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HT POWER SUPPLY

ROBERT PENFOLD



Have you got the "bottle" for it?

THIS power supply unit is primarily designed for use with battery powered valve radios that require a high tension (HT) supply of about 90 volts at a current consumption of up to 10 milliamps or so. The batteries for these receivers are now unobtainable, and they were pretty expensive when it was possible to buy them.

The solution used here is to have a d.c. to d.c. converter that steps-up the output from a 6V battery to about 90V. Unfortunately, a voltage step-up is inevitably accompanied by a step-down in current. The practical importance of this is that the current drain from the 6V supply is much higher than the output current to the receiver.

With a theoretically perfect circuit there would be a fifteen-fold increase in the input current to match the fifteen-fold step-up in voltage. In practice there are significant losses in the circuit, and the input current is likely to be closer to 30 times the output current.

PRACTICAL PROPOSITION

Even so, 6V at a relatively high current is a more practical proposition than 90V at a modest power where battery operation is required. Ninety volts can be provided direct from batteries using something like ten PP3 size 9V batteries wired in series, but this is far from ideal.

Many simple valve radios only draw a few milliamps from the HT supply. This power supply, plus something like four C or D-size cells in series, are then practical as the power source. In fact, four humble AA cells are adequate with some receivers. With sets that require 10mA or so the current drain from the 6V supply is quite high at around 250mA to 300mA, and some form of rechargeable battery is then preferable.

Although primarily designed to provide an output potential of 90V, the power supply unit has additional output potentials of 67.5V and 120V, which are also used with small valve radios. The maximum output current at 120V is somewhat reduced, but currents of up to about 8mA are available. The unit may be usable in other applications that require a high voltage at low supply currents, but it has only been tested with simple valve radios.



DRAWBACKS

Although the inverter method is simple and inexpensive, it does have two or three drawbacks. One of these is that the final output voltage varies considerably with changes in loading and the input voltage.

Experience has shown that the output voltage from 90V batteries was not particularly stable either. The output potential actually varied from about 100V when new down to about 70V when nearing exhaustion. While not desirable, a lack of accuracy in the output voltage of the supply is not too important either.

Another problem is the difficulty involved in obtaining several switched output voltages. In the absence of a transformer having several step-up ratios, some extra electronics is needed in order to provide the extra voltages. The third problem is a lack of efficiency. Simple inverter units tend to consume high input currents even if only a modest output current is being drawn.

HOW IT WORKS

The circuit finally evolved is based on a simple inverter, but it also uses switch-mode power supply techniques to control the output voltage and give improved efficiency with low output currents. The block diagram for the HT Power Supply is shown

STEPPING UP

One way of tackling this type of voltage conversion is to use a switch-mode power supply chip in the step-up mode. However, a step-up from just 6V to 90V and 120V is stretching things slightly with a supply of this type. Also, the high speed switching used in this type of circuit can generate radio frequency interference, which is clearly undesirable in this application.

The simpler alternative is to use a standard inverter circuit based on a 50Hz oscillator and a step-up transformer. The high voltage a.c. output from the transformer is rectified and smoothed to produce the high voltage d.c. output. For safety reasons, modern mains transformers use separate formers for the primary and secondary windings. As a consequence of this they work just as well if used in reverse as step-up transformers.

Note that what is normally the mains primary winding is referred to in this article as the secondary winding, which is its role in this application. Similarly, the low voltage secondary winding is called the primary winding here, since that is its function in this circuit.

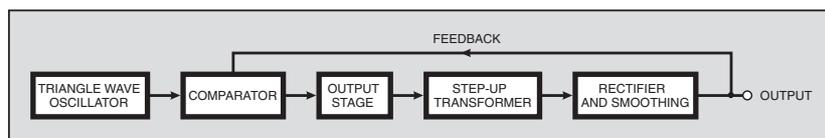


Fig.1. Block diagram for the HT Power Supply.

in Fig.1. The triangular oscillator and the comparator form a standard pulse width modulator, and the waveforms of Fig.2 help to explain the way in which this functions.

The pairs of waveforms represent the output signals of the triangular oscillator and voltage comparator stages. The triangular signal is fed to the non-inverting input of the comparator and a control voltage is applied to the inverting input. In Fig.2 the line through each triangular waveform represents the control voltage. The output from the comparator goes high when the triangular waveform is at the higher potential, and low when the control voltage is at the greater potential.

