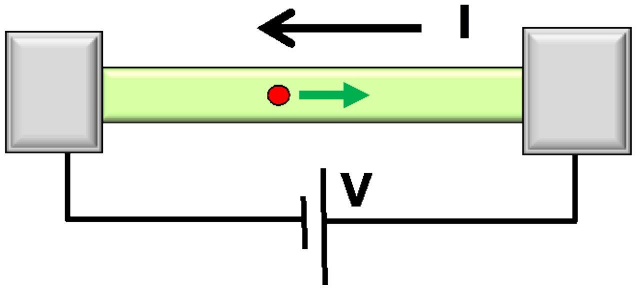
Section 24
Bipolar Junction Transistor - Fundamentals

24.4 Ebers Moll Model

Gerhard Klimeck
gekco@purdue.edu

PURDUE UNIVERSITY

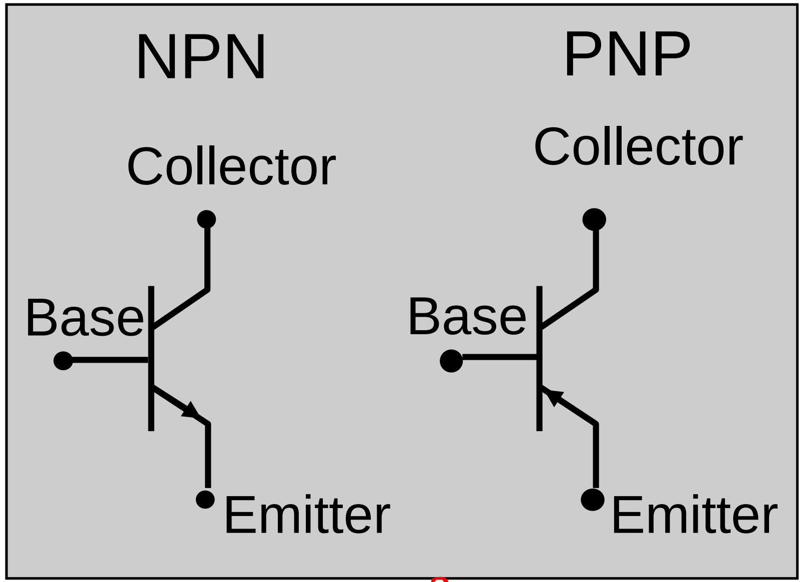
School of Electrical and Computer Engineering



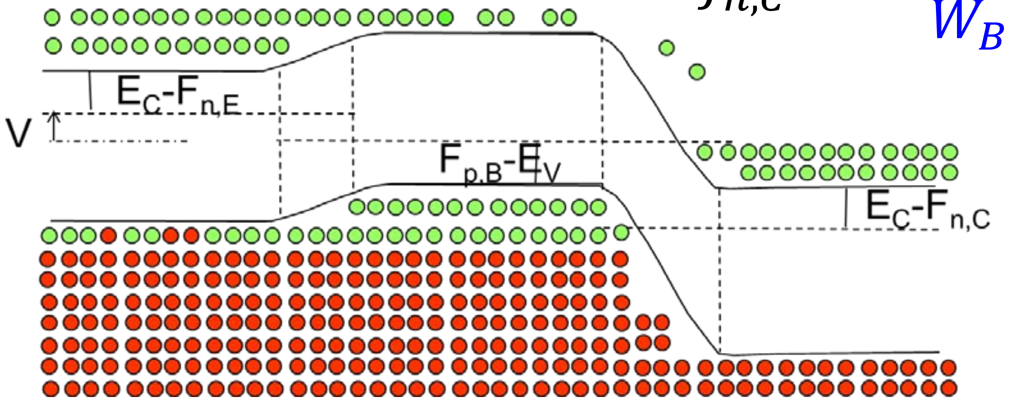
$$I = G \times V$$
$$= q \times n \times v \times A$$

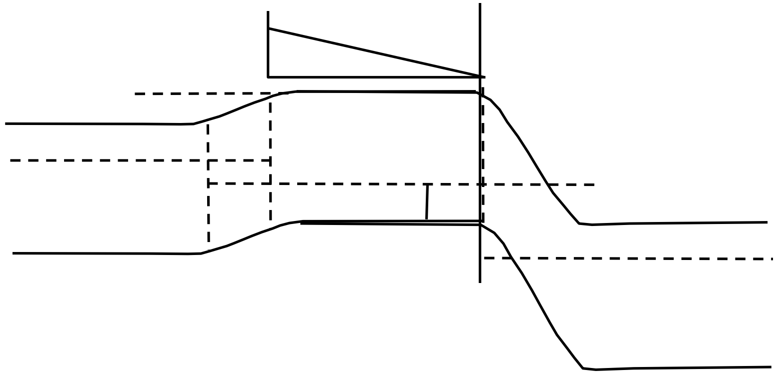
charge density velocity area

status



$$J_{n,C} = -\frac{qD_n}{W_B}\frac{n_{i,B}^2}{N_B}\left(e^{qV_{BE}\beta} - 1\right) + \frac{qD_n}{W_B}\frac{n_{i,B}^2}{N_B}\left(e^{qV_{BC}\beta} - 1\right)$$





