Compact piggyback design:

Battery saver for personal portables

While typical DC plugpack adapters can substitute for batteries in calculators, their use with portable audio equipment is often unsatisfactory due to high hum levels. This project solves that problem and saves on the cost of batteries without giving you hum between the ears.

by JOHN CLARKE

Although battery operated equipment has the advantage of being operable anywhere its greatest disadvantage is the need to replace the batteries periodically, whether the item is used or not. In many cases, battery operated equipment is used close to a mains power point and so battery costs can be saved by powering from the mains.

Nickel cadmium rechargeable batteries can be used, and charged periodically or continuously trickle charged, and these constitute a long term cost improvement over primary batteries which cannot be recharged. On the other hand, rechargeable batteries can only be justified if their portability is utilised. If the equipment is used mostly in the house, then operation from a power supply is more economical.

Our plugpack regulator eliminates the need for batteries and does away with the hum problems that can occur when audio equipment is used with a standard plugpack.

The plugpack has rescued many battery operated devices from the scrapheap by providing a cheap source of power, while the costs of dry batteries escalate. But most people who have tried a DC plugpack to power portable radios and cassette recorders have been very disappointed by the excessive hum level they produce. This hum is due to the 100Hz ripple superimposed on the plugpack supply output and is a common failing in most simple inexpensive DC plugpacks.

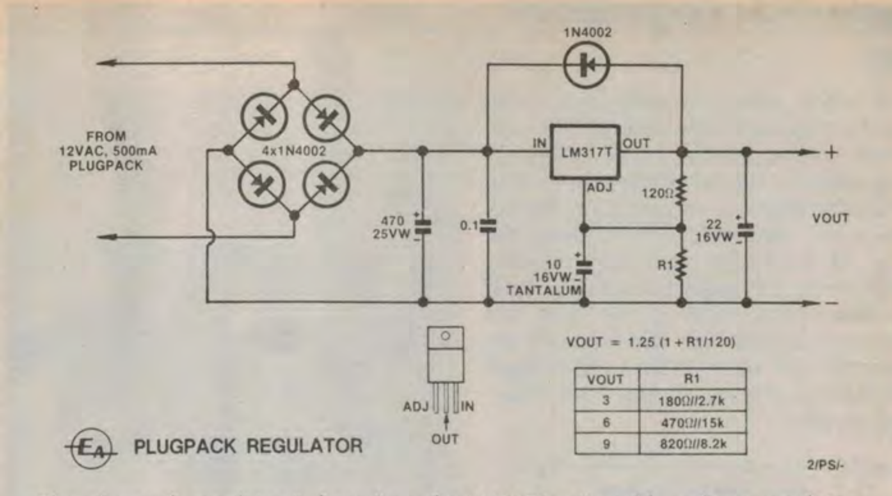
The most effective solution is to build a power supply fitted with a voltage regulator. The regulator, by the very fact that it regulates the voltage, acts as a very effective filter; so effective that its performance could only be matched by using very large and expensive electrolytic capacitors. Over and above this the regulator takes care of line voltage variations, and potential voltage variations due to changes in load, or output current.

Our plugpack regulator is housed in a small plastic utility box, glued onto the rear of an AC plugpack. The leads from the plugpack enter the regulator box and emerge fully regulated and without the ripple which causes hum. The voltage from the regulator is necessarily several volts less than the voltage available from the plugpack and so a 12V AC plugpack is a suitable choice.

Voltages available from the regulator can be selected from between 1.5 and 9V. This range is sufficient for virtually any piece of portable radio or audio equipment. At 9V the maximum current available before the regulation ceases is 350mA; at 6V, 430mA; and at 3V, 660mA. The regulator can be adjusted to any voltage required, by turning a small trimpot, or fixed resistors can be installed to provide a single preset voltage.

The plugpack regulator circuit is relatively simple and comprises an adjustable three terminal regulator, five diodes, and associated resistors and capacitors. A full wave bridge rectifier converts the AC voltage from the plugpack to pulsating DC and this is filtered to moderately smooth DC with the 470μF capacitor across the supply. For transient suppression, the 0.1μF capacitor is also included across the supply.

The remainder, and vital, part of the filtering is performed by the LM317T three terminal regulator which, as already hinted, also pegs the output voltage within very close limits over a wide range of input (line) voltage variations and output load (current) variations.



The plugpack regulator is based on the LM317T adjustable voltage regulator.

