A power supply for battery-operated valve radios

By Ian Robertson

Over the years our Vintage Radio columns have featured many battery-operated valve radios with 1.5V or 2V heaters. The most recent examples were featured in July & August 2016. But batteries for these radios can be hard to get and expensive. This power supply is a neat solution.

Apart from some portable models, most battery-operated valve radios were intended for use on farms and in remote regions where mains power was not available.

Those sets are quite collectible today but most Vintage Radio enthusiasts power them from a variety of jury-rigged power supplies, some of which are of doubtful safety.

This universal power supply is easy to build and could be installed inside the battery compartment of some radios.

If there is not enough space, it could be connected with two cables; one for the 1.5V or 2V filaments and one for the 90V or 135V B+ supply.

Of course, quite a few battery-powered radios used vibrators to produce the B+ supply and if you have one of these radios with a defective vibrator section, this power supply could also provide a work-around, either temporary or permanent.

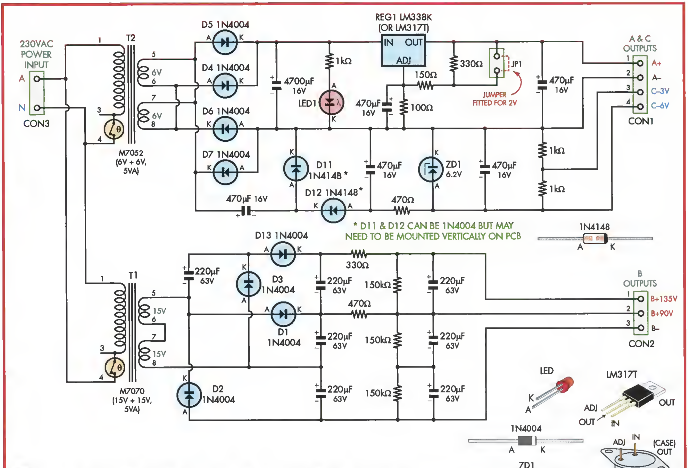
The supply uses three PCBs connected together and is designed to fit in a standard plastic instrument case. One of the PCBs doubles as the front panel while an additional (fourth) PCB is unconnected but functions as the rear panel.

There is no wiring between the three PCBs. Instead, they are butted at right-angles and soldered together, as shown in the photos.

Circuit details

The full circuit is shown in Fig.1. It employs two 240VAC transformers and is a straightforward analog design, avoiding the RF interference normally associated with more efficient switchmode power supplies.

The top section of the circuit is for the low voltage supplies and employs an LM338 or LM317T adjustable regulator.



UNIVERSAL BATTERY VALVE POWER SUPPLY

The circuit consists of two independent power supplies, with various voltages available to suit a wide range of battery-operated valve receivers. Provision is made on the PCB for either a TO-3 or a TO-220-case regulator.

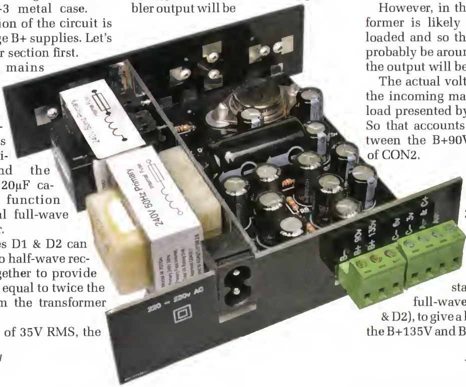
The example shown in the photos is fitted with the LM338 regulator which comes in a TO-3 metal case.

The lower section of the circuit is for the high voltage B+ supplies. Let's describe the lower section first.

It employs a mains transformer with two 15V windings connected in series to provide 30VAC. This is connected to diodes D1 & D2 and the two associated 220µF capacitors which function as a conventional full-wave voltage multiplier.

In effect, diodes D1 & D2 can be regarded as two half-wave rectifiers stacked together to provide an output voltage equal to twice the peak voltage from the transformer winding.

For a sinewave of 35V RMS, the peak voltage will be peak voltage will be V_{AC} x 1.414 and so the voltage doubler output will be about 85V, neglecting the voltage drop across diodes D1 & D2.



However, in this circuit the transformer is likely to be quite lightly loaded and so the peak voltage will probably be around 48V or so, and so the output will be more than 90V DC.

The actual voltage will depend on the incoming mains voltage and the load presented by the radio's circuit. So that accounts for the voltage between the B+90V and B- terminals of CON2.

Diodes D3 & D4, together with their two associated 220µF capacitors function as a half-wave diode pump rectifier.

