Run your CD player from your car battery

12/240V inverter for portable CD players

Here's how to use your portable CD player in your car without having to rely on the limited capacity of rechargeable nicad batteries. This small 12/240V inverter has been specially designed to power portable CD players but can also be used for other mains powered devices which draw 15W or less.

by JOHN CLARKE

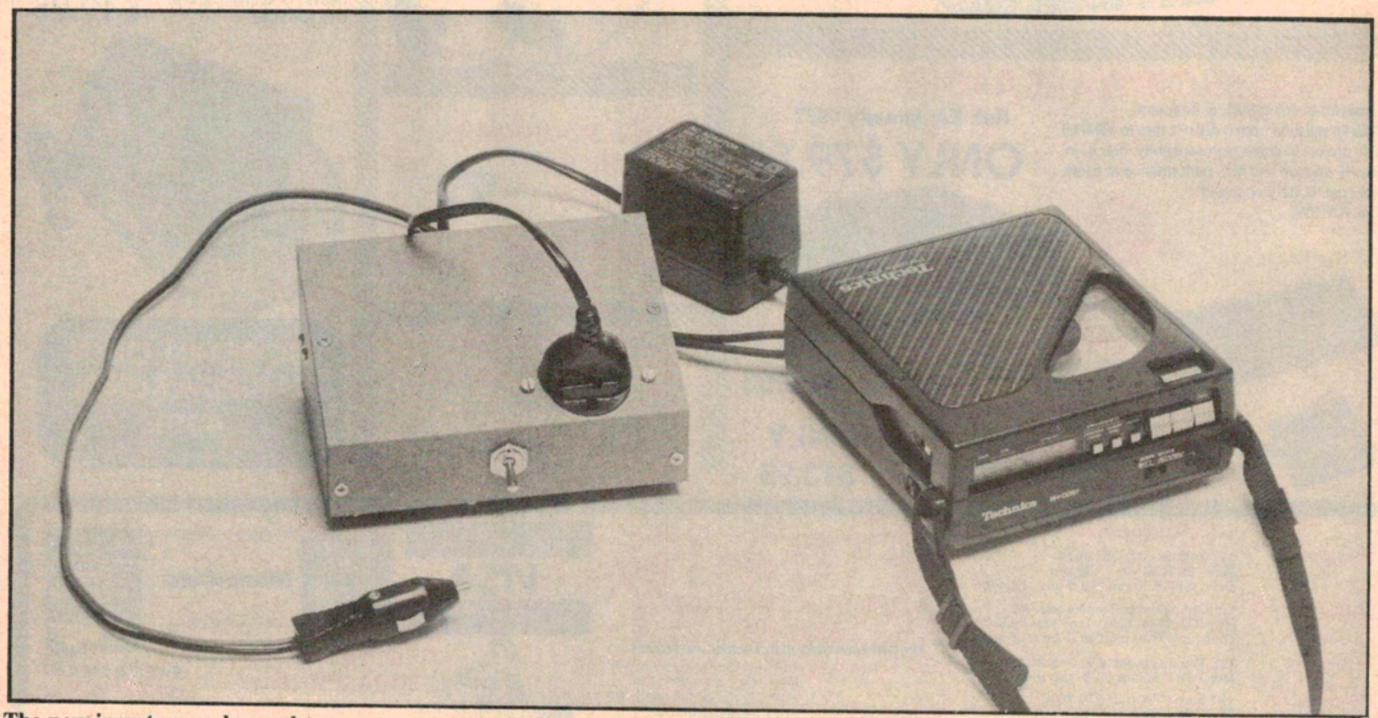
There is no denying it. Portable CD players are fantastic. They represent a mind-boggling concentration of high technology into a very small package. And even though their performance might not be up to the ultimate standards of conventional CD players, they are still streets ahead of any other hifi program source.

So it is not surprising that portable CD players are becoming so popular. They can be used virtually anywhere, on the run using headphones or at home, connected to the hifi system. However, their potential for use in the car has yet to be fully realised.

