# EE 322 Advanced Analog Electronics, Spring 2010
# Homework #1 solution

**HH 6.3. Design a 723 regulator whith outboard pass transistor and foldback current limiting to provide up to 1.0 amp when the output is at it regulated value of $+0.5\,\mathrm{V}$, but only 0.4 amp into a short-circuited load.**
I will first find the relationship between $R_2$ and $R_1$ with the formula

$$\frac{I_{\mathrm{max}}}{I_{\mathrm{SC}}} = 1 + \frac{R_2}{R_1 + R_2}\frac{V_{\mathrm{reg}}}{V_{\mathrm{BE}}}$$

assuming that having $R_1$ and $R_2$ above $1K\Omega$ will be sufficient to not draw significant current away from the current sensing resistor. We find

$$\frac{R_2}{R_1 + R_2} = \left(\frac{I_{\mathrm{max}}}{I_{\mathrm{SC}}} - 1\right)\frac{V_{\mathrm{BE}}}{V_{\mathrm{reg}}}$$

Inserting values from the problem we get

$$\frac{R_2}{R_1 + R_2} = \left(\frac{1}{0.4} - 1\right)\frac{0.5}{5} = 0.15$$

If we choose $R_2 = 1K$, we get

$$R_2 = 0.15(R_1 + R_2)R_2 = 0.15R_1 + 0.15R_2 0.85R_2 = 0.15R_1$$

$$R_1 = \frac{1 - 0.15}{0.15}R_2 = 5.7K$$

Next we want to find the value of the current sensing resistor, $R_S$. We will use the formula

$$I_{\mathrm{SC}} = \frac{1}{R_S}\left(1 + \frac{R_2}{R_1}\right)V_{\mathrm{BE}}$$

or

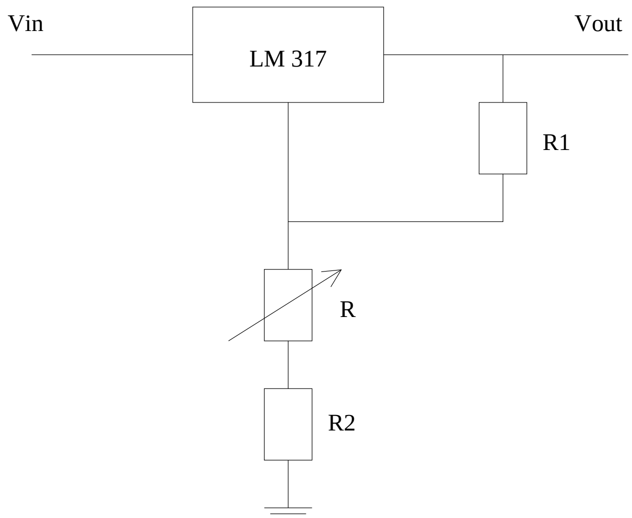
$$R_S = \frac{1}{I_{\mathrm{SC}}}\left(1 + \frac{R_2}{R_1}\right)V_{\mathrm{BE}}$$

Inserting values we get

$$R_S = \frac{1}{0.4}\left(1 + \frac{1}{5.7K}\right)0.5 = 1.25\,\Omega$$

Note that the value of $R_S$ is much smaller than the values we picked for $R_1$ and $R_2$.
**HH 6.5. Design a +5 volt regulator with the 317. Provide $\pm 20\%$ voltage adjustment range with a trimmer pot.**
Design a $+5\,\mathrm{V}$ regulator with the 317. Provide $\pm 20\%$ voltage adjustment range with a trimmer pot.

The $\pm 20\%$ voltage range corresponds to a voltage range of $V_{\mathrm{out}} \in [4; 6]\,\mathrm{V}$. The circuit is drawn below, with $R$ being an adjustable potentiometer, and $R_1$ and $R_2$ being fixed resistors.




