Constructional Project

GINORMOUS STOPWATCH

NED STOJADINOVIC — Part 2

Now you're "up and running", why not add some Giant Displays to your events Stopwatch.

THIS Large Digit Display unit was originally designed for use with the *Ginormous Stopwatch* module presented last month. It has 178mm (7-inch) characters and can use high brightness l.e.d.s for dazzling daylight performance.

It can also be driven from a standard computer *serial* port with the optional adapter, allowing it to be used as a scoreboard, bingo number display, clock, etc.

CIRCUIT OVERVIEW

The heart of the circuit is a PIC16C54 microcontroller and this has two relatively simple tasks. The first is to receive serial data from the *Stopwatch* module or computer serial port. The data reaches the micro via an optoisolator (IC4), as discussed in Part 1, and the individual digit modules can be daisy chained together up to a maximum of 16 modules.

The software responds to all 16 addresses but the *Stopwatch* module only uses seven of them. However, when driven from a computer using the Serial Port Converter, the Large Digit Display units will respond to all 16 addresses.

The second task is to switch on the various segments on the display to form the digits 0 to 9.

SOFTWARE

In keeping with the author's stated objective of designing without designing, he used two pieces of software from the Parallax web site at www.parallaxinc.com. These were from application notes concerning receiving serial data and utilising a jump table to display digits on a 7-segment display. Readers are referred to these notes.

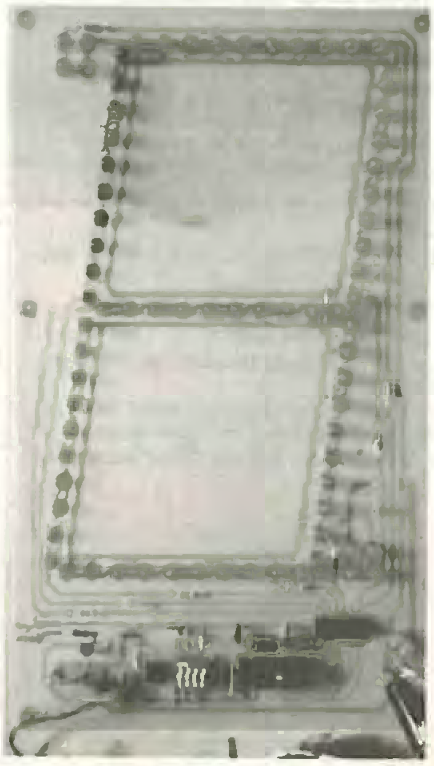
It is interesting to note that it was easiest to choose the same crystal frequency as the *Stopwatch* module (3·2768MHz). This allowed the author to play with the software's "bit_k" constant without worrying about serial link compatibility between the *Stopwatch* and Large Digit modules.

Of course, large display modules that are to be driven by a computer must comply with the standard computer baud rates and everything has been standardised at 9600 bits/sec.

It was necessary, though, to come up with a protocol to address the correct module and tell that module what number to display. This turned out to be quite easy, and it can be done in one byte.

First, consider the number to be displayed. In binary you need four bits to display the digits 0 to 9, like this:

Decimal	Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001



Completed "7-segment" Giant Display module. The figures measure 178mm by 100mm approx.

Actually, four bits will allow you to count from 0 to 15 (binary 1111), but we only need to count up to 9. Let's call these bits "n", as in "nnnn". Similarly, four bits will allow us to have modules numbered from 0 to 15, call these bits "d".

Computers and PIC micros like to deal in bytes, which are eight bits, so the software makes the "nnnn" and "dddd" bits into artificial bytes:

dddd becomes dddd0000, which is one byte

nnnn becomes 0000nnnn, which is another byte

The two bytes are ORed together (inclusive-OR) bit by bit to form a single byte which looks like ddddnnnn. This single byte contains both the module number and the digit to be displayed.

For example, to make module 1 display the number 1, the output byte would be 00010001. To make module 2 display the number 1 it would be 00100001.

CIRCUIT DIAGRAM

Referring to the circuit diagram in Fig.1, data is received via the optocoupler IC4. The driving device (e.g. the *Stopwatch*) switches an l.e.d. inside the optocoupler on and off and the light from its l.e.d. shines onto an optotransistor, switching it on and off in unison.

Resistor R1 holds the output of IC4, pin 5, at 5V until the transistor switches on and shorts pin 5 to ground. Pin 5 is connected directly to the PIC microcontroller IC2 at its pin RB7, which is set up as an input pin.

When output pin 5 of IC4 is at 0V, it switches on transistor TR1 and, via current limiting resistor R3, causes current to flow through optocoupler IC4 of the *next* digit module. In this way the modules are daisy-chained one to the next.

Dual-in-line switch S1 to S4 is used to set the digit's module address number by placing the relevant code on the PIC's RA0 to RA3 data pins. Pins RA0 and RA1 are normally held at 0V via resistors R4 and R5; pins RA2 and RA3 are normally held at 5V via resistors R6 and R7. This method of biasing was done simply to make the board design easier and the software takes it into account. When the appropriate switch is closed, the logic level seen by pins RA0 to RA3 is inverted

The status of the switches is read whenever a serial data byte is received by the

PIC via its RB7 input. The 4-bit status code forms the "dddd" bits referred to earlier.

