Constructional Project

GINORMOUS STOPWATCH

NED STOJADINOVIC — Part 1

Automatically times sporting events up to ten hours with a resolution of 1/100th of a second.

THE circuit presented here is a modernised version of a stopwatch designed and built by the author several years ago to time equestrian events where the start and stop gates were not readily visible to the timekeepers, necessitating some sort of remote triggering to get reasonable accuracy.

Also included is a large display unit so that the audience can be a part of the action – their hero has two fences to go and the clock is ticking, will he beat the current best time . . .

NEW TECHNOLOGY

This design is something of an object lesson in just how far hobby electronics has come in the last few years.

The first stopwatches the author built were entirely from discrete components and comprised several circuit boards all performing a single function. There was a clock generator board, two separate light emitting diode (l.e.d.) drivers, transmitter/receiver boards and various miscellaneous bits to glue them all together.

Needless to say, the whole device was a monster and required the services of a lead acid battery the size of half a house brick to keep it all running. Also needless to say, it cost a fortune to produce!

The current design uses a single PIC16C55 to generate all the timing and liquid crystal display (l.c.d.) functions. The transmitter/receiver sections are comprised of small commercial modules, complete with channel coding/decoding facilities.

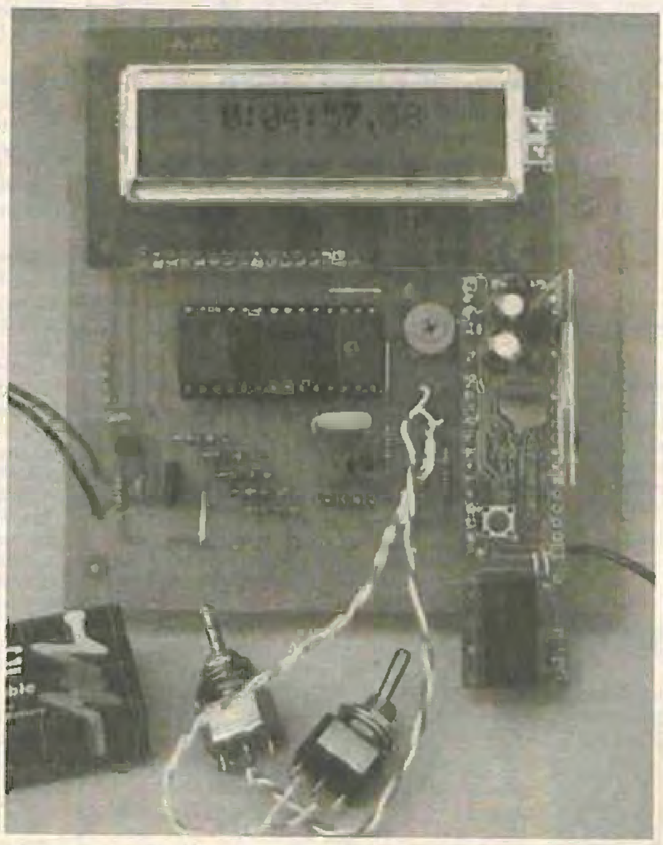
Furthermore, instead of a lead acid battery that could easily start a small car, a standard 9V cell is used. Oh, and the Stopwatch module outputs serial data for the Large Digit Display to-boot!

DESIGN OVERVIEW

The basic Stopwatch is fairly standard with the usual Start, Stop and Lap functions that can be triggered by pushbutton switches. The maximum time is ten hours (9:59:59·99 where the last digit is hundredths of a second).

There is an integral display on the main controller board, using an alphanumeric liquid crystal module, which can either be 16 characters by one line (16 × 1) or 16 characters by two lines (16 × 2), either will work.

As an optional extra feature, the design includes a radio control function. Two transmitters can be used in conjunction with optical "gate" detection units. The transmitters are of a type approved in the UK and operate on 418MHz using amplitude modulation (a.m.).



Photograph of the author's prototype test model of the Stopwatch control board. in the final version described additional switches are included. The relay on the receiver module (r.h.s. of photo) is not used.

The optical gate units are basically "door minders", the same as you might see in the doorway of shops. In normal operation, the beam units will transmit a coded signal to the Stopwatch module when the beam is broken, and the code will specify which beam was broken, i.e. Stop or Start.

The 418MHz receiver module on the Stopwatch assembly includes its own decoders which allow two channel operation, where one channel is Start and the other is Stop. In use, the receiver is taught the code of the transmitters following the method outlined in their respective data sheets.

