**This new electric fence circuit has considerably higher output than our previous economy design and is suitable for much longer fence runs. It is essentially a capacitor discharge design and uses a DC-DC inverter with high energy output.**

# New High Power ELECTRIC FENC

ELECTRIC FENCES are widely used on farms to control livestock. They can be set up quickly, are easily moved from place to place and they're much cheaper than permanent fencing.

This new electric fence controller is suitable for fence runs up to about 5km long.

We have mounted the controller in a section of 90mm plastic storm-water pipe fitted with standard end caps. This means it can be made waterproof and it can be attached to a fence post using standard 90mm fittings.

Our previous design was based on a standard 12V ignition coil. While this was a cheap approach it did not have the output for longer fences and was less effective against larger livestock such horses and cattle.

This new design has substantially higher energy storage and should be adequate for fence runs up to 5km long. It is designed to comply with the relevant Australian Standard AS/NZS 3129.

## Block diagram

The block diagram for the electric fence controller is shown in Fig.1. This comprises a 12V battery supply which is stepped up to 340VDC using a DC-DC converter. This charges a 7μF dump capacitor.

The charge in this capacitor is "dumped" through the step-up transformer once every second or so using a discharge circuit involving a Triac and pulse timer.

The pulse timer controls both the DC-DC converter and the Triac. It switches off the converter each time it fires the Triac and then switches it on again just after the dump capacitor has been discharged.

Now let's have a look at the full circuit which is shown in Fig.2.

## Circuit description

The DC-DC converter comprises a 7555 timer (IC1), Mosfet Q1 and transformer T1 plus diodes D1 and D2. IC1 is connected to oscillate at around 20kHz, as set by the .0039μF capacitor at pins 2 & 6 and the associated 4.7kΩ and 6.8kΩ resistors.

The 20kHz pulses from pin 3 are used to drive Mosfet Q1 and this drives transformer T1 which steps up the voltage and drives a half-wave rectifier consisting of two fast recovery diodes, D1 & D2, connected in series. They are connected in series because their 500V rating is insufficient to allow one diode to be used by itself.

Design by JOHN CLARKE


# E CONTROLLER

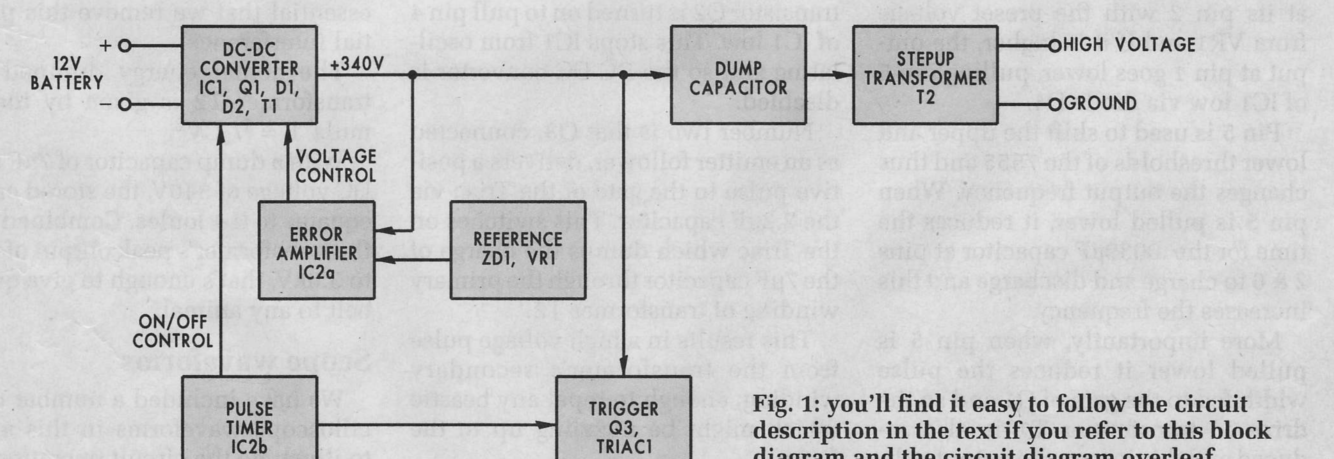



**Fig. 1: you'll find it easy to follow the circuit description in the text if you refer to this block diagram and the circuit diagram overleaf.**

The half-wave rectifier charges the 7µF 250VAC dump capacitor via the two 220Ω resistors and the primary winding of transformer T2.

The voltage stored in the dump capacitor is monitored by the error amplifier IC2a. The voltage is reduced by the voltage divider consisting of two 1.5MΩ resistors and the 10kΩ resistor and this feeds pin 2 of IC2a.

The non-inverting input of IC2a, pin 3, is connected to trimpot VR1 which taps off the reference voltage from the 4.7V zener diode, ZD1.

The gain of IC2a is set at 28 by the 10kΩ resistor at pin 2 and the 270kΩ resistor between pins 1 & 2. The .0047µF capacitor provides high frequency rolloff above 125Hz.

## Modulating the 7555

The error amplifier works in an unusual way to control the DC voltage across the dump capacitor at about