DISPLAY

Pins RB0 to RB6 of the PIC are used as the 7-bit output to the seven sets of 10 l.e.d.s that make up the seven segments of the display. The PIC16C54 cannot by itself handle the current required by the l.e.d.s and so IC3 acts as an intermediary buffer.

This device is a rugged little chip intended as a solenoid driver and can handle almost 50V and 500mA, and is nice and cheap as well. It is essentially seven open-collector Darlington transistors that can be turned on and off by the 5V and 0V logic level voltages from the PIC.

The l.e.d.s are arranged in pairs in a series/parallel arrangement, meaning that one pair is connected in series with the next pair. There is a voltage drop of nearly 2V across each l.e.d. or pair of l.e.d.s in a parallel arrangement and the five pairs are arranged in series.

Thus the five pairs will drop the 12V supply by 5 × 2V, or about 10V, leaving the ballast resistor with 2V (12V – 10V) to reduce to zero. The l.e.d.s run well at about 20mA and so a simple application of E = IR gives a value of 100 ohms for the ballast resistors.

The value of the ballast resistor is not critical and the l.e.d.s will put out good light from about 10mA to some 30mA, which is the maximum for most l.e.d.s. If you need to save power, try putting in 220 ohms ballast resistors and see how the light output looks.

The decimal point and colon l.e.d.s are done the same way except that the l.e.d.s are all in series as there are not as many of them. These l.e.d.s are not controlled in any way and are simply connected across the 12V power supply, via limit resistors R15 and R16, constantly remaining on while the power is on.

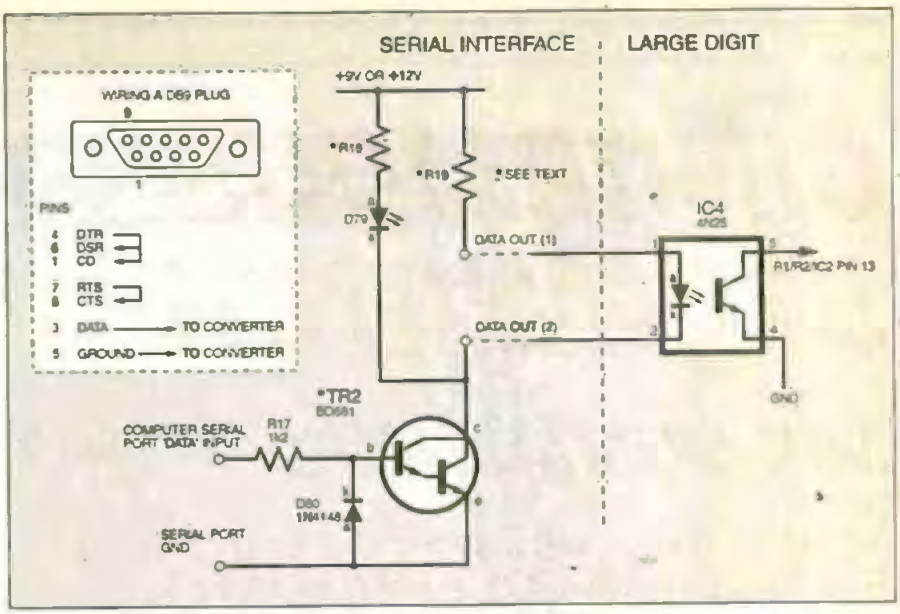


Fig.2. Circuit diagram for a simple Serial Port Converter Interface add-on. The values of resistors R18 and R19 should be 330 ohms for 9V and 560 ohms for 12V.

