Negative-output regulator tracks input voltage

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By using an astable multivibrator in a flyback arrangement to develop negative voltages from positive ones, this regulator ensures that its output tracks the input, such that $V_O = -V_{in}$. The voltage-controlled circuit requires only three active devices, all of them transistors.

Q_1 and Q_2 form the free-running oscillator, as shown in the figure. With Q_2 on, the V_{in} voltage is impressed across resistor L, causing the current through L to increase linearly. The peak value of current reached before Q_2 turns off will be directly proportional to the magnitude of the output voltage developed across capacitor C_4.

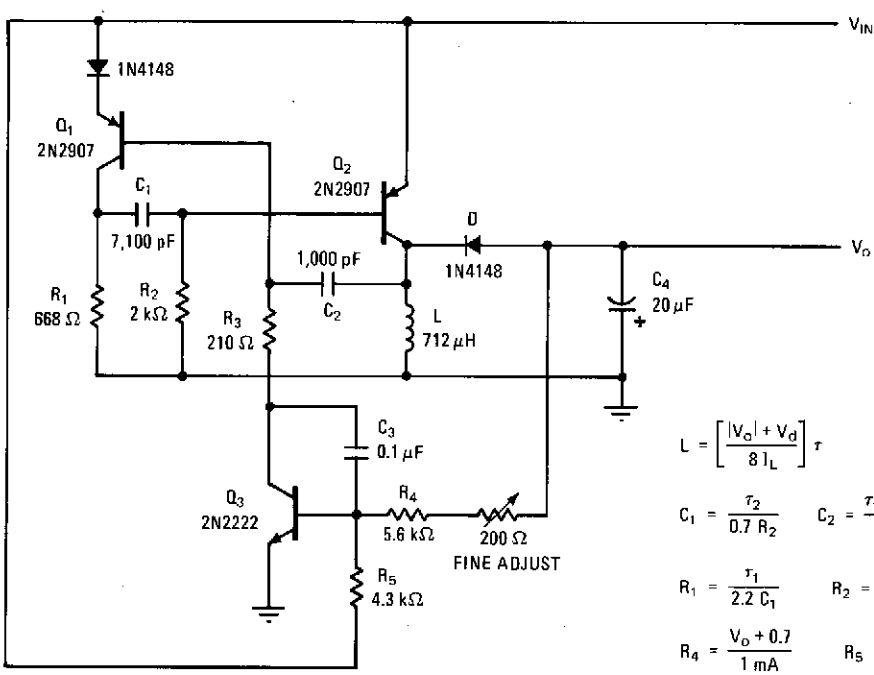
During the time the current through the inductor increases, no voltage can be developed across C_4 because diode D is back-biased. When Q_2 switches off, however, the collector voltage drops from V_{in}, and the capacitor charges to a negative voltage. This occurs because the charging current through the coil makes D turn on, thereby causing a negative voltage at the output.

The field across L then begins to collapse and D is biased on, placing the output voltage $(V_o + V_d)$ across L, where V_d is the diode drop. The current through L must then fall linearly to zero. This completes one cycle of the flyback operation.

The input voltage is next compared with the output voltage at the summing node, at the base of Q_3. This transistor amplifies the voltage difference and transforms it into a current that is used to control Q_2's turn-on time. Thus if V_{out} should fall, the control current will act to increase the on time of Q_2, thereby increasing the peak current through L and so raising the output voltage. This analysis assumes that V_{in} emanates from a stiff source—that is, an increased current demand will not cause a drop in V_{in} because of an increased voltage drop across the source's internal impedance.

Without Q_3, the load regulation would be directly proportional to a change in load current (I_L) and so a 10% change in I_L would cause a 10% change in load voltage V_L. Q_3 ensures that such a change in I_L causes only a 0.2% change.

Component values are given for a circuit that operates with an $I_L = 20$ milliamperes, a $V_o = -5$ volts, and an astable multivibrator operating at 50 kilohertz ($\tau = 20$ microseconds). Equations are given in order to facilitate the design of regulators for specific parameters. □



$$L = \left[\frac{|V_O| + V_d}{8 I_L}\right]\tau \qquad \frac{\tau}{2} = \tau_1 = \tau_2 \qquad I_p = 4 I_L$$

$$C_1 = \frac{\tau_2}{0.7 R_2} \qquad C_2 = \frac{\tau_1 (1 \text{ mA})}{|2 V_O|} \qquad C_3 = \frac{5\sqrt{LC_4}}{R_4} \qquad C_4 = \frac{\tau_2 I_L}{|\Delta V_O|}$$

$$R_1 = \frac{\tau_1}{2.2 C_1} \qquad R_2 = \left(\frac{|V_{IN}| - 0.7}{I_p}\right)\beta_{Q2} \qquad R_3 = \frac{|V_{IN}| - 0.8}{I_L}$$

$$R_4 = \frac{V_O + 0.7}{1 \text{ mA}} \qquad R_5 = \frac{V_{IN} - 0.7}{1 \text{ mA}}$$

Flyback follower. Regulator uses astable multivibrator Q_1–Q_2 and inductor to generate negative output voltages from positive inputs while also ensuring that $V_{out} = -V_{in}$. Differential amplifier Q_3 serves to develop feedback control voltage to readjust on time of Q_2 and thus voltage developed across L and C_4 when $V_{out} \neq -V_{in}$. Component values are given for $I_L = 20$ mA, $V_o = -5$ V, and f = 50 kHz.