How it works

To provide a better understanding of how the regulator works we have prepared a much simplified diagram of it (Fig. 1). As we show it the LM317T consists of a power transistor in an emitter follower configuration, with the base being fed from the output of an operational amplifier. The input to the operational amplifier is taken from the output of the emitter follower – thus making it a feedback system – but, more specifically, it is the voltage developed across R2. The op amp monitors the voltage across R2 and adjusts the drive to the power transistor to keep the output voltage within tight limits.

The whole system is so adjusted that it strives to maintain a constant value of about 1.25V across R2 which means that, in turn, it also maintains a constant current through R2 and thus, by definition, the same constant current through R1. By selecting the value of R1 we can nominate the voltage which will appear between the "OUT" terminal and the negative rail, which will be 1.25V higher than the voltage across R1.

Let us now consider what happens if the output voltage (between "OUT" and negative rail) tends to vary, due to either variations in the input voltage or variations in the load current. Let's say the voltage tends to rise. This would have the effect of trying to force more current through the R2, R1 network and increasing the voltage across R2. But the feedback network will have none of this; it will immediately pull down the forward bias on the transistor, thus lowering the output voltage until the requisite 1.25V is restored across R2.

Similarly, if the voltage should tend to fall, the reverse corrective action would occur. This is a greatly simplified explanation of both the regulator circuitry and the manner in which it functions in the circuit, but it should give the reader at least a basic grasp of what is involved. It also explains how the LM317T can precisely control the voltage between its output and "Adj" pins, while negligible current actually flows into or out of the "Adj" connection.

In practical terms, and reverting to our main circuit, R1 should be 744Ω for a 9V output, 456Ω for 6V and 168Ω for 3V. The table on the circuit diagram shows the parallel combination of standard 10% resistor values to obtain these specific resistances. Alternatively a single multiturn 1kΩ trimpot can be used and adjusted for the correct voltage.

(The values of R1 have been calculated on the basis of the quoted centre voltage of 1.25 for the LM317T. The actual spread is from 1.2V to 1.3V and this, together with normal resistor tolerances, could produce slightly higher or lower voltages. However, even under worst case conditions – assuming 5% tolerance resistors – the highest voltage would be about 13% high. Most appliances could cope with this without trouble but, in any case, typical variations would be much less than this.)

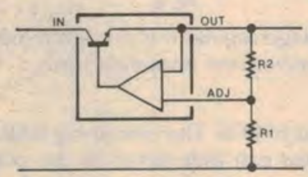


Fig 1


The regulator is glued to the plugpack.

The 10μF tantalum capacitor bypasses the voltage at the adjust terminal to ensure a stable output of the regulator without transients. Similarly the 22μF capacitor at the output provides decoupling and transient suppression.

An RF bypass capacitor in parallel with the 22μF capacitor may be desirable in some cases, but this is unlikely. Most circuits designed for battery operation would already have such a capacitor across the supply input terminals, to cope with ageing batteries. If it is felt that such a bypass is needed, it could be conveniently wired across the input socket for this supply, which will be discussed in detail later.

Diode D1, is used to protect the regulator against supply voltages entering the output of the regulator. In normal circumstances this diode is unused as it is reverse biased. If a voltage higher than the regulator voltage is applied to the output when, say, a charged capacitor is connected, the diode conducts and shunts the current from the regulator.

That more or less completes the circuit description. There is not much to it, but it offers high regulation performance. The circuit is completely safe since the plugpack is double insulated and does not require earthing.

Construction

Construction is on a printed circuit board (PCB) coded 83ps1, and measuring 62 x 46mm. The PCB is housed in a plastic utility box measuring 28 x 54 x 83mm. This box is glued to the rear of the plugpack to make a small neat unit.