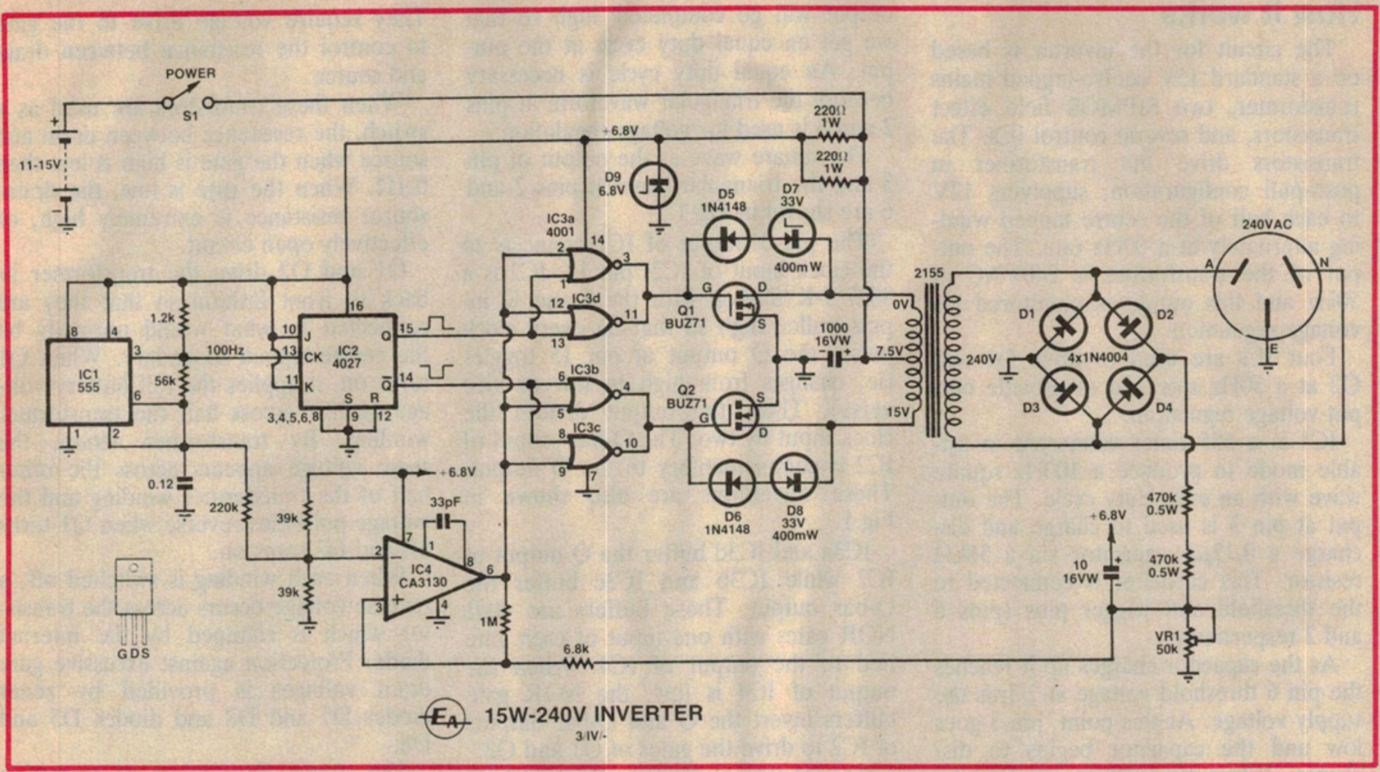
There are a number of problems in using a portable CD player in a car. First, unless you are a passenger, you can't use headphones. If you are the driver you could not even consider using headphones because you would be too isolated from the sounds of the road and surrounding traffic.

Second, there is the question of how you connect the CD player into your car's existing sound system. Unless they are new models, most systems make no provision for portable CD players. In the near future, more and more radio/cassette players will be fitted with jacks for connection of CD players.

Although the player can be operated using the internal rechargeable batteries of the CD player, it is far more practical to provide power via the car battery.



The new inverter can be used to power any portable CD player which has a plugpack adaptor and draws up to 15W.



The circuit employs field effect transistors Q1 and Q2 to drive a transformer in push-pull configuration. The output voltage is sampled and fed to IC4 which controls the "dead" time of each transistor during every half cycle.

This will provide unlimited playing time from the player.

Powering a CD player directly from the car battery is not as simple as it may appear. There are several safeguards necessary to ensure sound quality and to protect the CD player from the voltage transients common to a car electrical system.