Their output is stacked on that of the full-wave voltage doubler (D1 & D2), to give a higher total output at the B+135V and B- terminals of CON1.

This is likely to be between 130V and 145V, depending on mains voltage and circuit loading, as before.

The 330Ω resistor and three stacked 220µF capacitors provide extra hum filtering for the output while the parallel 150kΩ resistors across each 220µF capacitor are there to equalise the voltage across them.

So each 220µF capacitor should have one-third of the output voltage across it.

Low voltage regulator circuit

While the high voltage outputs are unregulated, the low voltage circuit is a combination of regulated and unregulated supplies.

It uses a second mains transformer with two 6V secondary windings connected in parallel to feed diodes D4 to D7 connected as a bridge rectifier feeding a 4700µF 16V capacitor.

This provides a filtered DC output of about 8.5V (depending on loading). This is fed to the adjustable 3-terminal regulator which has three resistors connected to its ADJ terminal set to give a regulated output of 1.5V.

If you want a regulated output of 2V, the shorting link must be installed across JP1.

Extra filtering of the regulator's output is provided by the 470µF capacitor connected across terminals A+ and A- of CON1.

Negative outputs

Battery-operated valve radios also often had C batteries to provide a negative grid voltage for the valves and this could be -3V, -4.5V or -6V.

These negative rails are provided by the diode pump circuit comprising diodes D11 & D12, in conjunction with two 470µF 16V capacitors.

The resulting filtered DC is fed to zener diode ZD1 via a 470Ω resistor and bypassed by an additional 470µF capacitor.

A voltage divider comprising two 1kΩ resistors then provides outputs of 3V and 6V at the C-3V and C-6V terminals of CON1.

If you require a C- rail of 4.5V, then ZD1 should be a 4.7V zener diode.

Construction

The power supply is primarily constructed on one main PCB measuring 55 x 110mm.

There are also three "supplementary" PCBs, one of which mounts

Here's how the four PCBs fit together, before mounting them in their case. Note this is before any insulation was fitted to the exposed mains.

the two power transformers and the "figure-8" mains input socket. They are 110 x 33mm.

Two other PCBs, 122 x 33mm, form the front and rear panels of the project.

(The set of four PCBs is available from the SILICON CHIP Online Shop for $25.00).

The front PCB has holes for the power LED and also a number of holes to suit connectors commonly used in battery-powered units.

The power transformer board is soldered at right angles to one edge of the main PCB via the use of the secondary windings pins (eight in all), which pass through the transformer board and solder to large pads provided on the edge of the main board.

Similarly, the front panel board solders at right angles to the main board along its front edge. The photos will explain this a little more clearly!

The rear panel board isn't actually attached to the main PCB. It can actually move around a little to allow for some flexibility when fitting the project in a case.

However, and this is most important, the three and four-pin DC output sockets must be passed through this panel **before** they are soldered in place – we'll get back to this a little later.

One other point which we'll also cover later but should be pointed out right up front is that the 230VAC mains connections to the transformers, along with the mains input socket, all have their pins exposed ready to trap the unwary.

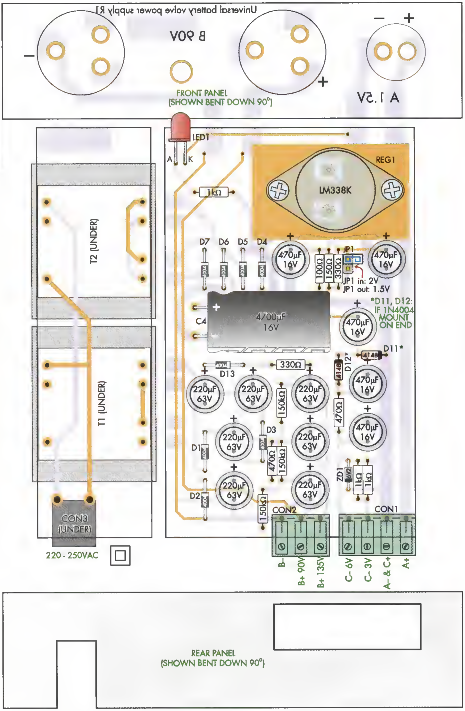
After completion, we covered ours with liberal coating of silicone sealant for absolute safety.

Begin construction by soldering in the 12 resistors – see the colour code table for identification. You should also double check their value with a DMM – especially if your eyes aren't as young as they used to be!

Some bands on resistors are also quite easy to mistake for other colours so a second check is always worthwhile.

After the resistors, solder in the nine 1N4004 diodes, taking care with their polarity.

