Low-power design also works as a battery charger

12/240V inverter for small appliances

This 12/240V inverter can be used to power mains appliances rated up to 40W, or to vary the speed of a turntable. As a bonus, it will also work backwards as a trickle charger to top up the battery when the power is on.

by JEFF SKEEN

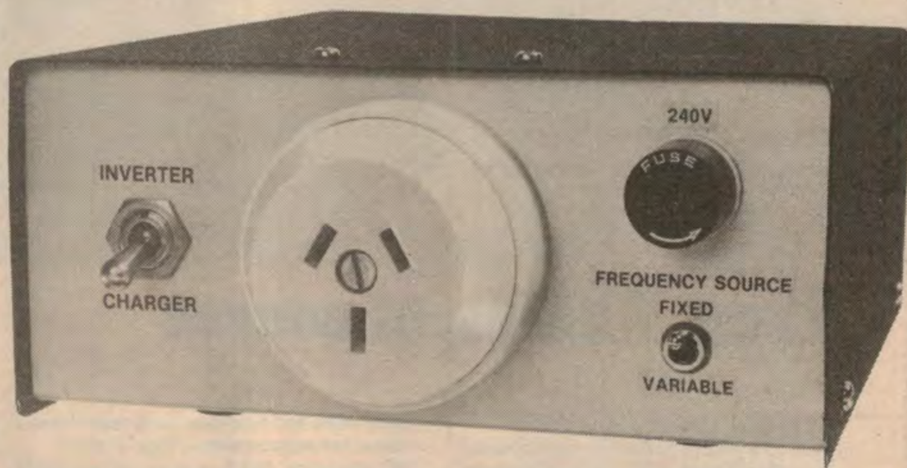
How do you operate a turntable in a caravan, or an electric shaver when you're in the bush? Our new 12/240V Inverter will let you do both things. It should prove particularly handy as a fixed frequency source for small appliances (including turntables) in recreational vehicles, or as a variable frequency source for a belt or idler-driven (but not direct-drive) turntable so that pitch and tempo of the music can be adjusted.

If you're roughing it in the bush, you need only have access to a 12V car battery to power a mains-operated "stubble grinder" – that is if you are uncivilised enough to use an electric shaver! We should point out, however, that this unit will not operate a fluorescent tube since the output is incapable of generating sufficient starting voltage.

Finally, back in civilisation, you can use the 12/240V inverter as an emergency battery charger or simply to top up the battery when power is available.

A transistor inverter can be either self-oscillating or driven. However, the low cost and relative compactness of a self-excited inverter are outweighed by two disadvantages: both frequency and output voltage are notoriously variable with changes in supply voltage and load. In addition, the transformer used in a self-excited inverter has to meet close specifications on leakage inductance, mutual inductance and winding resistance if the operating frequency is to stay within the design limits.

In a driven inverter, on the other hand, these problems are eliminated. The design presented here actually contains two separate oscillators: a crystal-locked oscillator giving a precise 50Hz output, and a variable RC oscillator with a nominal output frequency of 50Hz. Either of these oscillators may be selected to drive the inverter by means of a front panel switch.



View of the completed prototype, housed in a standard metal case. It can power appliances rated up to 40W, or can work backwards as a trickle charger.

