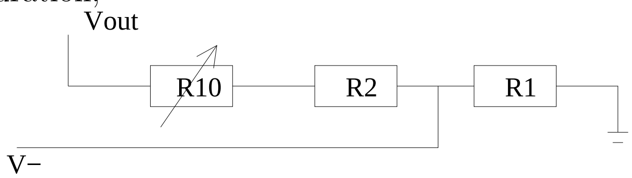
EE 322 Advanced Electronics, Spring 2012
Homework #1 solution

HH 6.1

We are going to place a voltage divider on both the reference, and on the output. The output problem hints that we should compare a fraction of the output to half of the input, so let us place a voltage divider across the input. I will use two $4.7K$ resistors for that. We thus have a input of $V_+ = 7.15/2 = 3.575\,\mathrm{V}$ on the input.

On the output we want to be able to adjust the voltage from $+5\,\mathrm{V}$ to $+10\,\mathrm{V}$. We must have a voltage divider which can take a fraction of this and compare it to the input of the comparator. I will use a $10K$ potentiometer as the variable element. Let's say that when the potentiometer has zero resistance we want $+5\,\mathrm{V}$ on the output whereas when the potentiometer has full resistance we want $+10\,\mathrm{V}$ on the output. We will use two more resistors in this configuration,



and the relevant equations are

$$V_{\text{out,max}} \frac{R_1}{R_{10} + R_2 + R_1} = V_- \quad \text{and} \quad V_{\text{out,min}} \frac{R_1}{R_2 + R_1} = V_-$$

Dividing the two equations and re-arranging we get

$$\frac{V_{\text{out,max}}}{V_{\text{out,min}}} = \frac{R_{10} + R_2 + R_1}{R_2 + R_1}$$

Which gives us

$$2\left(R_2 + R_1\right) = R_{10} + R_2 + R_1$$

or

$$R_2 + R_1 = R_{10} = 10K$$

Next we go back to the equation for the minimum voltage and find that

$$\frac{V_{\text{out,min}}}{V_-} = \frac{R_2 + R_1}{R_1} = \frac{R_2}{R_1} + 1$$

Inserting $V_{\text{out,min}}/V_- = 5/3.575 = 1.4$, we get

$$\frac{R_2}{R_1} = 0.4$$

Inserting $R_2 = R_{10} - R_1$ we get

$$\frac{R_{10} - R_1}{R_1} = 0.4$$

$$R_{10} - R_1 = 0.4R_1 \qquad R_1 = \frac{R_{10}}{1.4} = 7.14K$$

Then

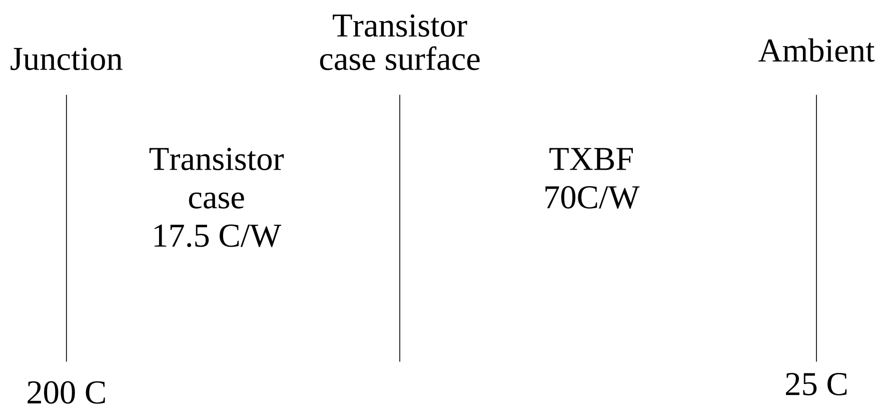
$$R_2 = R_{10} - R_1 = 10 - 7.14 = 2.86K$$

To limit the current to $I_{\max} = 50\,\mathrm{mA}$, we insert a current-sensing resistor, R_{CS} such that

$$V_{BE,min} = I_{\max} R_{CS} \Longrightarrow R_{CS} = \frac{V_{BE,min}}{I_{\max}} = \frac{0.5}{50 \times 10^{-3}} = 10\,\Omega$$

HH 6.2

The scenario is illustrated in this figure



The temperature difference can be written as

$$T_{\text{junction}} - T_{\text{ambient}} = (\theta_{\text{2N5320}} + \theta_{\text{TXBF}})\, P$$

And we wish to find $P_{\max}$ corresponding to $T_{\text{junction,max}} = 200°C$.

$$P_{\max} = \frac{T_{\text{junction,max}} - T_{\text{ambient}}}{\theta_{\text{2N5320}} + \theta_{\text{TXBF}}}$$

Inserting values we get

$$P_{\max} = \frac{200 - 25}{17.5 + 70} = 2\,\mathrm{W}$$

HH 6.3

I will first find the relationship between R_2 and R_1 with the formula

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

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

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

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

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

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

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.