Constructional Project

IN-CAR LAPTOP PSU

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Laptop operation for the outwardly mobile

MANY laptop (notebook) computers require a power supply having an output of between 14V and 23V. This makes it difficult to operate them from a car battery or other 12V source. One method would be to use a mains inverter (to give 230V a.c. from the 12V d.c. input) then connect this to the mains power adaptor supplied with the computer.

However, not everyone has an inverter and if this were to be its only use, buying one would be hardly worthwhile. Also, it would be a clumsy, bulky method and the efficiency of the arrangement would be low due to the losses at each stage.

ELEGANCE

The more elegant solution described here involves the use of a "boost switching regulator". This provides the necessary increase in d.c. voltage and stabilises the output so that it remains substantially constant despite changes in load and/or input voltage. The finished device is fairly efficient operating at between 83 per cent (at maximum power output) and 90 per cent (under a light load).

CURRENT SITUATION

The current drawn by a laptop computer comprises two parts. The first operates the actual electronic circuits. Its value will depend on the particular laptop used, its operating voltage and, to some extent, the application in hand. Most of the time, it is likely to be in the region of 1A.

The second element is the current used to charge the battery and its value will depend on the state of charge. When fully charged, the current will fall to a low value. When the battery is "flat" it will be at its highest – perhaps 2A. It can be seen that the total current requirement of a laptop may be 3A or more with a "flat" battery.

A graph of maximum current available from this Power Supply Unit (PSU) against voltage output is shown in Fig.1. This is based on measurements made on the prototype unit using a 12V input. It will be seen that, for example, some 2A is available at 24V, 2·5A at 20V and 3A at 15V.

If the input voltage fell below 12V, the maximum current would fall. In practice, a well-charged car battery will maintain 12V minimum so this is a reasonable assumption. The maximum output power (current multiplied by voltage) is 45 to 50 watts approximately.
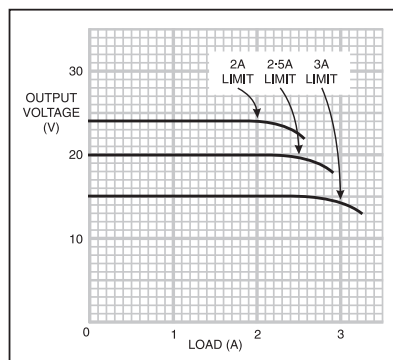

Fig.1. Graph showing maximum current against voltage output.

TRICKY QUESTION

So how can this power supply successfully operate a laptop computer if it may be incapable of delivering sufficient current under all conditions?

The trick is to use it *either* to charge the battery (with the laptop switched off) *or* to power it (with the battery fully charged) – not both at the same time. This will usually be found convenient.

In use, the laptop's battery will then "top up" any temporary high current needs. In fact, it may be found that the power supply will charge the battery when it is only partially discharged and operate the computer at the same time.

The user will soon find out what is possible using his or her particular machine.

INITIAL CHECKS

Before building this unit, it is important to make some checks using your own laptop. This will confirm that the circuit is likely to be suitable. ***However, due to the limited number of laptops checked with this circuit, no guarantee can be given that it will work correctly in every case.***

Look at the label on the computer's existing mains adaptor to determine the operating voltage. The power supply unit described here is suitable for computers requiring between 14V and 23V.

Note that the input voltage is not the same as the battery voltage. The author's HP Omnibook needs a 19V input as did a Dell Insipiron tested. These both used a 14·4V nominal battery pack. A Toshiba Satellite needed a 15V supply and used a 10·8V battery. The battery voltage is a few volts less than that of the supply because a higher voltage than its own is needed to charge it.

A BREAK IN

Check the laptop's current requirement to make sure it is less than that available. With a 19V machine, it can be assumed that 2·5A will be available from the new unit (see graph – Fig.1). For a 15V laptop, 3A would be available.

To measure the current drawn, make a simple "break in" circuit that will allow monitoring under various conditions. This consists of a line socket to match the plug on the existing mains adaptor and a plug of the same type as that needed for the laptop's input (see Fig.2).

The 19V laptops tested used the same standard "power-in" plug. The Toshiba needed a similar plug but having a larger diameter "pin". Note: the size of the pin may be found using a set of drill bits of known diameter in the output plug on the mains adaptor.