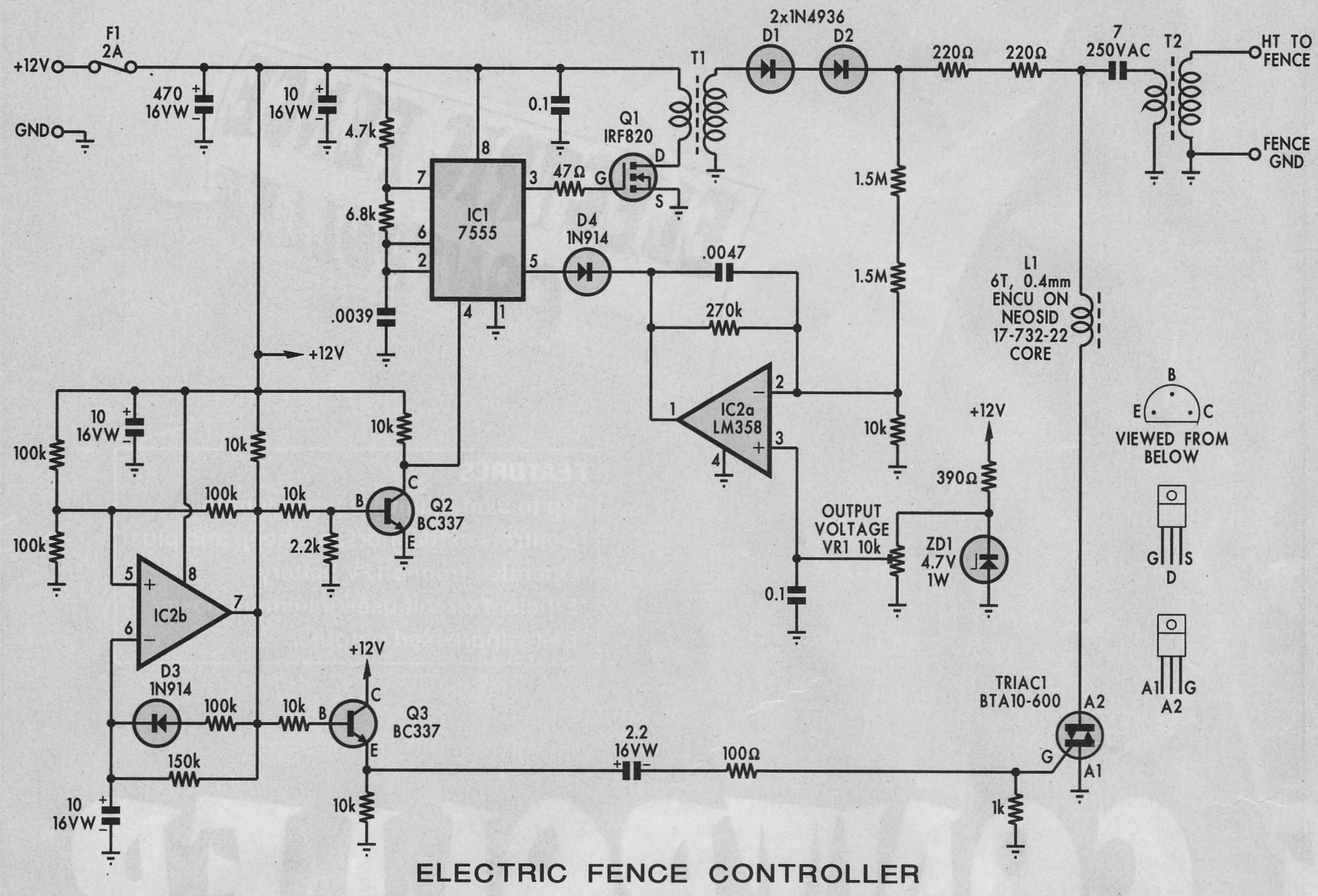



**Fig. 2: the circuit diagram shows just how simple the electric fence controller is. Beware the components on the secondary side of T1: they bite!**

340V DC. IC2a compares the voltage at its pin 2 with the preset voltage from VR1 and if it is higher, the output at pin 1 goes lower, pulling pin 5 of IC1 low via diode D4.

Pin 5 is used to shift the upper and lower thresholds of the 7555 and thus changes the output frequency. When pin 5 is pulled lower, it reduces the time for the .0039μF capacitor at pins 2 & 6 to charge and discharge and this increases the frequency.

More importantly, when pin 5 is pulled lower it reduces the pulse width fed to the gate of Q1 and so the drive to transformer T1 is also reduced and this lowers the output voltage.

## Pulse timer

The pulse timer is a 1.5Hz Schmitt trigger oscillator based on amp IC2b. The 10μF capacitor at pin 6 is charged via diode D2 and the 100kΩ resistor connecting to pin 7 and the 150kΩ resistor from pin 6 to 7.

When IC2b's output goes high, two things happen. Number one is that transistor Q2 is turned on to pull pin 4 of IC1 low. This stops IC1 from oscillating and so the DC-DC converter is disabled.

Number two is that Q3, connected as an emitter follower, delivers a positive pulse to the gate of the Triac via the 2.2μF capacitor. This switches on the Triac which dumps the charge of the 7μF capacitor through the primary winding of transformer T2.

This results in a high voltage pulse from the transformer's secondary winding, enough to repel any beastie which might be nuzzling up to the fence.

Inductor L1 is connected in series with the transformer primary and this controls the rise time of the pulse current from the dump capacitor.

Without the inductor, the very rapid turn-on time of the Triac would mean that a burst of radio interference would be radiated by the electric fence every time it fired.

When you consider how long the antenna (ie, the fence) could be, it was essential that we remove this potential interference.

The actual energy dumped into transformer T2 is given by the formula $E = {}^1/_2CV^2$

With a dump capacitor of 7μF and a DC voltage of 340V, the stored energy equates to 0.4 Joules. Combined with the transformer's peak output of close to 3.6kV, that's enough to give quite a belt to any animal.

## Scope waveforms

We have included a number of oscilloscope waveforms in this article to illustrate the circuit operation.

Fig.3 shows how IC1 is turned on and off by the pulse timer. The top trace shows the gated oscillation from pin 3 of IC1 while the bottom trace is the pulse waveform fed to pin 4. Each time the pulse is high, the oscillator output is disabled.

Note that the top trace waveform shows severe quantising error and looks random because the 20kHz oscillation is much too fast for the scope's sampling rate which is set by the very low timebase sweep speed of 250ms per division (ie, one sweep takes 2.5 seconds).

Fig.4 shows the charging and discharging of the dump capacitor every 1.5 seconds. The top trace is the waveform across the dump capacitor and as you can see, this builds up to 340V and then is abruptly dropped to zero. Each time it is to discharged to zero corresponds with the positive-going pulse on the bottom trace. This is the waveform at the emitter of Q3 which is used to trigger the Triac.

Fig.5 shows the high voltage waveform delivered by the secondary winding of transformer T2. It was measured via a 100:1 voltage divider and so the peak voltage is 3.6kV.

Fig.6 shows the operation of the DC-DC inverter transformer, T1. The top trace shows the waveform at the

## WARNING

**Be aware that this circuit produces high voltages and that a large amount of energy is stored in the dump capacitor. If you are not careful you could receive a nasty electric shock. Do not touch the PC board while the circuit is operating. You could get a shock from the dump capacitor, from diodes D1 & D2, the 1.5MΩ & 220Ω resistors, transformer T2 and inductor L1, as well as the Triac; all are charged to the 340V potential.**

**Naturally, the secondary winding of transformer (T2) can also give you a belt – that's the idea – but it is not as dangerous as the 340V side of the circuit.**

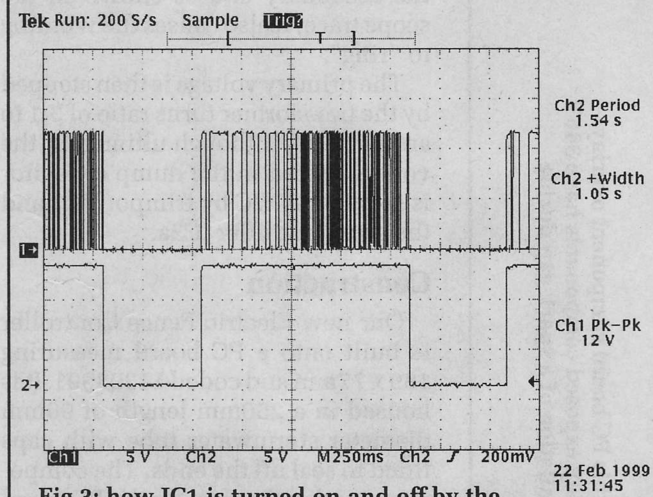



**Fig.3: how IC1 is turned on and off by the pulse timer. The top trace shows the gated oscillation from pin 3 of IC1 while the bottom trace is the pulse waveform fed to pin 4.**

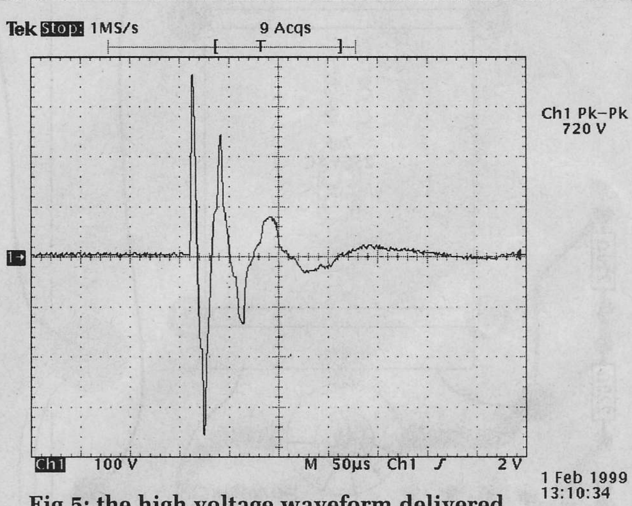



**Fig.5: the high voltage waveform delivered by the secondary winding of transformer T2. It was measured via a 100:1 voltage divider so the peak voltage is 3.6kV.**

