

40A Power Supply Unit

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SPECIFICATION

- ‡ **Input voltage:** 240
- ‡ Output voltage: 13.2V DC
- ‡ **Output current: 40A DC**
- ‡ **Over current protection:** current limiting at 40A
- ‡ **Short circuit protection:** Regulator shut off.
- ‡ **Over voltage protection:** Shuts off DC input and discharges input stage reservoir.
- ‡ **Over temperature protection:** Fan automatically operates as heat sink temperature of 65 °C.
- ‡ **Indicators:** Power ON LED and Short circuit Protection active LED.

THIS PROJECT describes a Protected 13.2V 40A Power Supply Unit which, provided the heat sinking and cooling fan are suitable, is capable of running at full power at 100% duty cycle. It features soft starting, over voltage, current limiting, short circuit protection and automatic fan control. It is a substantial project that is not for the novice constructor.

CIRCUIT DESCRIPTION

THE HEAVY CURRENT carrying connections are shown in bold in Fig 1. The mains input passes through an EMC filter, protection fuse F1 and ON/OFF switch S 1 to transformer TI. The secondary output of TI is rectified by D 1 but cannot pass through open relay contacts RL1a. To start the PSU switch, S2 is operated allowing limited current to pass via R1 to slowly charge the reservoir capacitor C1. As C1 charges, the RL1 a pulls in closing the relay contacts and shorting out R1 and S2 placing the PSU in the ON state.

Voltage regulator IC1 is the popular 723. A 7.2V reference on IC 1:6 is fed to non-inverting IC1:5. This is compared with a sample of the PSU output voltage via RI3, RI4 and RI5 to inverting input at IC1:4. The 723 can source 150mA at IC1:10, so transistor TR2 acts as a Darlington driver for the pass transistors TR3 to TR7

When the current through R21 reaches 8A (i.e. a total PSU current output of 40A) the voltage across R11 and R12 is 0.88V and is tapped from R II to bias a transistor inside IC1 which robs IC1: 10 of some current, forcing the PSU into a current limiting mode.



Terminals +S and -S are for remote sensing, where the PSU might be located

some distance from the equipment it is powering and a voltage drop occurs along the equipment DC power leads (Fig 2). The remote sense terminals draw very little current and are used purely to measure the voltage at the load. If the delivered voltage is below 13.2V, the PSU will increase the voltage at the output terminals to make up for the drop along the equipment leads so that exactly 13.2V is delivered to the load. If remote sensing is not used then shorting links must be connected across the PSU output terminals. Resistors R18 and R20 are included for forgetful operators.

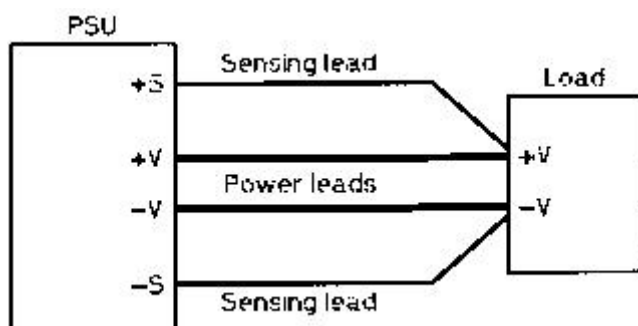


Fig 2: Using remote sensing.

Over voltage is only likely to occur if one of TR3 to TR7 fails short circuit. Over voltage protection is provided by D5, R16, R17 and SCR1. If the PSU output increases above 15V (at the load) then D5 conducts and fires thyristor SCR1. When SCR1 fires, it short-circuits the unregulated input discharging C1 via R3 and causing relay RL1 to drop out. When the relay drops out it prevents capacitor C1 from being recharged (in the next rectified half cycle and the PSU is latched in the OFF state).