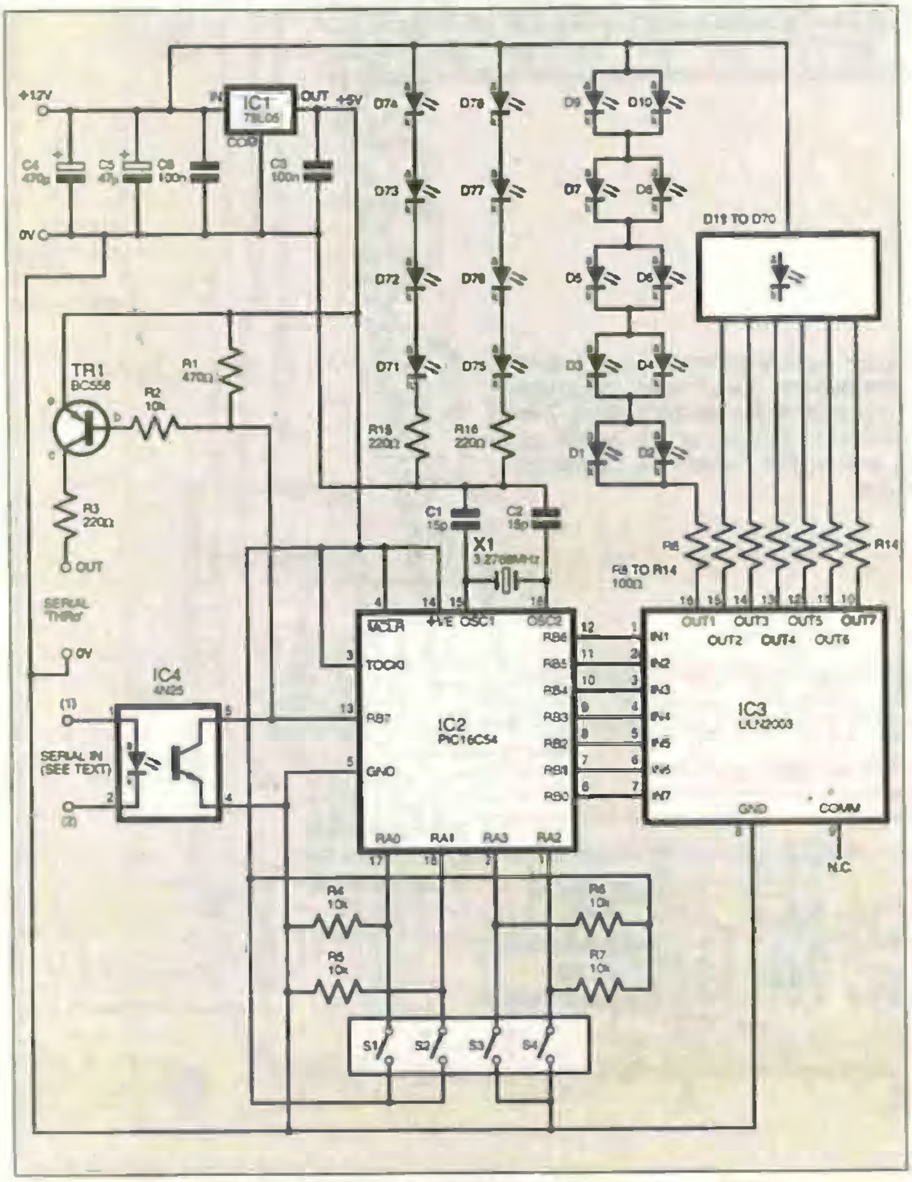


Fig.1. Circuit diagram for the Giant Digital Display module.

SERIAL PORT CONVERTER

The digit modules can also be driven from a computer serial port with the aid of a converter module interface (see Fig.2). This is simply a Darlington transistor switch (TR2) which converts the ±15V signals from the serial port to voltages of the correct polarity to drive the optocouplers.

The transistor also provides the reasonably heavy current required by optocouplers connected in "star" configuration (see the last section of this article).

The converter has its own power supply because it has to provide power to the internal l.e.d.s of the optocouplers. The battery used can be 9V or 12V merely by changing resistors R18 and R19. The values should be 330Ω for 9V and 560Ω for 12V.

The converter also has an l.e.d. on board (D79) to indicate serial port activity and is a great help for trouble shooting.

CONSTRUCTION

The printed circuit boards for the Large Digit Display and optional computer Serial Port Converter Interface board are available from the *EPE PCB Service* page, codes 247 and 248, respectively. The component assembly and track layout details for the boards are shown in Fig.3 and Fig.4.

There is nothing difficult about the construction but the l.e.d.s are, as may be expected, rather tedious. It is suggested that you test each segment as it is finished.

Start assembly of the Large Display board (Fig.3) with the top right segment. Insert all the l.e.d.s and make sure that they are all the correct way around, noting that some high brightness l.e.d.s have different orientations to those of ordinary l.e.d.s. If

