 and 7). When program digit 1 is at Vss, the least significant digit of counter 1 advances at a 2.5Hz rate. There is no carry-over from digit to digit. Program digit 1 has no effect if tied to Vdd or left floating. Only one program digit may be held at Vss at any one time.
PROGRAM DIGIT 1/LATCH CONTROL: besides setting a count in digit 1 of counter 1 in functions 6 and 7, this pin also allows the display to show counter 2 counting as described in functions 3 and 4.
PROGRAM DIGIT 4/WAITING STATE INDICATOR: besides setting a count in digit 4 of counter 1 (functions 6 and 7), this pin also indicates that the chip has been reset and is in the standby mode at power on. In functions 1-5, the waiting state indicator is at Vss until a start/stop transition has occurred. Once a start/stop transition has occurred, the output remains at Vdd.
NOTE: in functions 1 to 5, leading zeros are blanked for both counters 1 and 2. In functions 6 and 7, counter 2 has leading zero blanking. At switch on the display is blank for functions 1 to 5, and all zeros are displayed for functions 6 and 7.

FUNCTION 2: counters 1 and 2 start counting with a positive going pulse (logic high) at the start/stop input. A second pulse to the start/stop input stops the clock pulses to both counters, and stores and displays the contents of counter 2. A third pulse resets counter 2 and restarts both counters, with the contents of counter 2 being displayed. Subsequent pulses at the start/stop input repeat this sequence.

A pulse applied to the final event/stop input stops both counters and displays the contents of counter 2. Further pulses on the start/stop input causes the display to alternate between the contents of the two counters.

FUNCTION 3: as before, counters 1 and 2 start counting when a logic high pulse is applied to the start/stop input. A second pulse at the start/stop input resets counter 2, starts a new up count and displays the old count on the readout. If a pulse is now applied to the latch control input, the display will show counter 2 counting until another pulse is applied to the start/stop input.

A pulse on the final event/stop input stops both counters and displays the contents of counter 2. A pulse now applied to the start/stop input changes the display to show the contents of counter 1.

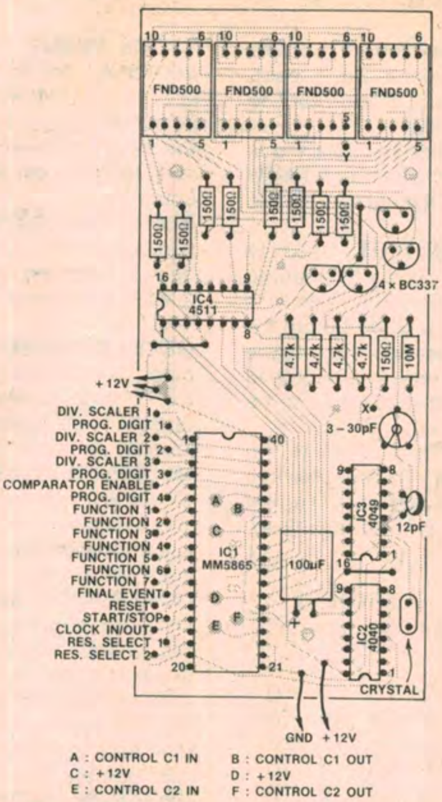
FUNCTION 4: counter 2 starts counting up beginning with a pulse applied to the start/stop input and is displayed counting. A second pulse on the start/stop pin stores and displays the contents of counter 2, while subsequent pulses update the display of the counter which continues counting. A pulse applied to the latch control pin will display counter 2 counting until the next pulse at the start/stop input. A pulse at the final event/stop input stops counter 2 and displays its final contents.

FUNCTION 5: counters 1 and 2 start counting up when a pulse is applied to the start/stop input. Counter 2 is displayed counting. A second pulse applied to the start/stop input stops counter 2 and the contents of counter 2 are displayed while counter 1 continues counting. A third pulse restarts counter 2 and displays counting.

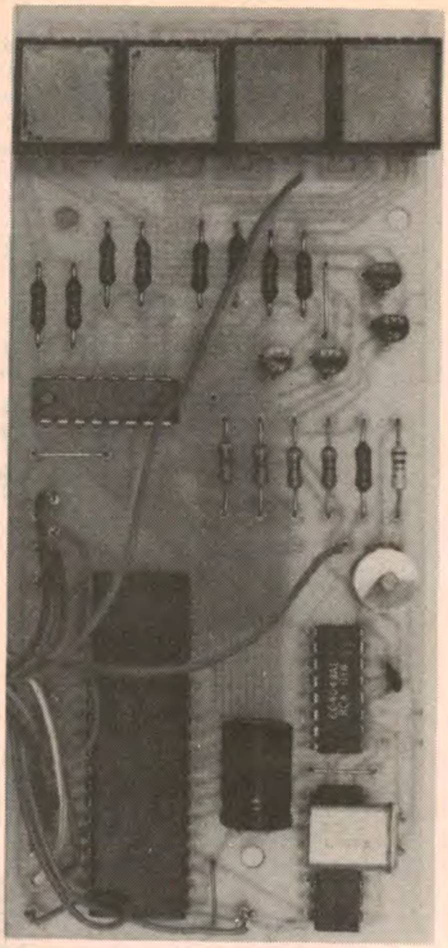
Subsequent start/stop pulses repeat this sequence of events. A pulse applied to the final event/stop input stops both counters and their contents are displayed as before.