Ebers Moll Model

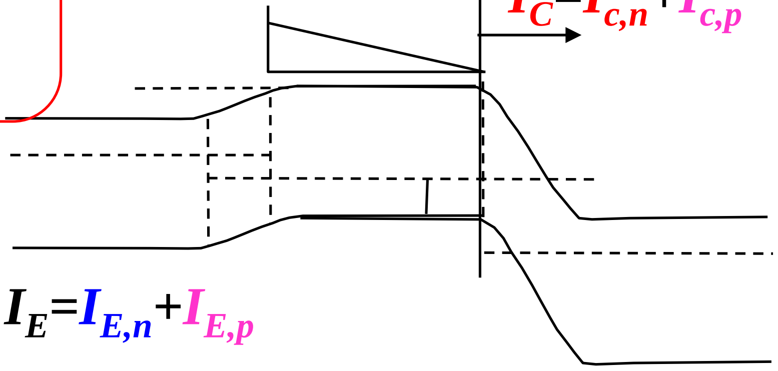
$$J_{n,C} = -\frac{qD_n}{W_B}\frac{n_{i,B}^2}{N_B}\left(e^{qV_{BE}\beta}-1\right) + \frac{qD_n}{W_B}\frac{n_{i,B}^2}{N_B}\left(e^{qV_{BC}\beta}-1\right)$$

Hole diffusion in collector

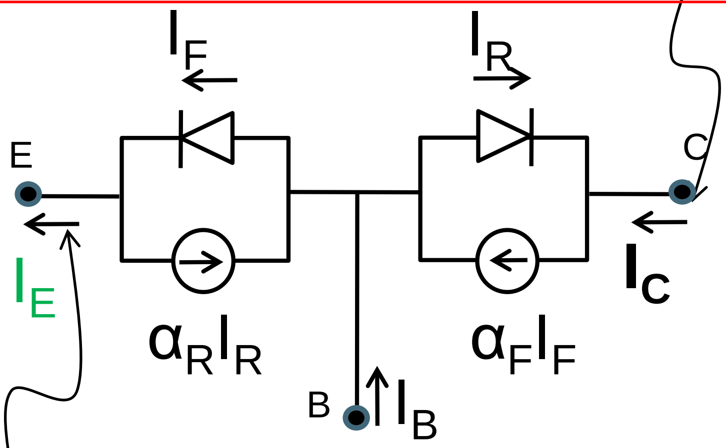
$$I_C = -A\frac{qD_n}{W_B}\frac{n_{i,B}^2}{N_B}\left(e^{qV_{BE}\beta}-1\right) + A\left[\frac{qD_n}{W_B}\frac{n_{i,B}^2}{N_B} + \frac{qD_p}{W_C}\frac{n_{i,C}^2}{N_C}\right]\left(e^{qV_{BC}\beta}-1\right)$$

$$I_C \equiv \alpha_F I_{F0}\left(e^{qV_{BE}\beta}-1\right) - I_{R0}\left(e^{qV_{BC}\beta}-1\right)$$

$I_C = I_{c,n} + I_{c,p}$



$I_E = I_{E,n} + I_{E,p}$



$$I_F = I_{F0}\left(e^{qV_{BE}\beta}-1\right)$$

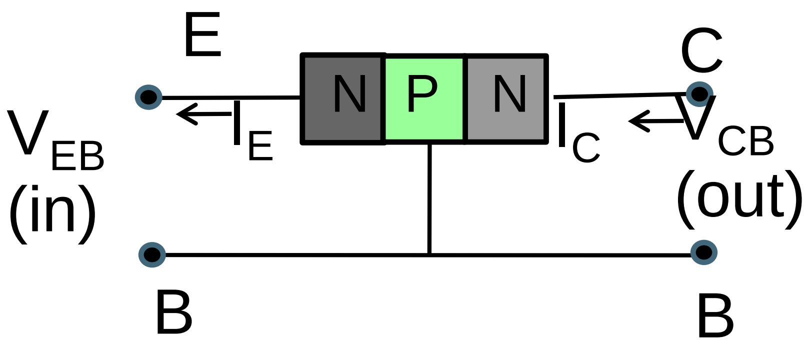
$$I_R = I_{R0}\left(e^{qV_{BC}\beta}-1\right)$$