First, the negative return of the DC supply should be isolated from the signal output ground to prevent the possibility of a current loop (ie, equivalent to an earth loop in an audio system). If this is not done, noise and distortion could well prove a problem. In addition, the DC supply to the player needs to be regulated and must incorporate transient suppression.

Some CD players are much more difficult than others to power from a car's electrical system. Whereas the Sony players need only a single 9V supply, others such as the Technics SLP-X7 require ±6V. This is very awkward as it requires the use of a DC-to-DC inverter. We could have designed such an inverter but then we had to face the fact that these players have a special DC power socket which would be hard to obtain.

12/240V AC inverter

Since all portable CD players are supplied with a 240VAC plugpack adaptor, we realised we could meet all the above problems with one solution — a 12V DC to 240VAC inverter circuit. The resulting inverter will power any portable CD player which has a plugpack AC adaptor and draws up to 15W. It will also run any other mains-powered appliance with a rated power consumption up to 15W.

Incidentally, we are indebted to Sean McCarthy of Swindon, UK for this project idea. Sean was a visitor to Australia during 1986.

As shown in the photographs, our new inverter is housed in a compact steel box with a sloping front panel. It has a mains socket mounted on the front lid and an on/off switch. A twin lead from the rear of the case is fitted with a plug which plugs into the car's cigarette lighter socket.

Alternatively, readers may wish to install the unit beneath the dash and permanently connect the unit to the vehicle 12V supply via the accessory fuse.

Although the inverter is only a low power unit, its line regulation is impressive. For an input voltage range of 11VDC to 15VDC, the output voltage changes from 240VAC to 249VAC. Load regulation at 12V input is equally impressive, changing from 242VAC at no load to 241VAC at 15W load.

The efficiency at full load (15W) is 82% with the current drain just on 1.5 amps DC. Standby current at no load is 120mA.

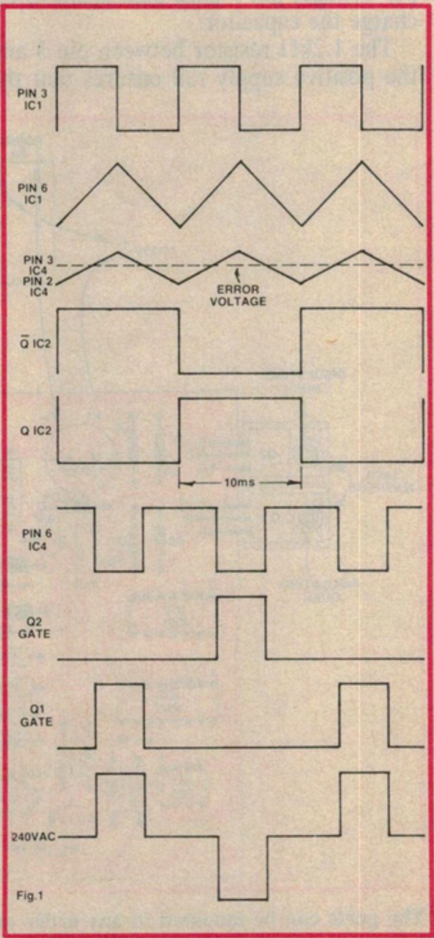


Fig.1: this diagram shows the waveforms at various points on the circuit.

How it works

The circuit for the inverter is based on a standard 15V centre-tapped mains transformer, two SIPMOS field effect transistors, and several control ICs. The transistors drive the transformer in push-pull configuration, supplying 12V to each half of the centre tapped winding alternately at a 50Hz rate. The output of the transformer is 240VAC at 50Hz and this output is monitored for voltage regulation.

Four ICs are used to drive Q1 and Q2 at a 50Hz rate and to provide output voltage regulation.

IC1 is a 555 timer connected in astable mode to produce a 100Hz square wave with an even duty cycle. The output at pin 3 is used to charge and discharge a 0.12μF capacitor via a 56kΩ resistor. This capacitor is connected to the threshold and trigger pins (pins 6 and 2 respectively).

As the capacitor charges up it reaches the pin 6 threshold voltage at 2/3rds the supply voltage. At this point, pin 3 goes low and the capacitor begins to discharge. When the voltage reaches the pin 2 trigger voltage at 1/3rd of the supply voltage, pin 3 goes high again to recharge the capacitor.