Ensure that you obtain data sheets for the transmitters, receiver and "door minders" when you order them.

Note that the Lap function is only available via a pushbutton switch.

Another special feature of the Stopwatch design is the serial output for the Large Digit Display unit, which will be described next month.

The serial output runs at 9600 bits/sec with N,8,1 protocol (no parity, eight bits and one stop bit). The physical design is exactly the same as used by musical instruments in the MIDI standard, which specifies everything linked together by optocouplers, making for a very rugged and almost foolproof piece of apparatus.

BRAIN BOX

As the PIC microcontroller is the brain of the outfit, we start with a discussion of this aspect of the design.

The fundamental part of the software is in the use of the RTCC (real time clock counter) to generate 0·01 (one hundredth) second clock signals, or 100Hz. Taking the easiest option, a 3·2768MHz crystal is used to generate the microcontroller's basic control frequency, which is then divided internally by four by the micro to produce an intermediate clock rate of 819200Hz.

Now the PIC's prescaler function is used to divide by 16 to give 51200Hz. Then the RTCC divides by 256 to give 200Hz, which is a period of 0·005 seconds, where twice 0·005 gives us the desired 0·01 seconds clock rate. The software reads and responds to the status of the RTCC, but never writes to it (an action which can create timing accuracy problems).

If you refer to the source code (see later), you will see that the main program loop is simply checking the position of the push-button switches and radio control signals. The prescale value of 16 means that every value of the RTCC counter will be held for 16 clock cycles.

In practical terms, the main program loop must have less then 16 cycles before testing for RTCC equalling zero (i.e. the RTCC rollover). Once the RTCC rollover has been detected, there are around 255 × 16 (4080) cycles in which to perform other parts of the program.

With the clock rate established, it is a simple matter of dividing it down by tens to get tenths and seconds, then by 60 to get minutes, etc., the only complication being that the l.c.d. demands numbers in ASCII format. In fact, this is quite easy to resolve as it simply means that a value of 30h (hexadecimal – 48 decimal) has to be added to the counter values.

This could have been done in the l.c.d. drive subroutine but it was just as easy to manipulate the counters with the 30h added.

DRIVING THE L.C.D.

The author claims no credit for the l.c.d. driving subroutine – he lifted it complete from a Parallax application note which is available from their web site at www.parallaxinc.com. It is strongly suggested that you have a good browse, especially the l.c.d. notes which are excellent.

It should also be mentioned that the main aim of any programmer is not to write any software unless forced into it, there is no percentage in recreating the wheel – unless, of course, you are learning to make wheels!

SERIAL OUTPUT

The serial output was rather more complicated due to timing limitations. There is simply not enough time to update the l.c.d. and the large display and get back in time for the RTCC rollover.

After much head scratching it was decided to do what all programmers must eventually do – cheat! Since the human eye cannot really follow numbers changing at one hundred times a second, it seemed that the display would probably look the same if it simply showed the number "8" while the stopwatch was running, but updating everything when it was stopped.

As far as can be determined, it works and nobody has come up and said "Oi, yer hundredths ain't runnin' proper".

Of course, it was not as simple as that due to the Lap function. Once the clock is stopped it doesn't matter how long it takes to update the displays (where *long* is measured in hundredths of a second) because the RTCC is halted, but freezing the display for a Lap requires an update while checking for RTCC rollover.

The solution was to check the RTCC value before calling the l.c.d. driver subroutine and vetoing the call if the rollover was getting close. This necessitated a whole heap of flags to mark the digits that have been updated, but seems to work quite smoothly.