The original project used 1N4148 diodes in two places but we'd prefer



The component overlay also shows the transformer board and the front and rear panels. Output can be taken from the screw terminals on the rear panel or from suitable sockets on the front panel, which match typical connectors used in battery valve radios. Do not neglect to insulate all the "bitey bits" on the PCB.

Parts List – Battery Valve Power Supply

1 main PCB, 55 x 110mm (SILICON CHIP code 18108171*)
1 transformer PCB, 110 x 33mm SILICON CHIP code 18108172*)
1 front panel PCB, 122 x 33mm (SILICON CHIP code 18108173*)
1 rear panel PCB, 122 x 33mm (SILICON CHIP code 18108174*)
1 2-part plastic case, 125 x 130 x 40mm (see text)
1 15V + 15V mains transformer (T1) (Altronics Powertran M7070A)
1 6V + 6V mains transformer (T1) (Altronics Powertran M7052A)
1 PCB-mount figure-8 mains socket (CON3; element14 Cat 9248161)
1 mains lead with figure-8 plug
1 2-pin header base, PCB-mounting
1 2-pin header
1 4-pin screw terminal block, PCB-mounting (CON1)
1 3-pin screw terminal block, PCB-mounting (CON2)
2 M3 x 6mm screws, nuts and washers
2 M3 washers

Semiconductors
1 LM338K TO-3 regulator (or LM317T – see text)
8 1N4004 silicon diodes
2 1N4148 silicon diodes (see text)
1 6.2V 400mW zener diode
1 5mm red LED

Capacitors
7 220µF 63V PCB electrolytics
5 470µF 63V PCB electrolytics
1 4700µF 16V PCB electrolytic

Resistors

1 100Ω	1 150Ω	2 330Ω
2 470Ω	3 1kΩ	3 150kΩ

* A set of the four PCBs (including the two panels) is available from the SILICON CHIP Online Shop (siliconchip.com.au/shop) for $25.00. All other parts are readily obtainable from your normal parts suppliers.

to see 1N4004 used instead, if only to give a higher margin for inrush current.

However, the PCB pattern may not allow for the slightly longer 1N4004s so if you elect to use these, they may need to be mounted vertically (obviously maintaining the correct polarity).

The only other diode is zener diode ZD1 – again, of course, it is polarised.

All other components are also po-

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	3	150kΩ	brown green yellow brown	brown green black red brown
❑	3	1kΩ	brown black red brown	brown black black red brown
❑	2	470Ω	yellow purple brown brown	yellow purple black black brown
❑	2	330Ω	orange orange brown brown	orange orange black black brown
❑	1	150Ω	brown green brown brown	brown green black black brown
❑	1	100Ω	brown black brown brown	brown black black black brown

The underside of the PCB assembly showing how the main board, transformer board and front panel are soldered to each other. The rear panel (right) is not secured at all but is held loosely in place by the two output sockets. The main board is soldered 2mm down from the edges of the transformer board and panel.

larised – the 220µF and 470µF vertical capacitors (don't mix 'em up!) and the main 4700µF filter capacitor which, as you will note from our photos, is a vertical type which lies horizontal on the board.

As well as soldering it in place, a dob of silicone sealant underneath will help stop any movement.

2-pin header JP1 is the last small component to solder in (fairly obviously, it's not polarised!).

All that's left is the LED and the TO-3 regulator. Leave the LED for the moment but solder in the regulator, which can only go in one way. Note that it is spaced above the board by a washer at each end, held in place by its mounting screws/nuts.

This allows a little air circulation under the case, assisting cooling and also avoids metal-to-glass stressing which might otherwise occur.

Incidentally, it is possible to use an LM317T TO-220 regulator instead of the now-harder-to-get LM338 TO-3 device shown in our photographs.

The TO-220 "ADJ" and "IN" pins mount to the same two holes as the TO-3. A hole has been provided on the PCB for the "OUT" pin as well. If you use an LM317T, a small "U" heatsink will also need to be inserted under the regulator.

Place the LED in its holes (anode, the longer lead, closer to the edge of the board) but don't solder it in yet.

Also, don't fit the DC output terminals (CON1 and CON2) yet – these have to be passed through the rear panel first.

Transformer board

The two mains transformers, along with the 2-pin mains socket, mount on the transformer board. T1, the 2 x 15VAC transformer, is closest to the mains socket.

Solder the mains socket in first, then solder the primaries of both transformers in place but leave the secondaries for the moment – they're used to solder the transformer board to the main board.

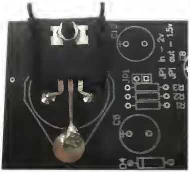
Only after soldering the two boards together should you trim the primary pins (eliminating the possibility of trimming the wrong ones!)

