general purpose variable power supply

easily adapted to individual requirements

A variable power supply is described that in spite of its simple design has two clear benefits. In the first place, it is built from discrete, readily available components, and in the second place, it can be readily adapted to individual requirements. Rules of thumb to do this are included in the article.

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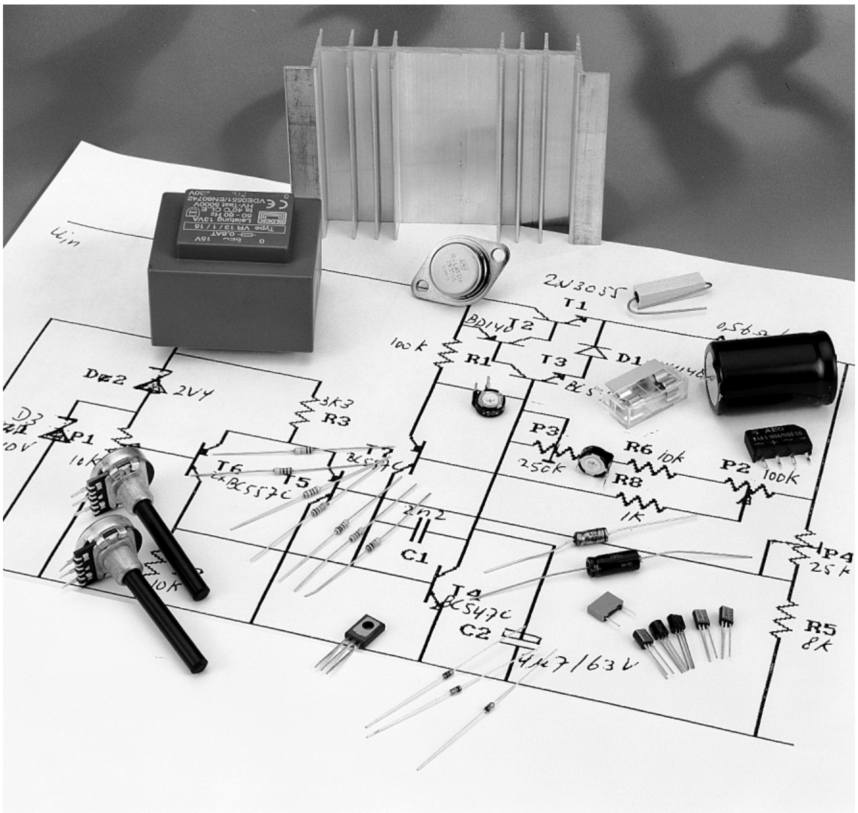

INTRODUCTION

The power supply is designed along fairly traditional lines, resulting in a unit whose output voltage as well as its current limiting is variable. In principle, both can be varied from nought, but in this design it was decided to make the peak values of voltage and current variable. These peak values can be varied from 10 V to 40 V and from 500 mA to 2.5 A. This makes the supply suitable for use in a variety of applications.

CIRCUIT DESCRIPTION

Although the supply does not contain a single integrated circuit, it is still very compact.

The circuit diagram in **Figure 1** deals merely with the regulator section, since the ratings of transformers, bridge rectifier and smoothing capacitors depend on the required output voltage and current.

The regulator proper is transistor T_1 in series with input and output terminals. In conjunction with transistors T_2 and T_3, it forms an emitter follower that has good current amplification and a low base-emitter potential.

The differential amplifier formed by T_5 and T_6 compares the voltage at the wiper of P_1 with a part of the output voltage derived from potential divider R_5-P_4. The amplifier tends to equalize these voltages by varying the drive to the emitter follower via T_4. When the output voltage exceeds the value set with P_1, T_4 will conduct harder and pull the base of T_3 to earth. Transistors T_1–T_3 then conduct less hard, whereupon the output voltage drops. When the output voltage is lower than set with P_1, the opposite happens.