FUNCTION 6: counter 1 is displayed at switch-on or reset and is preset to a specific value by the 4-program digit inputs (pins 39, 38, 37 and 36). An on-chip comparator is enabled by pulling pin 4 high and hold it there. Counter 2 is displayed counting up beginning with a pulse applied to the start/stop input. When the contents or counter 2 equal the contents or counter 1, counter 2 stops, its contents are displayed and the comparator output is enabled (goes high). A pulse applied to the reset input restores the original programmed value in counter 1 and disables the comparator output. The contents of counter 1 can be reprogrammed as desired, but the comparator input must first be left floating or pulled low (Vdd).

Another pulse applied to the start/stop input repeats this sequence. If the



The PCB assembly. Spare pads on board enable decimal points for digits 2 & 3 to be permanently enabled if desired. See circuit for switch wiring details.



PARTS LIST

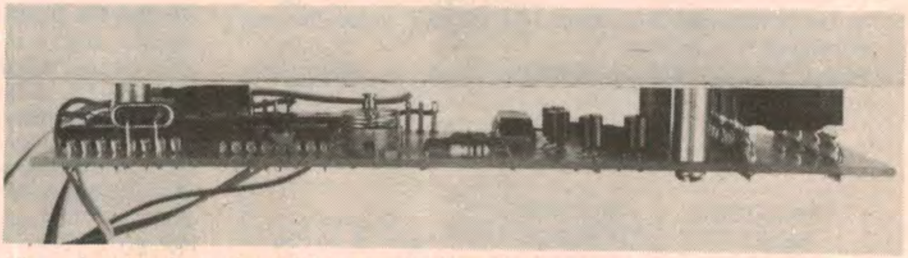
1 printed circuit board, code 81uc8, 61 × 145mm
1 4-pole, 3-position rotary switch
3 momentary contact pushbutton switches
1 knob to suit switch
1 DC plug and socket set
1 zippy box, 159 × 96 × 51mm
1 "Scotchcal" front panel
40 Molex IC pins
1 4.194304MHz crystal
3 12mm tapped brass spacers

SEMICONDUCTORS
1 MM5865 Universal Timer IC
1 4511 BCD to 7-segment decoder/driver
1 4069 hex inverting buffer
1 4040 12-stage ripple counter
4 FND500 common cathode displays
4 BC337 NPN transistors
3 1N4148 diodes

CAPACITORS
1 100µ16VW electrolytic
1 12pF ceramic (NPO)
1 3-30pF trimmer

RESISTORS (¼ or ½W, 5%)
1 × 10MΩ, 4 × 4.7kΩ, 10 × 150Ω

MISCELLANEOUS
Hookup wire, solder, screws, PC stakes etc.



View showing how the PCB is attached to the front panel using brass spacers.

comparator output pin is connected to the reset input, automatic reset will occur. However, this connection must be broken during digit programming.

FUNCTION 7: in function 7, counter 1 is displayed all the time. Counter 1 is preset to a specific value using the 4-program digit inputs, then the comparator and control C1 (pins 4 and 35) are enabled (pulled high). Pins 4 and 35 must be floating or connected to Vdd during digit programming, however.

A pulse at the start/stop input starts a down count in counter 1 from the preprogrammed value. When counter 1 reaches zero, the clock pulses to counter 1 are inhibited and the comparator output is enabled. This is not resettable without programming a new count into counter 1.

The comparator and control C1 inputs must be inhibited (pulled low) and a reset pulse must occur before a new count may be entered into counter 1.

So those are the seven functions at your disposal. Now you can see why the MM5865 timer IC is such a versatile device!

While it will be fairly obvious how most control pins are used, others may not be so obvious. The accompanying panel should clear up any remaining doubts that you may have. It lists each of the control pins in turn and details how they are used.

THE CIRCUIT

As previously stated, we elected to wire our timer according to function 1. The circuit is quite straightforward and can be divided into three sections: an external clock oscillator, the MM5865 timer IC, and the display circuitry.

For stability, we used a crystal-controlled clock to drive the timer IC. This consists of a simple "pi" type oscillator using one 4069 CMOS inverter (IC3a) and a 4.194304MHz crystal. The output is squared up by a second 4069 inverter (IC3b) and then divided by 128 by a 4040 14-stage binary counter (IC2) to give the required 32.768kHz.

