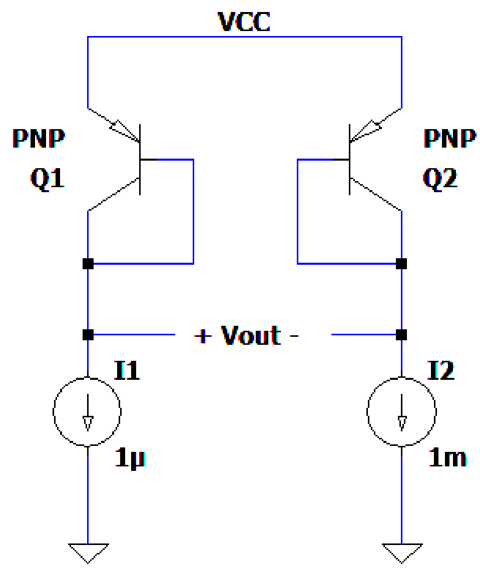
Temperature Sensor

Objective: Using BJT to make a circuit that can indicate the temperature.

In the shown circuit:



By Applying KVL:

$$V_{out} = (V_{CC} - V_{BE1}) - (V_{CC} - V_{BE2})$$

$$V_{out} = V_{BE2} - V_{BE1}$$

From the BJT char. Eq. $\left(I_C = I_S e^{\frac{V_{BE}}{V_t}} \right)$

$$V_{BE} = V_t \ln\left(\frac{I_C}{I_S}\right) \text{ So,}$$

$$V_{out} = V_t \ln\left(\frac{I_{C2}}{I_{S2}}\right) - V_t \ln\left(\frac{I_{C1}}{I_{S1}}\right)$$

$V_{out} = V_t \ln\left(\frac{I_{C2} \times I_{S1}}{I_{S2} \times I_{C1}}\right)$ **, Assuming the transistors are identical** $(I_{S1} = I_{S2})$

And since $I_{C1} = I_1$, $I_{C2} = I_2$, $V_t = \frac{KT}{q}$

$$V_{out} = \frac{KT}{q} \ln\left(\frac{I_2}{I_1}\right), \qquad V_{out} = \frac{K}{q} \ln\left(\frac{I_2}{I_1}\right) \times T$$

So the output of this circuit varies linearly with the temperature

but the value of the term $\frac{K}{q}\ln(\frac{I_2}{I_1})$ is small even after using a higher current ratio.

1. **The output could be further amplified by using a simple differential amplifier circuit.**
2. **Or we could adjust the current ratio to get the desired output**

Assume we want to represent the temperature as millivolts

So $\frac{K}{q}\ln\left(\frac{I_2}{I_1}\right) = \frac{1}{1000}$, $(\frac{K}{q} \cong 8.66 \times 10^{-5})$

$\ln\left(\frac{I_2}{I_1}\right) = 11.54$, $\frac{I_2}{I_1} = 103501.78$ **(if** $I_1 = 0.1\mu A$**)**

Then $I_2 = 10.35\text{mA}$

Then $V_{out} = T\ mV$ **(T is in kelvin)**