How it works

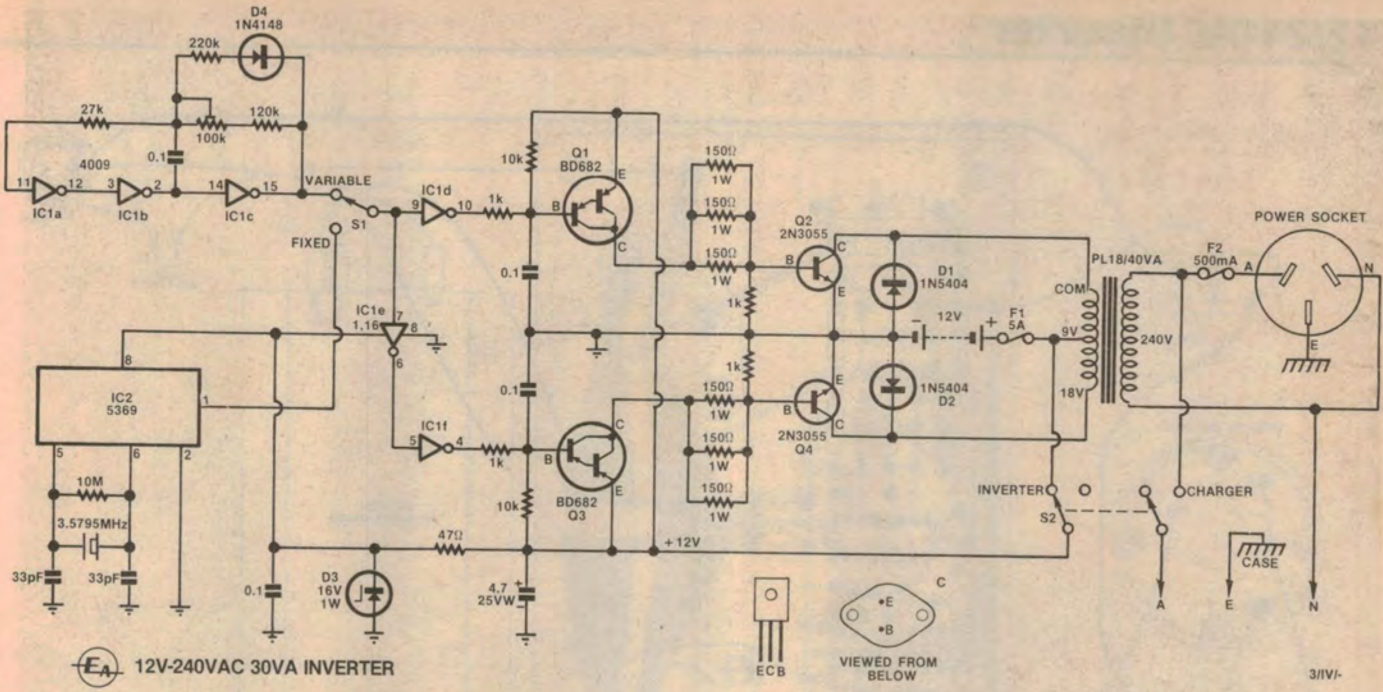
Four transistors and two integrated circuits form the heart of the design. Essentially, two antiphase signals are derived from either the fixed or variable frequency timebase and used to drive a transistor output stage. This in turn drives a transformer with a centre-tapped winding, which is used in the step-up mode rather than the normal step-down mode.

In more detail, gates IC1a, b, c form a standard three-inverter CMOS oscillator with a nominal output frequency of 50Hz. In practice, the output frequency can be varied over a small range – 44-58Hz on the prototype – by means of a 100kΩ trimpot. The 1N4148 diode and series 220kΩ resistor in the feedback path ensure a 50% duty cycle, and thus maximum efficiency of the inverter.

IC2, an MM5369EYRN CMOS mask programmable divider, provides the fixed frequency reference. It works in conjunction with an American standard colour TV subcarrier crystal operating at 3.5795MHz, and divides this frequency down to give a 50Hz output. This is a very economical method of obtaining an accurate 50Hz timebase since both the 5369 and the 3.5795MHz crystal are quite cheap.

However, there is one minor drawback in this application – the output of the 5369 has a 45%/55% duty cycle. While this ultimately results in some loss of efficiency, it is by no means serious enough to warrant a more expensive timebase.

Switch S1 selects between the outputs of the two oscillators and passes the signal to inverters IC1d and IC1e. IC1d, IC1e and IC1f buffer and invert the selected oscillator output to give two signals, 180° out of phase, as pins 4 and 10. These signals are then fed via 1kΩ current limiting resistors to PNP Darlington transistors Q1 and Q3. Thus,



The circuit consists of two switch-selectable oscillators driving a power amplifier stage and a step-up transformer.

when Q1 is on, Q3 is off and vice versa.