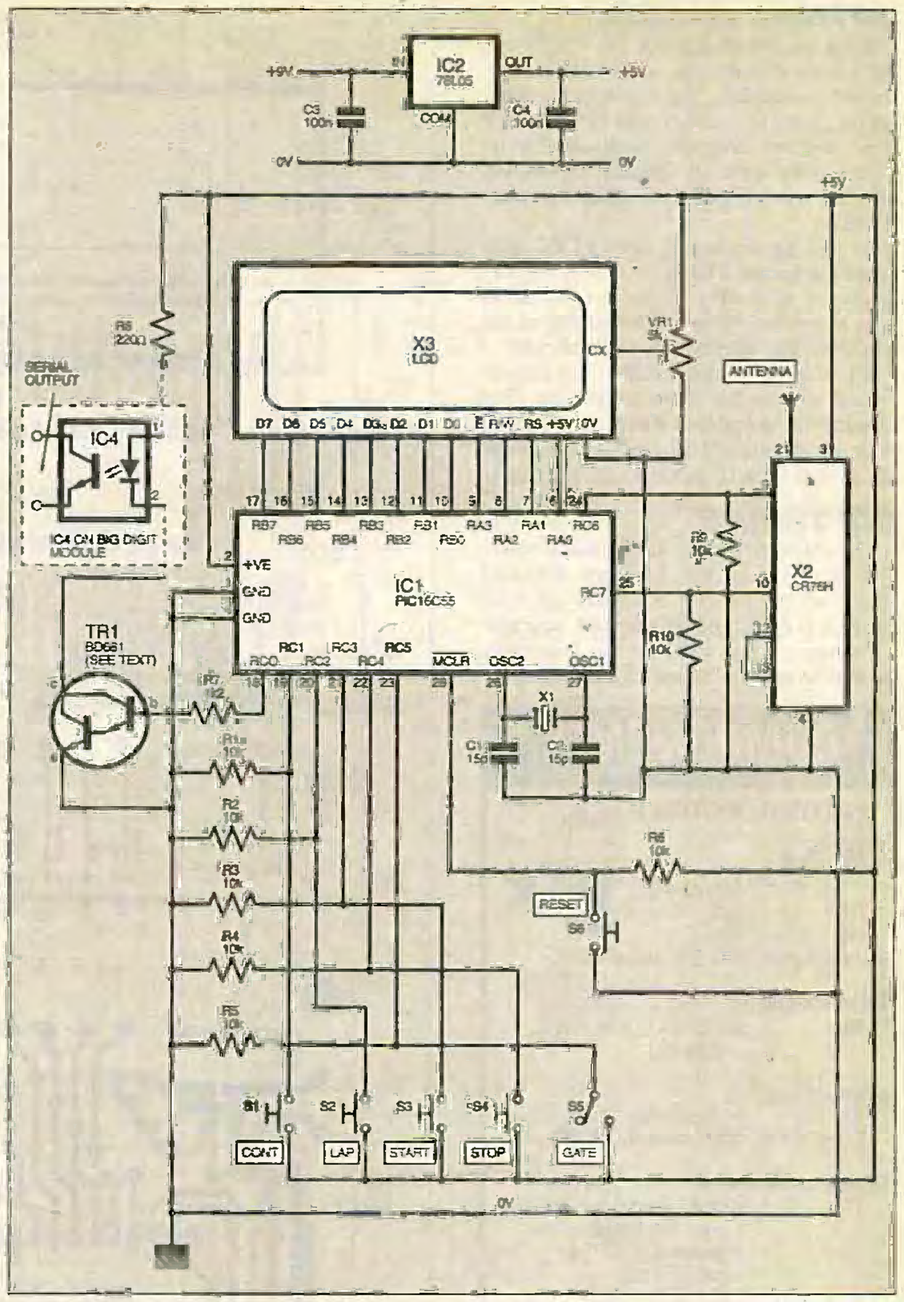


Fig.1. Complete circuit diagram for the Ginormous Stopwatch control module. Note that IC4 is part of the Large Digit Display unit described next month.

Note again that the serial output routine started life as a Parallax application note and you should have a look at their excellent description of the serial communications protocol.

MIDI STANDARD

As regular *EPE* readers will know, the MIDI standard specifies a very good way to send serial data from one electronic musical instrument to another. The MIDI standard was probably implemented to allow musicians to be very careless of connections with a high degree of impunity! It seems to work well.

The receiving instrument has an opto-coupler isolating it from the outside world – there is no electrical connection to the sending instrument. The sending instrument supplies the power to drive the l.e.d. within the optoisolator.

In the stopwatch module, as shown in the circuit diagram of Fig.1, when transistor TR1 is switched on by the PIC, current flows from the 5V power supply, through resistor R8 and optoisolator IC4 and finally to ground (0V) through TR1. Note that IC4 is actually part of the Large Digit Display to be described next month.

U.H.F. CONTROLLER

Living in this era is great, all you have to do is draw a box marked "UHF Module" and move onto the next part of the design. The module used here is a complete u.h.f. receiver which includes internal functions which decode the received signal and, when the code received matches that of one of the decoders, produces a logic low on the appropriate output pin (pin 9 or pin 10), which is fed directly into the PIC (pin 24 or pin 25, respectively).