Soldering the vertical boards

As we mentioned earlier, two of the three smaller boards are soldered at right angles to the main board. Because it's lighter, solder the front panel board on first by lining up the rectangular pads on it with the matching rectangular pads on the main board, with the front panel about 2mm down from the main board (see photo).

Tack one pad first to ensure the panel is straight with respect to the main board, then solder all four pads so the panel is secured.

Repeat for the transformer board. It



Alternative mounting for a TO-220 regulator instead of a TO-3. SILICON CHIP PCBs will have a hole for the OUT pin, rather than the method shown here.

On the top side, the main board and front panel sit flush together so they can slip into the guides in the case. Here you can clearly see the silicone sealant we applied to the exposed mains terminals after testing. Mains voltages can bite you!

"Surgery" required on the case halves to allow the transformers and the assembly to fit inside the case. The lighter grey area is where we ground out about half the case thickness with a Dremel for the transformer clearance; other areas are where the mounting pillars were removed (none of these are used).

is soldered to the main board in the same manner as the front panel (ie, 2mm down from the underside of the main board); the difference, of course, is that it is along the side of the main board.

The bottom edges of both the front panel and the transformer board should line up.

There is one more solder joint to be made, that is to join the transformer board and the front panel via the long pads on each which, if you've done everything correctly, should line up. You'll need a pretty fine iron bit to get in between T2 and the board.

Construction is now almost finished. All that remains is to poke LED1 through the front panel and solder it to the main board, then to fit CON1 and CON2 and the rear panel.

Pass both of these terminal blocks through the panel (they're a loose fit) then into the main board. The four-way socket goes to the edge of the main board. Solder both blocks in place.

At the same time, slip the rear panel over the mains socket and you're all done.

Mounting in its box

Because there are relatively high DC voltages present (not to mention 230VAC mains) we would always prefer to see the assembled boards mounted in their case.

The PacTec CM6-150 box we used (siliconchip.com.au/l/aaef) is almost perfect – but that "almost" bit causes a few problems.

The dilemma is that the box is not quite deep enough to fit the transformers. It's about 2mm too shallow. There are also a few mounting pillars which we don't use and, in fact, interfere with the mounting.

In our prototype, this was overcome by grinding off the mounting points with a Dremel grinder (or similar) – easy – and then removing about 2mm thickness from the inside of the case above where the transformers sit – same tool, not quite so easy!

The photos show how we achieved this. When completed it's a tight fit, but it's a fit!

The board assembly can be mounted so the front panel is flush with the front of the case, which puts the rear panel inset about 13mm (that's the way the mounting guides are moulded in the case) or vice-versa; ie, inset the front panel 13mm and have the rear panel flush. It's your choice.

Testing

First of all, beware the mains-carrying pads on the transformer board – you should only coat these after testing (just in case!).

1. Connect a meter to the B+ (135V) and B- connections using the 3-way pluggable screw terminals.

2. Connect power. The LED should light.

3. You should measure close to 145V. If not, switch off immediately and check your work.

4. If all is well, check the A+ and A- / C+ terminals. You should see very close to 1.5V with JP1 not shunted. Shorting JP1 should change the A voltage to 2V.

5. The A (filament) voltages will measure the same irrespective of load.

6. Check the C voltages – you should see close to 6V and 3V.

If all this checks out, you can disconnect AC power and only then apply the silicone sealant to the exposed mains points on the transformer PCB, then fit the top cover and your power supply is ready for use!

You can choose whether to have the front panel flush with the case and the rear panel inset (as shown here) or the opposite.

Modifications

Here are some simple modifications you can make to adapt the power supply for less common radios.

45V tap:

1. Add a 470Ω resistor between the anode of D3 and adjacent end of R13 (labelled on the PCB overlay).
2. Connect wire to junction of C10 and C11 and bring it out the rear. This will be your +45V connection.

4V output for A+ filament supply:

1. Replace R1 with 330Ω.
2. Fit jumper to JP1.
3. Replace the LM338K regulator with an LM1085IT-ADJ.

Install it on a small heatsink as per picture earlier in these instructions.

This regulator has a lower dropout voltage than the LM317 or LM338. This should allow up to about 700mA current draw before hum appears on the output.

Different bias voltages

If you remove ZD1, the bias voltages will become (approximately) -7V and -3.5V. Changing R6 and R7 (or replacing them with a pot of about 2.2kΩ) will allow you to vary the bias to whatever your radio needs.

Note though, that the bias voltage is now not regulated and will change a little if the load on the filament circuit changes.

Consider this if your radio has filament rheostats. SC