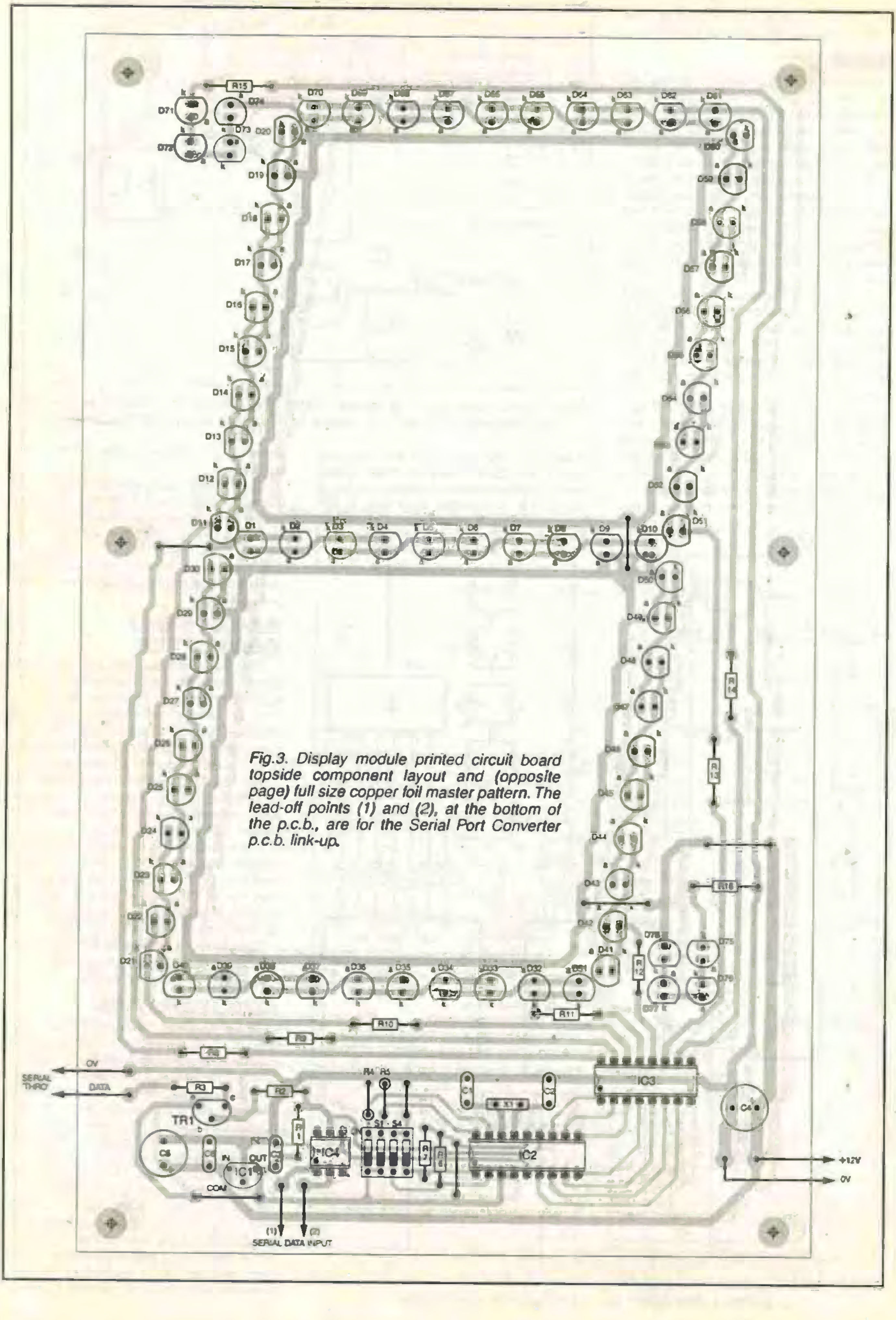
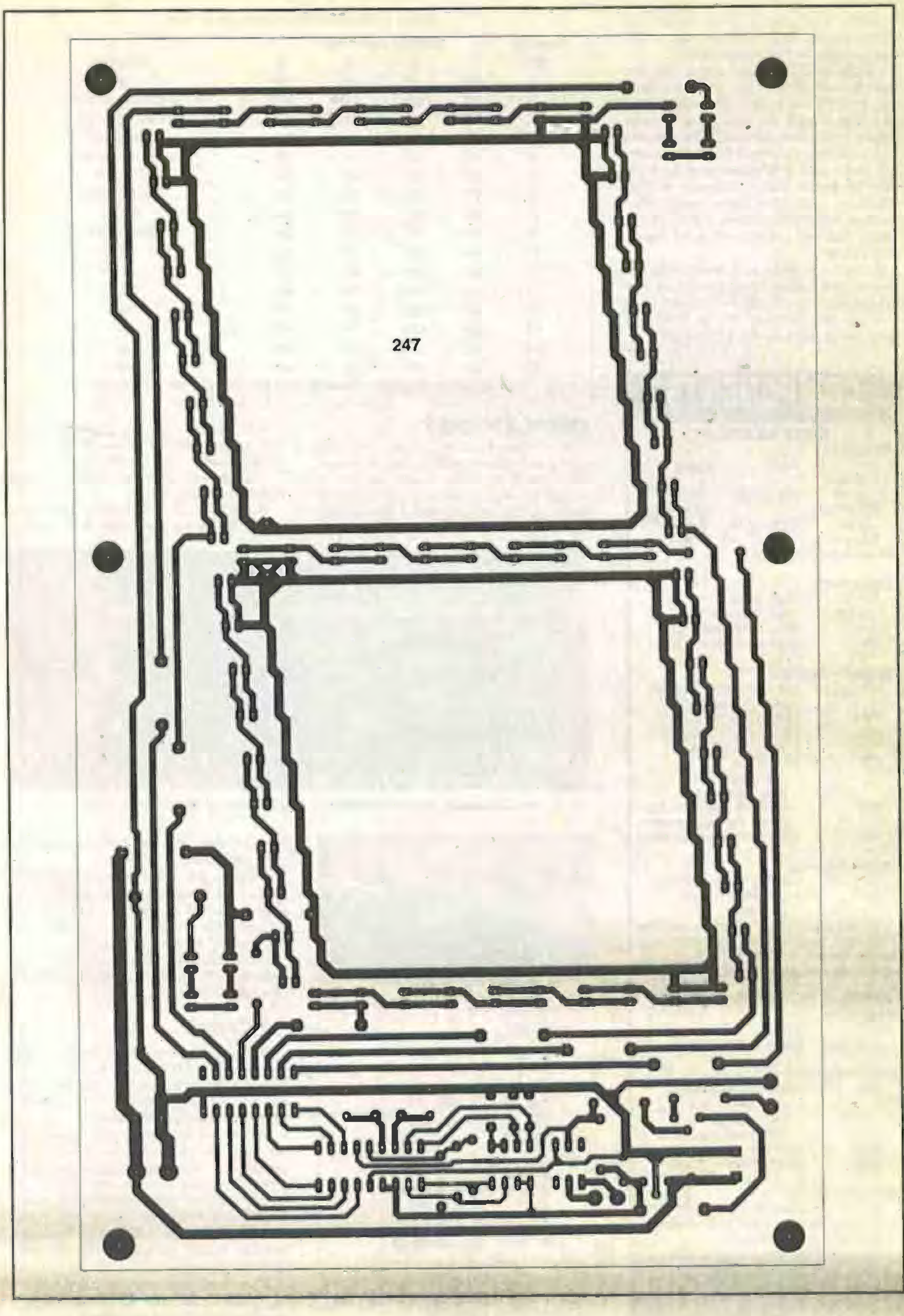