Note that the u.h.f. unit you receive may have outputs that are normally low, i.e. pressing the radio transmitter buttons will make the output go to 5V. This is not a problem as the software only looks for a change of state, either 0V to 5V or 5V to 0V, but note the comments at the end of the "Testing" section.

OPTICAL GATES

Since the reinvention of the wheel was not a high priority, the author used commercially available "door minders" as the optical gates. The design used by the author uses a modern integrated component to do all the dirty work of modulating/sending and then receiving/demodulating the infra-red beam.

One of the interesting parts of this particular design used by the author is the way the beam is doubly modulated to avoid false triggering. This is spelled out in the data sheet that accompanies the module.

In practice, any "door minder" can be used if local sources are more convenient. (See *Shoptalk* for suppliers.) Pretty much all of them use an output relay and it is a simple task to wire them up as shown later in Fig.3.

SOFTWARE

The software for the Stopwatch is available on 3.5-inch disk from the Editorial office (see the *EPE PCB Service* page for details and cost), and via the *EPE* web site.

Preprogrammed PICs for the Stopwatch are available as discussed in *Shoptalk*.

COMPONENTS

CONTROL MODULE

See **SHOP TALK** page

Resistors

R1 to R6		
R9, R10	10k (8 off)	
R7	1k2	
R8	220Ω	

All resistors 0·25W 5% carbon film.

Potentiometer

VR1	5k (or 4k7) min. horiz. preset

Capacitors

C1, C2	15p ceramic (2 off)
C3, C4, C5	100n ceramic (3 off)

Semiconductors

TR1	BD681 (or equivalent, e.g. *npn* Darlington transistor TIP141 or TIP142)
IC1	PIC16C55 microcontroller, preprogrammed
IC2	78L05 +5V 100mA voltage regulator

Miscellaneous

S1 to S4, S6	push-to-make switch (5 off)
S5	min. s.p.s.t. toggle switch
S7	min. s.p.d.t. toggle switch
WD1	active buzzer, 9V to 12V
X1	3·2768MHz crystal
X2	u.h.f. receiver/decoder module, Maplin CR76H
X3	alphanumeric l.c.d. module, 16 × 1 or 16 × 2 (see text)
X4	u.h.f. transmitter module, Maplin CR72P (2 off)
X5	door minder module – see text (2 off)

Printed circuit board, available from the *EPE PCB Service*, code 246; connecting wire; solder, etc.

