Low dropout voltage regulator

Three-terminal regulators require at least 2.5 V drop from input to output to operate correctly. This circuit only requires 0.75 V which makes it suitable for those critical applications where you don't have input voltage to spare.

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I NEEDED a voltage regulator with very low dropout voltage, capable of supplying 5 V at about 3 A. Since many three-terminal regulators have a dropout of 2.5 V or more, the circuit described here was devised using discrete components.

Although very simple, its performance was found to be comparable to that of IC regulators. The circuit of my prototype is shown in Figure 1, and it gave the following results:

Dropout voltage (@ 3 A)	0.75 V
Load Regulation (0-3 A)	less than 10 mV
Line regulation (Vin 6 — 15 V)	less than 10 mV
Ripple rejection (@ 3 A)	−63 dB
Output (no load)	4.96 V

Changes in the output voltage due to ambient temperature variations will be entirely dependent on the characteristics of the zener diode, ZD1 and transistor Q3. Thus, these should be kept clear of heat producing sources, e.g.: the heatsink for Q1 and the power transformer.

The circuit, as it stands, has no well-defined current limit, but this feature can be included with the addition of the components shown in Figure 2. Doing this, however, causes the dropout voltage to increase by 0.5 V. An alternative method of providing current limit without increasing the dropout voltage is to load the output to the required maximum output current and gradually increase the value of the resistor R1 until the output voltage just starts to drop. The disadvantage with this method is that R1 must be selected on test and will need to be re-adjusted if Q1 is ever replaced. Thus, if current limit is desired and a slight increase in dropout voltage can be tolerated, the method shown in Figure 2 is the preferred one.

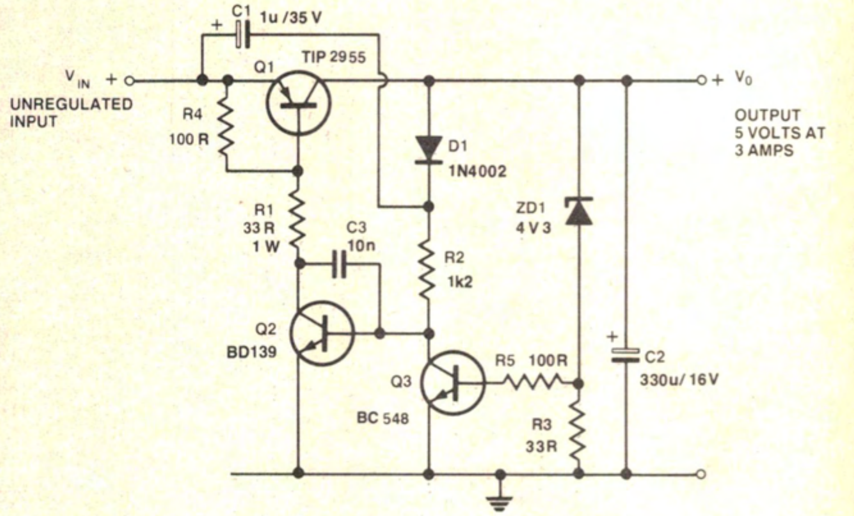

Figure 1. Circuit of the low dropout regulator. Design information is given so that the circuit can be arranged for other voltages.

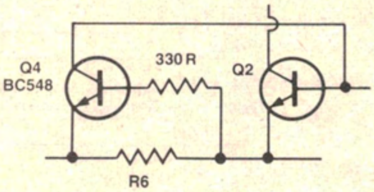

Figure 2. Adding current limit.

Another characteristic of the circuit is that, should a heavy load cause the output voltage to drop below approximately 1.2 V, the regulator will automatically shut itself off and can be restarted by removing the input voltage (or switching off at the mains), waiting several seconds, and then re-applying power. Merely removing the load will not allow a restart.

Components C1 and D1 are the startup components and allow reliable starts even with heavily capacitive loads. In order that the circuit may be adapted for any voltage and current (up to about 5 A), the following simplified design procedure is given.

(1) Select the output voltage, Vo (5 V)

(2) Select the maximum current, Io (3 A)

(3) Select a suitable transistor for Q1 (TIP2955 70 V, 10 A)

(4) R1 max. $= Vo/(Io/h_{FE\ min}\ Q1)$
$= 5/(3/20) = 33.3$
use 33R

(5) Dissipation of R1 $= Vo^2/R1 = 25/33$
$= 0.75$ W (use 1 W)

(6) Select a suitable device for Q2 (BD139 80 V, 1 A)

(7) R2 max. $= Vo/(Ioh_{FE\ min}\ Q1 \times h_{FE\ min}\ Q2)$
$= 5/(3/20 \times 40) = 1300$
use 1k2

(8) Dissipation of R2 $= Vo^2/R2$
$= 25/1200$
$= 21$ mW
(use $1/4$ W)

(9) Select a suitable device for Q3 (BC548 25 V, 100 mA)

(10) Select a suitable zener diode, ZD1.
Voltage $= Vo - V_{be}\ (Q3) = 5 - 0.65$
$= 4.35$ V (use 4V3 zener)

As the current flowing in Q3's base will usually be very small, it may be ignored. Thus, a low wattage, 400 mW or 1 W, zener may be used.

R3 should be chosen to bias the zener well into its operating region. A good rule of thumb is to select the current through the zener (I_z) to be a fifth of its maximum.

$R3 = V_{be}\ (Q3)/I_z$

$I_z = 0.2 \times (P_z/V_z)$ (P_z = zener power, V_z = zener voltage)

$= 0.2 \times (0.4/4.3)$ assuming 400 mW zener

$= 18.6$ mA.

Thus, R3 $= 0.65$ V/18.6 mA
$= 35$ ohms (use 33R, $1/4$ W)

(11) R4 ensures Q1 is not turned on by leakage. Its value is not critical. 100 ohm, $1/4$ W is usually suitable here.

(12) R5 is used as a precaution, preventing excessive current through Q3's base; 100 ohms is suitable.

(13) C1 is the startup capacitor. Any value between 1u and 4u7 should be satisfactory. Its voltage rating should exceed Vin.

(14) C2 should always be used for stability. A value of 100u per amp of load current is suitable. 330u was used in the prototype. Its voltage rating should exceed the output voltage rating.

(15) C3 is required for stability. 10n should suit.

(16) Mount Q1 on a suitable heatsink, according to the power it dissipates. (This should be low if Vin-Vout is low). ●