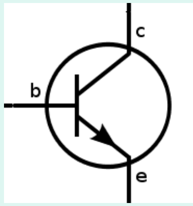
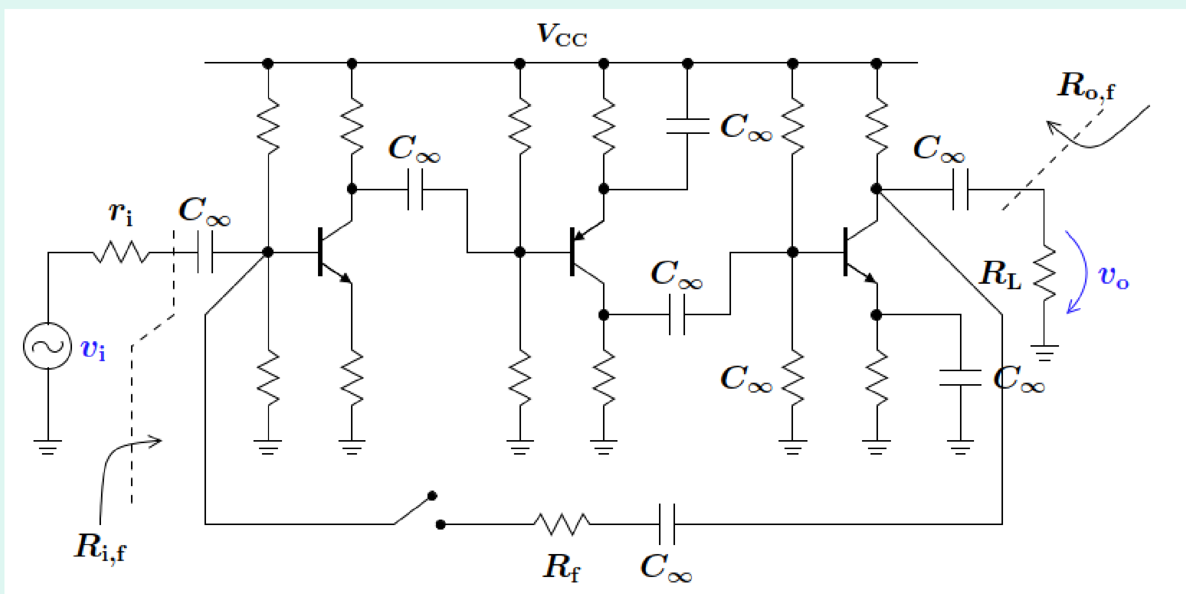


ELEC 301 - BJT small signal model, biasing circuit

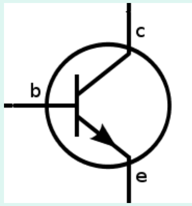
L11 - Sep 29

Instructor: Edmond Cretu



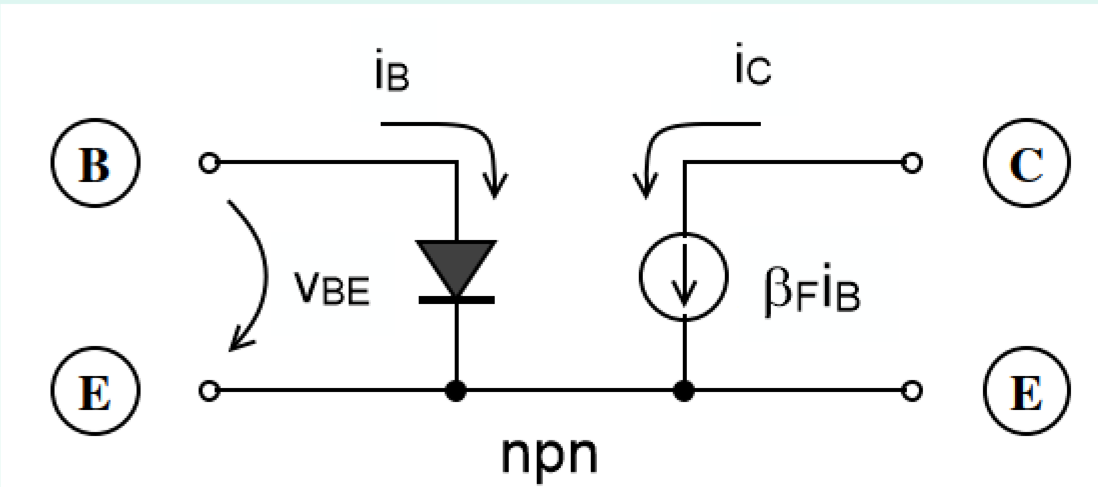
Last time

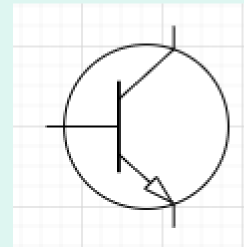
- Large signal models vs small signal models
- Diodes - large signal, small signal model
- BJTs - operating principle, operating modes, large signal model, simple small signal model