Approx. Cost Guidance Only **£25** ***excl. radio control***

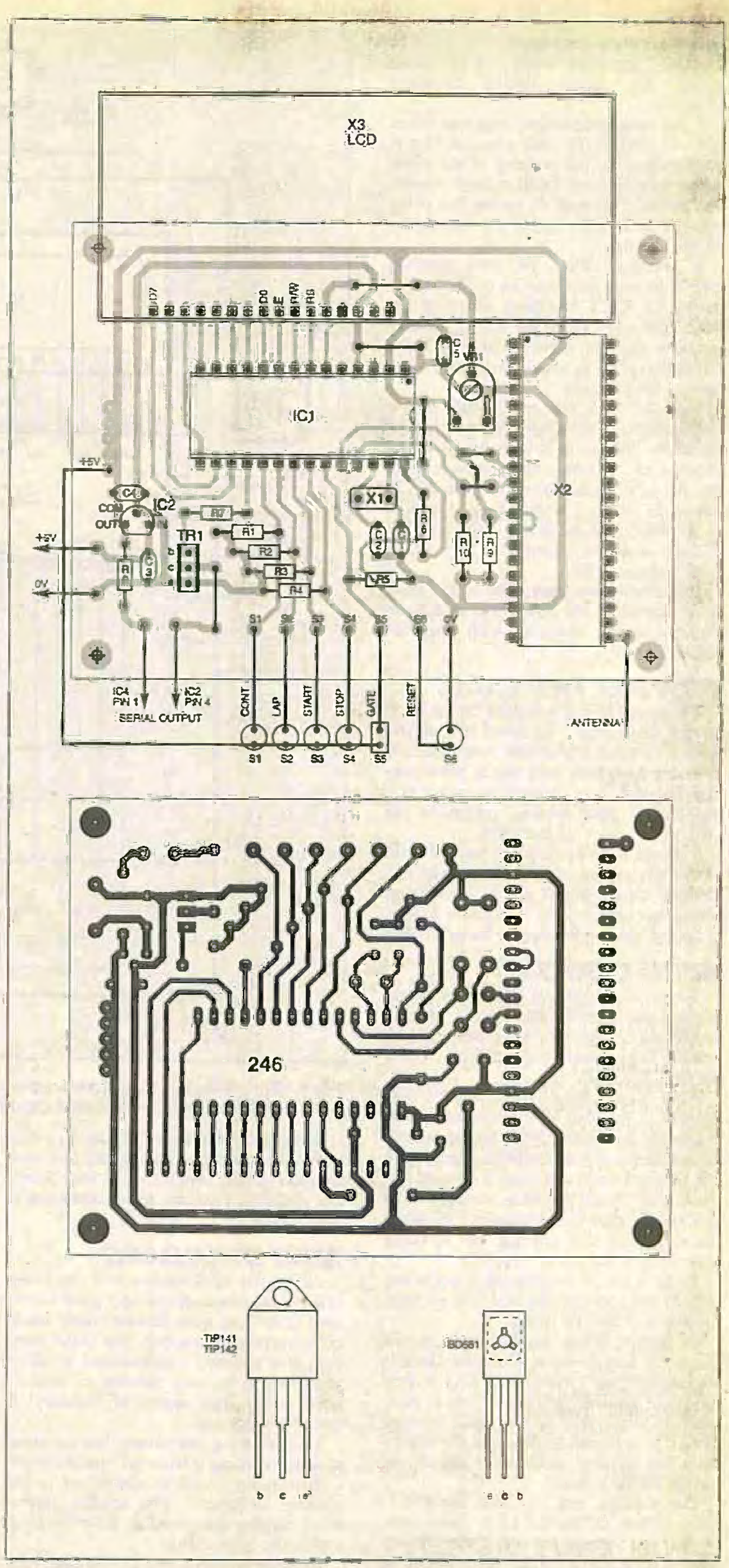


Fig.2. Printed circuit board component layout and full size copper foil track master pattern for the Stopwatch control module, plus pinouts for the TR1 alternatives.

CONSTRUCTION

Construction of the Stopwatch circuit is not very involved, but there are a few things to watch out for. The printed circuit board component layout and track details are shown in Fig.2. This board is available from the *EPE PCB Service*, code 246.

Put all of the resistors, transistor and power supply parts in first, followed by the sockets for the i.c.s., plus the two link wires between the PIC and receiver module positions.

If preferred, these two link wires could be replaced by toggle switches to isolate the effects of the optical gate transmissions when desired.

Do not at this stage put in the PIC or l.c.d. and receiver modules.

Now go around the board and look for 5V and 0V in all the right places and an open circuit in all the places that should not be connected yet (see Fig.1 and Fig.2). For example, the PIC socket should have pins 2 and 28 at +5V, pins 1, 4 and 19 to 25 at 0V, and the rest of the pin connections open circuit.

At the end of this checking you should know that there are probably no solder bridges to the power supply, that the pull-down resistors to pins 19 to 25 are working and that the master clear ($\overline{MCLR}$) is at +5V as it should be. You will also know that the power supply regulator IC2 is outputting the correct voltage of +5V.

After that, just insert the remaining components in any order that seems sensible, but leave the l.c.d. and the PIC until last.

The receiver has a couple of links to determine whether the outputs latch or are momentary when operated and you will need to connect its "link 2". This can be done on the module with a short piece of wire or else solder two pieces directly down to the Stopwatch module, where there is a link formed on the printed circuit board between pins 12 and 13 of the module's position.

Once all that is done, put in the PIC and the receiver module. The l.c.d. can be mounted directly on the board or via a 14-conductor ribbon cable – old computer cables work well. Just cut to length, strip and tin the conductors and solder them all in.

No particular case is recommended for the Stopwatch, and readers may use any plastic enclosure of their choice.

TESTING

Testing with microcontroller projects is generally of a "turn it on and see if its running" variety. So power it up and see if the l.c.d. starts up with a string of zeros separated by a colon and decimal point in the right places. Pressing the Start, Stop and Lap switches should have the desired effect.

Check for +5V at pin 3 of the receiver (X2) and ground at pin 4. Once the receiver has been taught the transmitter code (as described in its data sheet), you should find that pressing the transmitter's right-hand button should make pin 9 of the receiver change state and the left-hand button will do the same for pin 10.

The "door minder" units are tested as in the instructions that come with them. The toggle switch (S7) shown in Fig.3 will allow the buzzer (WD1) to sound when in position A, and allow the coded radio signal to be transmitted when in position B.

