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ADJUSTABLE VOLTAGE POWER SUPPLY USING LM317

It is difficult to use adjustable voltage three terminal regulators in constructing wide range adjustable voltage power supplies because in these regulators the maximum available output current is determined by the output voltage setting. With the LM317, for instance, if adequate heatsinking is provided, for a 5-volt input-output voltage differential the internal current limiting circuitry limits the output current to 2.2 amps. However, since the device is provided with safe area protection, which limits the maximum power dissipation of the package to 15 watts, the available output current falls with increasing input-output voltage differential. At a 25-volt input-output voltage differential, the safe area protection circuit limits output current to about 600 mA only.

This dependence of output current rating on output voltage setting is undesirable, for it not only makes the power supply inconvenient to use but also unnecessarily bulky and expensive. To survive an overload under a condition of low input-output voltage differential, the transformer and rectifiers would have to be rated for at least 1.5 amps. On the other hand, these components would not be effectively utilised when the power supply is set to deliver a low output voltage (and is hence operating under a large differential).

The output voltage of the power supply circuits described in this article is variable from 1.25 volts to 25 volts and the maximum output current remains fixed, irrespective of output voltage setting. In addition, circuits delivering an output current in excess of 1.5 amps (the maximum output current rating of the LM317 used by itself) are also described.

A basic adjustable voltage regulated power supply circuit using the LM317, such as that shown in Fig. 1, as well as a brief explanation of the working of the LM317 has already been given in an earlier issue of Electronics For You (EFY, Dec. 1984). The LM317 is a complete regulator having internal feedback, regulating and current passing elements and incorporating various types of protection circuits such as current limit (which limits short circuit current to about 2.2 amps), safe area protection (which limits package power dissipation to 15W for the TO-220 package and 20W for the TO-3 package), and thermal shutdown (to limit junction temperature T_j to about 150°C).

In operation, the LM317 develops an accurate reference voltage, typically 1.25 volts, between its output (OUT) and adjustment (ADJ) terminals. This reference voltage when

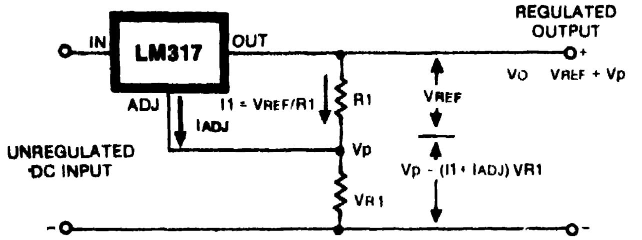


Fig. 1: Basic regulator circuit using LM317.

impressed across the program resistor R1 sets up a current $I1 = V_{REF}/R1$ in R1. I1 along with the quiescent current I_{ADJ} from the adjustment terminal of the IC flows in the output voltage set resistor VR1 (usually a potentiometer), so that the voltage V_p developed across VR1 is $V_p = (I1 + I_{ADJ})\,VR1$. The output voltage V_o at the output of the regulator is hence $V_o = V_p + V_{REF}$ given by

$$V_o = V_{REF}\ (1 + \frac{VR1}{R1}) + I_{ADJ}.\ VR1$$

The LM317 is designed to minimise I_{ADJ} and also to make I_{ADJ} independent of line and load changes. To achieve this, all the quiescent current is returned to the output terminal, thus establishing a minimum load current requirement. Typically, $I_{ADJ} = 50\mu A$ and $\Delta I_{ADJ} = 0.2\mu A$. The typical minimum load current requirement is 3.5 mA, but in some devices it may be as high as 10 mA.

By selecting R1 = 100 ohms, I equals 12.5 mA, and the condition of minimum load current is met. Also, since $I1 \gg I_{ADJ}$, the expression for output voltage simplifies to

$$V_o = V_{REF}\ (1 + \frac{VR1}{R1}$$

As explained previously, the output current in a simple circuit such as this is dependent on the output voltage setting. With increasing input-output voltage differential, the maximum available output current reduces since the safe area protection circuit within the IC limits package power dissipation.

In Fig. 2, transistor T1 alongwith current limit resistor R_{SC} limits the maximum output current to 0.5 amp, regardless of output voltage. Should the output current begin to exceed 0.5 amp, the voltage developed across Rsc will be sufficient to turn on T1 which then shunts VR1, thereby reducing output voltage to the extent necessary to maintain the output current within the 0.5 amp limit. Under output short circuit conditions, the safe area protection circuit within the IC will itself limit the output current to 0.5 amps as the device would then be operating under an input-output voltage differential of almost 30 volts.