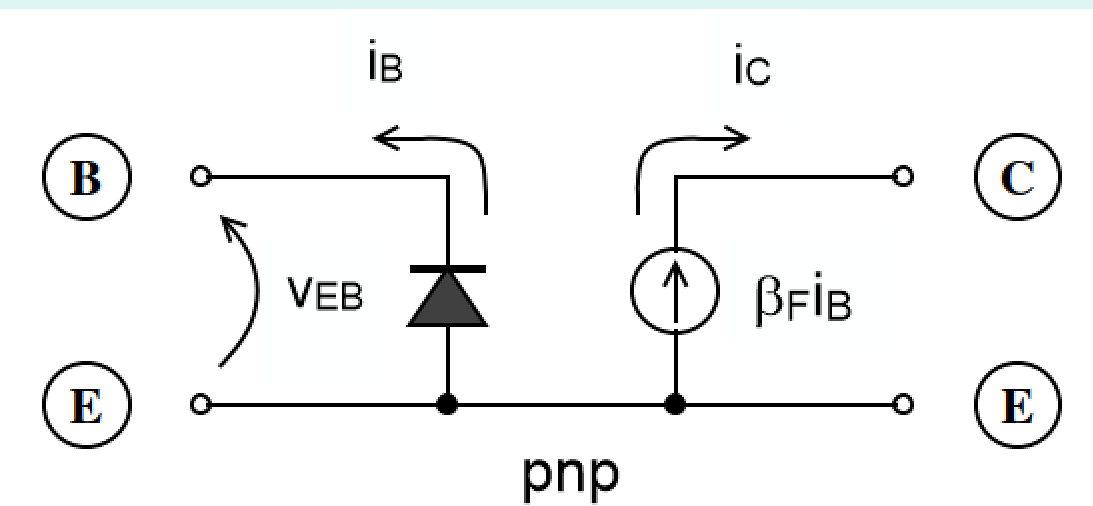
Large-signal model for BJT

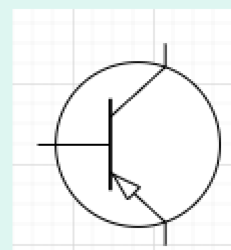
- REM: controlled current source orientation



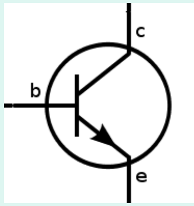


$$i_C = I_S e^{\frac{v_{BE}}{V_T}}, i_B = \frac{I_S}{\beta} e^{\frac{v_{BE}}{V_T}}$$

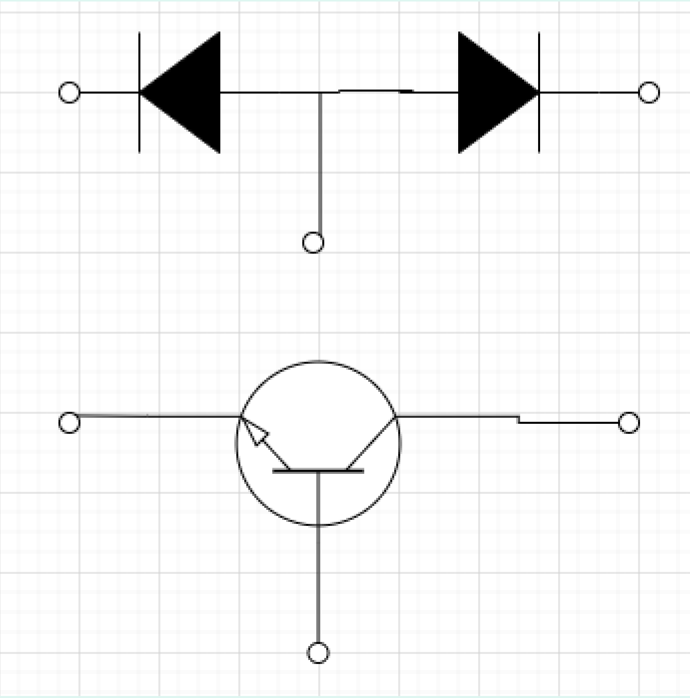




$$i_C = I_S e^{\frac{v_{EB}}{V_T}}, i_B = \frac{I_S}{\beta} e^{\frac{v_{EB}}{V_T}}$$



L11 Q01 - diodes and BJT

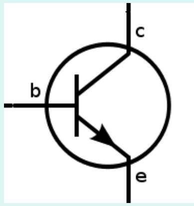


- Which one is the **wrong** statement when comparing two back-to-back diodes with a BJT structure?

A. They are the same three-terminal device

B. If we increase the base width significantly, they become the same device

C. A BJT is characterized by two coupled junctions

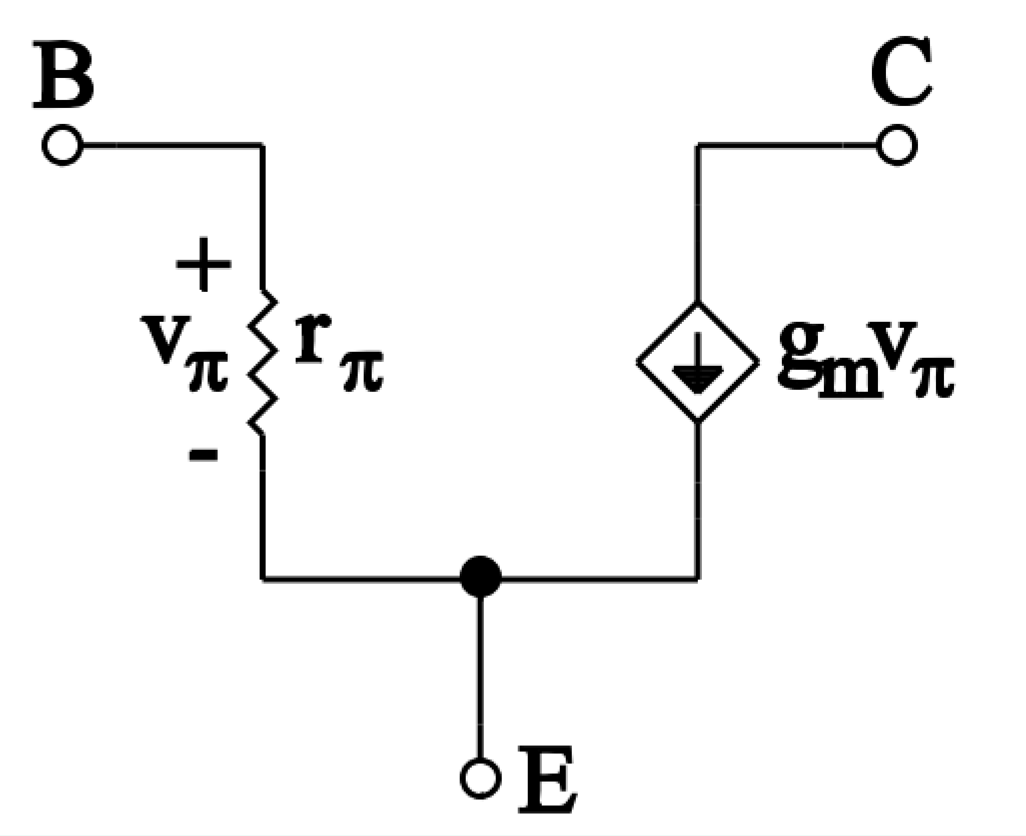


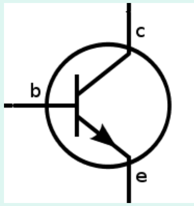
Basic Hybrid-π model for BJT

- Small signal model without considering capacitive effects, nor the Early effect

$$r_\pi = \frac{v_{be}}{i_{be}} = \frac{\beta}{g_m} = \beta\frac{V_T}{I_C} = \frac{V_T}{I_B}$$