The plug and socket are linked through short pieces of wire (*5A rating minimum*) but including a 0·05 ohm fixed resistor connected in series with the positive one. You could connect two 0·1 ohm resistors in parallel to obtain this value if it is more convenient. This arrangement allows a digital voltmeter (DVM) to be used to measure the voltage developed across the resistor and hence find the current (since many readers will not have a suitable ammeter to measure the current direct).
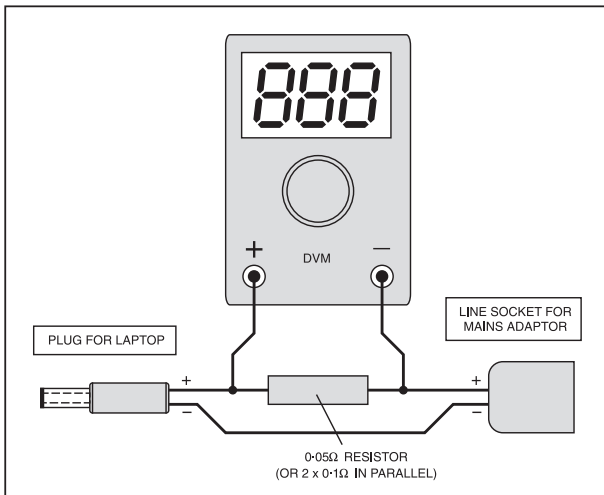

Fig.2. Set-up for monitoring Laptop current.

According to Ohm's Law, for each amp of current flowing, there will be 50mV (0·05V) "dropped" across the resistor. For example, a 75mV "drop" would indicate 1·5A. Such small voltage losses will not affect correct operation of the computer.

Using this set-up, measure the maximum current needed to charge the battery (that is, using a discharged unit and with the computer switched off). This was found to be a little over 2A for the 19V machines and some 2·5A for the 14V one – well within the capability of the power supply.

Now allow the battery to charge fully (note the current falls to a low value), switch the laptop on and measure the current again. This will find the current needed for the actual computer. This was found to be around 1A for each machine. In these cases, it will not be possible to charge the battery from "flat" and use the computer at the same time.

CIRCUIT DETAILS

The full circuit diagram for the In-Car Laptop PSU is shown in Fig.3. The nominal 12V input (the car battery supply derived from the cigar lighter socket) enters via terminal block TB1, fuse FS1 and the pair of diodes D1 and D2 connected in parallel.

The diodes provide reverse-polarity protection and, being Schottky devices introduce only a small voltage drop – some 0·3V to 0·5V depending on the load. The reason why *two* diodes are used rather than one is to share the current between them (and hence the power dissipation).

Fuse FS1 provides protection in the event of a short-circuit at either input or output. Current flows to capacitor C1 and charges it to provide a small reserve of energy.

IC1 is a boost switching regulator and most of the control circuitry is already built into it. Its pinout details are shown in Fig.5. Current enters at pin 5 (V+) and returns to 0V at pin 3. Capacitor C2 connected directly between the supply pins decouples it and promotes stability.

The network comprising resistor R1 and capacitor C3 in series connected to pin 1

(compensation), is necessary for the correct operation of internal circuitry. With a supply in place, the "switch" (pin 4) will now turn on and off at 100kHz (a frequency set by internal components). When "on" pin 4 is connected to the 0V rail.

ENERGY EXCHANGE

Suppose for the moment that the switch (IC1 pin 4) is *on*. Current flows from the supply through inductor L1 and via the switch to the 0V rail. Diodes D3 and D4, connected in parallel, do not conduct because their common anode (a) is at 0V (due to the "earthing" effect of the switch) while the cathodes (k) are at output voltage. They are therefore reverse biased.

The current flowing is limited by the inductance of L1 as energy is "soaked up" in its core as the magnetic field builds up. Given sufficient time, the inductor's core would magnetically saturate and the current would rise to a very high value.

However, by the time the current rises to some intermediate level, the switch turns *off*. Now, the magnetic field in the inductor's core collapses rapidly. This induces a high reverse voltage in its winding so that the end connected to IC1 pin 4 rises above that of the supply.