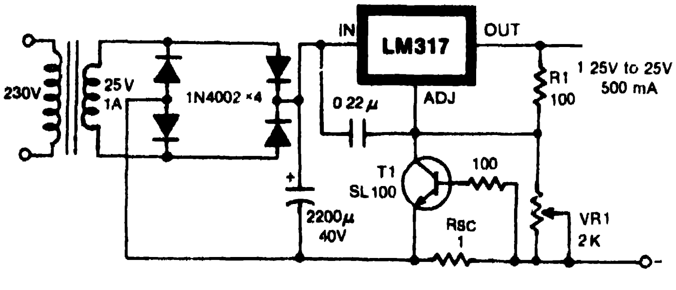


Fig. 2: 1.25V to 25V, 500mA regulated power supply using LM317.

When the LM317 is used in a circuit such as that shown in Fig. 2, the maximum output current is limited to about 0.5 amp only. The maximum output current can however be raised if required by the addition of an outboard series-pass transistor as shown in Fig. 3 where an external pnp booster transistor is used to raise the output current rating to 1.5 amps.

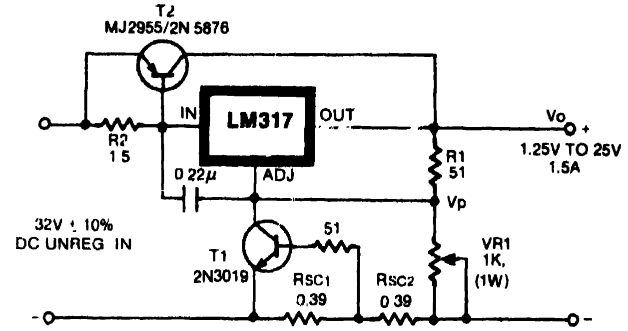


Fig. 3: 1.25V to 25V, 1.3-amp adjustable voltage regulator using pnp external booster transistors.

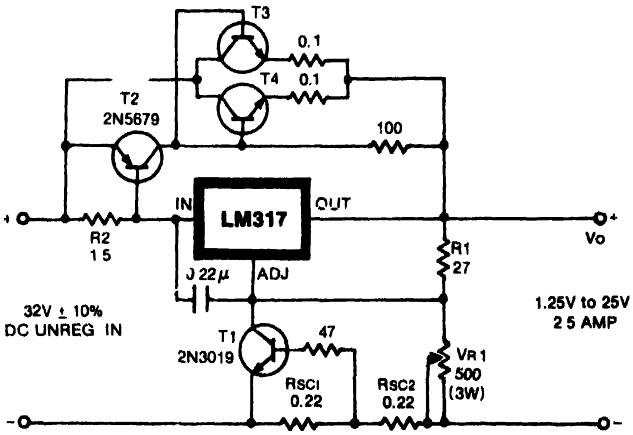


Fig. 4: 1.25V to 25V, 2.5-amp adjustable voltage regulator using npn external booster transistors.

At low output currents (< 0.4 amp), the voltage developed across R2 is insufficient to bring the external current booster transistor T2 into conduction and the entire output current is obtained via the regulator IC alone. When the output current exceeds 0.4 amp, the voltage developed across R2 is sufficient to bring T2 into conduction and the output current is then derived via the regulator IC as well as the booster T2. R_{SC1} along with T1 limits the output current to about 1.6 amps. As the output current approaches 1.6

Fig. 5: Actual-size common PCB layout for all the circuits.