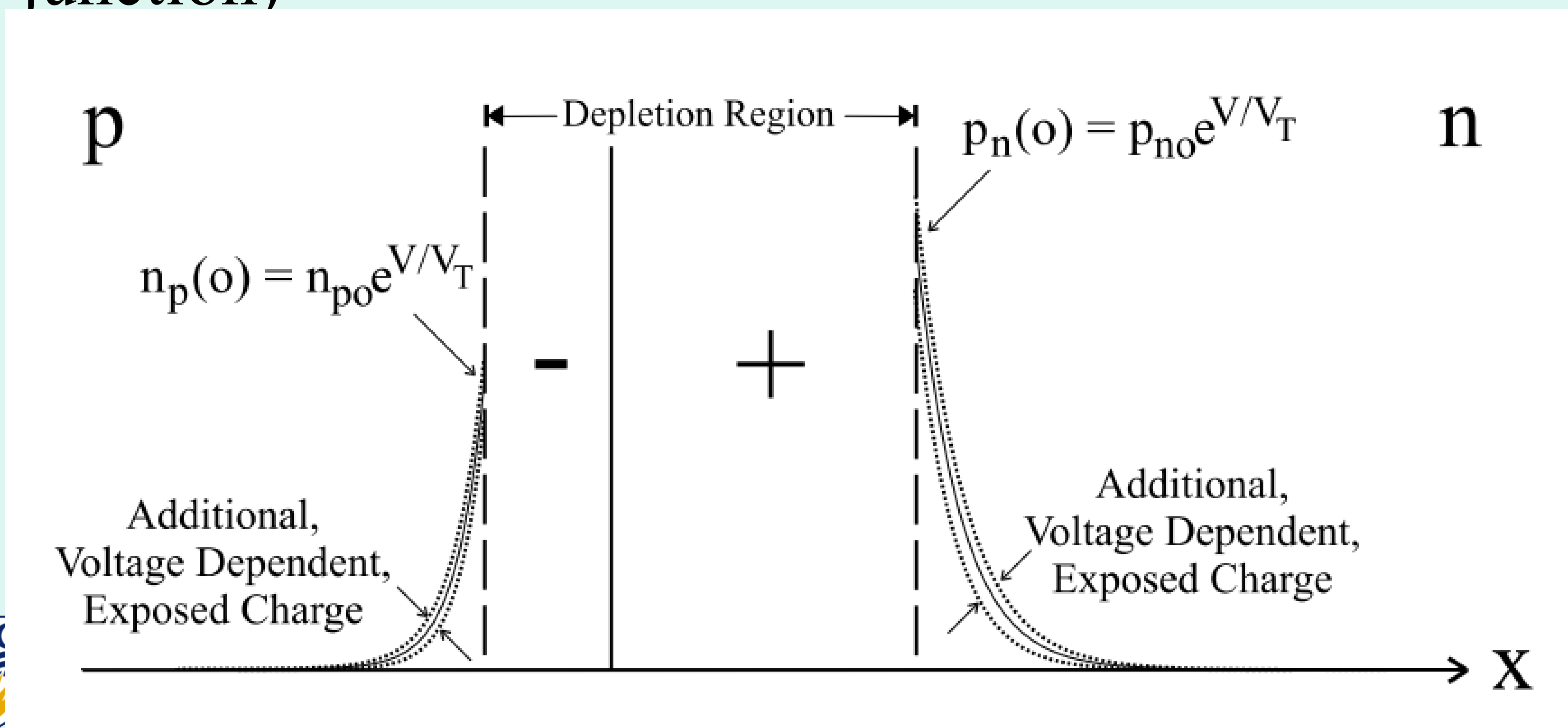
$$g_m = \frac{I_C}{V_T}$$

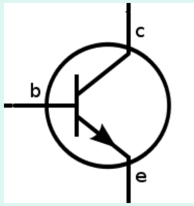




Junction capacitance EBJ

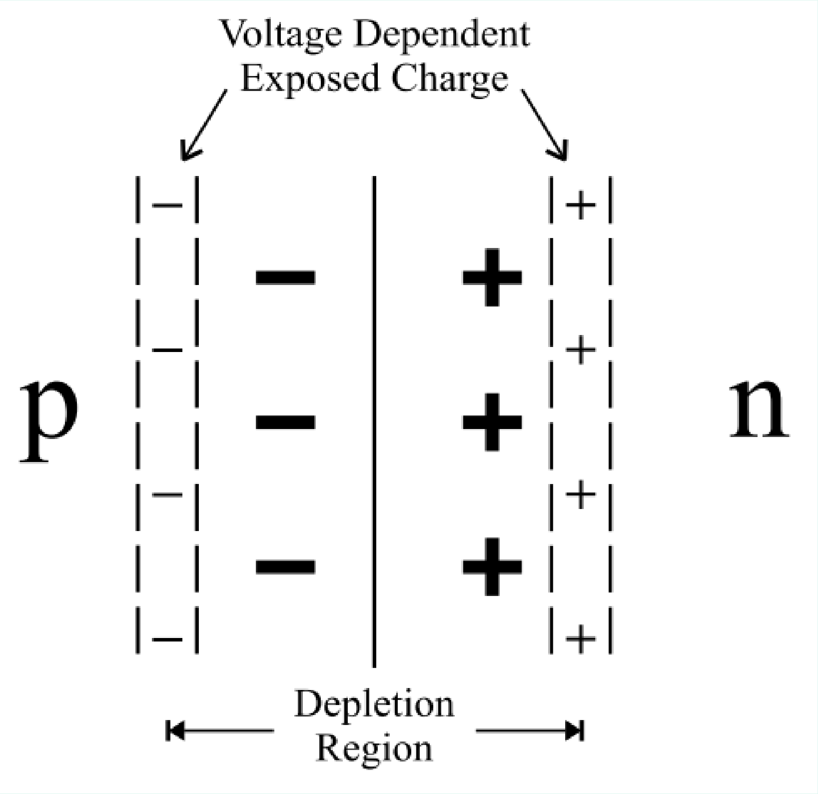
- C=dQ/dV
- EBJ - forward biased - diffusion capacitance (change in minority carrier concentrations on either side of junction)