The 1.2kΩ resistor between pin 3 and the positive supply rail ensures that the output will go completely high so that we get an equal duty cycle at the output. An equal duty cycle is necessary because the triangular waveform at pins 2 and 6 is used for voltage regulation.

The square wave at the output of pin 3 and the triangular wave at pins 2 and 6 are shown in Fig.1.

The pin 3 output of IC1 connects to the clock input of IC2, pin 13. IC2 is a 4027 J-K flipflop with the J and K inputs pulled high so that on every clock pulse, the Q output at pin 15 toggles (ie, changes from high to low or vice versa). Thus, the output divides the clock input by two. The Q-bar output of IC2 is complementary to the Q output. These waveforms are also shown in Fig.1.

IC3a and IC3d buffer the Q output of IC2 while IC3b and IC3c buffer the Q-bar output. These buffers are 4001 NOR gates with one input of each gate tied to the output of IC4. When the output of IC4 is low, the NOR gate buffers invert the Q and Q-bar outputs of IC2 to drive the gates of Q1 and Q2.

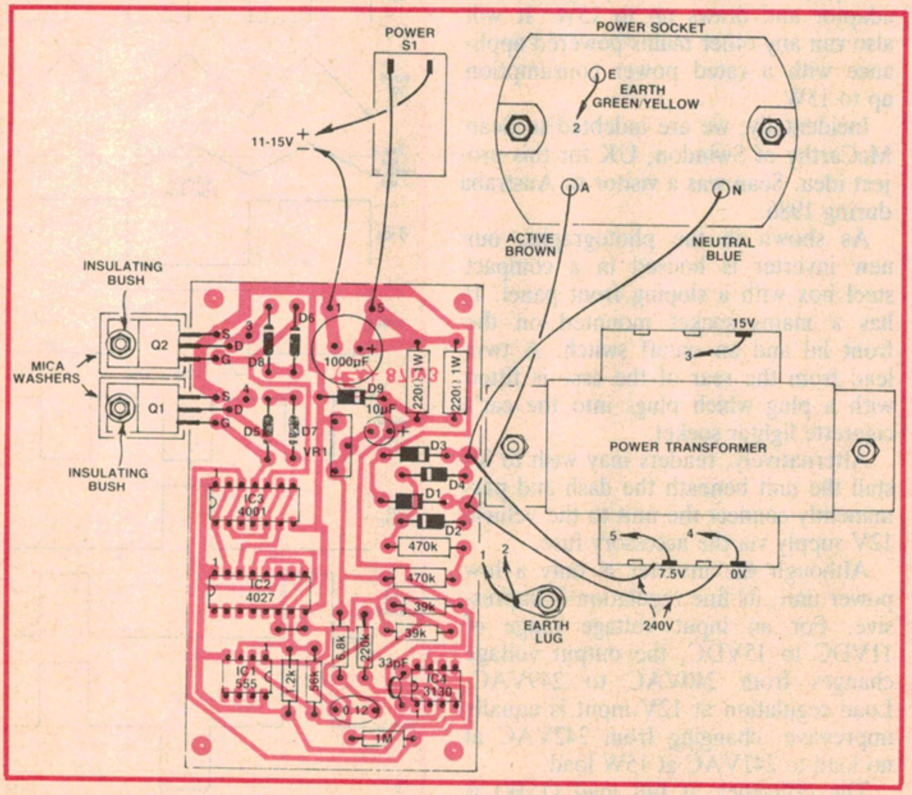
Q1 and Q2 are Siemens Power Metal Oxide Semiconductors, or SIPMOS for short. They can be regarded as conventional power field effect transistors with an integral reverse protection diode between the drain and source electrodes. They require voltage drive to the gate to control the resistance between drain and source.

When these transistors are used as a switch, the resistance between drain and source when the gate is high is less than 0.1Ω. When the gate is low, the drain-source resistance is extremely high, or effectively open circuit.

Q1 and Q2 drive the transformer in back to front fashion so that they are connected to what would normally be the centre-tapped secondary. When Q1 turns on, it applies the full battery voltage of 12V across half the transformer winding. By transformer action, the same voltage appears across the other half of the transformer winding and the voltage polarities reverse when Q1 turns off and Q2 turns on.