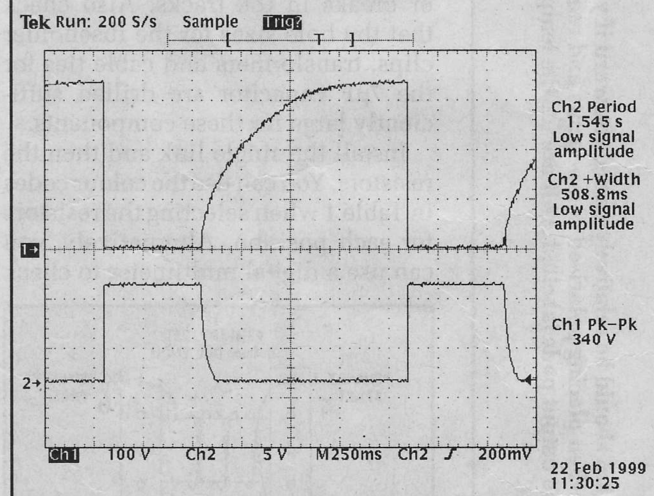



**Fig.4: the charging and discharging of the dump capacitor every 1.5 seconds. The top trace is the waveform across the dump capacitor and as you can see, this builds up to 340V and then is abruptly dropped to zero. Each time it is discharged to zero corresponds with the positive-going pulse on the bottom trace.**

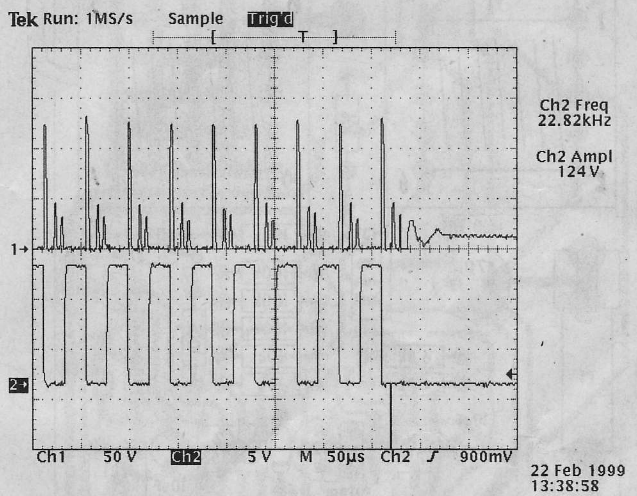



**Fig.6: the operation of the DC-DC inverter transformer, T1. The top trace shows the waveform at the drain of Mosfet Q1 while the bottom trace is the driving waveform from pin 3 of IC1, the 7555.**

drain of Mosfet Q1 while the bottom trace is the driving waveform from pin 3 of IC1, the 7555.

Note that the frequency of the bottom trace is 23kHz (nominally 20kHz) and it is essentially a clean pulse waveform. However the top trace shows evidence of ringing at a much higher frequency. What is happening?

The clue is the peak voltage of the waveform: 124V.

What is happening is that each time the waveform at pin 3 of IC1 goes positive, Mosfet Q1 turns on and feeds current through the primary winding of transformer T1. About 20μs later it turns off abruptly and this causes a high voltage (ie, 124V) to appear across the secondary and as shown in the scope trace, it also causes the winding to "ring".

The primary voltage is then stepped by the transformer turns ratio of 3:1 to around 370V although ultimately, the voltage stored in the dump capacitor is set at 340V DC by trimpot VR1 and the error amplifier IC2a.

## Construction

Our new Electric Fence Controller is built onto a PC board measuring 189 x 77mm and coded 11303991. It is housed in a 250mm length of 90mm diameter stormwater tube with caps fitted to seal off the ends. The component overlay diagram for the PC board is shown in Fig.7.

You can begin construction by checking the PC board for any shorts or breaks in the tracks. Also check that the hole sizes for the fuseholder clips, transformers and cable ties for the 7μF capacitor are drilled sufficiently large for these components.

Install the single link and then the resistors. You can use the colour codes in Table 1 when selecting the resistors for each position. Alternatively, you can use a digital multimeter to check

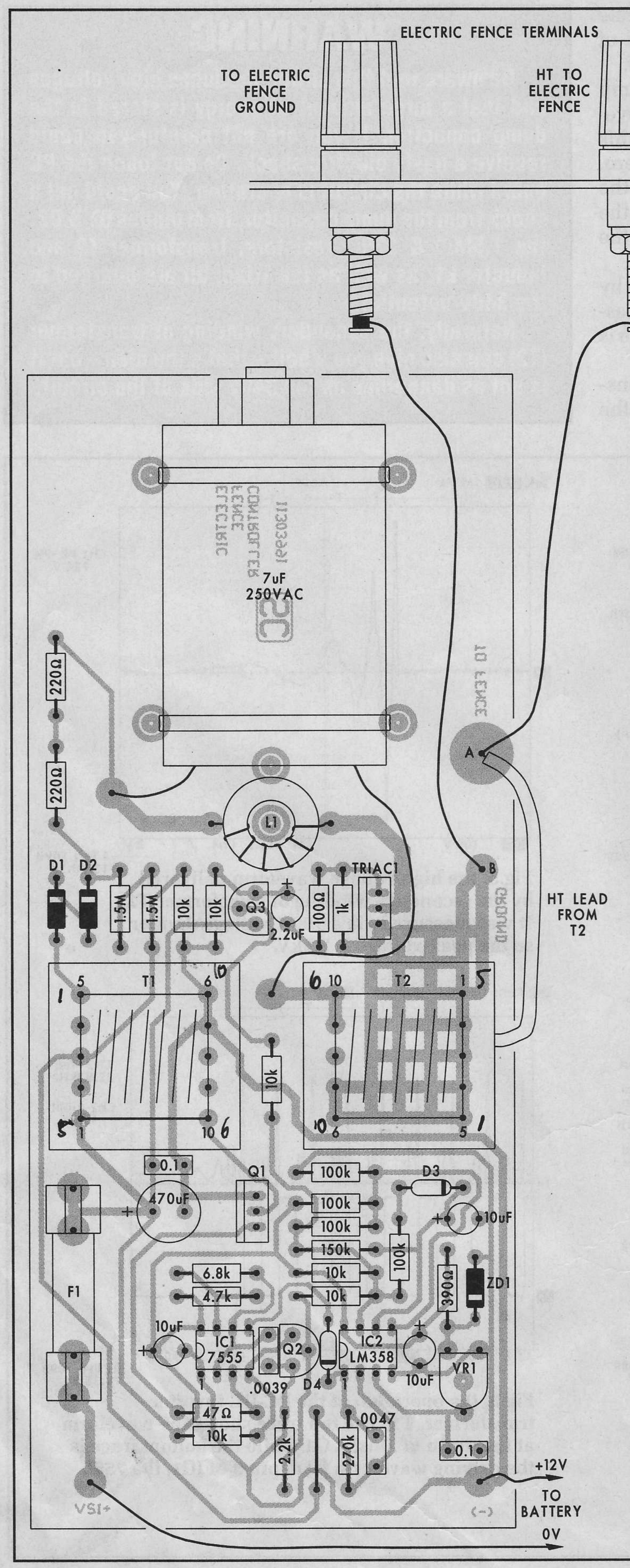



Fig 7: construction should be relatively straightforward if you follow this PC board component overlay. Just be careful when placing polarised components and remember many exposed components have 340V DC on them! The output pads labelled A&B are for the temporary installation of a spark gap during testing – see text.