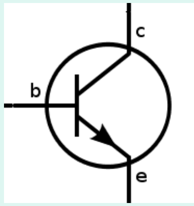




Junction capacitance CBJ

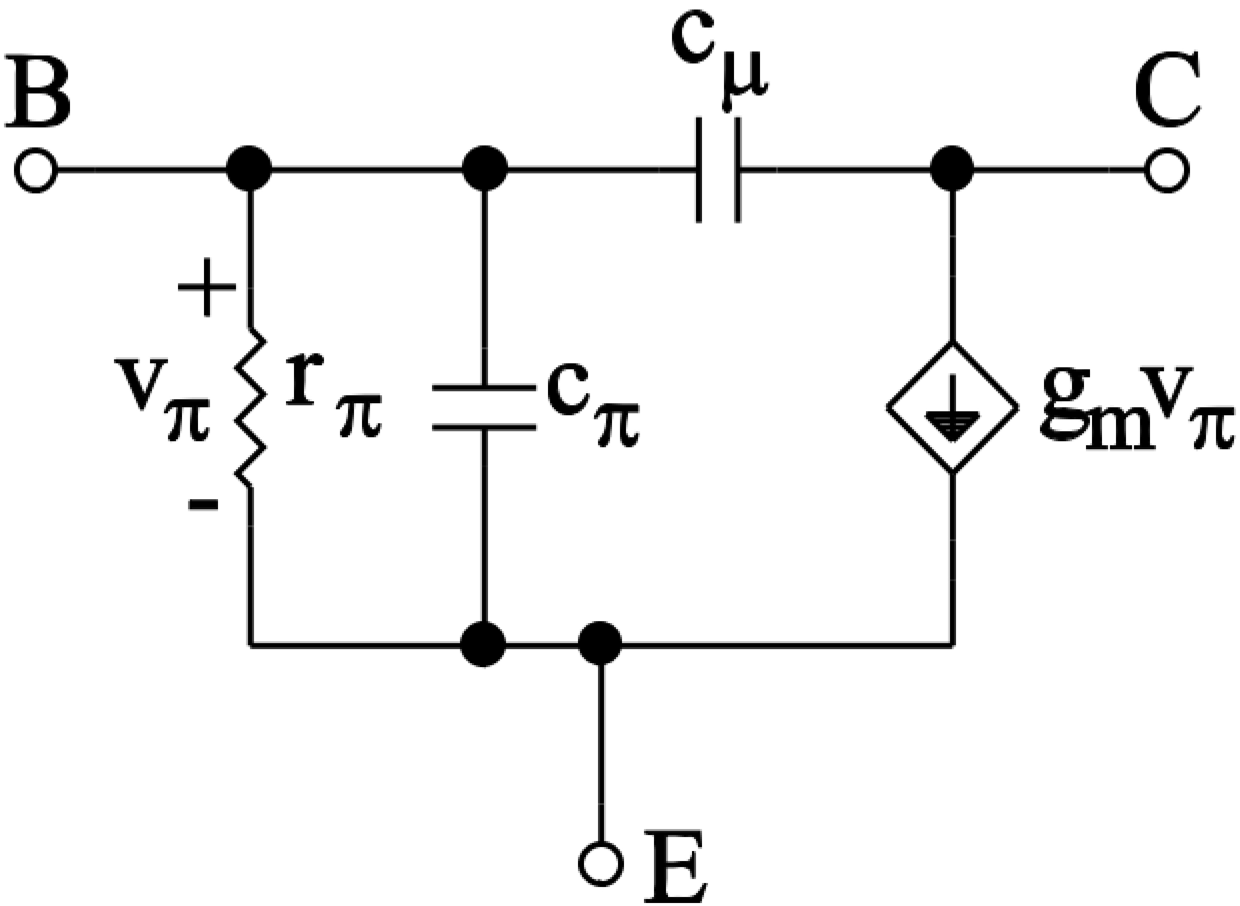
- Active mode => reverse biased CBJ
- "Space-charge capacitance" - dominant mechanism is the change in exposed charge on either side of the depletion region - $Q=f(V_{CB})$
- For small-signals the relation charge-voltage is linear => constant capacitance