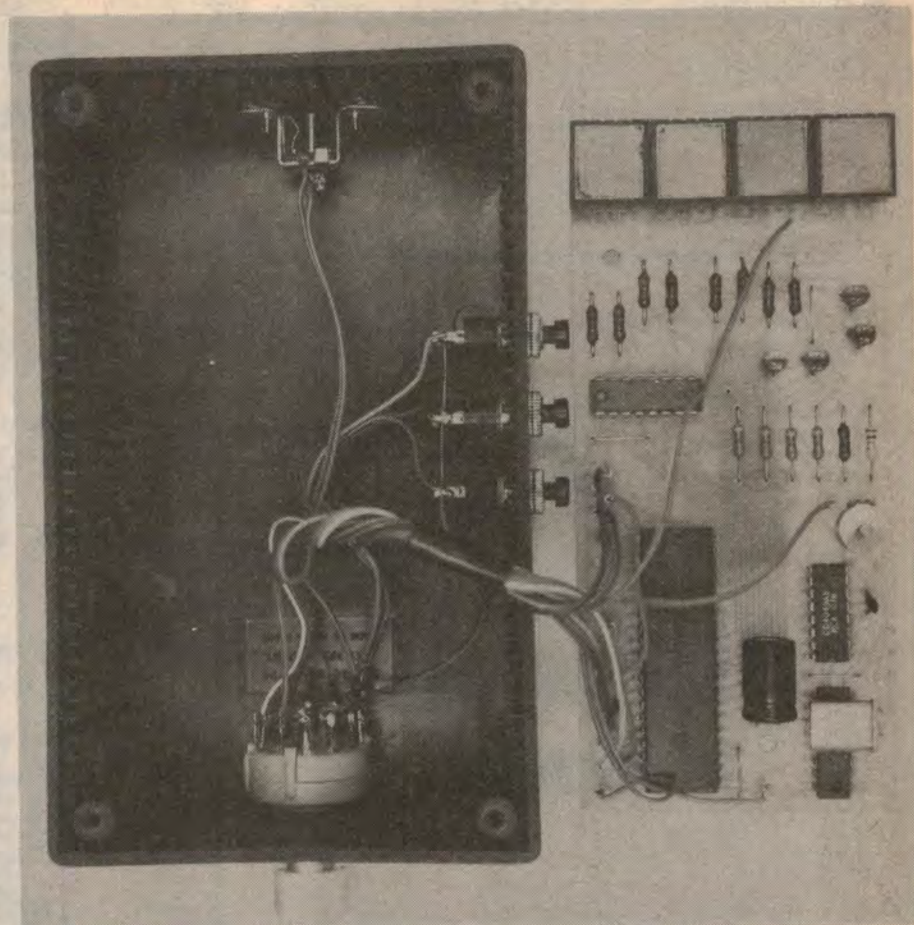
Some readers may be wondering why we have not made use of the MM5865's on-board oscillator. The reason is that this oscillator requires an external 32.768kHz crystal and these, unfortunately, are not easy to obtain and are quite expensive – despite the fact that they are used by the million in electronic watches.

It's actually far cheaper (and easier) to use the arrangement shown here – that is, to use an external 4.194304MHz crystal oscillator and divide down to the required frequency! This frequency (32.768kHz) is taken from pin 4 of IC2 and drives the timer IC direct via pin 19.

The four 7-segment LED displays interface to the 5865 via a 4511 BCD to 7-segment decoder/driver (IC4). Since the display is multiplexed, only a single decoder/driver is required. The common cathodes of the displays (type FND-500) are controlled by the digit drive outputs of the 5865 and are driven by four BC337 driver transistors (Q1-Q4).

Control pin switching makes up the remainder of the circuitry, as described above in function 1. The Start/Stop, Final Event/Stop and Reset inputs are all controlled by momentary-contact pushbutton switches, while a single 3-pole, 4-position rotary switch controls the timer resolution and divide scale inputs, and takes care of the decimal point switching. The three 1N4148 silicon diodes wired to switch S1c perform the Divide Scale decoding.

Power for the unit is supplied either from a 9-12V DC plugpack adapter or from a 12V car battery (typically via a cigarette lighter adapter). The unit is not suitable for operation from dry cells because of the current consumed by the 7-segment displays.



Internal view of the prototype with wiring completed. Note that the three 1N4148 diodes and a 150Ω resistor are wired direct to switch S1 (see circuit).

CONSTRUCTION

Construction of the Universal Timer is simple and should only take you a couple of hours. All components with the exception of the switches, diodes and DC input socket are mounted on a small printed circuit board (PCB) measuring 61 × 145mm and coded 81uc8.