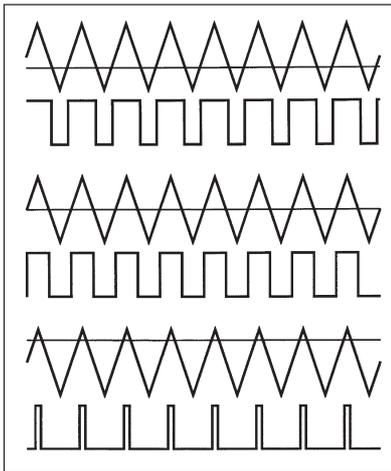


Fig.2. Example pulse width modulation (p.w.m.) waveforms.

Initially the control voltage is set quite low, giving an output from the comparator similar to the one in the top pair of waveforms. The comparator drives the primary winding of the step-up transformer via an output stage that can provide the relatively high drive currents involved here.

A rectifier and smoothing circuit processes the a.c. output signal of the transformer to produce a high voltage d.c. supply. Some of this voltage is fed back to the inverting input of the comparator, and

as the output potential rises the voltage at the inverting input increases slightly as well. At first this has little effect, with a squarewave output being produced, as in the middle pair of waveforms in Fig.2. As the output voltage increases further the output signal from the comparator becomes a train of narrow pulses, as in the bottom pair of waveforms in Fig.2.

This gives a form of negative feedback that tends to stabilise the output voltage at a certain level. With the output only lightly loaded the output waveform becomes a series of very narrow pulses that result in little power being fed to the transformer. At times the voltage at the inverting input of the comparator may even go above the peak potential in the triangular signal, resulting in the signal to the transformer being cut off.

With the output loaded more heavily the output voltage reduces, but the power fed to the transformer is then increased. This resists the fall in output voltage, keeping the voltage drop to a minimum. The regulation efficiency of this set-up is not very good, but as pointed out previously, highly stable output potentials are not really needed in this application.

A big advantage of this system is that it gives good efficiency at all output currents. With low output currents only brief pulses are fed to the transformer, giving a low average input current. As the load on the output is increased, the length of the pulses increases as well, giving a higher average input current. The input current therefore rises and falls in proportion to changes in the loading, avoiding large amounts of wasted power at low output currents.

Another advantage is that the output voltage is easily controlled. The feedback limits the maximum output voltage, and the more feedback that is used, the lower the maximum output voltage that can be achieved. With lower output voltages shorter pulses are needed to maintain the output potential at a given load current, and good efficiency is still obtained.

CIRCUIT OPERATION

The full circuit diagram for the HT Power Supply appears in Fig.3. Dual

op.amp IC1 is used in the triangular oscillator, which is a conventional design having IC1a as the integrator and IC1b as the trigger circuit. A squarewave signal is produced at the output of IC1b and a triangular signal is available from IC1a, but it is only the triangular signal that is needed in this application.

The transformer provides optimum results at a low frequency of around 50Hz to 70Hz. Timing components resistor R5 and capacitor C4 set the output frequency at about 65Hz.

A PMOS operational amplifier, IC2, is used here as the voltage comparator. The output of IC1a connects direct to the non-inverting input, pin 3, while resistors R6 and R7 provide an initial bias voltage to the inverting input at pin 2.

The output of IC2 drives the primary winding of step-up transformer T1 via common emitter switching transistor TR1.

The drive current to TR1 is less than a milliamp, but this is a power Darlington device that has a very high current gain. It is, therefore, able to supply a current of a few hundred milliamps to the primary winding of T1 (remember secondary equals primary here – see earlier note).

The secondary (primary) winding of T1 drives a full-wave bridge rectifier (diodes D1 to D4) and smoothing capacitor C5. Further smoothing is required, and resistor R10 plus the series capacitance of C7 and C8 provide this. A smoothing capacitor having a value of 220µF and a maximum voltage rating of 200V is needed, but a suitable component does not seem to be available. Instead, two 470µF 100V capacitors wired in series are used. These provide a capacitance of 235µF and a maximum working voltage approaching 200V. Resistors R11 and R12 ensure that capacitors C7 and C8 more or less evenly share the output voltage.

Negative feedback is provided by way of diode D5, resistor R9, and whichever of the three preset potentiometers (resistors, VR1 to VR3, is selected using switch S1. The presets control the amount of negative feedback and they are adjusted to produce the required output voltages.