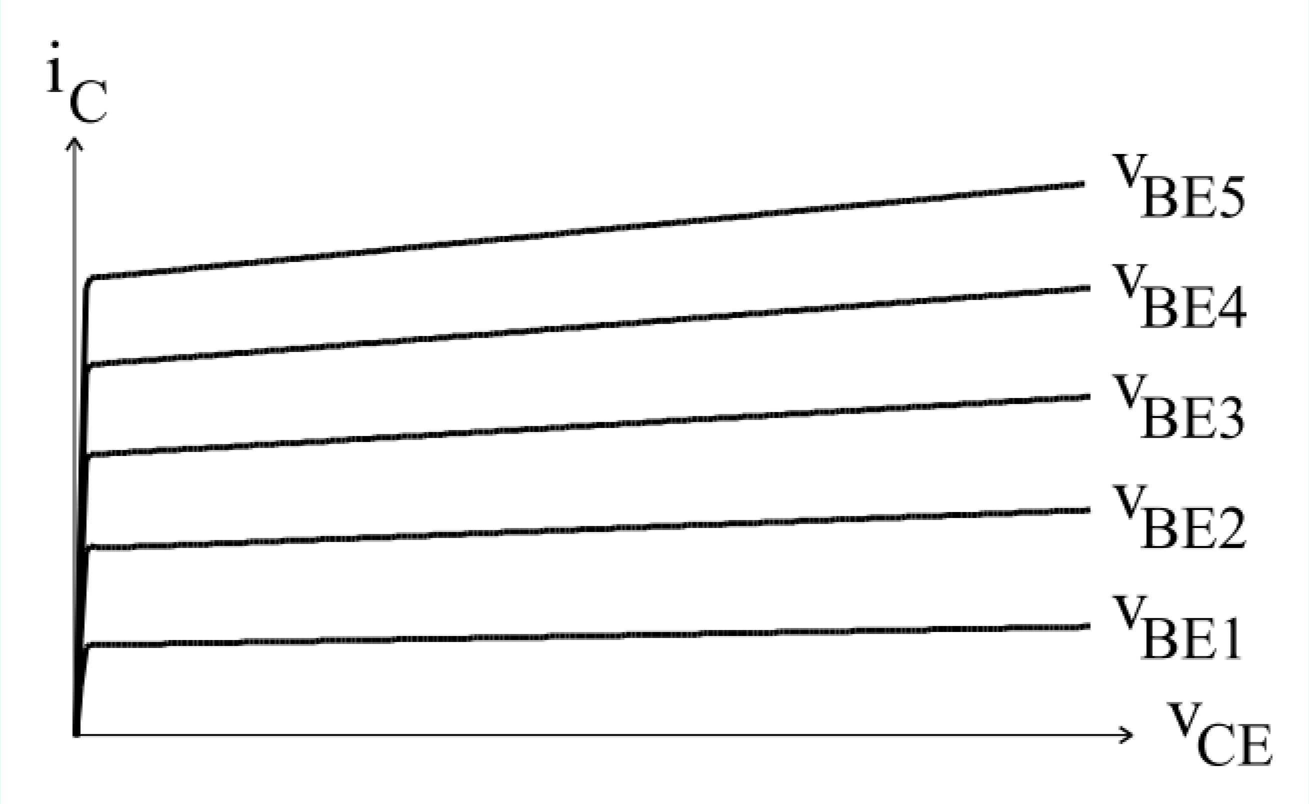
Hybrid-p model with junction capacitances

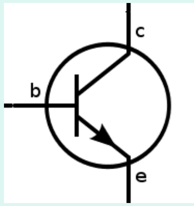
- Improved small-signal model



Further refinement - output resistance

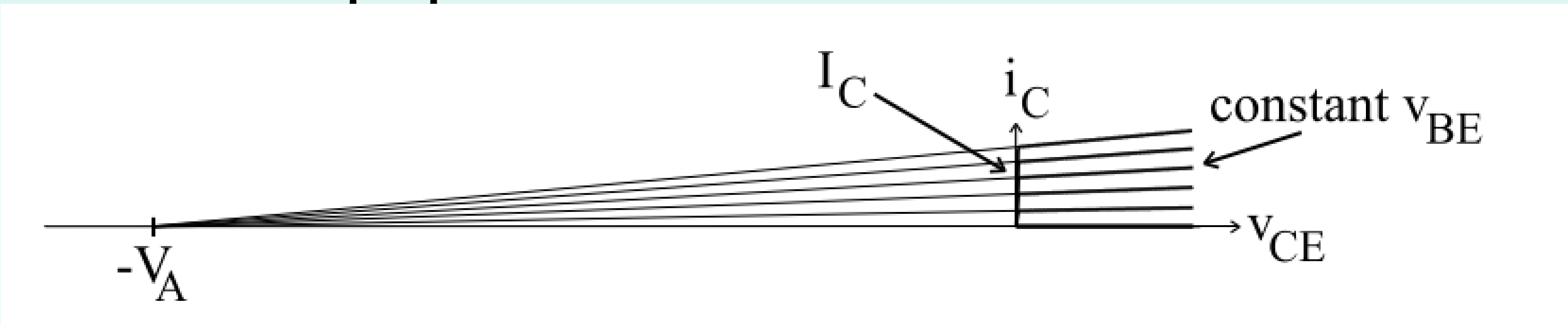
- Ideally i_C depends solely on v_{BE}, but it shows as well a dependence on v_{CE}





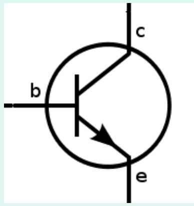
Early voltage and output resistance

- Early effect - widening of the CB depletion region as V_{BC} increases
- V_A = Early voltage - for modern BJTs~50..500V, lower for pnp



$$i_C = i_C\left(v_{BE}, v_{CE}\right) = I_S e^{\frac{v_{BE}}{V_T}}\left(1 + \frac{v_{CE}}{V_A}\right)$$