Transistor T_7 provides the requisite current limiting, for which R_4 functions as the current sensor. When the current through, and therefore the voltage across, this resistor exceeds a certain level, the potential across network P_3-R_6-P_2 increases to a value that causes T_7 to conduct harder (owing to the potential at the base of T_2). The resulting higher current into the base of T_4 causes this transistor to reduce the base voltage of T_3. The emitter follower then conducts less hard, whereupon the output voltage drops. Since the current through T_3 and D_1 is small, there is hardly any heat dissipation and the current limiting is virtually immune to temperature drift.

Summarizing the action of the potentiometers: P_1 enables the output voltage to be set between 0 V and maximum.

Potentiometer P_4 sets the peak output voltages according to

$$U_{max} = 10(1 + P_4/R_5) \quad [V]$$

where the values of P_4 and R_5 are in kΩ. When $P_4 = 0$ (wiper at U_{out}), the peak output voltage is 10 V, and when $P_4 = 25$ kΩ, $U_{max} = 40$ V.

Potentiometer P_2 enables the output current to be set between 0 A and a peak value determined by the setting of P_3. With $P_3 = 0$ (wiper at R_6), the peak output current is 2.5 A and with $P_3 = 250$ kΩ, the peak current is about 500 mA.

A PRACTICAL CASE

The rating of the transformer, bridge rectifier and electrolytic smoothing capacitor to precede the regulator is determined on the basis of the circuit in **Figure 2**.

Assume that an output voltage variable between 0 V and 18 V, and the current limiting variable between 0 A and 1 A, is required. This requires a mains transformer rated at not less than 18 V a.c. and an output current of not less than $\sqrt{2} \times 1 = 1.4$ A. Furthermore, losses in the bridge rectifier, series transistor (T_1) and resistor R_4 must be taken into account. This is why it is better to use the rule of thumb that the transformer rating should be about 50 per cent higher than the theoretically needed power: in this case, a secondary alternating voltage of 18 V and a rating of 27 VA.

By rule of thumb, the bridge rectifier should also be rated about 50 per cent higher than theoretically required. This means that the requisite one should be a 35 V/1.5 A type.

The value of smoothing capacitor *C* determines the minimum input voltage to the regulator. Since the wanted output voltage is 18 V, and the potential drop across R_4 with an output current of 1 A is 0.56 V, and the drop across T_1 is about 3 V, the minimum input voltage is 21.6 V.

The transformer provides, after rectification and smoothing, a voltage of $\sqrt{2} \times 18 = 25.4$ V. This should be reduced by about 1.4 V to account for losses in the bridge rectifier, but in practice these losses are compensated by the fact that most transformers provide a higher voltage than nominal.

The maximum permitted ripple voltage is the difference between the available direct voltage and the requisite input voltage, that is, 3.8 V.

The value of *C* in microfarad is calculated with the formula $C = IT/U_r$, where *I* is the peak output current in A, *T* is the period after full-wave rectification (0.01 s), and U_r is the ripple voltage in V. Substituting the values found earlier

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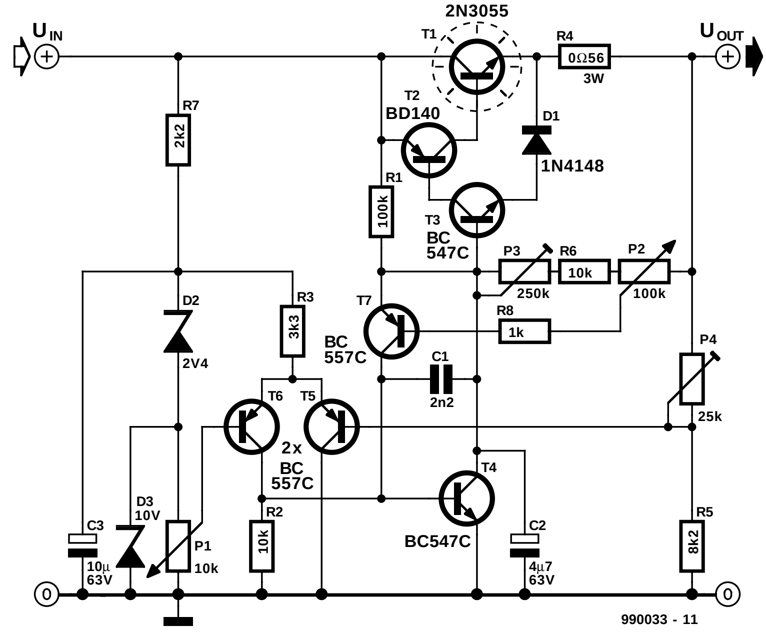

Figure 1. Circuit diagram of the regulator section of the power supply unit.