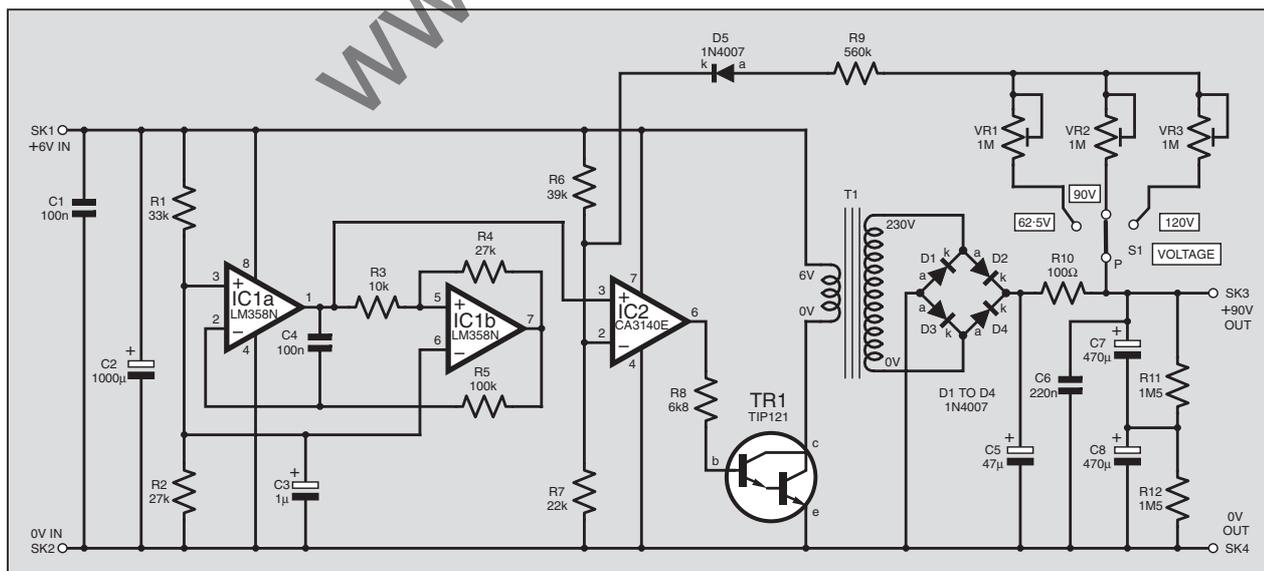


Fig.3. Complete circuit diagram for the HT Power Supply for use with battery powered valve radios.

CONSTRUCTION

The HT Power Supply is built on a piece of stripboard and the component layout, hard wiring and details of breaks required in the copper strips on the underside of the board are shown in Fig.4. The board has 36 holes by 39 copper strips, and it can conveniently be cut from one of the standard size boards that have 39 copper strips.

Stripboard is easily cut using a hacksaw or junior hacksaw, but use no more than moderate pressure since some stripboards are quite brittle. The three mounting holes are 3mm dia. and will accept metric M2.5 mounting bolts.

The breaks in the copper strips can be made using a special tool or a twist drill bit of about 5mm dia. Make sure that the



strips are cut across their full widths, but do not cut so deeply into the board that it is weakened.

Next, the link-wires and components can be added to the board. The CA3140E used for IC2 has a PMOS input stage and therefore requires the standard anti-static handling precautions. The most important of these is to fit it on the board via a holder. The LM358N used for IC1 is not vulnerable to static charges but it is also advisable to use a holder for this device.

Do not fit IC2 until the board and all the hard wiring has been completed, and try to touch the pins as little as possible. Keep this component away from any likely sources of static electricity once it has been removed from the anti-static packaging.

The link-wires are made from 24s.w.g. (0.56mm) tinned copper wire. Some of the link-wires are quite long and should be insulated with pieces of sleeving to ensure that there are no accidental short circuits. Transistor TR1 is a power device, but in this circuit it does not dissipate much power, and no heatsink is required.

Capacitor C4 should be a type having 5mm (0.2-inch) lead spacing, and it should then fit easily into this layout. Capacitor C5 must have a working voltage of 200V

or more. Unfortunately, you are not exactly "spoiled for choice" with high voltage electrolytic capacitors, and it will probably be necessary to use a component having a much higher voltage rating of 350V or 450V.

