Blackboard Notes for lecture - 3

slide 8:

A theoretical relationship between i_c and v_{CE} is that i_c is parallel with v_{CE}. when v_{CE} reaches a certain value, but in practical product. when you measure a NPN transistor, the i_c is not parallel with v_{CE} anymore. we call it early effects.

To model the effects:

$$I_c = I_s \exp^{\frac{V_{BE}}{V_T}} \left(1 + \frac{V_{CE}}{V_A}\right). \quad V_A \text{ is early voltage.}$$

slide 9:

if we have a small perturbation (δV) on V_{CE}, then. $V_{CE} + \delta V \to V_{CE}$

$$I_c = I_s \exp^{\frac{V_{BE}}{V_T}} \left(1 + \frac{V_{CE} + \delta V}{V_A}\right)$$

$$= I_s \exp^{\frac{V_{BE}}{V_T}} \left(1 + \frac{V_{CE}}{V_A} + \frac{\delta V}{V_A}\right)$$

$$= \underline{I_s \exp^{\frac{V_{BE}}{V_T}} \left(1 + \frac{V_{CE}}{V_A}\right)} + I_s \exp^{\frac{V_{BE}}{V_T}} \cdot \frac{\delta V}{V_A}$$

$$= I_{co} + \underline{I_s \exp^{\frac{V_{BE}}{V_T}} \cdot \frac{\delta V}{V_A}}$$

it means with the inclusion of early effects. there is one more current ($I_s \exp^{\frac{V_{BE}}{V_T}} \cdot \frac{\delta V}{V_A}$) in the collector lead. and the current is

$$\delta I = I_s \exp^{\frac{V_{BE}}{V_T}} \cdot \frac{\delta V}{V_A} \Rightarrow \frac{\delta V}{\delta I} = \frac{V_A}{I_s \exp^{\frac{V_{BE}}{V_T}}} \approx \frac{V_A}{I_c}$$

then can be modeled with a resistor(r_o)

Slide 18:

when $v_S = 0$, Base and Emitter will be short,

the transistor will operate at cutoff state.