Start construction by checking that the

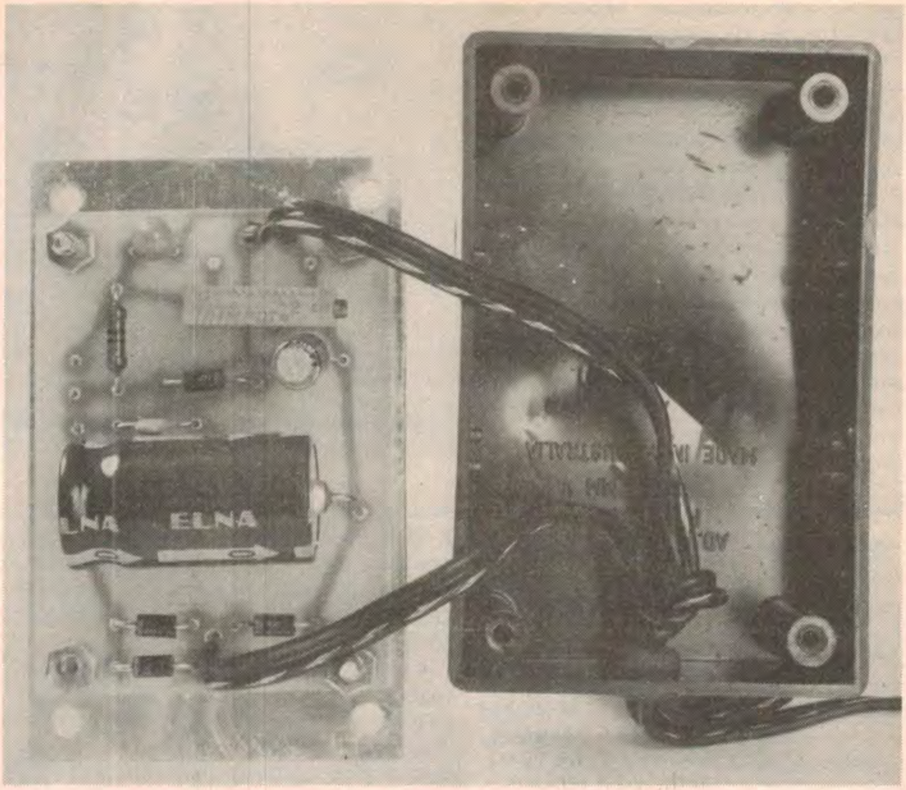
PCB will fit within the utility box. If not file the edges of the board until it has sufficient clearance. Now mark the mounting holes on the lid of the box so that, when the board is mounted on the lid, the whole assembly will fit inside the box. At this stage mark the mounting position for the regulator which is fitted on the copper side of the PCB, but mounted on the lid. The leads of the regulator will need to be bent through 90 degrees, and Fig. 2 shows the mounting details.

PARTS LIST

1 PCB coded 83ps1, 62 x 46mm
1 plastic utility box, 28 x 54 x 83mm
1 AC plugpack 12V 500mA, Ferguson PPB12/500
1 DC plug and socket (see text)
4 6mm spacers
1 TO220 mica washer and bush
1 LM317T three terminal adjustable regulator
5 1N4002 1A silicon diodes
1 470µF/25VW axial electrolytic
1 22µF/16VW PC electrolytic
1 10µF/16VW tantalum
1 0.1µF ceramic
1 120Ω ¼W resistor
1 1kΩ multi-turn trimpot (see text)

MISCELLANEOUS
Nuts and screws, solder, grommet, polarised figure-8 flex if needed (see text).

NOTE: Components with ratings higher than specified may be used, provided they are physically compatible.



The PCB is mounted on the metal lid of the case using 6mm spacers.

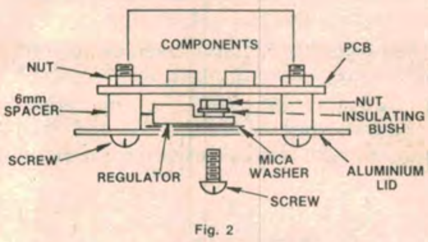
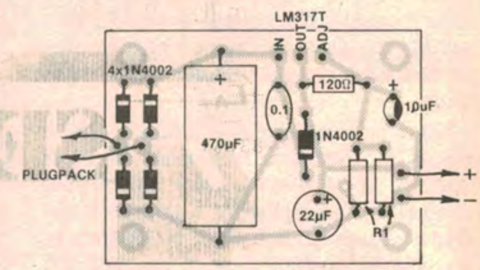


Fig. 2

The voltage regulator is mounted using a mica washer and insulating bush.



Follow this component overlay diagram.

Drill holes for these mounting positions, and also a hole at the end of the plastic box suitable for a small grommet. Deburr all the holes, particularly around the regulator mounting hole. This is to prevent swarf punching through the mica insulating washer.

Insert and solder all the components into the PCB, making sure that they are oriented correctly. Solder the regulator to the underside of the PCB and bend the leads so that it can be secured to the case lid. Place a smear of heatsink compound on both sides of the mica washer and then bolt the regulator to the case lid, as shown in Fig. 2.