This component will probably be quite large, but the component layout has been designed to accommodate a large axial lead capacitor. A radial lead capacitor will probably not fit easily into this layout. Make quite sure that electrolytic capacitors C2, C5, C7 and C8 are all fitted into the board with their correct polarity. Mistakes here could cause costly damage and could even be dangerous.

BOXING UP

◆ The prototype is housed in a slightly oversized instrument case, and a medium size case or one of the larger metal or plastic boxes is adequate to accommodate everything. It is assumed here that the 6V battery will be a large external type. If the unit is powered from internal batteries a suitably large case will be needed, and a suitable on/off toggle switch must be added into the positive battery lead. Sockets SK1 and SK2 will then be unnecessary.

COMPONENTS

Resistors

R1	33k
R2, R4	27k (2 off)
R3	10k
R5	100k
R6	39k
R7	22k
R8	6k8
R9	560k
R10	100Ω
R11, R12	1M5 (2 off)
All 0.25W 5% carbon film	

See
SHOP
TALK
page

Potentiometers

VR1, VR2,	
VR3	1M min. carbon preset, horizontal (3 off)

Capacitors

C1	100n ceramic
C2	1000μ axial elect. 10V
C3	1μ radial elect. 63V
C4	100n polyester
C5	47μ axial elect. 450V
C6	220n polyester, 250V
C7, C8	470μ radial elect. 100V (2 off)

Semiconductors

D1 to D5	1N4007 1A 1000V rectifier (5 off)
IC1	LM358N dual op.amp
IC2	CA3140E PMOS op.amp
TR1	TIP121 or TIP122 npn power Darlington

Miscellaneous

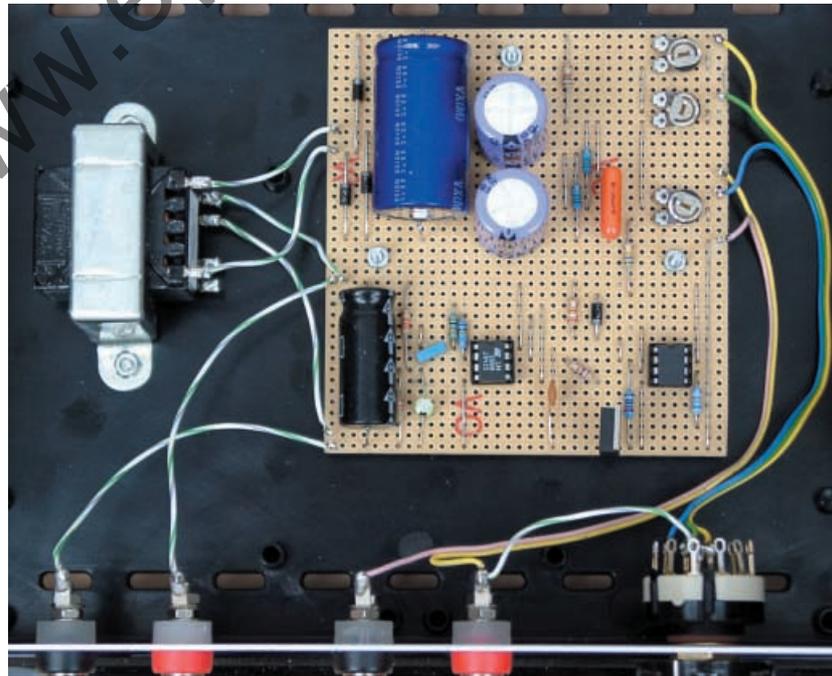
SK1, SK3	4mm terminal post (red - 2 off)
SK2, SK4	4mm terminal post (black - 2 off)
T1	Standard 230V mains transformer, with twin 6V 500mA secondaries (see text)
S1	1-pole/2-way rotary switch, with end-stop set for 3-way operation

Medium size instrument case, see text; 0.1-inch matrix stripboard, size 36 holes by 39 strips; 8-pin d.i.l. holder (2 off); control knob; multistrand connecting wire; solder pins; solder; fixings, etc.

Approx. Cost
Guidance Only

£20

excluding batts & case



Interwiring from the circuit board to the front panel mounted components and the "step-up" transformer.

