# Reducing the dropout voltage of programmable regulators

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A programmable regulator's dropout voltage—the minimum allowable potential between its input ($V_{in}$) and output ($V_{out}$)—can be improved by adding an external output stage and negative feedback. The resulting regulated output voltage ($E_{out}$) not only approaches $V_{in}$ more closely, but the the current-drive capability is also better, thanks to the outboard power-transistor stage.

The design technique used to achieve this improved performance is described here for Fairchild's popular $\mu$A78MG regulator, which has a nominal dropout voltage of 3.0 volts. As shown in the figure, a change in $V_{in}$ causes $V_{out}$ to increase temporarily. The corresponding increase at $E_{out}$ that is applied to the control input of the $\mu$A78 forces $V_{out}$ lower, toward the value it had initially. If the resistor network $R_1$ to $R_3$ is optimized, $E_{out}$ can be brought to within 1.5 V of $V_{in}$.

Consider the case where the output voltage $E_{out}$ is to be kept at 12.5 V ±50 mV for a $V_{in}$ ranging from 14 to 15.5 V. When $V_{in}$ is at 14, $V_{out}$ cannot be above 11, owing to the dropout voltage of the regulator. Thus with an output voltage of 12.5, the voltage at the base of $Q_1$ is 13.1 (0.6 V higher).

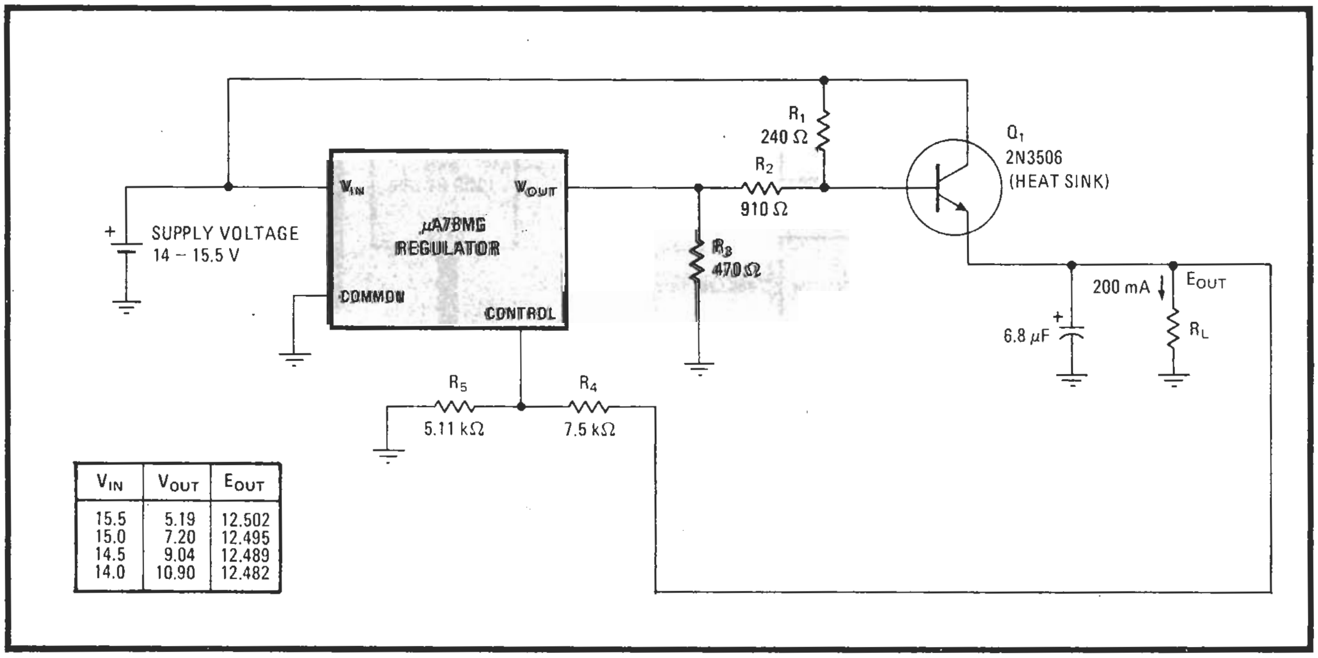
Now $R_1$ can be selected to pass a given value of transistor base current, $I_b$, of say, 1.2 milliamperes, and a current through $R_2$ of perhaps twice this value (2.4 mA), plus a small amount to account for variations in $I_b$. Thus $R_1 = (14-13.1)\text{V}/3.75\text{ mA} = 240\ \Omega$, and $R_2 = (13.1-11)\text{V}/2.4\text{ mA} = 910\ \Omega$.

The next condition to be addressed is the case where $V_{in}$ assumes a value of 15.5 V, so that $R_3$ may be determined. Because $V_{out}$ ultimately decreases with an increase in $V_{in}$, $V_{out}$ should be made to move to its minimum value so that the maximum dynamic range of the circuit is realized. From the data sheet of the $\mu$A78, $V_{out(min)} = 5.0$ V. Note that changes in $V_{out}$ are scaled by the $R_2/R_1$ ratio, and these resistors ensure that a change of $910/240 = 3.8$ V occurs for every 1-V increase in $V_{in}$.

Thus the current through $R_2$ at this time will be $(13.1-5.0)/910 = 8.8$ mA, and assuming the minimum (quiescent) current of the regulator is 2 mA, the current through $R_3$ is $(8.8+2.0) = 10.8$ mA. Therefore $R_3 = 5/10.8 = 470\ \Omega$. The table summarizes the actual dynamic performance of the regulator. Note the apparent dropout voltage of the regulator has been reduced to $14.0-12.482 \approx 1.5$ V when $V_{in}$ is at its minimum.

The junction temperature of the on-chip power transistor is $T_j = \theta_{JA}P_T + T_A$, where $\theta_{JA}$ is the junction to ambient thermal resistance (80 Ω, see data sheets) and $T_A$ is the ambient temperature. Thus, assuming $T_A = 25°\text{C}$, $T_j = 35°\text{C}$, well below the 125°C thermal shutdown temperature of the $\mu$A78.

A check on the chip's temperature will confirm that the regulator's thermal shutdown point has not been reached. The temperature reaches a maximum when $V_{in} = 14.0$. At this voltage, the regulator's output current is



| $V_{IN}$ | $V_{OUT}$ | $E_{OUT}$ |
|---|---|---|
| 15.5 | 5.19 | 12.502 |
| 15.0 | 7.20 | 12.495 |
| 14.5 | 9.04 | 12.489 |
| 14.0 | 10.90 | 12.482 |

**Closer.** Outboard power transistor stage, and resistor pad $R_1$–$R_3$ set $E_{out}$ to within a few volts of $V_{in}$, so that ($E_{out} - V_{in}$) is below $\mu$A78's dropout value. $Q_1$ also provides increased current capacity. Table summarizes dynamic range attained for example using technique discussed in text.

20.8 mA, and the output power is 20.8 (14 − 11) = 62.5 mW. The quiescent current is 4 mA (see data sheets), and the quiescent power drain becomes 4(14 V) = 56 mW. As a consequence of these figures, the total output becomes $P_T$ = 118 mW. □