The transmitters are activated simply by connecting their power supply inputs as shown in Fig.3. Breaking the gate beam when S7 is in position B will cause transmission to start, lasting for as long as the beam remains broken.

To test this function, make sure the Gate switch (S5) is off, then break the gate beams in turn. The coded transmission signal should cause the Stopwatch to start and stop. Now switch S5 on and break the beam of one of the gates a few times, noting that the Stopwatch should alternately start and stop each time.

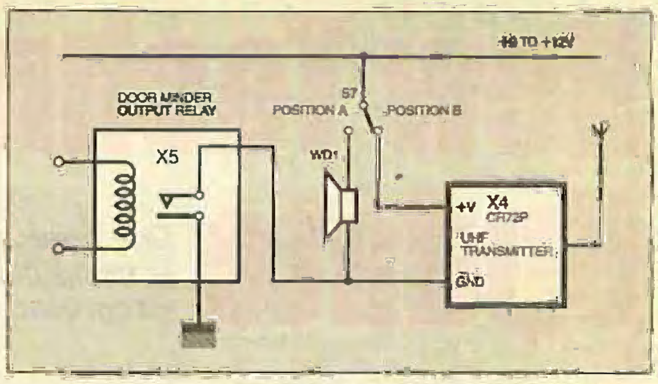
It is important to note that in this mode the Stopwatch has a time delay built in so that once the gate has been triggered there is a pause of about one second before the gate can be triggered again. This prevents the stopwatch being started and stopped by, say, a horse's four legs passing in front of the gate.

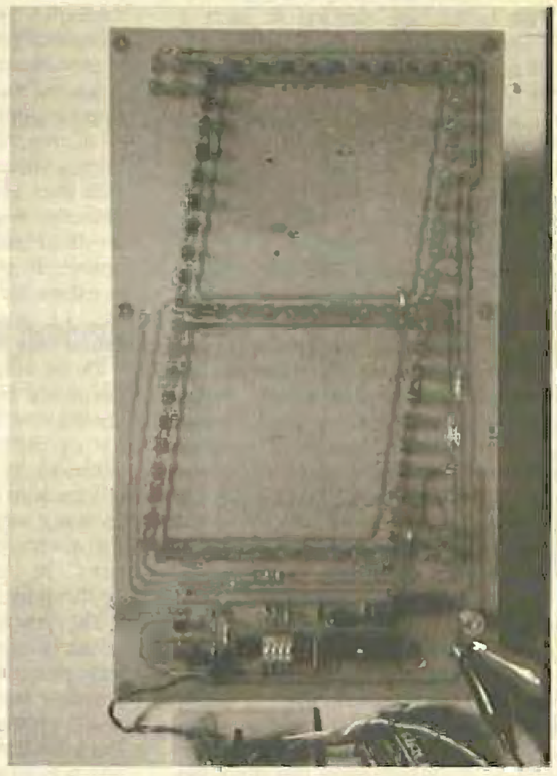
As mentioned, the software automatically tests the u.h.f. radio outputs to see if they are normally high (5V) or normally low (0V). It does this at reset so if you are using toggle switches to isolate the radio module outputs from pins 24 and 25 of the micro (the *start radio* and *stop radio* inputs), you should make sure the switches are closed before you reset the Stopwatch.

Hopefully all should be well, and your timer should be ready to stir up the action at all those tense sports events, especially after you have built Part Two next month ...

LARGE DIGIT DISPLAY

Next month, in Part Two, we describe the Large Digit Display that can be used with the Ginormous Stopwatch. Each digit board measures an astonishing 248mm × 142mm, and uses 78 l.e.d.s!





One digit of the Large Digit Display to be described next month.

LEGAL REQUIREMENTS

This design uses radio frequency modules that do not require a licence for use within the UK. However, in order to comply with Home Office regulation MPT1340, the transmitter and receiver enclosures must be clearly labelled as indicated below with lettering not less than 2mm in height:

MPT 1340
W.T.
LICENCE
EXEMPT

The *transmitter* antenna must be of an integral type. The Radio Communications Agency (RA) defines an integral antenna as "one which is designed to be connected permanently to the transmitter or receiver without the use of an external feeder". It is important, therefore, that the antenna is not accessible from the outside world and must not be removable.

In this instance, as long as the actual antenna wire is covered by a suitable sheath, such as a length of plastic wire-cladding and sealed at one end using a suitable adhesive, then it can be considered as integral. The *receiver* antenna can be integral or external as required.