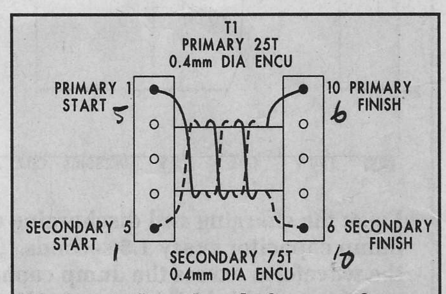



**Fig. 8: winding details for transformer T1. This one is the simpler of the two but take care with the starts and finishes and direction of winding.**

each resistor value before it is inserted in the PC board. Insert and solder in the PC stakes and the diodes, including zener diode ZD1.

The capacitors can be mounted next, with the exception of the 7µF 250VAC dump capacitor. Note that the electrolytic capacitors must be oriented with the correct polarity.

Be sure to orient the two ICs correctly when installing them and also be careful to put each one in the correct position.

Since they are both 8-pin ICs it is quite easy to put them in the wrong position – they don't work if you do that!

Then insert the two transistors, Mosfet and Triac and trimpot VR1. The fuse clips can be installed and are best mounted with the fuse clipped in place before soldering. Otherwise you might solder the clips in back-to-front and their lugs will stop you putting the fuse in.

The 7µF capacitor is mounted and held in place with two cable ties wrapped around its body and through the PC board. Attach the two wires to the terminals on the PC board as shown.

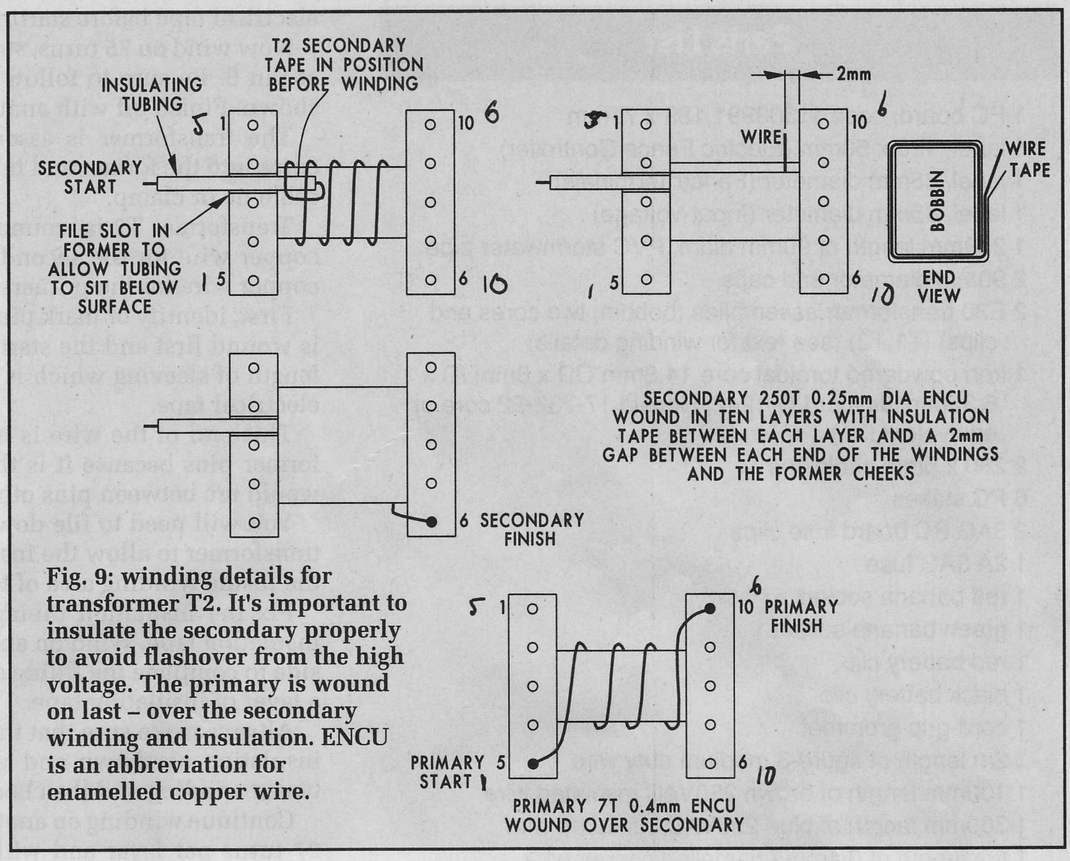



**Fig. 9: winding details for transformer T2. It's important to insulate the secondary properly to avoid flashover from the high voltage. The primary is wound on last – over the secondary winding and insulation. ENCU is an abbreviation for enamelled copper wire.**

By the way, depending on where you buy your kit or the parts, the dump capacitor may be 6.5µF or 7µF 250VAC.

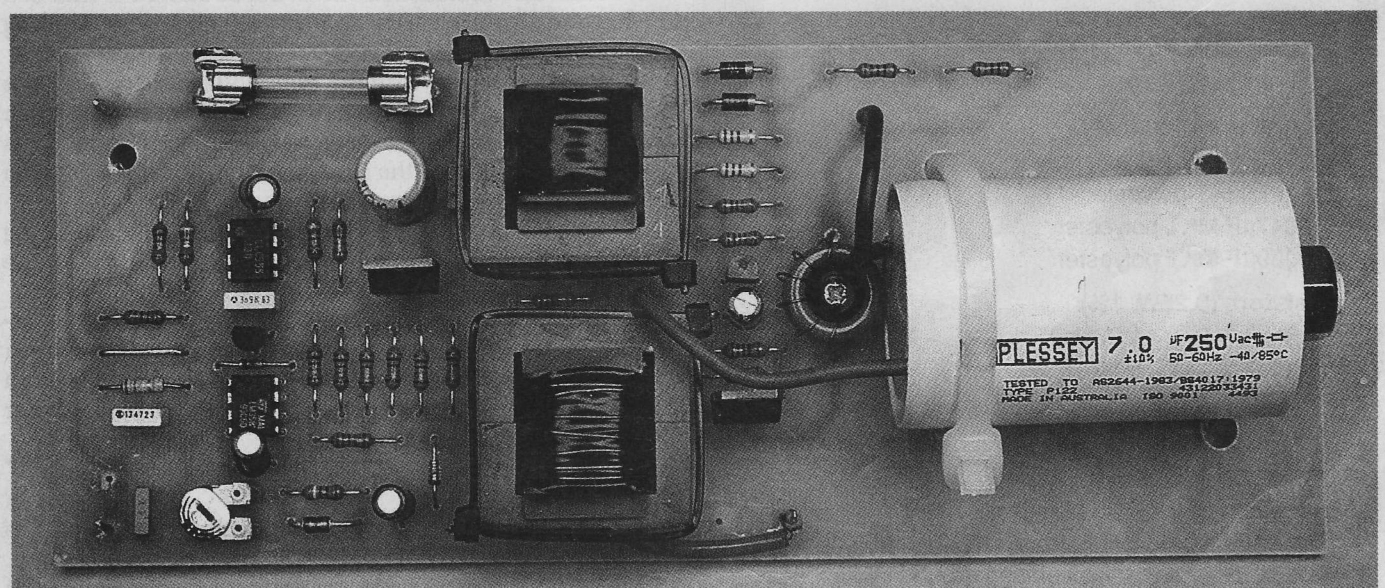
## Winding the transformers

Transformer T1 is wound using 0.4mm enamelled copper wire. Fig.8 shows the winding details.