A PSU of this category will develop a fair amount of heat in TR3 to TR7; roughly 350W at 13.2V 40A output and this must be transferred to the environment via suitable heat sinks. Previously published designs have either had a fan that continuously runs (which after prolonged periods becomes intensely irritating) or one that must be switched on by the operator requiring the operator to periodically test heat sink temperature (scorched fingers). Other designs simply shut the PSU down until it has cooled, which is pretty user unfriendly if you happen to be working it rare DX station. This design overcomes both of these problems by using a simple but effective auto-matte fan controller,

A 4.7V reference is set up by R5 and D2. Bead thermistor RT1 is thermally coupled to a hot spot on one of the heat sinks (ie, on top of TR3). At Low ambient temperatures the thermistor has a high resistance and TR1 is switched off. Under heavy usage the PSU heat sink warms up and so does thermistor RT1.

As 65 – C the thermistor value has dropped sufficiently for R6 to develop 0.65V and switch on TR1 driving the DC fan, blowing cooling air over the heat sinks. As the heat sink cools so does RT1 and at 55 – C the reverse process occurs and the fan is switched off. Switching is gradual with the result that the PSU is not tripped out by the fan operating and the fan runs for just long enough to cool the PSU down.

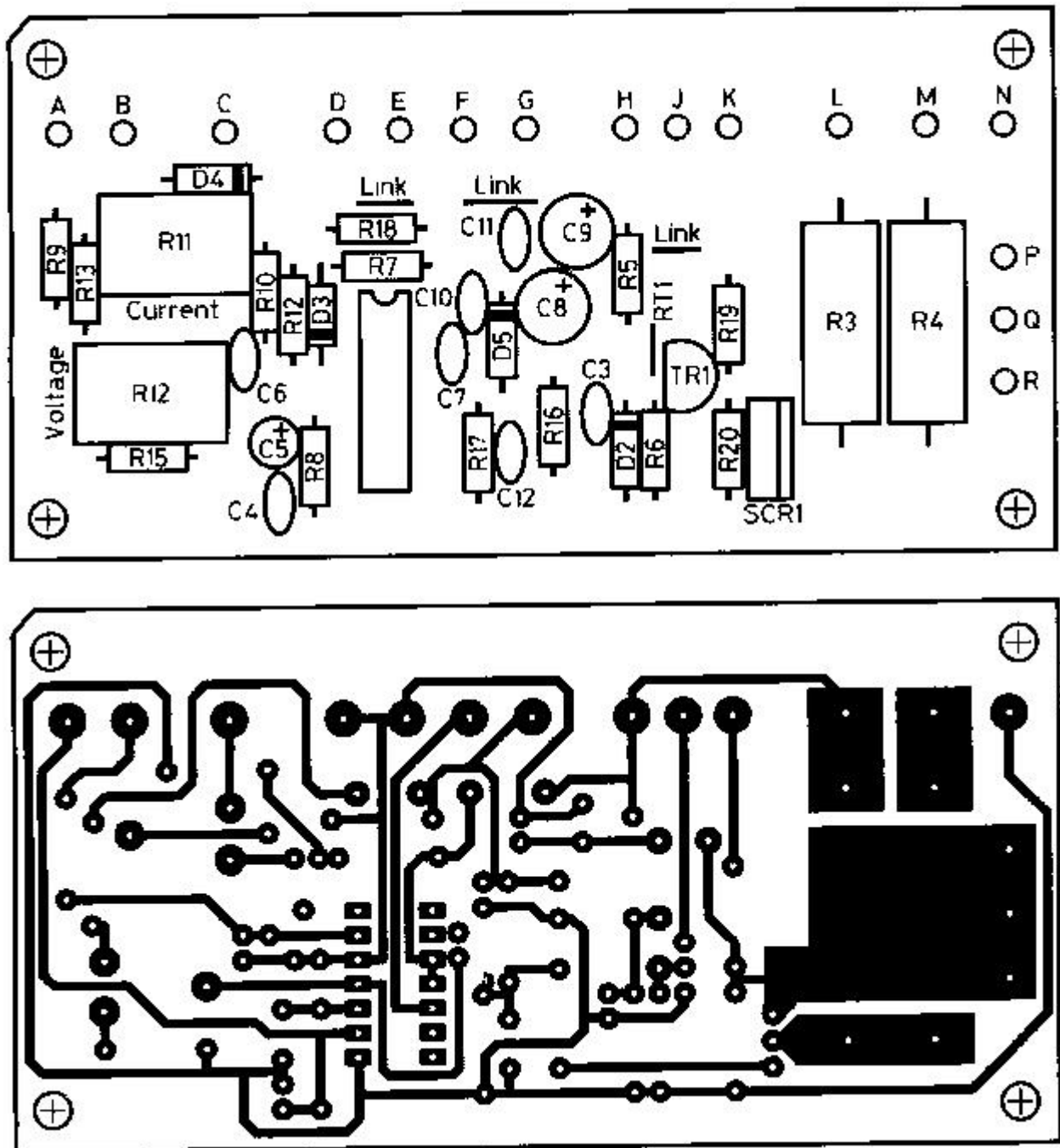


Fig3 Component Overlay with PCB track

The PCB has one corner truncated at 45°, to aid component location & identification. Refer to the component location diagram shown in **Fig3a** with tracking shown in Fig 3b.

Use wires that is 8AWG, (10 SWG, 0.128in OD, 3mm OD) for all heavy-duty connections. Doubling up 2.5mm² domestic ring main black & red will do. R4, shown in Fig1 (part1) not used. Fit thick wire link on PCB board. Resistor R2 and capacitor C2 are soldered directly across the solder tags for C1 with C1 bolted to the chassis with a clip. Relay RL1 is a 40A 24V truck relay or a 40A 12V car relay could be used and R42 included.

The two heat sinks (with transistors TR3 to TR7 & R21 to R25) are fitted to the inside of the rear panel, see Fig 4, along with the DC fan and mains IEC plug. Transistors TR3 to TR7 must be fitted with TO3 thermal washers and spigots. Use heat sink paste to give good thermal contact. Check that the collectors, emitters and bases of TR3 to TR7 are a very high resistance to ground (i.e., not short circuited).

