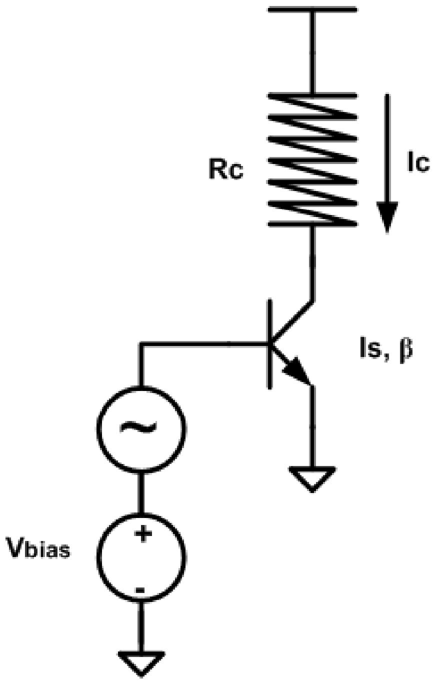
Part 1. Temperature Variation of CE Amplifier



Assume $R_c \gg r_o$,

$$A_v = g_m \cdot R_c$$

$$A_v = \frac{I_c}{V_{th}} \cdot R_c$$

$$A_v = \frac{I_s \cdot e^{V_{bias}/V_{th}}}{V_{th}} \cdot R_c$$

$$S_{\Delta T} = \frac{\partial A_v}{\partial T} \cdot \frac{T}{A_v} = \frac{T \cdot I_s}{A_v} \cdot \frac{\partial}{\partial T}\left(\frac{e^{V_{bias}/V_{th}}}{V_{th}} \cdot R_c\right)$$

$$S_{\Delta T} = \frac{T \cdot R_c \cdot I_s}{A_v} \cdot \left[\frac{V_{bias} \cdot e^{V_{bias}/V_{th}}}{V_{th}^{3}} - \frac{e^{V_{bias}/V_{th}}}{V_{th}^{2}}\right] \cdot \left(-\frac{k}{q}\right)$$

Assume $V_{bias} \gg V_{th}$,

$$S_{\Delta T} \approx -\frac{T \cdot R_c \cdot I_s}{A_v} \cdot \frac{V_{bias} \cdot e^{V_{bias}/V_{th}}}{V_{th}^{3}} \cdot \frac{k}{q}$$

$$S_{\Delta T} \approx -\frac{T}{A_v} \cdot \frac{V_{bias}}{V_{th}} \frac{g_m R_c}{T}$$

$$\boxed{S_{\Delta T} \approx -\frac{V_{bias}}{V_{th}}}$$

Example: Suppose that at room temperature, 27C, the common emitter amplifier is biased at VBE=0.75V, the measured gain is -100. Estimate the gain at 28C.

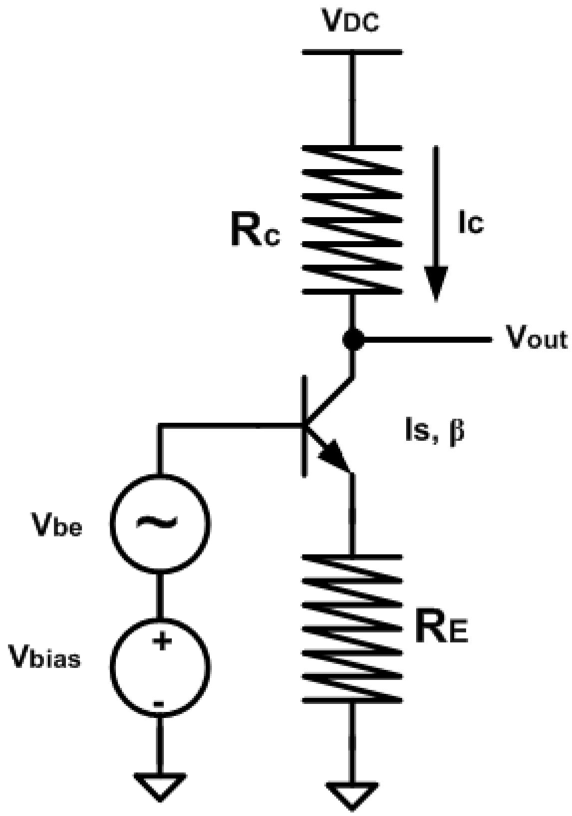
$$S_{\Delta T} = \frac{\Delta A_v}{A_v} \cdot \frac{T}{\Delta T} = -\frac{V_{BE}}{V_{th}}$$

$$\frac{\Delta A_v}{-100} \cdot \frac{300K}{1K} \approx -\frac{750mV}{25mV} = -30$$

$$\Delta A_v = 10$$

- The gain under T=28C is: $A_v' = -90$
- The gain drops 10% when temperature increases by 1C

Temperature Variation of CE Amplifier



Ignore r_o, use small signal analysis,

$$A_v = -\frac{g_m R_C}{1 + g_m R_E + \frac{R_E}{r_\pi}}$$ (Exercise to verify)

$$\boxed{A_v = -\frac{g_m R_C}{1 + g_m R_E(1 + 1/\beta)} \approx -\frac{g_m R_C}{1 + g_m R_E}}$$

$$S_{\Delta T} = \frac{\partial A_v}{\partial T} \cdot \frac{T}{A_v} = \frac{T}{A_v} \cdot \frac{\partial}{\partial T}\left(\frac{g_m R_C}{1 + g_m R_E}\right)$$

$$S_{\Delta T} = \frac{\partial A_v}{\partial T} \cdot \frac{T}{A_v} = \frac{T \cdot R_C}{A_v} \cdot \left[\frac{1}{(1 + g_m R_E)} - \frac{g_m R_E}{(1 + g_m R_E)^2}\right] \frac{\partial g_m}{\partial T}$$

$$S_{\Delta T} = \frac{\partial A_v}{\partial T} \cdot \frac{T}{A_v} = \frac{T \cdot R_C}{A_v} \cdot \frac{1}{(1 + g_m R_E)^2} \frac{\partial g_m}{\partial T}$$

$$S_{\Delta T} = \frac{1}{(1 + g_m R_E)^2} \frac{T \cdot R_C}{-\frac{g_m R_C}{1 + g_m R_E}} \frac{\partial g_m}{\partial T}$$

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Plug Av into the formula,

$$S_{\Delta T} = \frac{1}{(1+g_m R_E)^2} \frac{T \cdot R_c}{\frac{g_m R_c}{1+g_m R_E}} \frac{\partial g_m}{\partial T}$$

$$S_{\Delta T} = \frac{1}{(1+g_m R_E)} \underbrace{\left[\frac{\partial g_m R_c}{\partial T} \cdot \frac{T}{g_m R_c}\right]}$$

This term is exactly the $S_{\Delta T}$ of Common emitter amplifier in part 1

$$\boxed{S_{\Delta T} = \frac{1}{(1+g_m R_E)} S_{\Delta T,\, CE}}$$

Comparing to Common Emitter Amplifier

- The emitter degeneration reduce the gain by a factor of $(1+g_m R_E)$
- The emitter degeneration reduce the thermal sensitivity also by the same factor of $(1+g_m R_E)$