$$r_o \simeq \frac{V_A}{I_C}$$



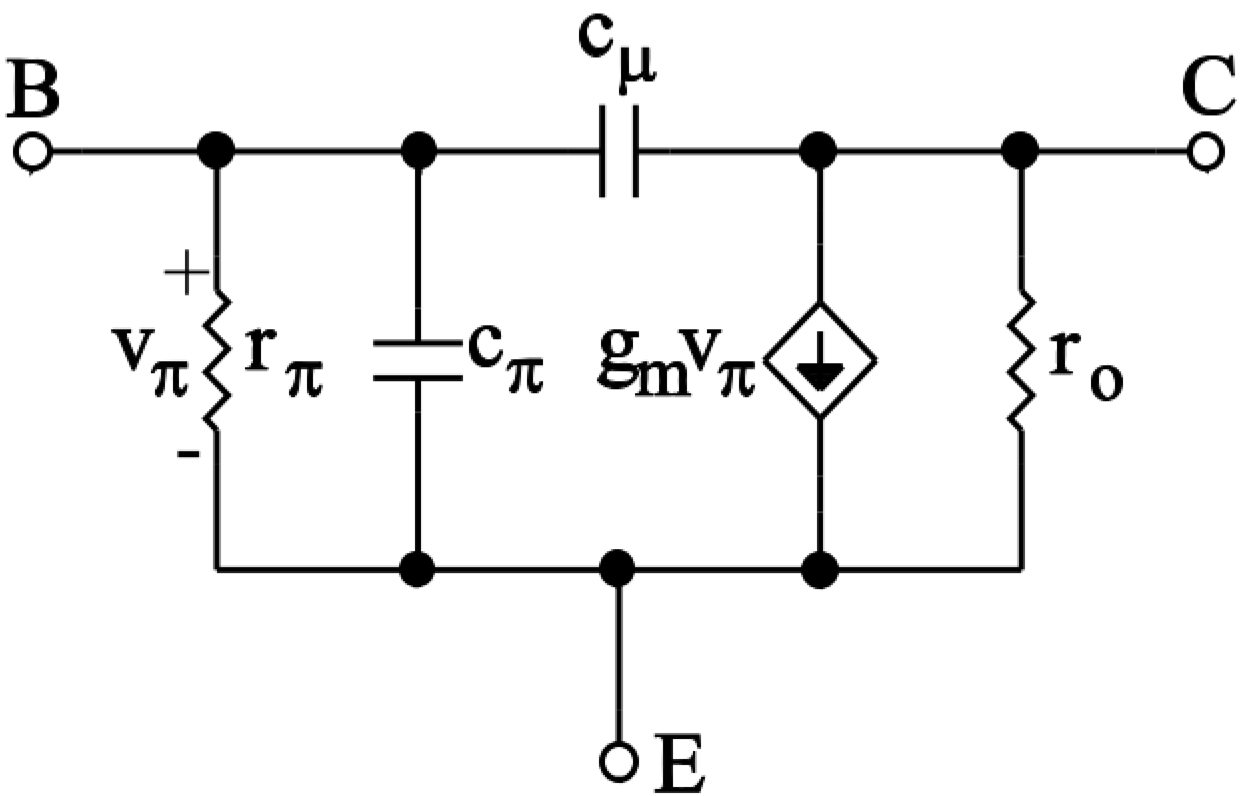
Complete Hybrid-π small-signal model

- Adding all the effects so far

$$r_\pi = \frac{v_{be}}{i_{be}} = \frac{\beta}{g_m} = \beta \frac{V_T}{I_C} = \frac{V_T}{I_B}$$

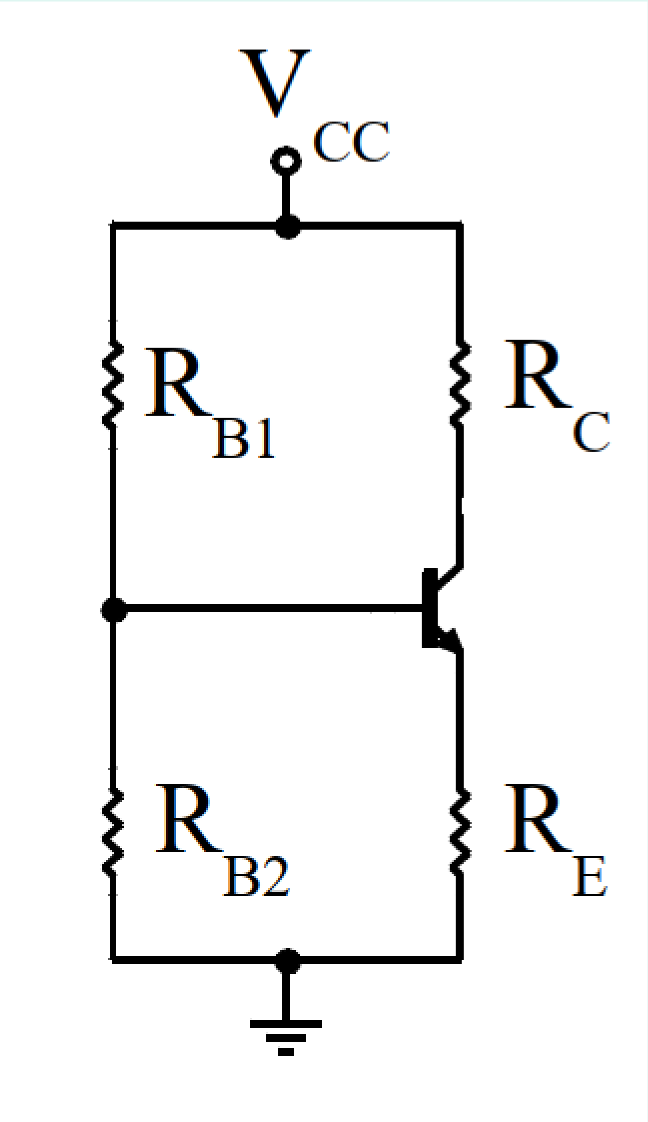
$$g_m = \frac{I_C}{V_T}$$

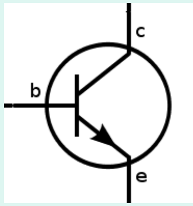
$$r_o \simeq \frac{V_A}{I_C}$$



BJT biasing

- The basic bias circuit
- V_{CC} often imposed by application
- Biasing trade-off:
  - operation in active mode
  - gain
  - dynamic operating range
  - power consumption
  - input impedance
  - quiescent point stability





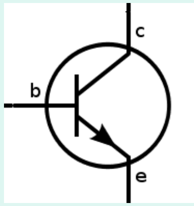
L11 Q02 - R_C role

- What happens if, for given V_{CC}, R_{B1}, R_{B2}, R_E, and β, we increase R_C ?