Fig 3: (a) Component overlay and (b) PCB tracking [Enclosed].

The cooling fan needs to be sufficiently large to cool the heat sinks under worst case conditions, that is when drawing 40A and dropping 350W across the power transistors. The easiest choice here is to fit the largest you can. Transistor TR1 can sink up about 200mA.

The PSU fan forces air into the PSU. After circulating around the inside of the case the air is forced out of the rear panel through the areas marked CUT-OUT (see Fig 4) at the base of the rear panel beneath the heat sinks. To duct the air over the PSU heat sinks two home made heat sink covers are required. These can be manufactured by folding either plastic or aluminum sheet at 90°.

The cover is slid over the heat sink with the lower fold of the cover aligning with the base of the PSU case. The two outer folds align with and are affixed to the outer heat sink fins. The cover thus forms a vertical chimney preventing the air escaping sideways or downwards.

If using metal for the covers ensure that it doesn't short out the power transistors.

Bead thermistor RT1 has its leads cut to about 0.25in (6mm) and two flying leads soldered. The soldered joints are then covered with heatshrink sleeving and the bead is mounted on top of TR3 (or TR4 or TR5 etc). A small piece of expanded polystyrene is then placed over the bead to prevent draughts from the fan affecting it and a small home-brew metal clip is used to hold it in place.

The PC pins on the PCB connect as follows:

- 1) A to DSI anode (light duty).
- 2) B to DS I cathode (light duty).
- 3) C to TR3 emitter/R21 node (light duty).
- 4) D to +OUT positive terminal (light duty).
- 5) E to DS2 anode (light duty).

- 6) F to TR2 base (light duty).
- 7) G to +S remote sense terminal (light duty).
- 8) H to DC fan positive (light duty).
- 9) J to DC fan negative (light duty).
- 10) K to DS2 cathode (light duty).
- 11) L to C1 positive terminal (heavy duty).
- 12) M to RLI coil positive (light duty).
- 13) N to -OUT remote sense terminal (light duty).
- 14) P to RL1 coil negative.
- 15) TR to C1 negative terminal (heavy duty).
- 16) R to CI negative terminal (heavy duty).