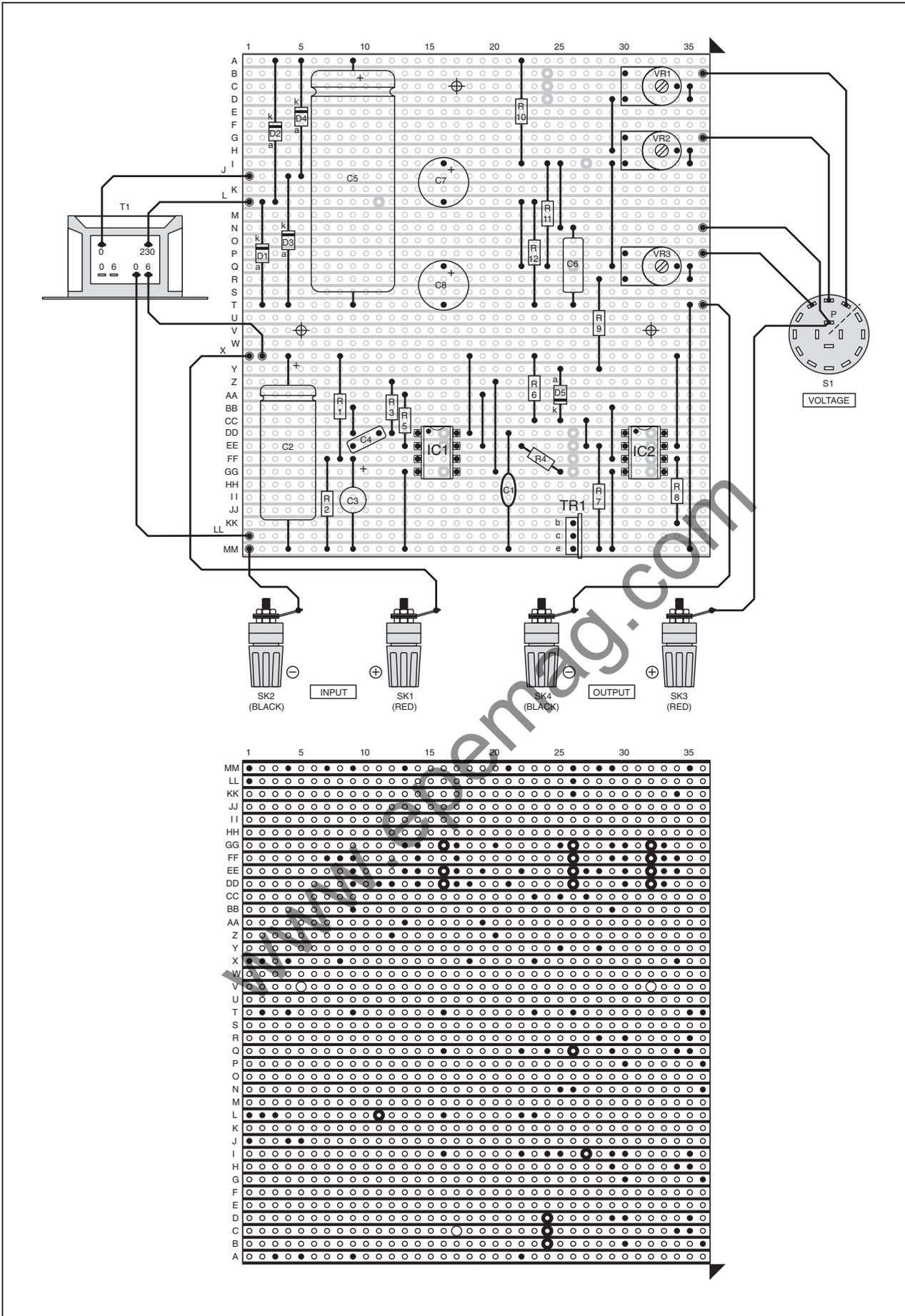


Fig.4. Stripboard topside component layout, interwiring and details of underside copper track breaks.

There is no sensitive wiring so the layout of the unit is not critical. The circuit board is mounted on the base panel of the case using M2-5 fixings, which should include spacers about 6mm or more in length. This is especially important if a metal case is used, as a gap of at least a few millimetres is then needed between the high voltage connections on the underside of the board and the case.

Transformer T1 can be a type rated at 3V-0V-3V at 100mA if output currents of no more than about two or three milliamps are required. The centre tap (0V) is ignored and the input signal is applied to the two 3V leads.