Fig.3. Display module printed circuit board topside component layout and (opposite page) full size copper foil master pattern. The lead-off points (1) and (2), at the bottom of the p.c.b., are for the Serial Port Converter p.c.b. link-up.



247

in doubt, you can check by temporarily connecting the l.e.d. in series with a 1kΩ resistor across a 12V power supply.

Flip the board over and solder only one lead of each l.e.d. When you have done that, go back and grasp both leads of each l.e.d. and re-melt the solder while gently pulling upwards on the leads. This will seat each l.e.d. onto the circuit board and generally make sure it is pointing straight out from the board. This is important as high brightness l.e.d.s only appear bright when you look directly onto them, if they are tilted they look dull and this makes the display look patchy.

Go back and solder each second lead and give the first soldered lead a touch up with fresh solder if necessary. Now solder in all of the ballast resistors (R8 to R16) and some power leads for the 12V supply.

COMPONENTS

DIGIT MODULE

Resistors

R1	470Ω
R2, R4 to R7	10k (5 off)
R3, R15, R16	220Ω (3 off)
R8 to R14	100Ω (7 off)

See SHOP TALK page

All resistors 0·25W 5%.

Capacitors

C1, C2	15pF ceramic
C3, C6	100n ceramic
C4	470μ radial elect. 16V
C5	47μ radial elect. 10V

Semiconductors

D1 to D78	red l.e.d., 5mm, normal or high brightness
TR1	BC558 *pnp* transistor
IC1	78L05 +5V 100mA voltage regulator
IC2	PIC16C54 microcontroller, preprogrammed
IC3	ULN2003 7 x Darlington driver, common emitter
IC4	4N25 or 4N28 optoisolator

Miscellaneous

S1 to S4	4-way d.i.l. on/off switch
X1	3·2768MHz crystal (see text)

Printed circuit board, available from the *EPE PCB Service*, code 247; 6-pin d.i.l. socket; 16-pin d.i.l. socket; 18-pin d.i.l. socket; connecting wire; solder, etc.

SERIAL PORT CONVERTER

Resistors

R17	1k2
R18, R19	330Ω for 9V, 560Ω for 12V

Semiconductors

TR2	BD681 (or equivalent, e.g. TIP141 or TIP142) *npn* Darlington transistor
D79	red l.e.d., 5mm
D80	1N4148 signal diode

Miscellaneous

Printed circuit board, available from the *EPE PCB Service*, code 248; connector to suit serial port lead used.

Approx. Cost Guidance Only £35 (Standard l.e.d.s)

Table 1: Module Selection Switches

Module No.	Switch Settings 1	2	3	4	Display
0	off	off	off	off	★
1	off	off	off	on	hundredth seconds
2	off	off	on	off	tenth seconds
3	off	off	on	on	seconds
4	off	on	off	off	ten seconds
5	off	on	off	on	minutes
6	off	on	on	off	ten minutes
7	off	on	on	on	hours
8	on	off	off	off	ten hours
9	on	off	off	on	★
10	on	off	on	off	★
11	on	off	on	on	★
12	on	off	off	off	★
13	on	on	off	off	★
14	on	on	on	off	★
15	on	on	on	on	★

★ Used in computer version with the Serial Port Converter.

DISPLAY TEST

To test the segment, connect the 12V supply and connect a flying lead to ground (0V). Touch the flying lead to the end of resistor R13 that is nearest to the bottom of the board. The segment should light up nice and bright.

If it does not, look for l.e.d.s the wrong way around, broken tracks, or the wrong ballast resistor value, in that order.