Start by locating pin 1 on the coil former. If the former is not marked then use a pencil to label pin 1 yourself, as shown on Fig.7.

Now strip the enamel insulation off the end of the 0.4mm wire and solder the wire onto pin 1. Wind on 25 turns in the direction shown and terminate the end on pin 10, after stripping off the enamel insulation.

Insulate the winding with a layer of




**This view of the completed PC board is not far off full size, so your board should look very similar! Note the missing cable tie around the 7µF capacitor – this was removed and an additional hole drilled (top left) to allow mounting in an alternative case. For stability the second cable tie should be used, even if this means drilling new holes in the PC board.**

## Parts List

1 PC board, code 11303991,189 x 77mm
1 label, 125 x 50mm (Electric Fence Controller)
1 label, 85mm diameter (Fence Terminals)
1 label, 85mm diameter (Input Voltage)
1 250mm length of 90mm diam. PVC stormwater pipe
2 90mm diameter end caps
2 E30 transformer assemblies (bobbin, two cores and clips) (T1,T2) (see text for winding details)
1 iron powdered toroidal core 14.8mm OD x 8mm ID x 6.35mm, Jaycar LO-1242, Neosid 17-732-22 core or equivalent (L1)
2 280 x 5mm cable ties
6 PC stakes
2 3AG PC board fuse clips
1 2A 3AG fuse
1 red banana socket
1 green banana socket
1 red battery clip
1 black battery clip
1 cord-grip grommet
1 2m length of figure-8 medium duty wire
1 100mm length of brown 250VAC insulated wire
1 300mm length of blue 250VAC insulated wire
1 8m length of 0.4mm enamelled copper wire
1 15m length of 0.25mm enamelled copper wire

**Semiconductors**
1 7555, LMC555CN CMOS timer (IC1)
1 LM358 dual op amp (IC2)
1 IRF820 500V 3A or P6N60E 600V 6A Mosfet (Q1)
1 BTA10-600 Triac (Triac1)
2 BC337 NPN transistors (Q1,Q2)
2 1N4936 500V 1A fast diodes (D1,D2)
1 4.7V 1W zener diode (ZD1)
2 1N914, 1N4148 switching diodes (D3,D4)

**Capacitors**
1 470μF 16VW PC electrolytic
3 10μF PC electrolytic
1 6.5μF or 7μF 250VAC
1 2.2μF 16VW PC electrolytic
2 0.1μF MKT polyester
1 .0047μF MKT polyester
1 .0039μF MKT polyester

**Resistors** (0.25W, 1%)

| | | |
|---|---|---|
| 2 1.5MΩ | 1 270kΩ | 1 150kΩ |
| 4 100kΩ | 5 10kΩ | 1 6.8kΩ |
| 1 4.7kΩ | 1 2.2kΩ | 1 1kΩ |
| 1 390Ω | 2 220Ω | 1 100Ω |
| 1 47Ω | | |

**Miscellaneous**
1 12V 2.4Ah or larger battery; 2 clamps for 90mm conduit; 1-3 2m long galvanised ground stakes; self-insulated timber posts or steel posts and insulators; fence tape, etc.

electrical tape before starting on the secondary.

Now wind on 75 turns, starting at pin 5 and finishing at pin 6. Be sure to follow the winding directions as shown. Finish off with another layer of electrical tape.

The transformer is assembled by sliding the two cores into the former and holding them together with a cable tie or clamp.

Transformer T2 is wound using 0.25mm enamelled copper wire for the secondary and 0.4mm enamelled copper wire for the primary. Fig.9 shows the details.

First, identify or mark pin 1. The secondary winding is wound first and the start is insulated with a 50mm length of sleeving which is held onto the bobbin with electrical tape.

This end of the wire is not connected to the transformer pins because it is the high tension end and it would arc between pins otherwise.

You will need to file down the cheek section of the transformer to allow the insulating tubing to sit flat on the inside winding area of the bobbin.

Fix the insulation tubing in place as shown with insulation tape. Wind on about 10-turns neatly side by side to complete the filling of the first layer. Cover it in a layer of insulation tape.

Always make sure that the wire passes out from the insulation as shown and with a 2mm clearance between winding and the cheeks of the former.

Continue winding on another nine layers, with about 27 turns per layer and with insulation tape between each layer. Terminate the finish of the winding at pin 6.

We must emphasise that the insulation and placement of the winding in the 10 layers is most important, otherwise the transformer will suffer from flashover and ultimately, it won't work. Each layer must be insulated with a layer of electrical tape and be sure to start and end the tape at the top section of the bobbin rather than at the sides. The reason for this is to improve clearance between the windings and the ferrite cores which are slid in place after the windings are completed.

Note also that the wire must not be started or finished beyond a 2mm clearance gap at each end of the winding area in the former.

By comparison with the high voltage secondary, the primary winding is easy. Wind on 7 turns of 0.4mm enamelled copper wire between pins 5 and 10, as shown. Then slide the cores into the former and secure them with a cable tie or clips.

Insert and solder the transformers in place, making sure that they are oriented with pin 1 as shown on the diagram of Fig.7.

Inductor L1 is wound using 6 turns of 0.4mm enamelled copper wire and these are terminated as shown on the PC board. You can secure the toroid in place with a cable tie or with a 3mm screw, nut and plastic washer or a small rubber grommet.

## Warning

Before applying power and commencing to test the unit, please heed the warning earlier in this article. Contrary to what you might think, the primary side of the output transformer is in fact more dangerous than the high voltage secondary.

Of course, we would prefer not to get across either!

## Testing

Having warned you about the high voltages, we can talk about testing the circuit.

The first step is to wind trimpot VR1 fully anticlockwise. Then apply 12V to the circuit and check that there is 12V between pins 1 and 8 of IC1 and between pins 4 and 8 of IC2.

Switch off power. Temporarily tie pin 6 of IC2b to pin 8 with a 10kΩ resistor. This disables the pulse timer and means that IC1 operates continuously.

Connect a multimeter between ground and the cathode of diode D2 with the meter set to read 400V DC or more. Now switch on the power and adjust VR1 slowly until the meter reads 340V. Switch off and wait for the voltage across the dump capacitor to discharge to below 12V.

Disconnect the 10kΩ resistor between pins 6 & 8 of IC2. We are now almost ready for the high voltage check and this should be a mere formality if you have been successful to this point.

## High voltage check

Don't reapply the power just yet. Instead connect a piece of tinned copper wire between the high voltage terminals on the PC board, ie, between terminals A & B.

Then cut the wire with your side cutters and bend the cut wires slightly apart so that you have a spark gap about 5mm wide.