The energy then discharges through the pair of diodes D3 and D4 in parallel (as with D1/D2 to share the power dissipation), and is stored in capacitor C4. A voltage greater than that of the supply therefore builds up across this capacitor. It can be seen that the energy stored in the inductor while the internal switch is *on*, is transferred to the capacitor when it is *off*.

ON BALANCE

The voltage appearing across capacitor C4 is applied to the potential divider consisting of resistor network VR1/R2 (upper arm) and R3 (lower arm). Preset VR1's sliding contact may then select a fraction of the voltage at the junction of R2 and R3 and this is monitored by IC1's feedback input (pin 2).

An error amplifier built into IC1 compares the voltage at pin 2 with a 1·23V reference. If the voltage rises above this value, the switch lowers its peak current and has the effect of reducing the output voltage to restore balance. If the feedback voltage falls below the reference voltage value, the peak switch current increases.
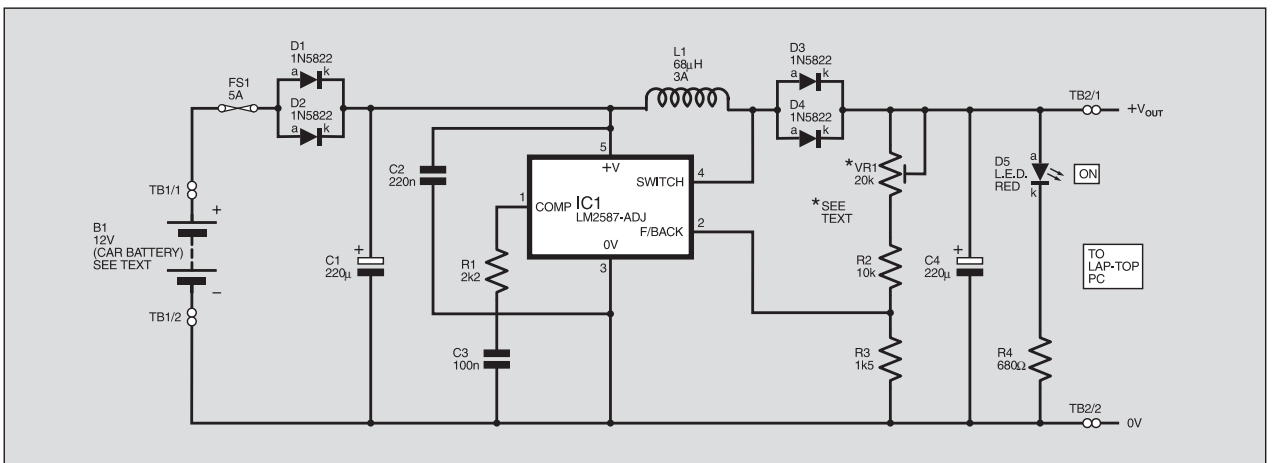

Fig.3. Complete circuit diagram for the In-Car Laptop Power Supply Unit (PSU).

In this way, the output voltage is maintained at the required value despite changes in external conditions (load and input voltage). All that is needed is to adjust preset VR1 to provide the correct output voltage at the end of construction.

Light-emitting diode, D5, operates in conjunction with current-limiting resistor R4 and provides the "on" indicator.

CONSTRUCTION

Construction of the In-Car Laptop PSU is based on a single-sided printed circuit board (p.c.b.). This board is available from the *EPE PCB Service*, code 443. The topside component layout and actual size copper master pattern are shown in Fig.4.

Commence construction by drilling the

Component layout on completed circuit board.

two mounting holes in the positions indicated. Solder fuseholder FS1 and the two pieces of terminal block TB1 and TB2 in place. Follow with inductor L1 and all resistors (including preset VR1). It makes for much easier adjustment later if you use a *multiturn,* top adjustment, type preset for VR1.

Some of these devices have an in-line pin arrangement while others have a triangular pinout. Either type can be accommodated on the p.c.b. so use the holes that correspond. A standard vertical preset could be used but adjustment would be more difficult.

Add the four Schottky diodes D1 to D4, taking care over the polarity of each. Follow with all capacitors taking care over the polarity of electrolytic units C1 and C4. Note that capacitor C4 must be of a *low impedance* type while C1 (which has the same value) could be a standard type.

Add regulator IC1 noting the orientation – its flat (metal) face towards the top edge of the p.c.b. Carefully bend the pins as necessary to make it fit. Take special care when soldering IC1 in position because it is a

relatively expensive device and will be damaged by excessive heat.