While most DC plugpacks are fitted with an output lead and connector, some, such as the Ferguson AC plugpack PPB12/500, are fitted with screw terminals. If your plugpack has a fitted lead this should be cut short and wired to the AC input of PCB. The remaining lead and connector can then serve as the output lead for the regulator circuit. If your plugpack has no fitted lead, as in the case of the Ferguson AC model cited above, it will be necessary to provide a suitable length of figure-8 twin lead, preferably with a colour streak to indicate polarity.

Before mounting the PCB on the standoffs, check that the regulator is electrically isolated from the lid by measuring with a multimeter, switched to the "ohms" range. Now the lid can be secured onto the plastic box base and the regulator is ready for testing. If a trimpot is used, a hole in the side of the plastic box directly opposite the screw of the trimpot will facilitate adjustment without removing the lid.

We used "Airfix plastic cement" to glue the back of the plugpack to the base of the box. Before glueing, roughen the mating surfaces with a file so that the glue will have sufficient "key" to the plastic. While the glue is curing clamp the two pieces together.

Connect a multimeter on the DC volts range and plug the plugpack into the mains and switch on. The voltage should be as set by R1. If a trimpot is used adjust it for the required voltage. Now the regulator is ready to be put into service.

The low voltage plug to be used at the end of the regulator lead will depend on the matching socket already fitted to the appliance to be powered or, if one is not fitted, the type which is most easily fitted. There are four popular types. There is the audio jack type normally used for earphone connections, which comes in two sizes; 2.5mm and 3.5mm. If one of these is contemplated, make sure that it cannot be confused with any existing socket on the appliance.

The other type is power plug with a hole down the centre which mates with a pin electrode on the socket. These come in two sizes also; 2.1mm and 2.5mm. Both types of socket have the facility to break one connection when the plug is inserted. This is commonly used to isolate the battery when the external power supply is plugged in.

Some appliances have an external power inlet socket built into the unit so a suitable plug with the correct voltage and polarity can be inserted into the socket. To make sure that the correct polarity is applied, check with the manual or open up the case and check polarity by following the wires to the battery terminals. Generally the red wire is positive and the black negative, although this is not necessarily the case.

Neither type of socket, as fitted to various appliances, is necessarily always wired in the same way. In the case of the power plug and socket, for example, the outer conductor is frequently positive, but some manufacturers adopt the opposite convention.

For those appliances without an external power socket one will have to be installed. Open the case and find a suitable free area where a socket can be fitted without fouling when the lid is replaced. Drill a hole for the socket, and mounting holes if needed, and mount the socket. Use the circuit diagram (Fig. 3) to help

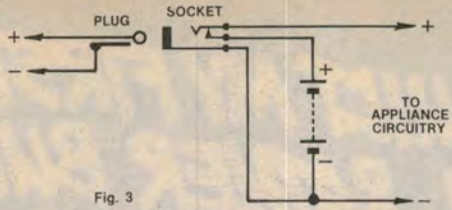


Fig. 3

Fig. 3: This circuit disconnects the internal battery when external power is used.

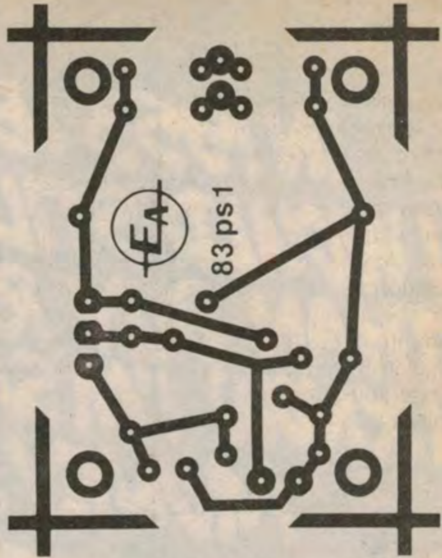
We estimate that the current cost of parts for this project is

$14

This includes sales tax but does not include the price of the plugpack.

you in wiring the socket from the battery connections. When complete the lid can be replaced and the plug connected to the regulator leads.

Although we have recommended a 12V AC plugpack, this is by no means the only power source that can be used. If voltages below 6V only are required then a 9V 200mA DC plugpack can be used and this constitutes a considerable saving over the 12V AC plugpack. Alternatively, the plugpack regulator can be



The full size printed circuit board pattern is shown above.

used in cars by tapping the 12V via the lighter socket. In either case, the rectifier diodes are unnecessary and the voltage is applied to each side of the 470μF capacitor.

Over all, the circuit has proved to be both reliable and effective, with no audible hum from the audio equipment. In fact a similar unit has been powering a portable radio for patients in the intensive care ward of Concord Repatriation Hospital for several months.