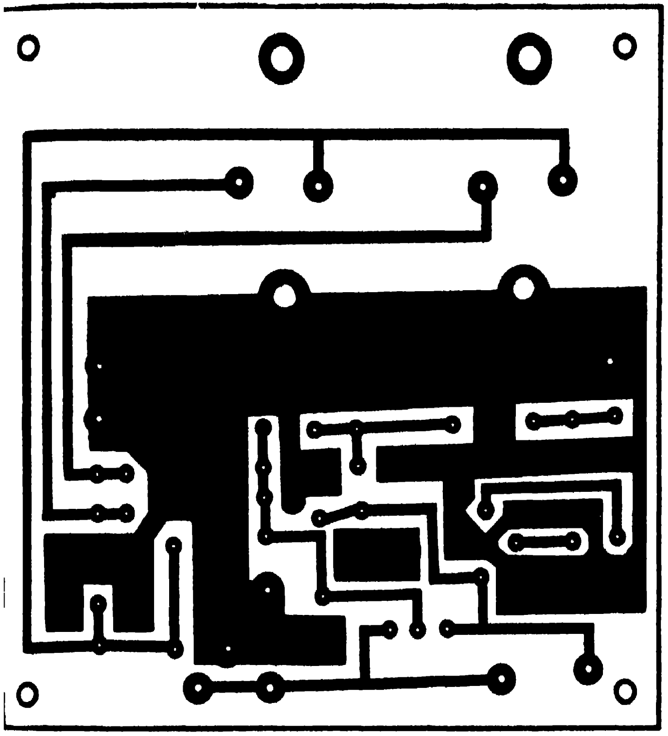
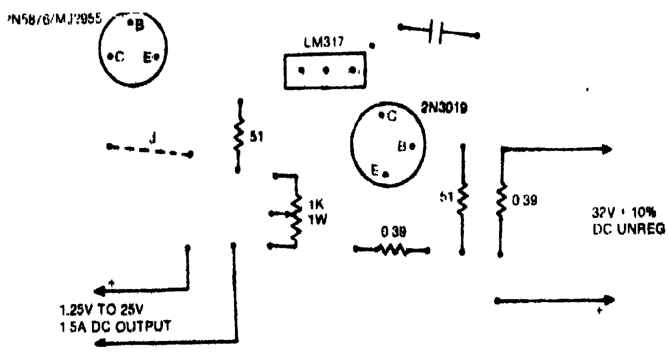


Fig. 7: Components layout for circuit in Fig. 3.



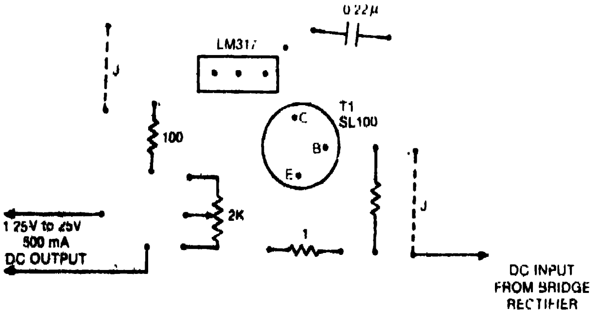


Fig. 6: Components layout for circuit in Fig. 2.

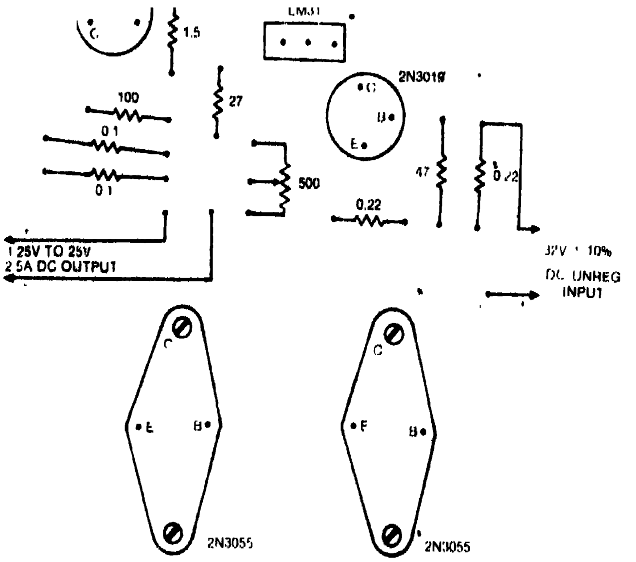


Fig. 8: Components layout for circuit in Fig. 4.

amps, the voltage drop across R_{SC1} brings T1 into conduction and it shunts V_R, thereby reducing the output voltage so that the output current remains within the 1.6 amp limit.

Should a short circuit occur across the output, T1 is driven hard into saturation and its collector potential falls to about 0.2V (relative to its emitter terminal). At this time the output voltage is $V_O = V_P + V_{REF} = 1.45V$. Hence the short circuit current is limited to $I_{SC} = 1.45V/(R_{SC1} + R_{SC2})$. With component values as shown, this works out to approx 1.9 amps.

For higher output currents, a number of pnp power transistors, each with a series emitter resistor, may be connected in parallel and used in place of T2 as the external series-pass element. However, at high output currents (> 2 amps), better load regulation is achieved with the circuit shown in Fig. 4. Since high power pnp transistors are both expensive and difficult to obtain, the circuit in Fig. 4, which makes use of readily available and inexpensive npn power transistors, works out cheaper, although it makes use of one extra transistor. □