Before soldering the l.e.d. in place, extend its leads (if necessary) using single-strand connecting wire so that the top will
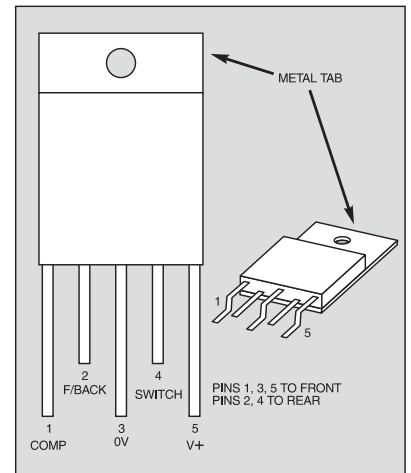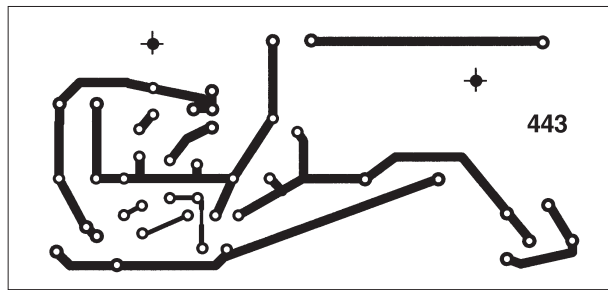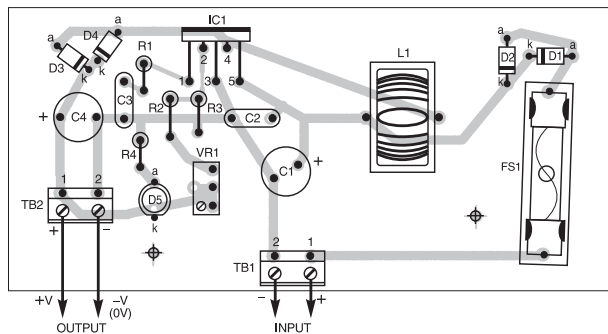

Fig.5. Pinout details for the LM2587.

Fig.4. Printed circuit board component layout, full-size copper foil master pattern and wiring for the Laptop PSU.

end up slightly higher than the lid of the case (so that it will show through a hole drilled for it later). Solder it in position taking care over the polarity. Adjust preset VR1 sliding contact to approximately midtrack position.

TESTING

Note that a metal box **MUST** *be used to house this circuit since it will behave as a heatsink for IC1. For the prototype unit, a diecast enclosure (sprayed black) was used. However, other types of aluminium box should be suitable as long as everything fits.*

In operation, up to 10W of the input power will be wasted. Most of this is given off as heat by only a few components. IC1 itself will dissipate some 4W, the inductor 3W approximately and the input and output diodes, D1 to D4, some 0·75W each.

To remove the heat safely from IC1, it must have an adequate heatsink – hence the use of a metal box. The i.c. metal tab is internally connected to 0V so that, in use, the case will assume 0V (battery "negative" potential). Metal parts of the car are also at 0V so this is acceptable practice.

With IC1 tab pressed against the side of the case, mark holes in the base of the box to correspond with the p.c.b. mounting holes. Mark also positions for two holes to accept the strain-relief rubber grommets that will be used to protect the Input and Output wires passing through the box. Drill these holes through.

Attach the p.c.b. temporarily on short plastic stand-off insulators so that the underside soldered joints remain several millimetres clear of the base of the box (to avoid short circuits). Mark the position of the hole in IC1 tab and also the position of a few ventilation holes in the side of the box in the region of the input and output diodes. Remove the circuit panel again and drill all these holes.

It would be wise to apply a little thermal transfer compound to IC1 tab (the surface that makes contact with the case). This will help in conducting the heat away.

Now re-mount the circuit board and attach IC1 firmly to the side of the case. *Make sure its pins are not left under any strain*. Drill a hole in the lid for the l.e.d. to show through (but do not fit the lid). Insert the rubber grommets in their holes and add the fuse.

FINISHING OFF

Make up an Input lead to connect the unit to the car's cigar lighter socket. The wire used should be rated at 5A *minimum* and should not be any longer than necessary (say, one metre maximum) to avoid an excessive voltage drop. Fit the correct type of plug on one end. Pass the other end through one of the rubber grommets and connect the wires to terminal block TB1 taking care over the polarity.