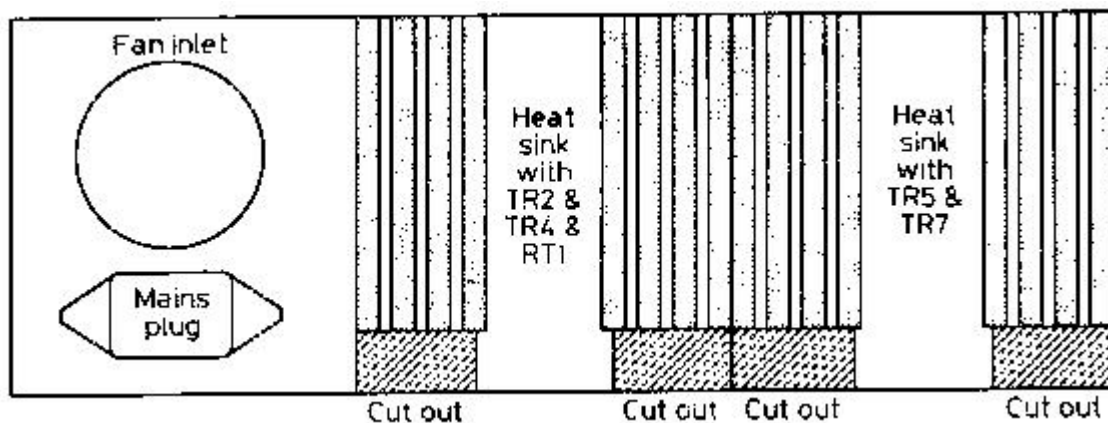


Fig 4: Rear panel details.

There are a few large copper areas on the PCB and it is advisable to liberally apply solder over these regions. Finally, note that the PSU must not be started under load. If you try to start it under load then you are likely to burn out R1.

TEST & CALIBRATION

CHECK AND RECHECK your wiring; if you've made a mistake it might turn out to be more frightening than you would expect.

Set R11 (current limit) fully clockwise and R14 (voltage) fully counter clockwise. Apply the mains - there should not be any voltage at the output terminals. Press and hold momentary action START switch S2 - after about five seconds the relay should pull in and LED DS2 should light up. The output voltage will be below 13.2V - so adjust R 14 to obtain 13.2V output.

You need to adjust R11 so that the PSU just goes into current limit mode when 40A is being drawn. For this you require a 0.33Ω variable resistor that can handle 550W. This might seem to be a problem but in reality it's fairly easy to make a variable transistance using some 2N3055 transistors mounted on a heat sink as shown in Fig 6.

You will also need a 40A Ammeter or a smaller Ammeter and shunt. Set the variable transistance to maximum resistance and connect it to the PSU output. Adjust the *variable transistance* until exactly 40A is flowing and then adjust R11 to the point where the PSU just about goes into current limit mode, (i.e. the PSU output voltage just begins to fall). Remove the variable transistance.

The short circuit test involves connecting a substantial connector in line with your 40A Ammeter across the PSU outputs. The PSU output current should drop to just about zero and DS1 (FAULT) LED should light up. Remove the connector and check that DS1 goes out and the 13.2V output returns.

CONCLUSIONS

THE MOST EXPENSIVE part of this project is the transformer; the cheapest place to obtain one is from a rally. The transformer can be made up from two transformers with secondaries of 15V at 25A. Make sure they are connected in the correct phase. The secondary voltage must not be more than 18V RMS off load and not less than 15V under full load.

Capacitor C1 can be made up by connecting two $47,000\ \mu\text{F}$ capacitors in parallel or one $100,000\ \mu\text{F}$. Diode D1 can be made from four 50A diodes arranged in a bridge if a 50A bridge is not available as a complete device. Likely sources for relay RL1 are commercial vehicle or truck dealership Parts Departments or commercial vehicle repair works.

M1, in Fig 1, is a fan motor and not a meter as shown.