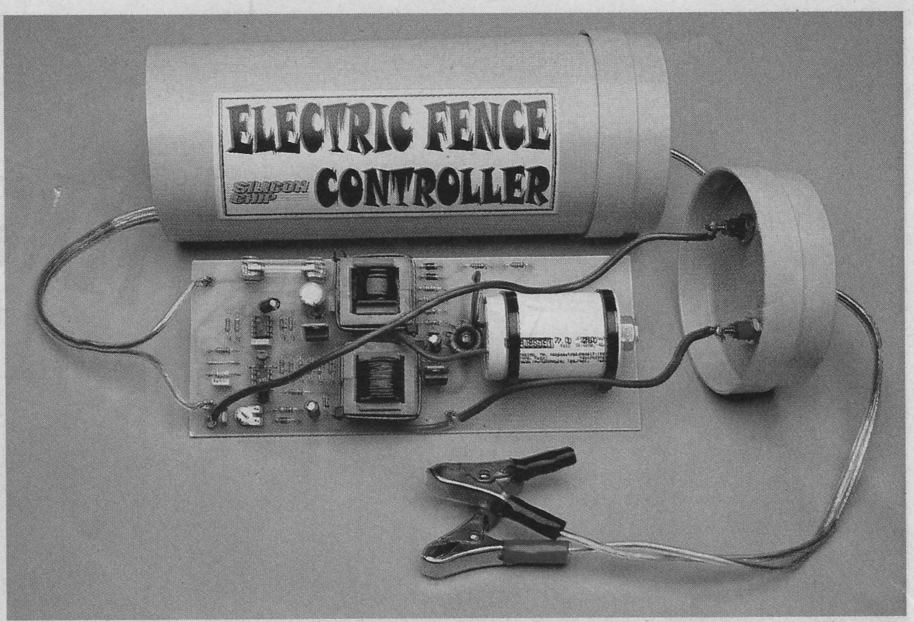
Now apply 12V to the circuit again and you should get a healthy spark every 1.5 seconds.

## Final assembly

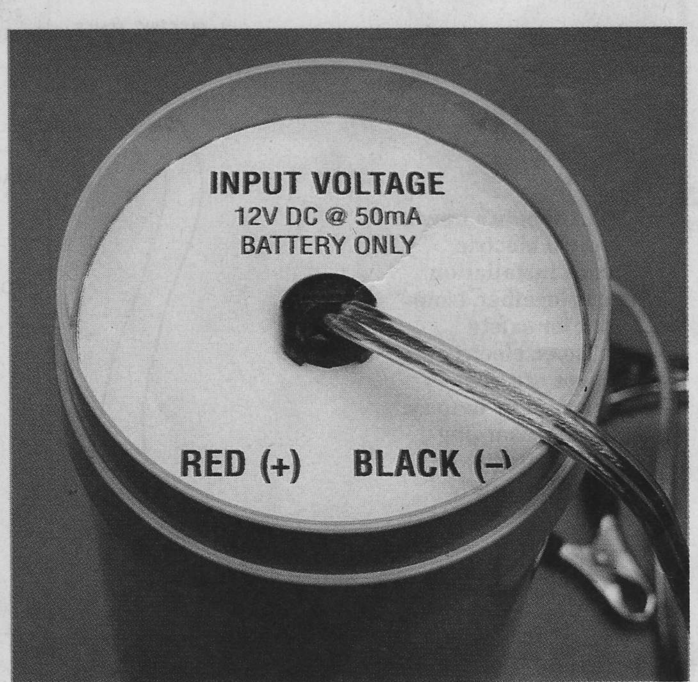
While we built our prototype Electric Fence Controller into a length of 90mm plastic stormwater pipe, an alternative approach would be to house the PC board in a sealed plastic weatherproof box such as one sold by Dick Smith Electronics with catalog number H-2865. Measuring 146 x 222 x 55mm, this box has plenty of room for the PC board and the lid is fitted with neoprene gasket to ensure a water-tight seal.

We understand that this box will be included in the Dick Smith Electronics kit for this project.

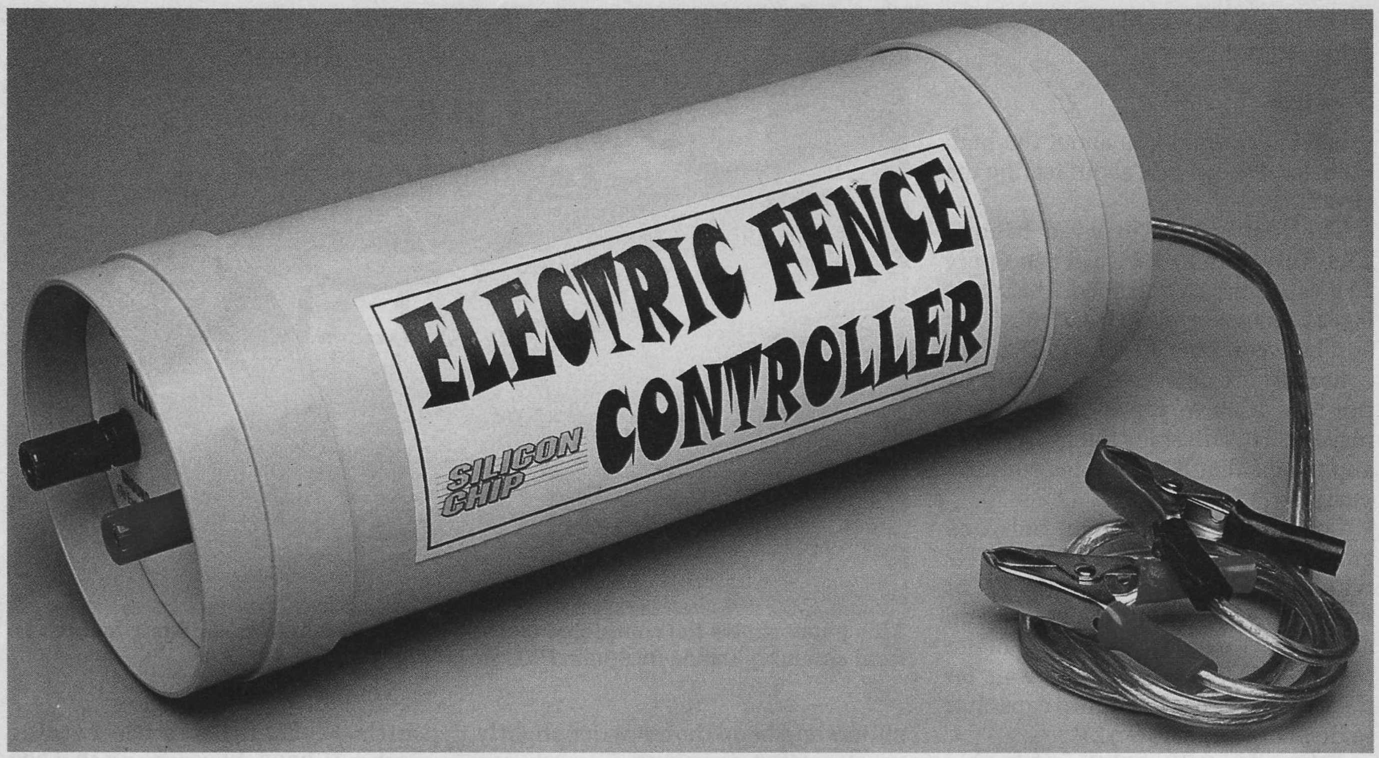
We have designed a number of labels for the Controller. As with the PC board pattern, they can be downloaded from the SILICON CHIP website, www.siliconchip.com.au




**This photo shows the completed electric fence controller immediately before final assembly inside its 90mm PVC stormwater pipe "case".**


**The two end caps in position, complete with labels. If used out in the open (ie without covering) it would be a good idea to apply some silicone sealant inside the cap to waterproof the terminals and (especially) the power cable hole.**




**Finally, the completed controller. The caps are a push fit on the 90mm PVC pipe and are quite watertight. The label at the battery end states red and black for +12V and 0V: this of course refers to the colour of the battery clips, not the wire! Incidentally, if you don't like the pretty pink pipe and groovy grey caps, they're also available in boring old white.**

The first measures 125 x 50mm and has the words "Electric Fence Controller". This can be glued to the pipe itself, as shown in our photos. There are also two 85mm diameter labels, one of which fits inside each end cap. One is labelled "Fence Terminals" and the other is "Input Voltage".