Plug the unit into the supply (*not with the engine running*). The l.e.d. should light up. Apply the voltmeter probes to TB2 terminals and adjust preset VR1 to provide the required voltage. At this point, and to save time later, charge up the laptop battery fully, using the computer's mains adaptor.

Make up a laptop connection lead (using the same type of wire as that used for the Input) with the correct type of plug on the
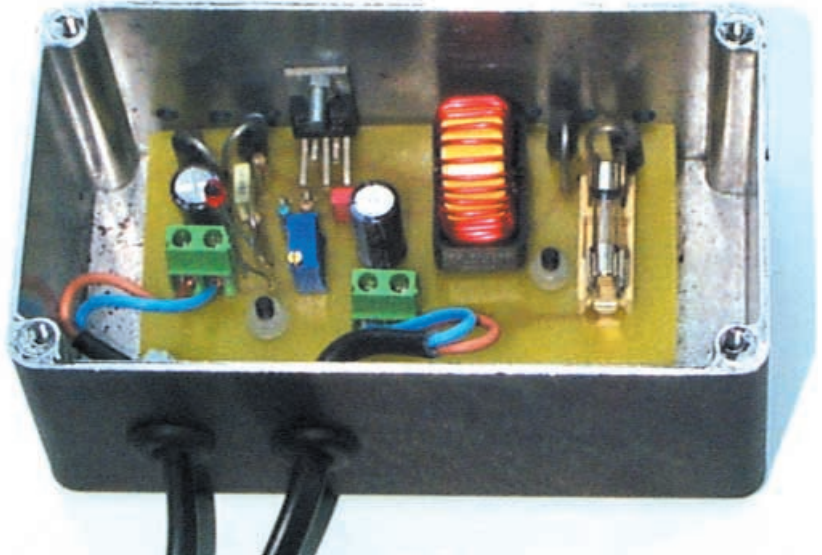
Finished power supply showing the p.c.b. mounted in a diecast box.

end. As with the input lead, this should not be any longer than necessary. Pass the end of the wire through the remaining rubber grommet and connect it to TB2. *Make sure you observe the input polarity of the computer* – this might be indicated next to its socket. Apply strain relief (tight cable ties, for example) to both input and output leads leaving a little slack inside the case.

Drill a few ventilation holes in the lid of the box. Fit the lid but do not screw it down yet. Adjust the position of the l.e.d. so that its top protrudes slightly through the hole drilled for it. Make any adjustments as necessary.

FINAL TESTING

Before connecting the laptop to the new supply, re-check the output voltage and polarity since mistakes here could damage the computer. Note that the unit MUST NOT be used with the car engine running.

With the battery fully charged from the mains, connect the laptop computer to the new supply and check for correct operation. Feel IC1 and diodes D1 to D4 at intervals to make sure they are not overheating. It is normal for them to become quite warm.

Allow the battery to run down again and check that it charges correctly with the computer switched off. If this is not satisfactory, check the voltage near the computer using the break-in arrangement (Fig.2) used earlier to make sure it does not fall below the correct operating value.

HIGH SIDE

It seems that manufacturers often set the output voltage of their mains power supplies slightly on the high side of the nominal value. The author has found that this is commonly around 3% more. For example, for 19V laptops, the actual voltage may be found to be 19·5V approximately.

Presumably, this allows for voltage drops along the wiring so that the voltage at the computer input is always maintained at 19V minimum on full load. If operation still proves to be unsatisfactory, set the new unit's output voltage to the same value as that provided by the existing mains power supply as measured by an accurate voltmeter.

In use, the unit should become only warm. However, if it is delivering high power over a prolonged period, it will become quite hot. If this is so, make sure it is placed so that this will not damage any heat-sensitive parts of the car such as plastic parts.

FINAL POINT

Take care to avoid using this power supply for long periods and run down the car battery. A typical car battery has a capacity of 40Ah (amp-hours). If 2A is drawn, it will be run down in 20 hours and there could be insufficient capacity to start the car after a much shorter period of use. Make sure the car is regularly used to keep the battery charged but *YOU MUST NOT* operate this device with the engine running. □