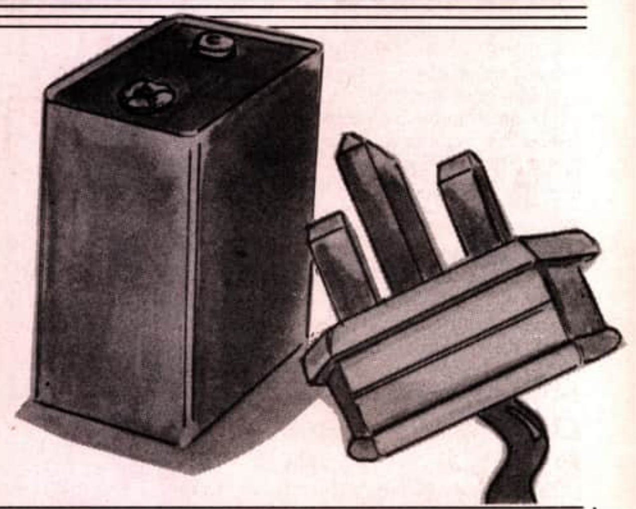
Constructional Project

HUM-FREE BATTERY ELIMINATOR



ANDY FLIND

Musicians may hum the tune, but never amplifiers and PSUs!

TOWARDS the end of the article describing the guitarists' Personal Practice Amplifier (last month), brief mention was made of using it with a mains power adaptor. Earthing of the negative rail was recommended to increase safety and reduce hum, but at the time this had not been tried with the prototype. At least, not with one of the little plug-in mains adaptors that are so common nowadays.

RIFF, RAFF AND NAFF

The musician for whom this project was designed took it home, boxed it up and wired it very neatly, added a 20mA l.e.d. power indicator, and installed a partly-charged PP3 NiCad battery. Readers can guess how long that lasted, probably not even for the first riff!

Next, he fitted a switched power socket for a 9V 300mA plug-in adaptor. Result: hum. Lots and lots of hum! So the author's phone rang again, and soon the unit was back on the bench for investigation.

The construction of mains adaptors varies with make and use. Some contain just a transformer to produce a low-voltage a.c. output, but general-purpose types usually have a transformer, rectifier and perhaps a decoupling capacitor to generate a d.c. supply. Most have no active regulation and so the output voltage varies with load.

Mains adaptors have to provide the specified voltage at full load. At lesser loads they produce higher voltages, often up to the peak value of the sinewave from the transformer – nearly 50 per cent higher. There is generally some a.c. ripple on the output, which at light loads often has an unpleasant "sawtooth" waveform because the capacitor is charged only at the peaks of each cycle.

It can be difficult to earth the output of one of these adaptors as they normally use the "double insulated" approach to provide an isolated output. The earth pin is often just a plastic dummy provided only to open the protection cover in the mains socket.

HUMBUG

The difficulty with using a mains adaptor with the Practice Amplifier centred upon the TDA2822 output amplifier. Firstly, this becomes more sensitive at higher supply voltages. With around 12V from the (nominally) 9V plug-in unit, much noise and instability became apparent. Secondly, the TDA2822 does not appreciate supply rail hum.

Ripple from the adaptor supply was measured at just 0·1V r.m.s., but this was still enough to render the amplifier quite unusable. Disconnecting the leads from the volume control and shorting them to their screens made no difference, confirming that the hum was entering via the power supply. More decoupling proved unhelpful. A 1000μF capacitor applied close to the chip supply pins had no effect.

SIMPLE HUM-BUCKING

A means of reducing the adaptor supply voltage and ripple was clearly needed to solve the problem. One method tested was an active ripple suppressor. Whilst this was not the solution eventually adopted, it worked quite well. The circuit is shown in Fig. 1 for readers who might like to experiment with it. It works as follows:

Resistor R1 is chosen so that about five milliamps flows through diodes D1 and D2. The voltage drop across these is about 1·2V, providing a voltage with "headroom" beneath the ripple for the active part of the circuit. This still has the full ripple imposed on it so it is smoothed by resistor R2 and capacitor C1, and then