When each winding is switched off, a reverse voltage occurs across the transistor which is clamped by the internal diode. Protection against excessive gate drain voltages is provided by zener diodes D7 and D8 and diodes D5 and D6.

The above description of operation applies to a simple push-pull inverter but our circuit also has regulation. This is obtained by having a certain amount of "dead" time between Q1 turning off and Q2 turning on, and vice versa.



The parts can be mounted in any order on the PCB. Note that the metal tabs of the two transistors must be isolated from the metal case using mica washers and insulating bushes.

Regulation

A full wave rectifier consisting of diodes D1 to D4 is connected across the transformer output winding. The resulting rectified output is attenuated using the two series 470kΩ resistors and a 50kΩ trimpot. A 10μF capacitor filters the signal to provide a smooth DC voltage which is proportional to the peak-to-peak output voltage from the transformer.

This sample DC voltage is applied via a 6.8kΩ resistor to the non-inverting input of IC4, which is an op amp connected as a comparator.

The other (inverting) input of IC4 is fed an attenuated version of the triangular waveform from pin 2 of IC1 via a 220kΩ resistor. This input (pin 2) is also referenced to half supply by the 39kΩ voltage divider resistors connected between the positive supply rail and ground.

The waveforms at pin 6 of IC1 and those at pins 3 and 2 of IC4 are shown in Fig.1. The output of IC4 (pin 6) is high whenever its pin 3 voltage is higher than its pin 2 voltage and vice versa. Therefore, the output of IC4 changes each time the voltage at pin 2 flicks above or below the voltage at pin 3.

As previously mentioned, the IC3

12/240V inverter

NOR gates invert the Q outputs from IC2 whenever pin 6 of IC4 is low. When pin 6 is high, both transistors are switched off due to the low output of each NOR gate. Thus, IC4 controls the "dead" time of each transistor during every half cycle.

The resulting 240VAC waveform from the output of the transformer is shown in Fig.1.

So voltage regulation is obtained as follows: If the output from the transformer is too high, then the voltage at pin 3 of IC4 rises relative to the triangular waveform of pin 2 and this increases the "dead" time of the transistors.

If the output voltage drops, the voltage at pin 3 of IC4 is reduced relative to the triangular waveform at pin 2, reducing the "dead" time of the transistors and so increasing the drive to the transformer.

The gain of this feedback system is very high to keep the output voltage relatively constant. Note the 1MΩ resistor between the non-inverting input and output of IC4. This in conjunction with the 6.8kΩ resistor at the non-inverting input sets a small amount of hysteresis for IC4 to prevent high frequency oscillations.

Power for the ICs is derived from the 12V supply and regulated using a 6.8V zener diode fed by the two 220Ω paralleled dropping resistors. The regulation isolates the ICs from the supply to the transformer to prevent false triggering. In addition, a 1000μF capacitor connected to the positive supply of the transformer helps reduce the transients and supply drop as the transformer primary winding is switched on and off.

Construction

Our prototype inverter was housed in a case measuring 150(W) x 103(D) x 70mm (H) at back and 35mm (H) at the front. Most of the components are installed on a small printed circuit board (PCB) coded 87iv3 and measuring 97 x 58mm. The power switch and mains socket are mounted onto the top lid while the remaining components are mounted on the base of the case.

Start construction by installing the parts on the PCB. Make sure that all the diodes are oriented correctly and note carefully the diode to be used at each location. For example, diodes D7 and D8 are zeners and are different from small signal diodes D5 and D6. Zener diode D9 should have a stress relieving loop in the lead to allow for expansion.