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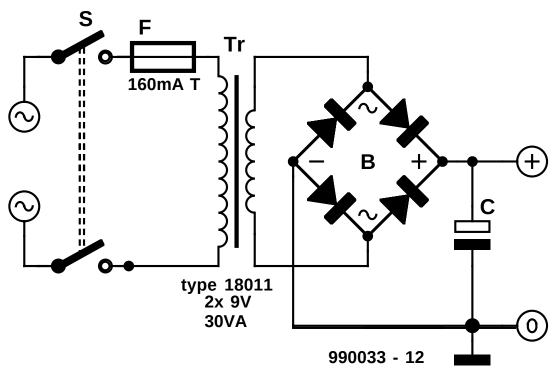

Figure 2. Circuit diagram of the power section: the values and ratings of the components depend on individual requirement.

gives:

$$C = 1 \times 0.01/3.8 = 2632 \quad [\mu F)$$

Bearing in mind the drop across the bridge rectifier, this value should be rounded upward to, say, 3300 µF. The operating voltage should 35 V There may be situations where a value of 3300 µF is not easily obtained, and a 4700 µF type should then be used.

It is advisable to precede the mains transformer by a mains fuse. This should be rated at $1.25I_{max}$, that is in this case:

$$1.25 \times 27/230 = 147 \text{ mA},$$

which is rounded upward to 150 mAT (T is slow-blow).

HEAT SINK

Finally, the rating and size of a suitable heat sink must be determined. Again, this may be done with the aid of rule of thumb.

The maximum dissipation of the series transistor is the product of the input voltage and the maximum output current. In this case, this is

$$26 \times 1 = 26 \text{ W}.$$

It will be assumed that the case temperature of the transistor should not rise above 70 °C. The inner junction will, of course, get hotter (in the case of an 2N3055 about 105 °C), but this does not matter, because the transistor is capable of withstanding 120–150 °C.

The heat sink temperature of 70 °C is about 50 °C higher than the average room temperature. This means that there is 50 K (K=°C) available to dissipate 26 W. This means that the thermal resistance of the heat sink should be $50/26 = 1.9 \text{ K W}^{-1}$.

When a heat sink of this rating is used, the power supply can provide an output voltage of 1 V and an output current of 1 A for hours without any problems whatsoever. If t is assumed that this extreme situation will never arise and that T_1 may on occasion get hotter than 70 °C, a heat sink with a thermal resistance of 3 K W^{-1} may be used. Bear in mind that isolation washers between transistor and heat sink increase the thermal resistance by 0.2–0.9 K W^{-1}, depending on the material of the washer.

It should be noted that a heat sink at 70 °C can singe your skin badly and it should therefore never be touched with bare hands.

ADDITIONAL NOTES

Although the regulator circuit can be used for many requirements, the input voltage to it should not drop below 15 V to ensure that zener diodes D_2 and D_3 continue to function correctly.

Also, it is advisable to insert a fuse between the smoothing capacitor and the regulator. Its rating should be equal to, or slightly higher than, the peak output current.

To ensure the requisite stability, an electrolytic capacitor with a value of about 1/10 of that of the smoothing capacitor should be added across the output terminals.

SETTING UP

When the unit has been completed and checked thoroughly, connect a voltmeter (50 V d.c. range) to the output terminals, turn P_1 fully clockwise (maximum), and adjust P_4 until the voltmeter shows the wanted output voltage (for instance, as in the foregoing example, to 18 V).

Terminate the output by a 24 V, 50 W load (a halogen light bulb is ideal for this) in series with an ammeter (set to 10 A). Turn P_3 fully clockwise (lowest current), adjust P_2 for maximum current, and set P_3 for the wanted maximum current.

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