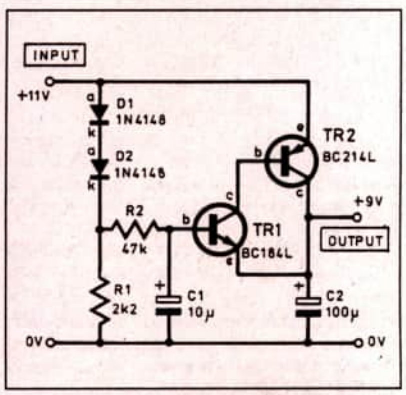
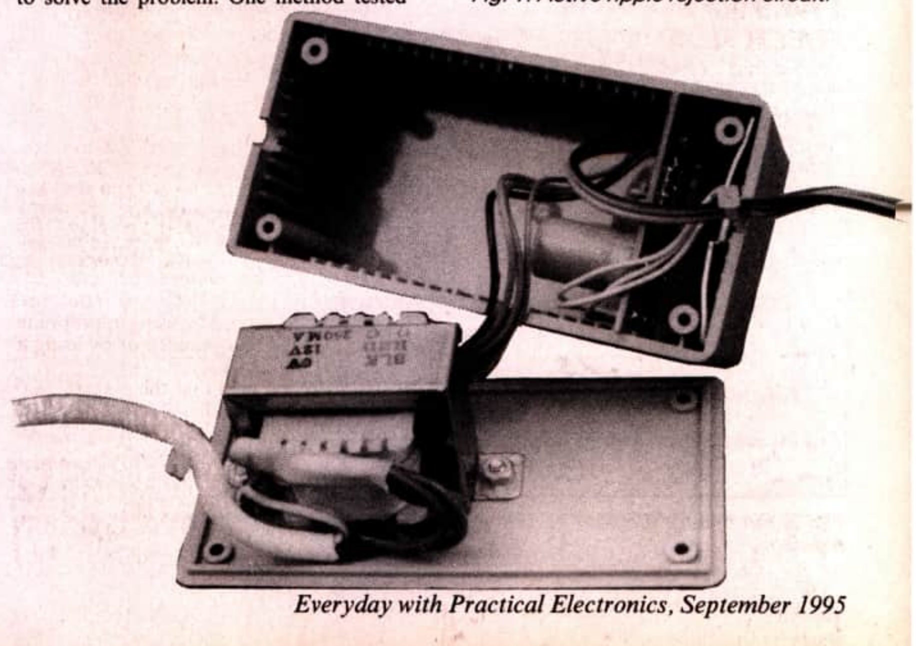


Fig. 1. Active ripple rejection circuit.



buffered by transistors TR1 and TR2 connected as a complementary Darlington pair.

With the component values shown, the ripple is reduced to less than one per cent. It works quite well and could provide a cheap and simple solution. The diodes reduce the voltage a little, as does the base-emitter drop of transistor TR1. The total loss is about 2V.

However, the circuit does not actually regulate the output voltage and may not be suitable for use with some adaptors. Nor does it solve the problem of earthing the output, and, due to the way power socket switches are constructed, it could not easily be housed inside the amplifier's case. Connection somewhere in the lead between supply and project would be required.

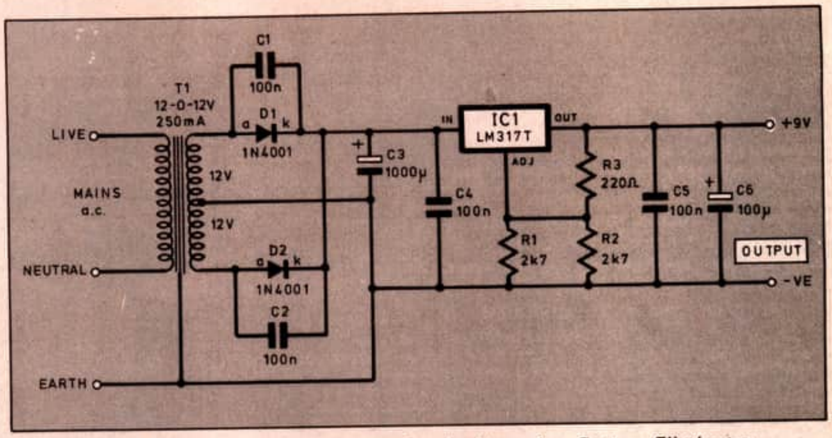


Fig. 2. Complete circuit diagram for the Hum-free Battery Eliminator.

CURING THE RIPPLE

Consequently, to achieve reliable and repeatable results, it was decided to design a regulated supply with a much higher performance than found in most commercial units. The full circuit diagram for this is shown in Fig. 2.

Transformer T1 is a 250mA type with 12V-0-12V secondary windings. Diodes D1 and D2 perform full-wave voltage rectification, with capacitor C3 providing d.c. voltage smoothing. The two small-value capacitors C1 and C2 reduce noise generated by the diode switching. Regulator IC1 is an LM317T, an adjustable output voltage type. In Fig. 2, the values of resistors R1, R2 and R3 determine the output voltage, set here to 9V.