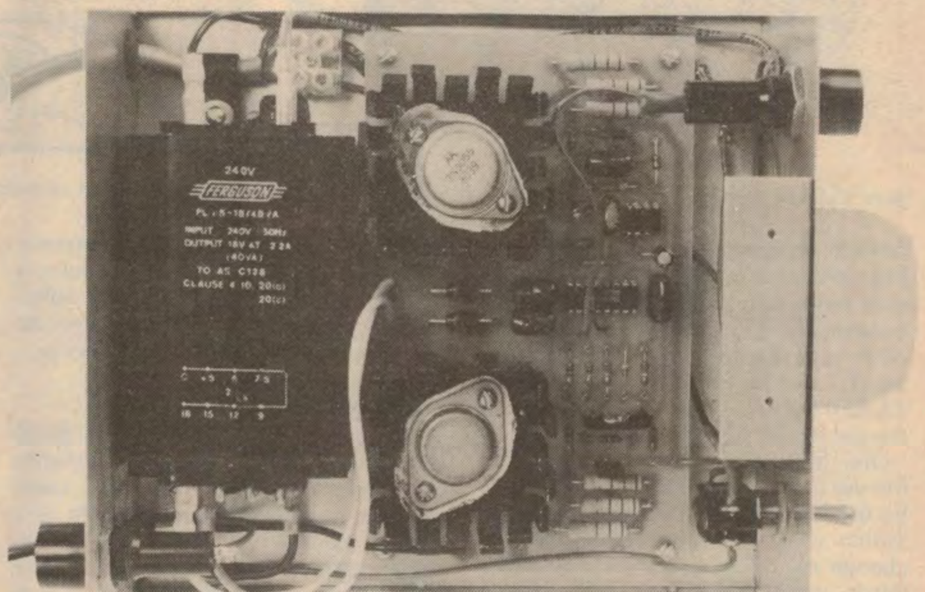
Note the 0.1μF capacitors connected to the bases of the BD682 Darlington transistors. These slow the switching times of the Darlingtons to produce a degree of waveform rounding to reduce switching spikes in the output of the inverter. The 10kΩ pullup resistors ensure that the BD682 transistors are fully cut-off when the outputs of IC1d and IC1f go high.

The output transistors (Q2 and Q4) are 2N3055 types, one for each phase, and are connected across the transformer primary. Base drive current to the 2N3055s is limited by a parallel combination of three 150Ω 1W resistors to about 200mA to ensure low saturation voltages in Q2 and Q4 at maximum load. The 1kΩ resistors pull the bases to ground potential to ensure cut-off of the 2N3055s when the BD682s are cut-off.

How does the transformer itself work? Consider Q2 turned on. This pulls Q2's collector low and applies approximately 12V to half of the transformer primary. By transformer action, 12V appears across the other half of the winding so that the collector of Q4 has +24V applied to it. Similarly, when Q4 turns on and Q2 is off, Q2 has +24V applied to its collector.

Thus the whole transformer primary has a 50Hz square wave applied to it, ie. +24V peak in one direction and then the other, in a push-pull mode. Therefore, the voltage applied to the whole transformer primary is about 24V RMS. The transformer then steps this waveform up in the secondary to provide a nominal 240V RMS (after losses).

Diodes D1 and D2 protect the output



Be sure to use a metal case, and keep all mains wiring neat and tidy. There is no need to isolate the transistor cases from the heatsinks.