A. we decrease the voltage gain

B. we increase the power consumption

C. BJT gets closer to operating in the saturation regime



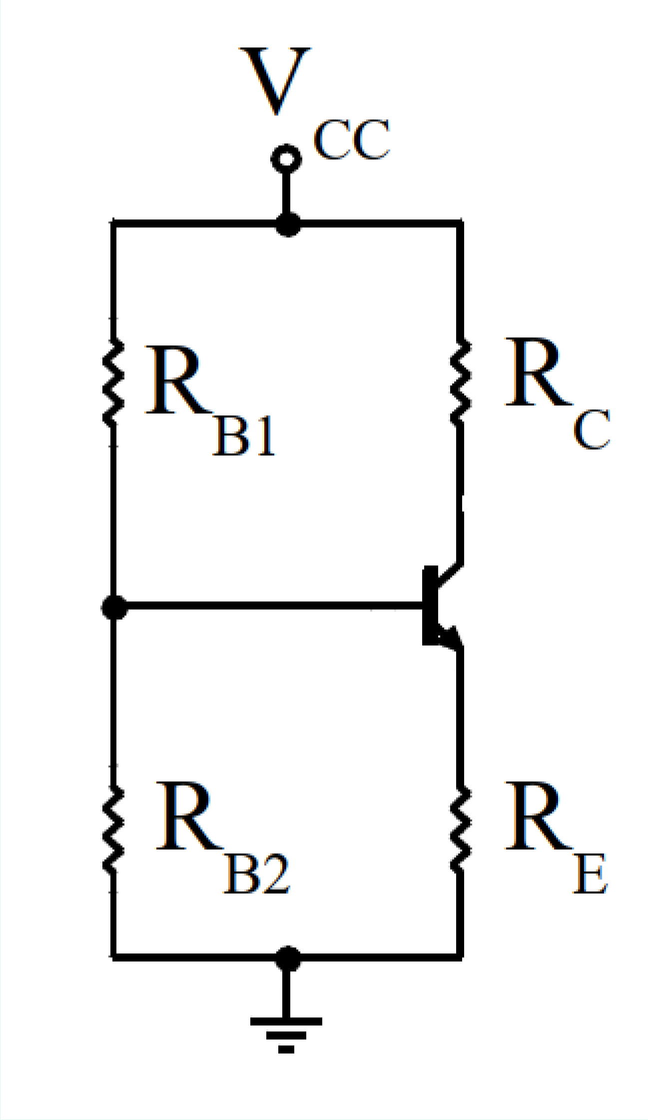
L11 Q03 - bias current

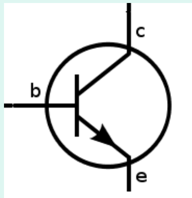
- How do we want the current through R_{B2} to be, in comparison with the base current I_B?

A. $I_{RB2} >> I_B$

B. $I_{RB2} \eqsim I_B$

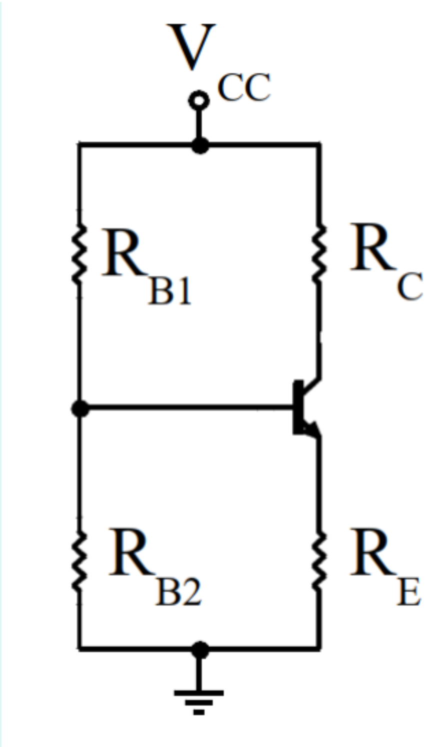
C. $I_{RB2} << I_B$

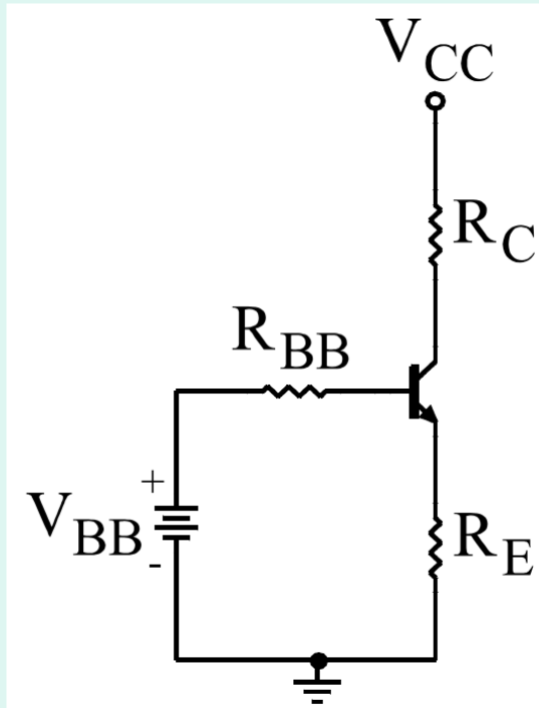




BJT biasing

$$I_B = -\frac{V_{BE}}{(1+\beta)\,R_E + R_{BB}} + \frac{V_{BB}}{(1+\beta)\,R_E + R_{BB}}$$