Capacitor C6 provides additional output decoupling, although the regulator itself removes nearly all the ripple. The circuit to be supplied will also normally have its own decoupling. Capacitors C4 and C5 are required to ensure regulator stability. The output of this circuit is a stable d.c. voltage of the correct value regardless of load (within the limits of the transformer) and virtually free of ripple and noise, a huge improvement over most commercial adaptors.

Since the circuit is connected to the mains with a standard three-pin plug, it is simple to earth any point of the output as required, either negative or positive rail. Even if a "floating" output is required, the transformer metalwork can be earthed, which again helps to reduce noise.

LM317T REGULATOR

A little additional information may be useful for constructors who would like to know a bit more about the LM317T regulator chip, and perhaps set a different output voltage. The regulator is a 3A device in a TO220 package, as shown in Fig. 3.

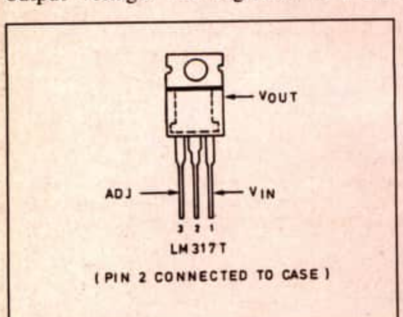


Fig. 3. Pinouts for the LM317T voltage regulator.

There is also a 100mA version available in a TO92 package for low-power applications. Both devices can accept input voltages up to 40V but need a minimum of 3V difference between input and output pins. However, with high differential voltages across the chip, a watch must be kept on its heat dissipation. Additionally, a minimum load of 5mA should be taken from the output at all times, although this can conveniently be drawn by the voltage determining network.

The output voltage is determined by the ratio of two resistances in a feedback network, as shown in Fig. 4. The usual formula given for determining the resistance values is $V_{out} = 1{\cdot}25 \times (1 + R2/R1)$ volts, but the author prefers a slightly different approach. Essentially, the chip operates by maintaining a constant 1·25V between the output and "adjust" pins. This means that a 220 ohm resistor (R1) between output and "adjust" will draw 1·25/220 milliamps, slightly more than the 5mA minimum load required, leaving only the value of R2 to be selected.

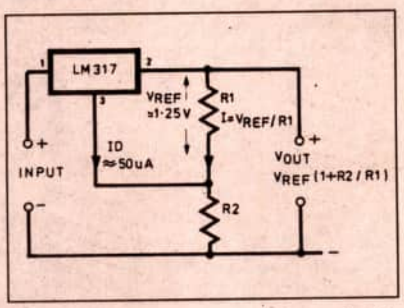


Fig. 4. Simple voltage regulator circuit.

The voltage across resistor R2 is clearly the required voltage less 1.25V, whilst the current which will pass through R2 is that from R1 plus 50µA. The 50µA is the current which flows from the "adjust" pin, ignored in original formula. With the current and required voltage figures known, the necessary resistance can be easily calculated from R = V / I. The precise resistance value can be obtained by using appropriate resistors in series or parallel, or by using a preset potentiometer.

It should be noted that the potential between output and "adjust" may not be exactly 1·25V, in fact the data sheets quote 1·2V to 1·3V, a variation of about four per cent.

(Further information about the LM317T was given in EPE October 1994 issue, page 796. Ed.)

CONSTRUCTION

Using a printed circuit board for a circuit as simple as this seemed to the author to be "overkill". Instead, most of the components are mounted on a small piece of 0·1 inch grid stripboard having 14 strips by 18 holes, as shown in Fig. 5.

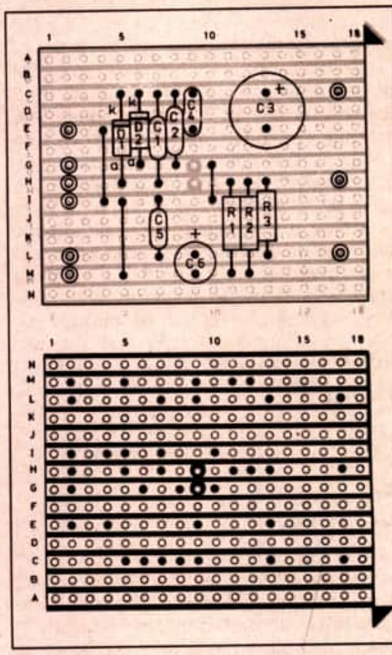


Fig. 5. Stripboard layout and track details for the Hum-free Battery Eliminator.