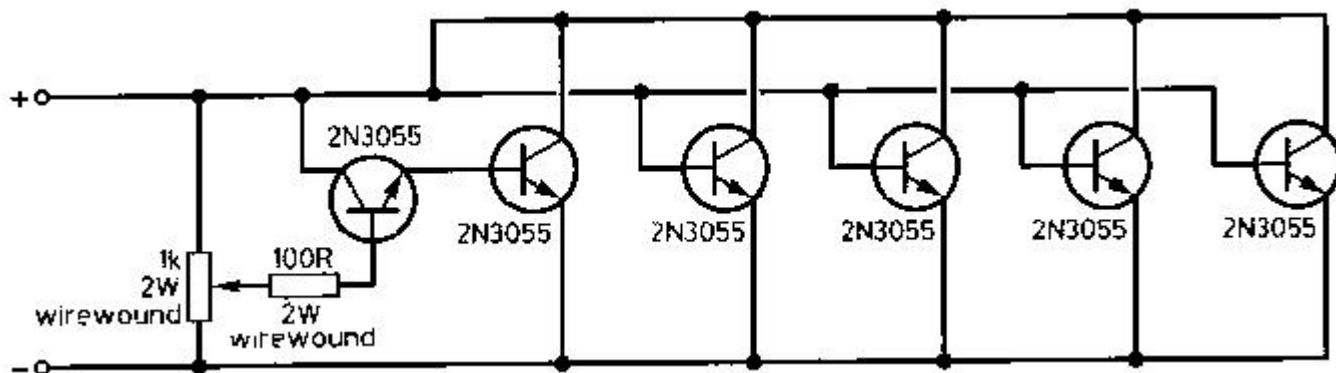


Fig 6: variable transistance.

COMPONENTS LIST

Resistors

All 0.25W 5% unless otherwise noted

1 R1	10R 5W
2 RI8, R20	10R
4 R2, R5, R7, R8	1k
1 R3	2R7 3W
1 R4	See text
1 R6	220R
3 R9, RI0, RI9	470R
1 RI I	100R
3 R12, R16, R17	120R
1 R13	5K6
1 R14	1k
1 R15	6k8
5 R21,R22, R23, R24, R25	0R11 7W
1 RTI	4k7 Bead thermistor

Capacitors

1 C1	94000uF 35V Electrolytic
7 C2, C3, C4, C6, C7, C10, C11	10nF 50V Ceramic
1 C5	1uF 35V Electrolytic
2 C8, C9	100uF 35V Electrolytic
1 C12	100nF 50V Ceramic

Semiconductors

1 D1	50A 50V PIV Bridge rectifier
1 D2	4V7 400mW Zener Diode
1 D3	1N4148 Signal Diode
1 D4	9V1 400mW Zener diode

1 D5	15V 400mW Zener diode
1 DS1	Red 5mm LED
1 DS2	Green 5mm LED
1 TR1	BC184 NPN
6 TR2, TR3, TR4, TR5, TR6, TR7	2N3055
1 SCR1	13A Thyristor
1 U1	LM723 Voltage Regulator

Miscellaneous

1	50A binding post, red +OUT
1	50A binding post, black, OUT
1	5A binding post, red (Remote Sense positive)
1	5A binding post, black(Remote Sense negative)
1	FI Fuse5A
1	Fuseholder, panel mount
1	Fuseholder, rubber boot
1	IEC mains Euro socket with integral EMI filter block
1	IEC socket rubber boot
1	M1 24 VDC 0.2A maximum DC Axial Fan
1	PCB
1	Project case
1	RL1 24 V DC 40A. Truck relay (or 12V 40A car relay & R4)
1	S1 ON/OFF SPST switch 240V 6A
1	S2 START Momentary action switch3A
1	T1 Transformer 240/16V @ 50A 50Hz single winding primary, single winding secondary specified at full load
2	Heatsink, 1.2in C/W or better heat sinks capable of holding 3 TO3 devices each
1	Home-brew heatsink cover
6	Feet for project case
6	TO3 style thermal mounting kits
16	PC Pins
	Hook up wire
	Heatshrink sleeving
	Heavy duty wire
	Metal gauze and filter for fan entry hole
	M3 Solder tags
	M3 spacers