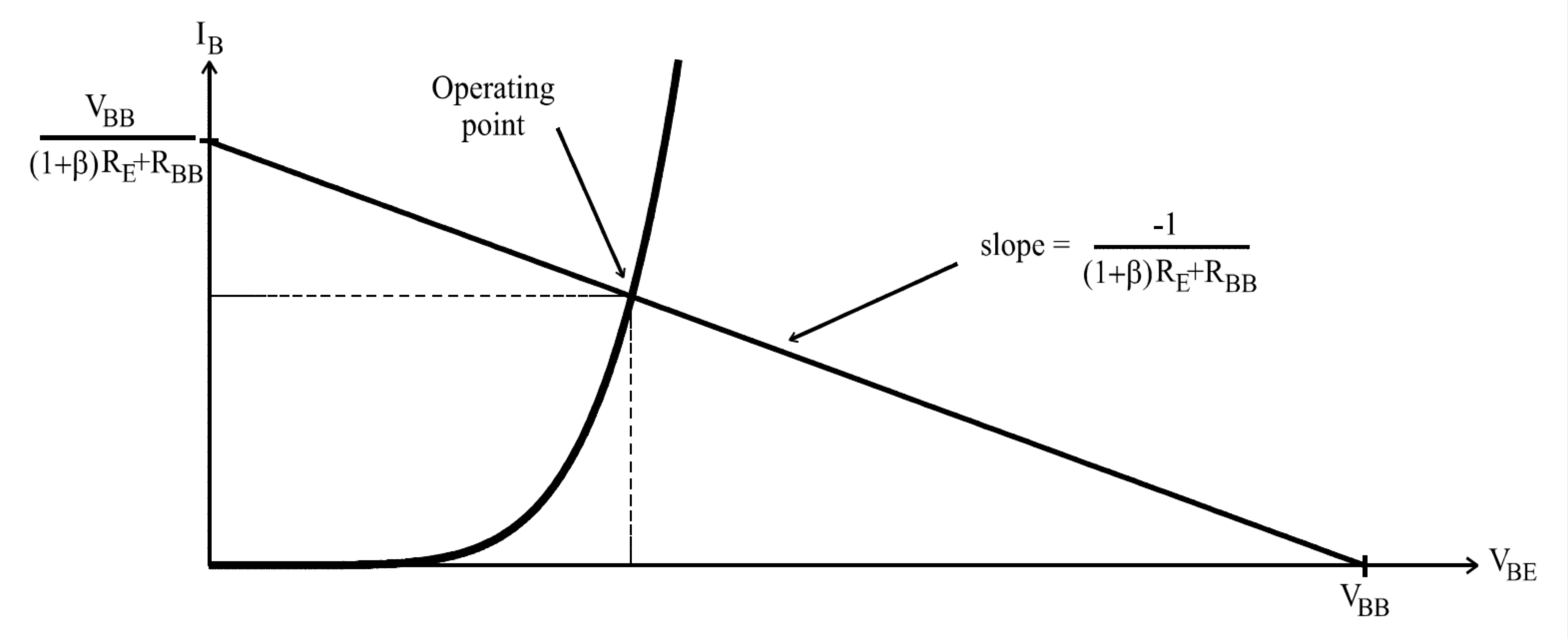


$$I_B = \frac{I_C}{\beta} = \frac{I_S}{\beta}\, e^{\frac{V_{BE}}{V_T}}$$

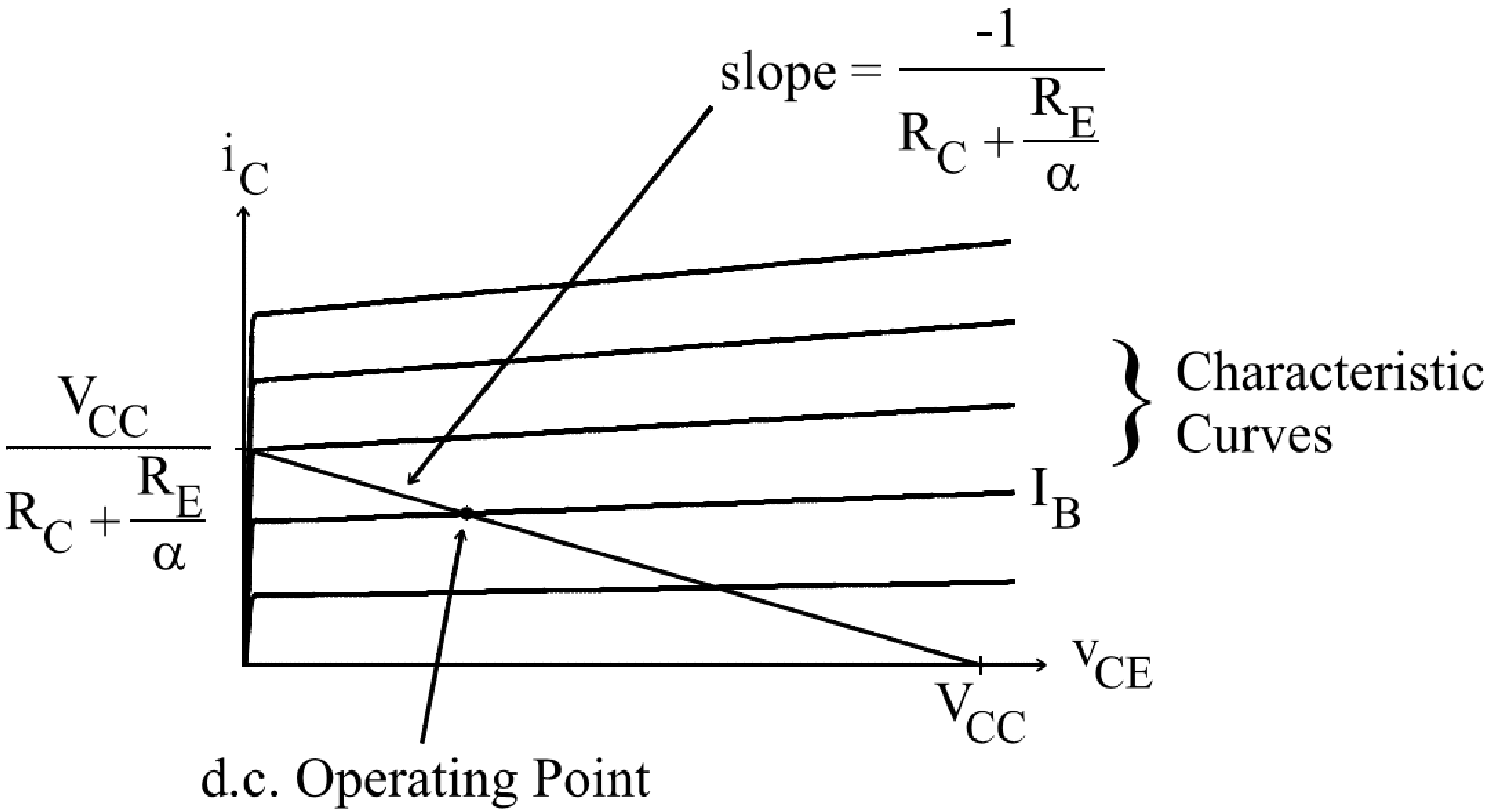
$$V_{BB} = V_{CC}\frac{R_{B2}}{R_{B1}+R_{B2}}, \; R_{BB} = R_{B1} \,||\, R_{B2}$$

Operating point - (V_{BE}, I_B)

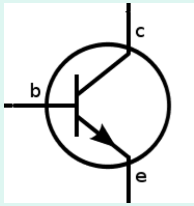
- I_B vs V_{BE}



Operating point (V_{CE}, I_C)



$$I_C = -\frac{V_{CE}}{\left(R_C + \frac{R_E}{\alpha}\right)} + \frac{V_{CC}}{\left(R_C + \frac{R_E}{\alpha}\right)}$$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