The stripboard should be carefully cut and filed to fit into the slots at the sides of the suggested case. There are two track cuts to be made in the board, and three link wires.

One of the links appears to connect to a strip that goes nowhere else. In fact, as the "adjust" pin is a point where noise might enter the circuit, the strips to either side of the one connected to "adjust" are also connected to the negative rail to help guard against this.

Little needs to be said regarding construction, save that three of the 100n capacitors (C1, C2 and C5) have their leads bent outwards and this should be done with care as they are fragile. Testing consists of simply connecting up the components, thoroughly checking the assembly when complete, attaching a meter and applying power. **However, be extremely careful as mains voltages are present around the transformer. If in any doubt, consult a qualified electrician.**

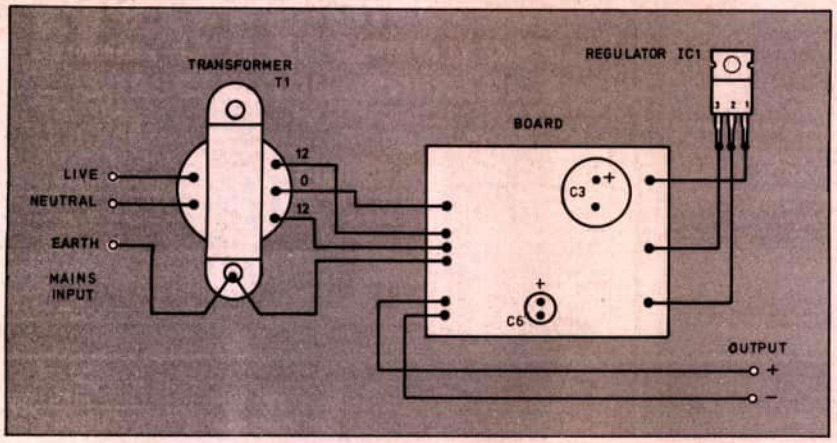


Fig. 6. Connections between board, transformer and regulator.

In the unlikely event of problems, the circuit could be supplied with 12V d.c. from a current-limited supply in place of the transformer whilst trouble-shooting takes place.

CONNECTIONS

Connections between board, transformer and regulator are shown in Fig. 6. The regulator is bolted to a small piece of aluminium which is wedged into the end of the case behind the pillars to which the lid is screwed. The heatsink tab on the regulator is internally connected to the output pin, so it should *NOT* be allowed to come into contact with any other part of the circuit.

The mains earth lead does not have to be connected to the negative rail. It can be connected to positive or, where a double-insulated transformer is used (the type with separate bobbins for primary and secondary windings), it could be omitted altogether. (If a metal case is used, the case MUST be connected to the Earth lead.) All three arrangements were tried with the Practice Amplifier and none produced any audible hum. An l.e.d. could be added to indicate that the unit is operating.

HUMBLE HOUSING

There are many ways in which this power supply can be housed. The prototype was fitted into an ABS plastic box with internal dimensions of 49·5mm × 99·5mm × 40mm. Although the prototype shown in the photograph was built with a mains plug on a short lead, another was constructed as a plug-in unit, with the plug fixed directly to the case. This was awkward to wire though, and is not really recommended.

Cases with moulded plugs are available, but the problem with these is that the Earth pin is usually a plastic dummy. With some types it might be possible to remove this and replace it with a metal pin taken from an ordinary plug.

Ripple from this battery eliminator is practically unmeasurable, and voltage regulation from zero to 250mA is better than one per cent. It has completely eliminated the Practice Amplifier problem experienced by the author's musician friend. With the volume control fully up there is no audible hum.

The unit may well prove beneficial for use with other equipment having problems with mains power supplies, and could also be used as a bench power supply for test equipment, etc. It runs cooler than many commercial units, a two-hour test at 270mA produced only comfortable hand-warmth, mostly from the transformer. □

COMPONENTS

Resistors

R1, R2 2k7 (2 off)
R3 220Ω
All 0·25W 5% carbon film or better

See SHOP TALK Page

Capacitors

C1, C2, C4, C5 100n ceramic (4 off)
C3 1000µ radial elect. 35V
C6 100µ radial elect. 25V

Semiconductors

D1, D2 1N4001 rectifier diode
IC1 LM317T adjustable positive voltage regulator, 3A

Miscellaneous

T1 12V-0-12V 250mA mains transformer

Plastic ABS case, 49·5mm × 99·5mm × 40mm (internal measurements); 0·1 inch stripboard, 14 strips × 18 holes; 2-pin output socket – to suit application; mains plug and cable; connecting wire, solder, etc.

Approx cost guidance only **£8**