The constraints are that the $V_{\text{out,min}} = 4\,\text{V}$ when $R = 0$, and $V_{\text{out,max}} = 6\,\text{V}$ when $R = R_{\max}$. Also, the voltage across $R_1$ is $V_{\text{ref}}$.

$$\alpha = \frac{V_{\text{out,max}}}{V_{\text{ref}}} = \frac{R_1 + R_{\max} + R_2}{R_1}$$
$$\beta = \frac{V_{\text{out,min}}}{V_{\text{ref}}} = \frac{R_1 + R_2}{R_1}$$

The value of $V_{\text{ref}} = 1.25\,\text{V}$. $\alpha = \frac{6}{1.25} = 4.8$, and of $\beta = \frac{4}{1.25} = 3.2$. The ratio of $R_1$ and $R_2$ is

$$\frac{R_2}{R_1} = \beta - 1 = 2.2$$

The ratio of $R_{\max}$ to $R_1$ is

$$\frac{R_{\max}}{R_1} = \alpha - 1 - \frac{R_2}{R_1} = \alpha - \beta = 4.8 - 3.2 = 1.6$$

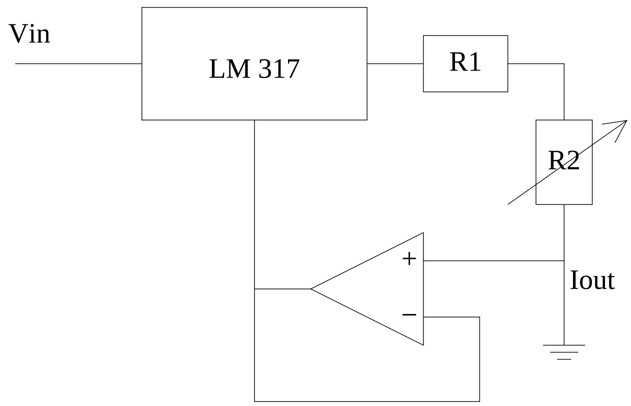
If we then select $R_{\max} = 1\,\text{k}\Omega$, we get $R_1 = 625\,\Omega$, and $R_2 = 1.38\,\text{k}\Omega$.
This circuit looks like Figure 6.29, except that the potentiometer, $R_2$ is in series with a resistance which I will call $R_3$. I will leave $R_1 = 240\,\Omega$. In that case, when the output is $V_{\text{out}}$, we have

$4\,\text{V}$,

$$\frac{R_1}{R_1 + R_2 + R_3} = \frac{1.25}{4} = \frac{3}{8}$$

**HH 6.7. Design an adjustable current source for output currents from $10\,\mu$A to $1\,$mA using a 317. If $V_{\text{in}} = +15\,$V, what is the output compliance? Assume a dropout voltage of $+2\,$V.**

Design an adjustable current source for output currents from $10\,\mu\text{A}$ to $10\,\text{mA}$ using a 317. If $V_{\text{in}} = +15\,\text{V}$, what is the output compliance? Assume a dropout voltage of $2\,\text{V}$. We will use the circuit in Figure 6.38B. We will use two resistors, one fixed and one adjustable.




The voltage between the output pin and the adjust pin is $V_{\text{ref}} = 1.25\,\text{V}$. The output current is then

$$I_{\text{out}} = \frac{V_{\text{ref}}}{R_1 + R_2}$$

The maximum current flows when the resistance is minimized,

$$I_{\text{out,max}} = \frac{V_{\text{ref}}}{R_1}$$

So that

$$R_1 = \frac{V_{\text{ref}}}{I_{\text{out,max}}} = \frac{1.25}{1 \times 10^{-3}} = 1.25\,\text{k}\Omega$$

The minimum current flows when the resistance is maximized,

$$I_{\text{out,min}} = \frac{V_{\text{ref}}}{R_1 + R_2}$$

So that

$$R_2 = \frac{V_{\text{ref}}}{I_{\text{out,min}}} - R_1 = \frac{1.25}{10 \times 10^{-6}} - 1.25 \times 10^3 = 123\,\text{k}\Omega$$

We can thus achieve the currents we want by using a $1.25\,\text{k}\Omega$ resistor, $R_1$, in series with a $0 - 123\,\text{k}\Omega$ potentiometer, $R_2$.

The compliance voltage range is the range of voltages on the output pin over which these currents can flow. The highest current is the most restrictive current. The maximum voltage on the output pin consistent with a $15\,\text{V}$ input, and drop-out voltage of $2\,\text{V}$, and the voltage drop across feedback resistors is

$$\begin{aligned} V_{\text{out,max}} &= V_{\text{in}} - V_{\text{dropout}} - V_{\text{ref}} \\ &= 15 - 2 - 1.25 \\ &= 11.75\,\text{V} \end{aligned}$$