When these are fitted to the end caps, you can drill the two holes for the fence terminals and cut out the hole for the cord grip grommet in the

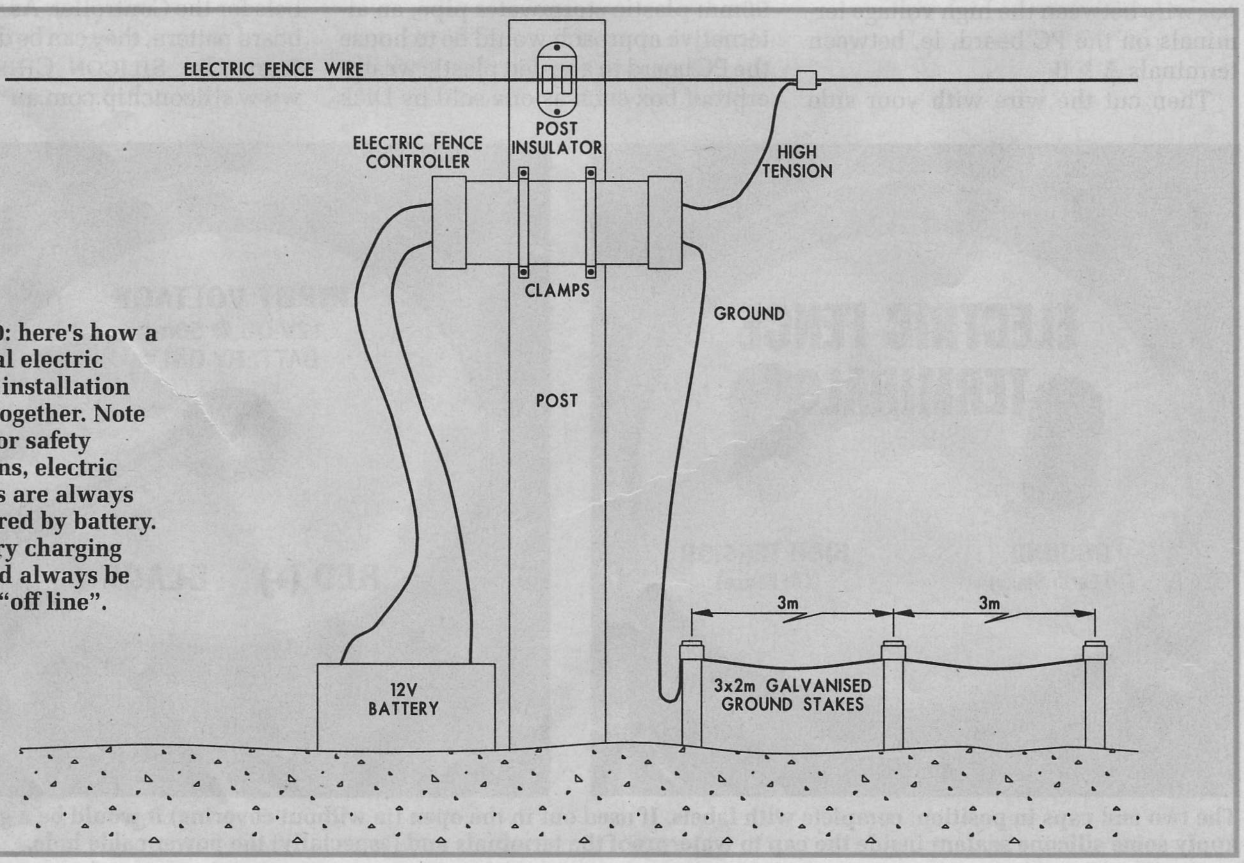



**Fig.10: here's how a typical electric fence installation goes together. Note that for safety reasons, electric fences are always powered by battery. Battery charging should always be done "off line".**

other end cap. Attach the terminals and connect and solder the earth lead and the high tension lead.

Solder a length of figure-8 cable to the 12V input PC stakes on the PC board. Feed the end of the cable through the stormwater pipe and the hole in the end cap and then place the assembled PC board into the tube.

The figure-8 cable is anchored in the end cap using the cord grip grommet. Both end caps can then be fitted onto the tube. To stop the board rattling inside the tube, you can wrap it in some foam rubber or bubble-wrap.

Attach the battery clips to the figure-8 cable, using red for positive and black for negative. Don't get these back-to-front otherwise you will blow the fuse. Then give the system another test, with the spark gap wires still across the output terminals.

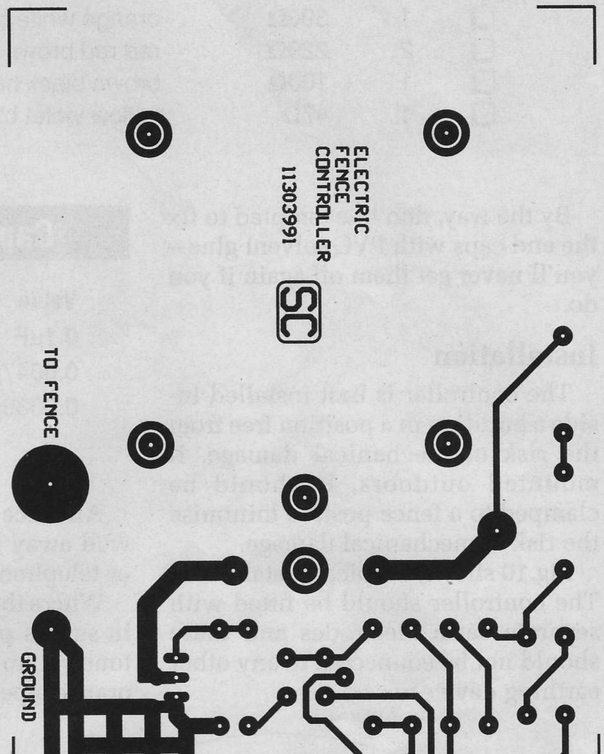
Does it still give a nice, juicy spark? Yep? Good. Now you can remove the spark gap wires before final assembly (the fence won't operate satisfactorily with the spark gap left in place).