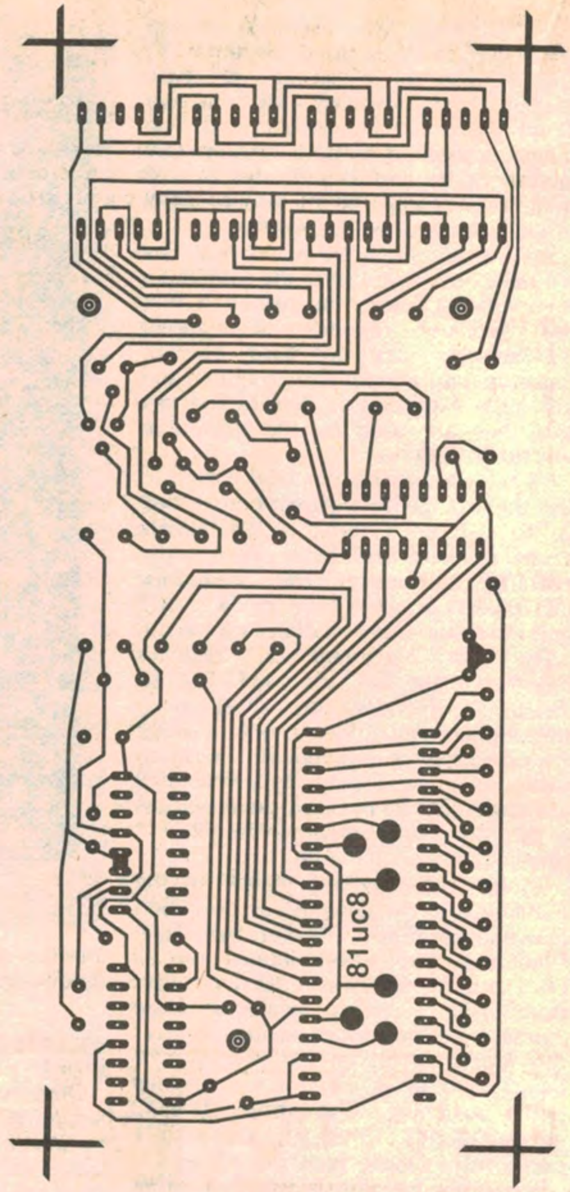
Commence construction by mounting the various components on the PCB according to the overlay diagram. Fit the wire links and resistors first, and then the capacitors, transistors and ICs. Make sure that all polarised components are correctly oriented and do not apply too much heat when soldering as the tracks are rather narrow and may lift from the board.

Observe the usual precautions when soldering the CMOS ICs into circuit – try to avoid handling the pins; earth the barrel of the soldering iron to the earth track on the PCB; and solder the power supply pins first. Although not used in the prototype, we recommend that you use a 40-pin low-profile socket for MM5865 IC. PC stakes are recommended for all external connections to the board.

The four 7-segment displays are mounted on the board using Molex IC socket pins. The reason for this is to raise the displays to a level where they can protrude through an aluminium panel when the board is mounted (see photographs).

The last component to go onto the board is the 4.194304MHz crystal. Before mounting, bend the leads of the crystal at right angles. The crystal is then

ACTUAL SIZE ARTWORK



Actual-size artworks for the front panel and printed circuit board.

soldered into position such that it lies flat on top of the 4040 IC as shown in the photograph. Note that the 100μF electrolytic capacitor is mounted in similar fashion.

We mounted the assembled PCB inside a small plastic zippy box measuring 159 × 96 × 51mm. Using the front panel artwork as a guide, drill holes in the case for the three pushbutton switches, the rotary switch and the DC input plug. The PCB itself is mounted on the lid of the box using three 12mm-long brass spacers.

Before mounting the board, however, it will be necessary to cut a slot in the lid (front panel) to accept the displays, using the front-panel artwork as a template. This done, the mounting holes for the three brass spacers can be marked and drilled. Use countersunk screws when attaching the spacers, and make sure that the screws are flush with the surface of the lid so that the "Scotchcal" front panel can be fitted.

Once the wiring has been completed, the unit should be carefully checked for possible errors. In particular, check the PCB carefully for such things as incorrect component placement, reversed component polarity and improperly etched or broken board tracks. Testing involves simply switching the unit on and trying it out.

Remember that all leading zeros are blanked, and therefore no digits will be showing at switch on. Only the appropriate decimal point will be alight.

If you have a frequency counter handy you can check that the master oscillator is running at the correct frequency. If not, you will have to check the unit against a stopwatch. The trimmer capacitor allows the oscillator to be set precisely to the correct frequency.

As you can see from the wiring diagram, the unused control pins are all brought out to separate pads on the PCB. This has been done to make it easy for you to change from one function to another. Once you've got the timer working in function 1, why not experiment with other modes?

We estimate that the cost of parts for this project is approximately

$42.00

This includes sales tax.