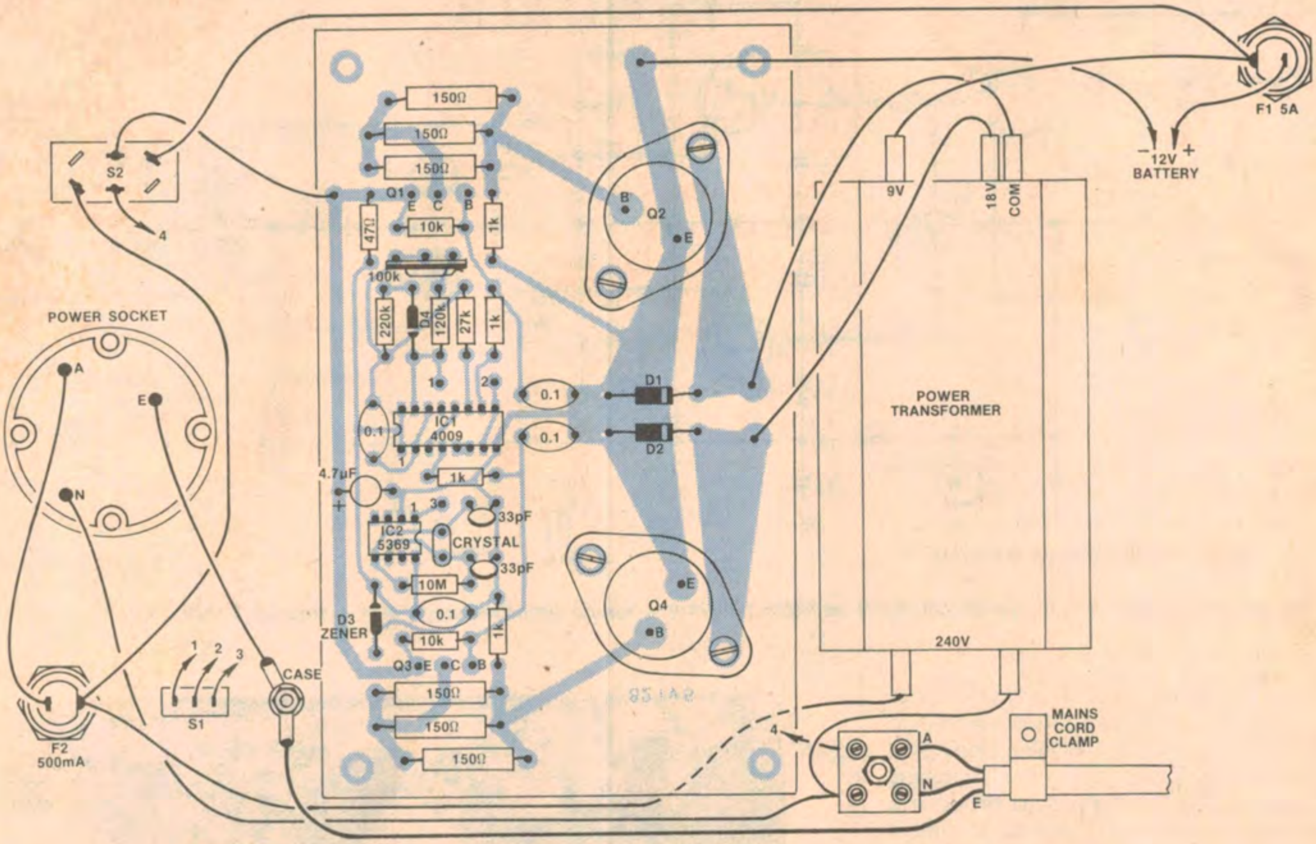
SPECIFICATIONS

INVERTER MODE

No load output voltage: 275V AC (approx) at 12.25V input.
No load input current: 700mA at 12.25V input.
Output voltage with resistive load: see graph.

CHARGER MODE

Charging current: 600mA (maximum).
Charging voltage (no load): 15V peak.



Note that the connection details to switch S2 may vary according to the type of switch supplied.

transistors against reactive currents flowing in the transformer windings, and provide protection against reversed battery connection. If the battery is accidentally connected the wrong way round, D1 and D2 will be forward biased and the 5A fuse will blow. No further damage to the circuit will occur.

One further advantage accrues from the use of D1 and D2: the circuit can also be used in reverse as a battery charger! Switch S2 selects either the inverter or charger modes of operation and, in the latter case, connects the output transformer to the mains in the conventional manner. Diodes D1 and D2 full-wave rectify the transformer output to provide a no load voltage of approximately 15V peak.

The charging current is approximately 0.6A maximum – sufficient to trickle charge a partially flat battery when a mains supply is available.

Power for the inverter circuitry is derived directly from the 12V battery. A 47Ω resistor, a 4.7µF capacitor and a 0.1µF capacitor decouple the supply line to the CMOS ICs, while a 16V zener diode clips any voltage spikes that could otherwise damage the ICS.

For applications where the frequency of the 240V supply is non-critical, the 5369 and associated circuitry can be omitted for a saving of approximately $9. If the frequency of the RC oscillator is to remain fixed at approximately 50Hz, the trimpot and series 120kΩ resistor can be replaced by a single 150kΩ resistor.

Construction

A single printed circuit board (PCB) coded 82iv5 and measuring 146 x 90mm accommodates most of the components. Using the wiring diagram as a guide, commence construction by soldering the various components to the PCB. Check your work carefully as you go, and make sure that all polarised components (transistors, diodes, ICs and the electrolytic capacitor) are soldered in the right way round.

The two CMOS ICs and the 2N3055 output transistors should be left till last. Observe the usual precautions when soldering the CMOS ICs: connect the barrel of your soldering iron to the earth track on the PCB using a small clip lead, and solder the supply pins first. The supply pins are pins 8 and 16 for the 4009, and pins 2 and 8 for the 5369.