If all is well, continue inserting l.e.d.s, testing, inserting, testing...

If any l.e.d.s are a tight fit at their skirts, gently file down their sides until there is room for them to sit without colliding with their neighbours.

Completed control and power supply area of the Display p.c.b.

Because the colon and decimal point l.e.d.s are intended to be permanently turned on, they (and/or their ballast resistor) should be omitted if those functions are not required on any of the boards.

Put in all the other components and sockets for IC2 to IC4, but do not install the i.c.s yet.

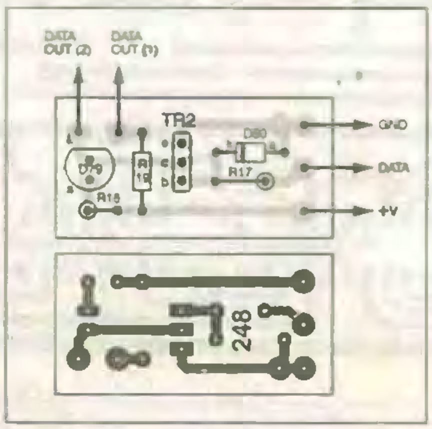


Fig.4. Printed circuit board details for the Serial Port converter.

TESTING

Power up the board and at the IC2 socket test for 5V and 0V at pins 5 and 14. This will test the power supply regulator IC1, and will also show up any solder splashes or broken tracks to these pins.

Switch off the power and insert IC3, the l.e.d. driver device. To now test the operation of the various segments, take a flying lead and connect one end to 5V, say to the link wire immediately below IC1. Touch the other end of the flying lead in turn to pins 1 to 7 of IC3's socket and you should see each of the segments light accordingly.

If you have connected the colon or decimal point l.e.d.s, they should have turned on when you applied the power.

Now power down and carefully put the PIC (preprogrammed, of course) into its socket, being very careful about orientation. Remember that it is a CMOS chip and so be sure to briefly ground yourself to discharge static electricity before handling it. Also insert IC4.

Turning on the power should now give you a nice big figure "0" and if not, immediately power down and start looking for causes. The *Stopwatch* article last month has some tips on troubleshooting this type of circuit.

If you are using the *Stopwatch* module, connect it to one digit board via a handy length pair of leads, being careful to connect signal and ground wires the correct way around. Select the module address number via the d.i.l. switch (S1 to S4) as per Table 1. Note that the software "knows" that switches S3 and S4 are connected in order of RA3 and RA2 (instead of RA2 and RA3 as might be expected).

Power up both boards and start the Stopwatch. This should immediately start the digit board displaying the selected time unit. If it just sits on "0", use a logic probe or similar to test for a fast changing signal on pin 5 of the optocoupler, IC4.

PORT INTERFACE

If using the Serial Port Converter, connect up the digit board and power as above. Now run the QBASIC demo program, making sure that the module d.i.l. switches are all off. Put in a different switch setting from the list each time you run the program and the module should immediately display the correct number.

You will know if the converter is working by observing its l.e.d. Whenever serial data is being transmitted it will flash quite noticeably.

STAR CONNECTION

The digit modules are designed to be hooked up in "daisy chain" configuration, see Fig.5a, and this should work well in most cases. It is possible, especially when many modules are used for the signal to get a bit lost in its trip down the chain; remember the design allows up to 16 digit modules to be used.

In this case, use the "star" configuration in Fig.5b where the driver transistor in the Stopwatch or Serial Port Converter switches all of the optocouplers directly. Note that this will put quite a strain on the battery of the Serial Port Converter or *Stopwatch* module as it now has to power all of the optocouplers at the same time.

To select a battery size, assume that each module uses about 15mA when running and plan accordingly. For example, 10 modules times 15mA is 150mA and so a battery of 1·2Ah (amp hour) capacity will drive the display for eight hours.

COMPUTER SERIAL PORTS

While developing this project the author came across a strange fact: not all computer serial ports operate at quite the same speed and the modules will consequently malfunction on some computers.

For those programming their own PIC and wanting to drive the modules from a computer port, try varying the value of "bit_k" in the software for the PIC. The comments section in the source code tells you how to do it.

If you only want to drive the modules from a computer, a slightly different source code for the PIC has been included (called **serin4.src**) which requires the use of a 4MHz crystal instead of the 3·2768MHz one, and operates at 2400 baud. The slower baud rate is unnoticeable to our slow human senses and results in a design which is forgiving of long serial cables and bit rate errors in the computer or micro.