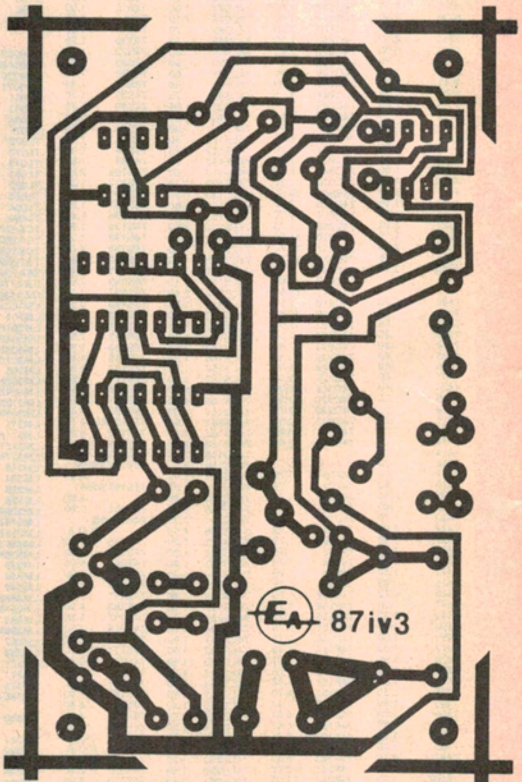
We used PC stakes to terminate the external connections since this helps with the wiring at a later stage.

Note that IC1 is oriented differently to the remaining ICs. The two electrolytic capacitors should be oriented as shown on the overlay diagram. The resistors and remaining capacitors can be inserted any way around.

The leads for the BUZ71 transistors should be bent so that the devices mount perpendicularly and to the left of the PCB. This will allow the transistors to be bolted to the side of the case for heatsinking.

Once the PCB is complete, work can begin on the case. The transformer mounts in the rear right hand side of the case (the deep end) to allow clearance for the lid. The PCB mounts close to the left hand side of the case and is mounted on 9mm standoffs.

If you have purchased a kit with drilled metalwork, some of the following steps will not be necessary. Otherwise, drill holes in the base of the case for mounting the PCB, transformer and earth lug. The holes for securing the transistors to the case can be drilled after temporarily mounting the PCB on the standoffs and marking the hole positions.



Above: full-scale artwork for the PCB.

PARTS LIST

1 PCB, code 87iv3, 97 x 58mm
1 sloping front metal cabinet, Jaycar Cat. No. HB-6080
1 Arlec 2155 transformer, 15V 1A centre tapped (or equivalent)
1 flush-mounting 3-pin mains panel socket
1 2A SPST toggle switch
1 cigarette lighter plug
4 12mm spacers
1 earth lug
1 cord clamp grommet
2 sets of insulating hardware for T0-220 package (mica washer, bush, screw and nut)

Semiconductors
1 555 timer IC
1 3130 CMOS op amp
1 4001 quad 2-input NOR gate
1 4027 dual J-K flipflop
2 BUZ71 SIPMOS transistors
4 1N4004 1A diodes
2 1N4148, 1N914 diodes
2 33V 400mW zener diodes
1 6.8V 1W zener diode

Capacitors
1 1000μF 16VW PC electrolytic
1 10μF 16VW PC electrolytic
1 0.12μF metallised polyester
1 33pF ceramic