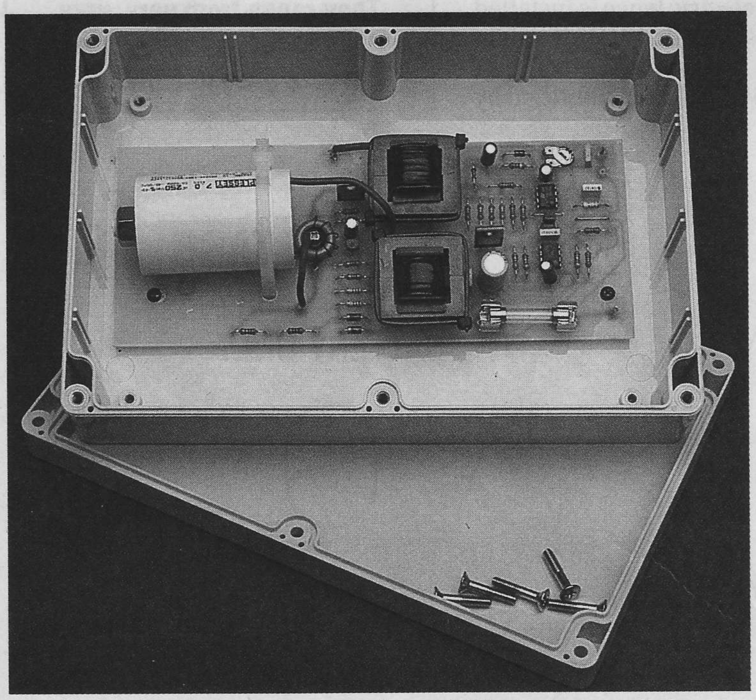
Use some silicone sealant to waterproof all joints around the end caps and wire entry point.


**Above: the label we prepared for the electric fence. It was glued onto the PVC pipe with spray adhesive.**

**Right: the full-size PC board pattern for those who wish to make their own. You can also use this to check commercial boards for etching defects.**

**All three labels and the PC board pattern are available for downloading from the SILICON CHIP website, www.siliconchip.com.au**



**An alternative mounting approach would be to use a sealed weatherproof case such as this one from Dick Smith Electronics. As luck would have it, the holes for one of the capacitor-holding cable ties line up perfectly with the mounting points moulded into the case. For security, another cable tie should probably be used, necessitating a new pair of holes drilled in the PC board.**

## Resistor Colour Codes

| | No. | Value | 4-Band Code (1%) | 5-Band Code (1%) |
|---|---|---|---|---|
| ❑ | 2 | 1.5MΩ | brown green green brown | brown green black yellow brown |
| ❑ | 1 | 270kΩ | red violet yellow brown | red violet black orange brown |
| ❑ | 1 | 150kΩ | brown green yellow brown | brown green black orange brown |
| ❑ | 4 | 100kΩ | brown black yellow brown | brown black black orange brown |
| ❑ | 5 | 10kΩ | brown black orange brown | brown black black red brown |
| ❑ | 1 | 6.8kΩ | blue grey red brown | blue grey black brown brown |
| ❑ | 1 | 4.7kΩ | yellow violet red brown | yellow violet black brown brown |
| ❑ | 3 | 2.2kΩ | red red red brown | red red black brown brown |
| ❑ | 1 | 1kΩ | brown black red brown | brown black black brown brown |
| ❑ | 1 | 390Ω | orange white brown brown | orange white black black brown |
| ❑ | 2 | 220Ω | red red brown brown | red red black black brown |
| ❑ | 1 | 100Ω | brown black brown brown | brown black black black brown |
| ❑ | 1 | 47Ω | yellow violet black brown | yellow violet black gold brown |

By the way, don't be tempted to fix the end caps with PVC solvent glue – you'll never get them off again if you do.

### Installation

The controller is best installed inside a building in a position free from the risk of mechanical damage. If mounted outdoors, it should be clamped to a fence post, to minimise the risk of mechanical damage.

Fig.10 shows a typical installation. The controller should be fitted with separate earth electrodes and these should not be connected to any other earthing device.

## Capacitor Codes

| Value | EIA | IEC |
|---|---|---|
| 0.1µF | 104 | 100n |
| 0.0047µF | 472 | 4n7 |
| 0.0039µF | 392 | 3n9 |

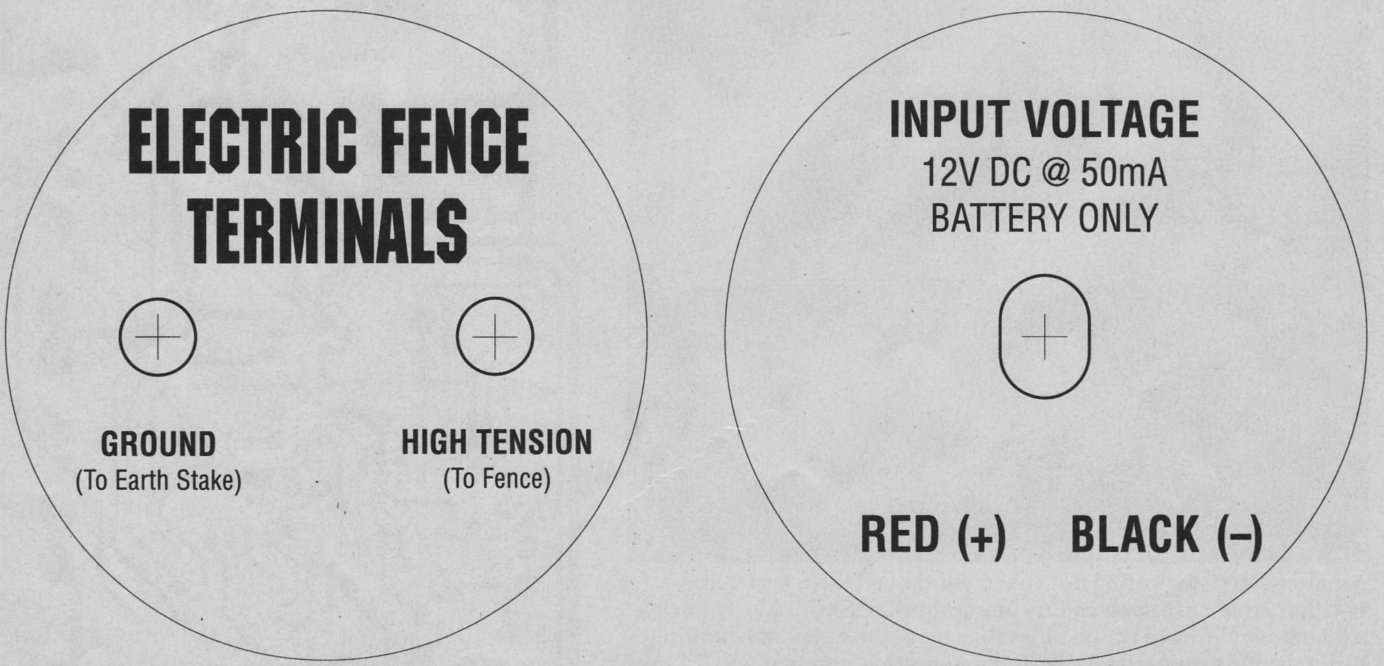
All fence wiring should be installed well away from any overhead power or telephone lines or radio aerials.

Where the electric fence is installed in such a position that people might touch it and it is not using white or orange tape, it should be identified by suitable signs clamped to the wire or fastened to the posts at intervals not exceeding 90m.

Such signs should bear the words "ELECTRIC FENCE" in block letters no less than 50mm high. **SC**

**COMING NEXT MONTH**

**We have developed a number of testers to check the output from this, or any other electric fence. They range from very, very simple to very simple – and all are easy to build.**




**The two end labels, designed to fit inside a standard 90mm PVC (stormwater) pipe end cap. These labels can be photocopied or the originals downloaded from the SILICON CHIP website, www.siliconchip.com.au**