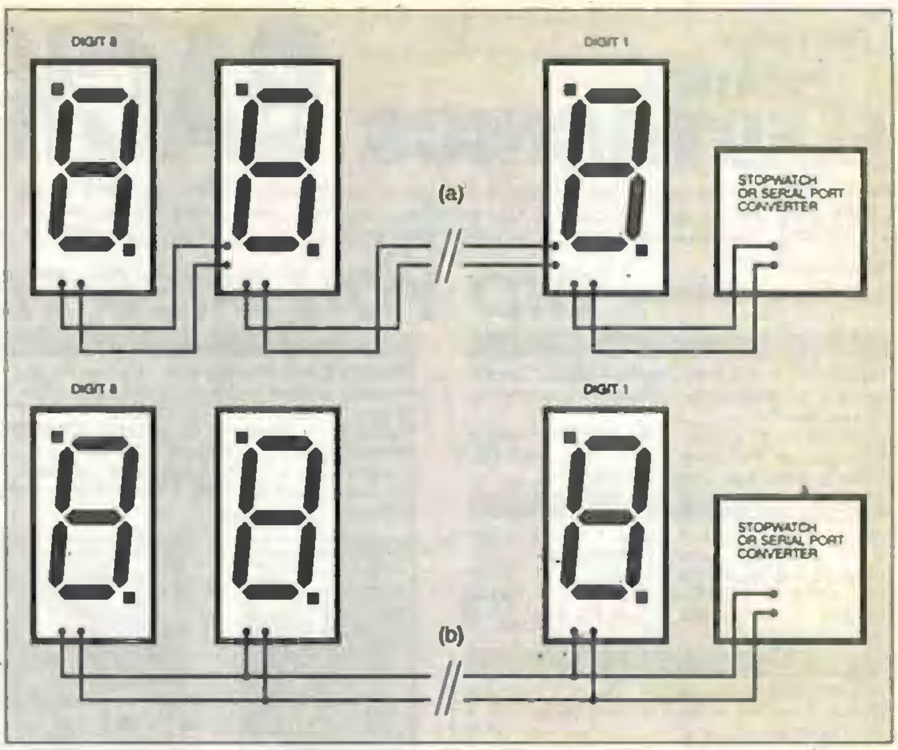


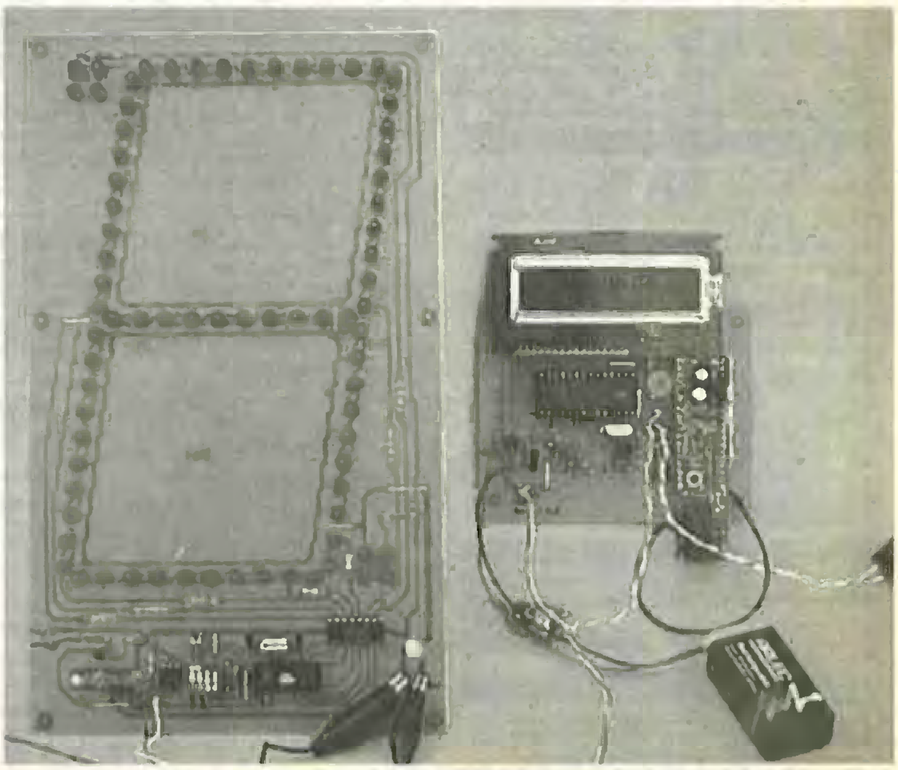
Fig.5. Suggested method of connecting the Giant Display modules to the Stopwatch (Part 1) or Serial Port Converter. (a) In "daisy chain" fashion or (b) "star" configuration.

SOFTWARE

The software for the Large Digit module, including the QBASIC demo program, is available on a 3·5-inch disk from the Editorial office (see *EPE PCB/Software Service* page for details and cost), and free via the *EPE* web site.

Preprogrammed PICs for this module are available as discussed in *Shoptalk*.

Note that since publicaton of Part 1 the software has been revised by the author. The new version is on the *EPE* disk and website □



One Display module being driven by last month's Stopwatch.

SHOP TALK
with David Barrington

PIC Micro-Probe

The component listing for the *PIC Micro-Probe* calls for a piece of "i.c. holder" type stripboard, with a central channel, devoid of copper, running across the copper tracks. This will cost you around £5, but for just under £2 you can use a piece of standard stripboard and cut away the copper tracks as necessary. The rest of the components should be readily available.