The 2N3055 transistors are mounted on TO-3 "Powerfin" heatsinks measuring 50mm square by 25mm high. Smear the underside of the transistors with thermal grease, then bolt the transistors and heatsink assemblies to the PCB using machine screws and nuts. There is no need to electrically isolate the transistors from the heatsinks, but don't forget to solder the transistor leads on the underside of the PCB.

Once the PCB assembly has been completed, you can start fitting the hardware to the case. The case we used measures 160 x 184 x 70mm and consists of an aluminium base fitted with a steel lid.

Temporarily position the various items inside the case and mark and drill mounting holes for the PCB, transformer, mains terminal block and solder lug. You will also have to drill holes for the mains socket, the two front panel switches, the front and rear panel fuses, and entry holes for the mains cable and the battery leads. Deburr all holes with a large drill.

This done, mount the various items of hardware in the case and complete the wiring according to the wiring diagram. The mains cord enters through a grom-

We estimate that the current cost of components for this project is

$55

This includes sales tax.

"Horizontal jitter, my eye! I'm calling the vet!" (Radio-Electronics).

meted hole on the rear of the chassis and must be securely clamped. Terminate the active (brown) and neutral (blue) leads in the insulated terminal block, and solder the earth lead (green or green/yellow) to the solder lug bolted to the case.

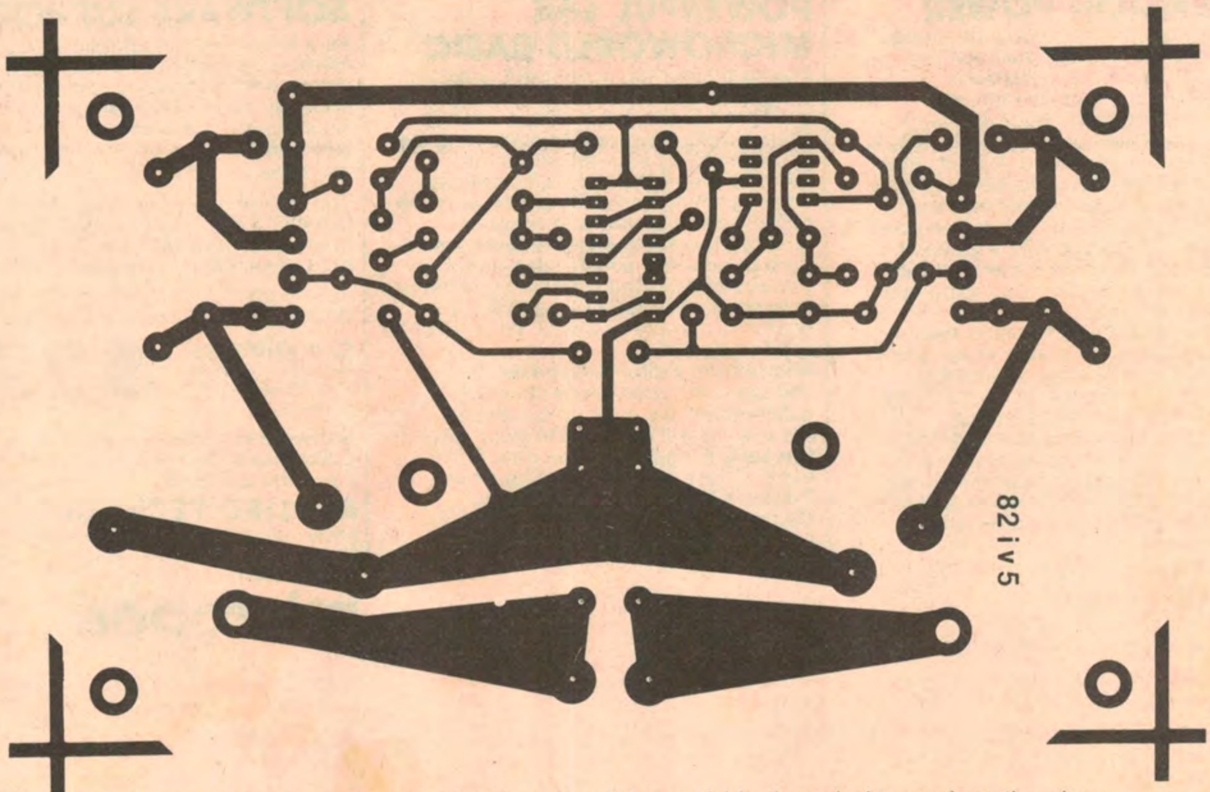
Note that all wiring, with the exception of the wiring to switch S1, should be mains rated. Cover any exposed switch or fuse terminals at mains potential with insulating tape, and don't forget to fit rubber grommets to the entry holes for the battery leads and mains socket wiring. The battery leads (red for positive, black for negative) are secured by wrapping them in insulating tape and using a suitable clamp fashioned from scrap aluminium.