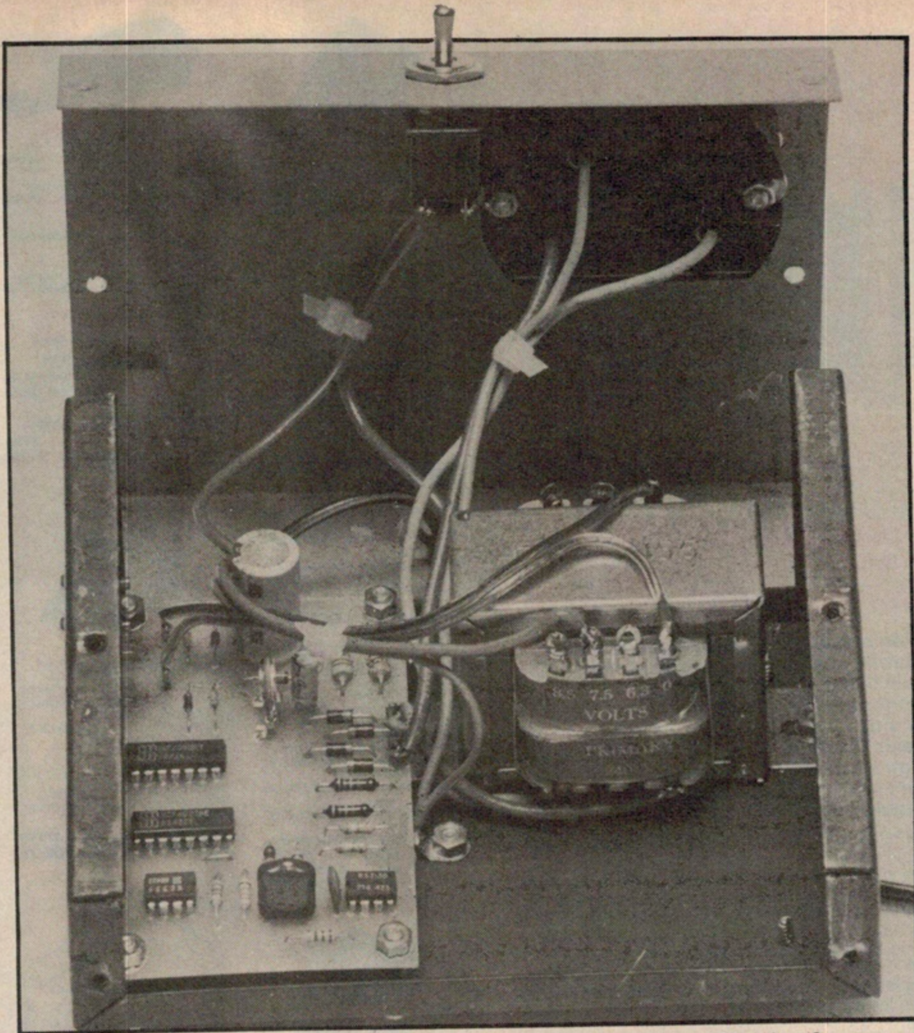
Resistors (0.25W, 5%)
1 x 1MΩ, 2 x 470kΩ 0.5W, 1 x 220kΩ, 1 x 56kΩ, 2 x 39kΩ, 1 x 6.8kΩ, 1 x 1.2kΩ, 2 x 220Ω 1W, 1 x 50kΩ miniature vertical trimpot

Miscellaneous
Screws, nuts, shakeproof washers, heatsink compound, solder, mains wire, cable ties, heavy duty hookup wire.

Holes are also required in the lid for the mains socket, power switch S1, and the cord clamp grommet. The mains socket mounts on the top of the lid very close to the front. It should be located as far to the front and as far to the right as possible without fouling the sides of the case. The switch mounts alongside the socket on the front of the lid. The cord clamp grommet mounts on the rear of the lid.

To make the round hole for the socket, drill a number of holes around the circumference of the required hole and knock out the centre piece. The hole can then be filed to a smooth finish. This done, bolt the transformer, PCB and earth lug to the case.

The two transistors must be insulated from the case using mica washers and insulating bushes. Smear heatsink compound on each of the mating surfaces before bolting the transistors to the case. This done, check that each transistor case is indeed isolated from the case by testing with a multimeter (switched to the "ohms" range).



You will have to follow the layout shown here to get the parts to fit into the recommended case. Take care to ensure that leads carrying 240V AC don't short to adjacent connections.

Be sure to use mains-rated cable for the 240V wiring. This includes the leads from the 240V output of the transformer to the PCB and all leads to the mains socket. The earth wire should also be mains rated and should have the standard green with yellow stripe insulation.

The remainder of the wiring can be run using medium-duty hookup wire. This wiring includes the leads between the low voltage terminals of the transformer and the PCB, and between the PCB and the switch. Figure eight twin cable can be used for wiring the ground and +12V wires to the cigarette lighter plug.

Once construction is complete check your work carefully for possible wiring errors. In particular, make sure that all the parts on the PCB are correctly positioned and oriented. It is also a good idea to recheck the isolation of the two switching transistors.

Testing

To test the inverter, connect a multimeter set to 1000V AC to the output socket and plug the inverter into the cigarette lighter socket of your car. Alternatively, you can use a 12V DC bench supply capable of supplying 2A. Measure the output from the inverter and adjust VR1 for a reading of 240VAC.

You can test the regulation by connecting up your CD player and again measuring the AC voltage. It should still be very close to 240V AC.

Note that for accurate setting of the output voltage, it is necessary to use a moving iron meter or true RMS meter. However, for this inverter application, the actual voltage is not critical and a conventional analog or digital multimeter will be adequate.