For higher output currents a transformer having twin 6V 500mA windings is required. In order to obtain the highest possible output current at 120V the two windings can be used in parallel. In other words, wire the two 0V tags together and also connect the two 6V tags together. For most purposes though, only one of the windings is needed and the other one can be left unconnected.

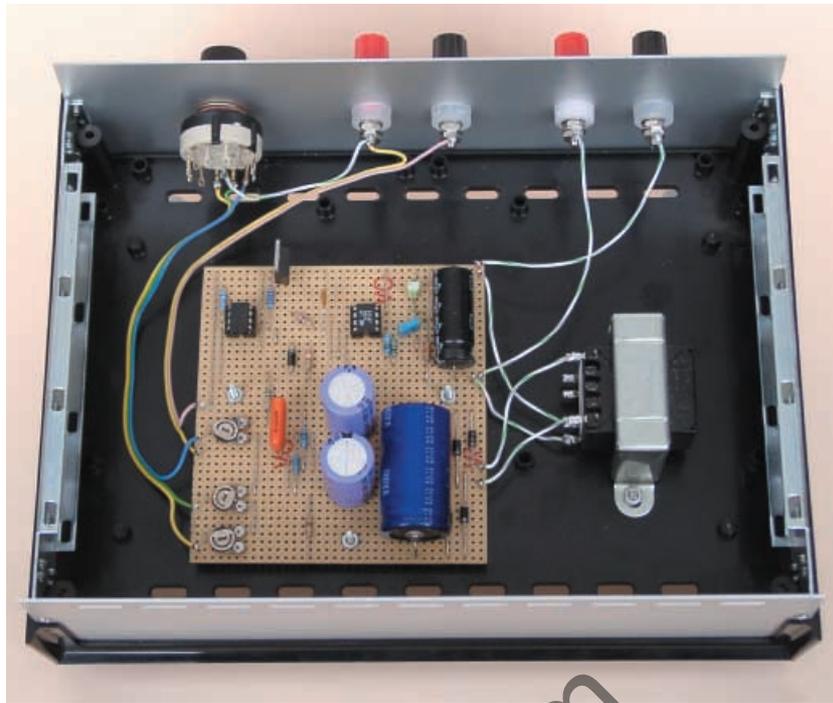
Terminal posts are used as for the input and output sockets on the prototype. These can be connected to bare wires and they will also accept 4mm plugs. However, any sockets that are appropriate for a power supply can be used.

Switch S1 is a 12-way single-pole rotary switch having an adjustable end-stop, which is set for 3-way operation in this case. Alternatively, a 3-way 4-pole switch can be used, with three sections of the switch being left unused.

With everything fitted in the case the small amount of hard wiring is added. This wiring is also included in Fig.4. The unit should then be given a thorough check for errors prior to testing.

ADJUSTMENTS

A multimeter is needed in order to set the correct output voltages, but even the cheapest of digital or analogue instruments will suffice. The multimeter is connected across sockets SK3 and SK4, and should be set to a suitably high voltage range, such as the 199.9V range on a



Completed unit showing positioning of components and circuit board inside the metal instrument case.

digital type. Initially all three presets (VR1 to VR3) should be set for minimum output voltage, or fully counter-clockwise in other words.

After a final check of the wiring connect the 6V battery to sockets SK1 and SK2, being careful to get the polarity correct. The voltage indicated by the multimeter should build fairly rapidly to around 60V. If it does not, disconnect the battery immediately and thoroughly check the wiring, etc. for errors.

If all is well the presets can be set for the correct voltages. The loaded output voltages will be significantly different to the unloaded voltages, especially when high output currents are drawn. Therefore, it is best to set each output potential with the unit powering the appropriate radio receiver. It

can take as much as a few seconds for the output voltage to fully respond to changes in the settings of the presets, so wait for the reading to stabilise after each adjustment has been made.

The prototype was set for output voltages of 67.5V, 90V and 120V, but the presets can be set for any desired output potentials from about 60V to 120V. You can also have the presets set for the same output potential, but with different levels of loading, so that (say) two 90V receivers can both be operated with the optimum supply potential.

The output voltage of the unit is not dangerously high even when set to 120V. However, it can supply a noticeable electric shock, and the output of the unit should be treated with due respect.

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