The PIC used in this project should be the 10MHz version. For those who want a "plug-in and go" preprogrammed PIC16F84, one is available from **Magenta Electronics** (☎ *01283 565435* or ***http://magenta2000.co.uk***) for the inclusive price of £5.90 (overseas readers add £1 for postage). For those who wish to program their own PICs, the software is available from the Editorial Offices on a 3·5in. PC-compatible disk, see *EPE PCB Service* page 937. If you are an Internet user, it can be downloaded *Free* from our FTP site: **ftp://ftp.epemag.wimborne.co.uk/pubs/PICS/microprobe**.

Magnetic Field Detector – Starter Project

Just a couple of pointers regarding purchasing of components for the *Magnetic Field Detector*, this month's starter project. The first concerns the 100μA "centre zero" meter, some readers may have difficulty in locating one. The meter used in the prototype came from **Maplin** (☎ *01702 554000*), code RW98G.

If you have trouble tracking down the UGN3503U Hall effect sensor, the above company list one as order code GX09K. They also supplied the OP77G precision op.amp, code UL05F. The alternative TL071CP low-noise op.amp should be stocked by most of our component advertisers.

Ginormous Stopwatch – Giant Display

This month we complete the *Stopwatch* project with the construction of a *Giant Digital Display* module. Most of the component supply "bugs" were ironed out last month.

The high voltage 4N25 opto-coupler, code AY44, and the ULN2003 Darlington array, code AD93B, are listed by **Maplin**. The BD681 Darlington transistor may be hard to find, but the suggested alternative TIP141 and TIP142 should be readily available. Note the differing pinouts for the TIP devices (Fig.2 last month).

Ready programmed PICs are available from the author for the sum of £10 each (for either the Display module or Stopwatch) or £50 for six in any combination, with free postage to anywhere in the world. *Payments should be made out to Mr. N. Stojadinovic.* His E-mail address is: **vladimir@u030.aone.net.au** or write to: **Mr. N. Stojadinovic, PO Box 320, Woden ACT, 2606, Australia**.

A programmed PIC16C54 is also available from **Magenta Electronics** (☎ *01283 565435* or ***http://magenta2000.co.uk***) for the inclusive price of £5.90 (overseas readers add £1 for postage). For those who wish to program their own PICs, the software is available from the Editorial Offices on a 3·5in., PC-compatible disk, see *EPE PCB Service* page. If you are an Internet user, it can be downloaded *Free* from our FTP site:

ftp://ftp.epemag.wimborne.co.uk/pubs/PICS/stopwatch.

The two printed circuit boards are available from the *EPE PCB Service*, code 247 (Digit) and 248 (Port Conv.).

Loft Guard

Most of the components called-up for the *Loft Guard* project should be readily available from your usual supplier. The only problems that are likely to crop up may be finding the high value resistors.

The *single* 100 megohm resistor (R7) was only found listed under the "cermet film" range stocked by ***Electromall*** (☎ *01536 204555* or RS ***http://rswww.com***), quote code 158-222. As the article points out, you could use three 33 megohm resistors (in series); the p.c.b. is also designed to accept these. This resistor (33M) came from the **Maplin** "high voltage" metal film range, order code V33M.

Note that to make up the 20 megohm resistor (R10) you will need two 10 meg types. Once again, the "series" pads have been included on the p.c.b.

The last mentioned company also supplied the miniature light-dependent resistor (l.d.r.), code AZ83E, and the high power warning buzzer, code FK84F. Although most of our components advertisers should be able to offer something similar. You could, of course, use the good old standard ORP12 l.d.r. if you wish.

Even though the semiconductors are specific versions, they should be in plentiful supply. The p.c.b. is available from the *EPE PCB Service*, code 249.

Teach-In 2000

If you have only just picked up on our new *Teach-In 2000* series with this issue, and being a newcomer to electronics, you may feel a bit apprehensive about ordering the various parts for the demonstration "exercises". Fear not, some of advertisers have put together component and hardware packs specially for the new series. A few more will be added as the series progresses, but we do not expect that to be until at least part seven.

To date, participating advertisers are as follows and readers are advised to contact them for more details:

ESR Electronic Components (☎ *0191 251 4363* or web ***http://www.esr.co.uk***) Hardware/Tools and Components Pack.

Magenta Electronics (☎ *01283 565435* or ***http://www.magenta2000.co.uk***) – Multimeter and Components Kit 879.

FML Electronics (☎ *01677 425840*) – Basic Components Sets.

N. R. Bardwell (☎ *0114 2552886*) – Digital Multimeter special offer.

PLEASE TAKE NOTE

Demister One-Shot — Nov '99

Page 844 Fig.4. On the p.c.b. component layout diagram, the "body" outlines of capacitors C1 and C2 should be transposed – see photograph at top of page 845. The electrolytic, shown as a circle, should connect to the IC1 pin 8 copper track (+) and the common GND track (–). The actual annotations are correct.