APPLICATION NOTE 1861

Pass Transistor Boosts Current from Negative Linear Regulator

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Abstract: The addition of a pass transistor to the circuit of Figure 1 allows the linear regulator (LDO) to deliver more current to the load. A detailed power dissipation analysis is included to assist circuit developers in choosing the proper power rating of each component. Furthermore, lab data shows that the device is stable across temperature, line, and load.

Adding four components to a negative linear regulator (U1 in Figure 1) increases the allowable load current by 60%. Cost for the components is less than $0.17 in 1k quantities.

Connecting the SET terminal to ground sets U1’s output voltage to -2.5V. U1’s maximum load current is 200mA, and the extra components (Q1, R1, R2, and R3) draw another 120mA maximum from the load, producing (without degrading the output regulation) a total maximum load current of 320mA.

R1 reduces the power dissipated in Q1, prevents thermal runaway in Q1, and provides momentary protection against short-circuited outputs. It also prevents oscillation by limiting gain in the Q1 loop. Current flowing through U1 from OUT to VSS produces a voltage drop of VR2 across R2 and R3, and thereby allows Q1 to conduct load current as VR2 approaches the base-to-emitter threshold of Q1. The threshold (VBE) is approximately 0.7V at room temperature.
Choose the values of $R_1$, $R_2$, and $R_3$ to ensure that $R_2$, $R_3$ and $Q_1$ dissipate maximum power at the maximum load current (320mA in this case). At 320mA, $U_1$ conducts 200mA and $Q_1$ conducts 120mA.

Component power dissipation at maximum load is as follows:

\[
\begin{align*}
PR_1 &= I_{R1}^2 \times R_1 = 120\text{mA}^2 \times 9.1\Omega \approx 131\text{mW} \\
PQ_1 &= V_{Q1} \times I_{Q1} = (VSS - V_{R1} - V_{OUT}) \times I_{Q1} = (5\text{V} - 1.1\text{V} - 2.5\text{V}) \times 120\text{mA} \approx 168\text{mW} \\
PR_2 &= I_{R2}^2 \times R_2 = 100\text{mA}^2 \times 18\Omega = 180\text{mW} \\
PR_3 &= I_{R3}^2 \times R_3 = 100\text{mA}^2 \times 18\Omega = 180\text{mW} \\
PU_1 &= V_{U1} \times I_{U1} = (VSS - V_{R2} - V_{OUT}) \times I_{U1} = (5\text{V} - 1.8\text{V} - 2.5\text{V}) \times 200\text{mA} = 140\text{mW}
\end{align*}
\]

To provide higher load current, you can easily modify the circuit by increasing the power-dissipation ratings of $R_1$, $R_2$, $R_3$, and $Q_1$. Table 1 details the components shown for 320mA load current. For power dissipation, the circuit board should have ample copper connected to the leads of power-dissipating components. Heat then conducts through the component leads to the circuit board, spreads into the copper areas, and is removed from the board by convection.

Table 1. Figure 1 Components

<table>
<thead>
<tr>
<th>Component</th>
<th>Manufacturer</th>
<th>Part Number Description</th>
<th>Package</th>
<th>Power Dissipation</th>
<th>Allowable Power Dissipation at +85°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R_1$</td>
<td>KAMAYA, INC.</td>
<td>RMC18-9R1JB 9.1Ω ±5% Resistor</td>
<td>1206</td>
<td>250mW derate 4.55mW/°C above +70°C</td>
<td>181.75mW</td>
</tr>
<tr>
<td>$R_2$, $R_3$</td>
<td>KAMAYA, INC.</td>
<td>RMC18-18RJB 18Ω ±5% Resistor</td>
<td>1206</td>
<td>250mW derate 4.55mW/°C above +70°C</td>
<td>181.75mW</td>
</tr>
<tr>
<td>$Q_1$</td>
<td>Central Semiconductor Corp.</td>
<td>CMPT222A NPN Transistor</td>
<td>SOT23-3</td>
<td>350mW derate 2.8mW/°C above +25°C</td>
<td>182mW</td>
</tr>
<tr>
<td>$U_1$</td>
<td>Maxim Integrated Products</td>
<td>MAX1735EUK25 200mA Negative LDO</td>
<td>SOT23-5</td>
<td>571mW derate 7.1mW/°C above +70°C</td>
<td>464.5mW</td>
</tr>
</tbody>
</table>
Figure 2. Curves and waveforms characterize the output of Figure 1: output voltage vs. load current (a), output voltage vs. supply voltage (b), output voltage vs. temperature (c), line transient response (d), load transient response (e), and shutdown response (f).

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