The PCB is mounted using 9mm tapped brass spacers and machine screws. It must be positioned carefully in the case so that the T0-3 heatsinks do not short to the transformer frame or so that it does not foul the front panel switches. You should also check to ensure that the 2N3055 mounting screws do not short against the bottom of the case.

Because the case is made of only light gauge aluminium, additional support must be provided for the front panel so that it does not bend when you push a plug into the socket. We solved the problem by means of an L-shaped aluminium bracket as shown in the photographs. This is secured to the front panel using the same screws and nuts that support the mains socket, and is subsequently fastened to the lid of the case using self-tapping screws.

Ignore, for the moment, the urge to "hook 'er up and try 'er out"! Before so doing, go back over the project and check carefully for wiring errors. In particular, you should check the action of switch S2 with a multimeter, as the wiring details may vary according to the switch type.

Assuming that all is well, connect up a 12V battery and check that the voltage



Actual size reproduction of the PC pattern. Finished boards will be available through the usual retail outlets.

PARTS LIST

1 printed circuit board, code 82iv5, 145 x 89mm
1 metal case, 160 x 184 x 70mm
1 PL18/40VA low profile transformer
1 2-way insulated mains terminal block
4 9mm tapped brass spacers
1 mains cord and plug
2 car battery clips
5 rubber grommets (4 small, 1 large)
1 mains cable clamp
1 small clamp (to secure battery leads)
2 fuseholders, type 3AG panel mount
1 5A fuse, 3AG
1 0.5A fuse, 3AG
1 surface-mounting mains socket
1 SPDT switch
1 DPDT 5A, 240VAC switch
1 solder lug
1 metre black, 240VAC rated hook-up wire
2 metres red, 240VAC rated hook-up wire
1 10cm length, green, 240VAC rated hook-up wire
1 10cm length, 3-way rainbow cable
2 TO-3 heatsinks, 50 x 50 x 25mm
1 piece scrap aluminium, 65 x 60 x 1mm
2 small self-tapping screws

SEMICONDUCTORS
2 2N3055 NPN transistors
2 BD682 PNP Darlington transistors
2 1N5404 diodes
1 1N4148 diode
1 16V 1W zener diode
1 4009 hex inverter
1 5369EYRN oscillator divider with 50Hz output (available from Dick Smith Electronics)

CAPACITORS
1 4.7μF 25VW electrolytic
4 0.1μF greencaps
2 33pF ceramic

RESISTORS
(¼W, 5% unless stated)
1 x 10MΩ 10%, 1 x 220kΩ, 1 x 120kΩ, 1 x 27kΩ, 2 x 10kΩ, 4 x 1kΩ, 6 x 150Ω 1W, 1 x 47Ω, 1 x 100kΩ large trimpot

MISCELLANEOUS
Machine screws and nuts, washers, solder, etc.

across the primary of the transformer (ie, between the collectors of Q2 and Q4) is approximately 24V AC. Next measure the voltage across the secondary (240V side) of the transformer. You should get a reading of approximately 275V AC unloaded.

Note: exercise extreme care when measuring these voltages. An electric shock could be fatal!

If everything is operating normally, the heatsinks on the 2N3055 transistors will run slightly warm to the touch. If, however, one heatsink becomes quite hot while the other stays cold, the selected oscillator is probably not working.

As a final check, connect up your turntable, select the variable frequency oscillator, and check that the speed of the turntable can be varied by varying the 100kΩ trimpot. A conventional panel-mounting potentiometer can be used in place of the trimpot if frequent adjustment of the oscillator is required.

That's it! Next month we plan to describe a high-power 300VA inverter that can run lighting, colour TV sets and VCRs, stereos or other appliances in the absence of mains power. Given the power generating problems of the eastern states, it should prove a popular project.