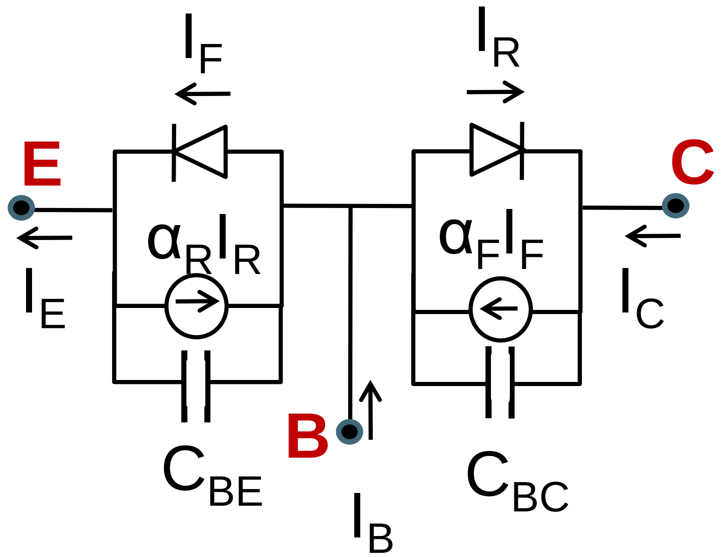
Temperature dependent

$$I_E = -A\left[\frac{qD_p}{W_E}\frac{n_{i,E}^2}{N_E} + \frac{qD_n}{W_B}\frac{n_{i,B}^2}{N_B}\right]\left(e^{qV_{BE}\beta}-1\right) + A\frac{qD_n}{W_E}\frac{n_{i,B}^2}{N_B}\left(e^{qV_{BC}\beta}-1\right)$$

$$I_E \equiv I_{F0}\left(e^{qV_{BE}\beta}-1\right) - \alpha_R I_{R0}\left(e^{qV_{BC}\beta}-1\right)$$

Common Base Configuration





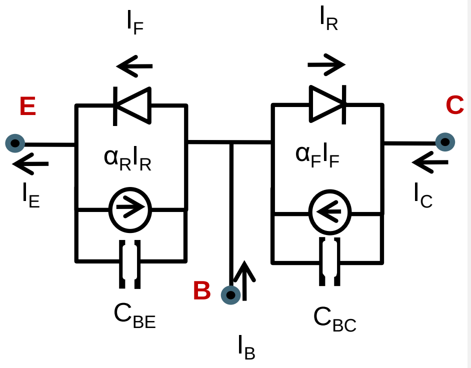
Junction capacitance and diffusion capacitance

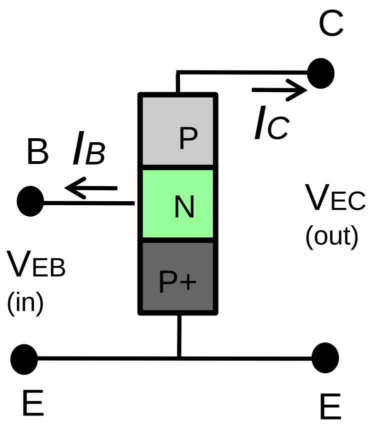
How would the model change if this was a Schottky barrier BJT?

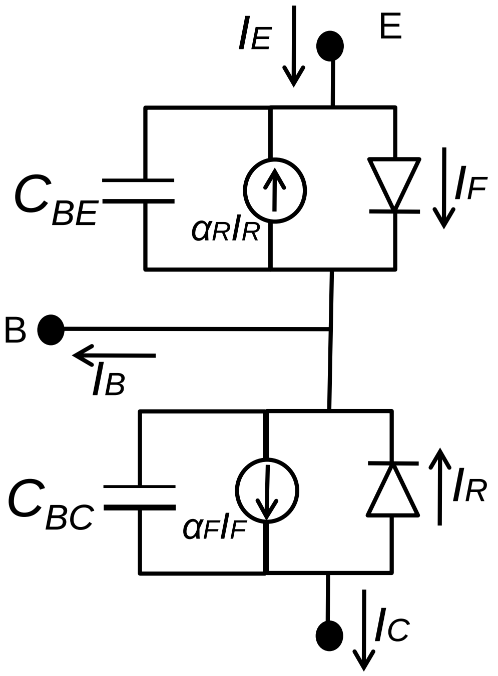
The original transistor was a metal/ semicond / metal device
No minority carriers, no diffusion capacitance but the “rest” about the same.

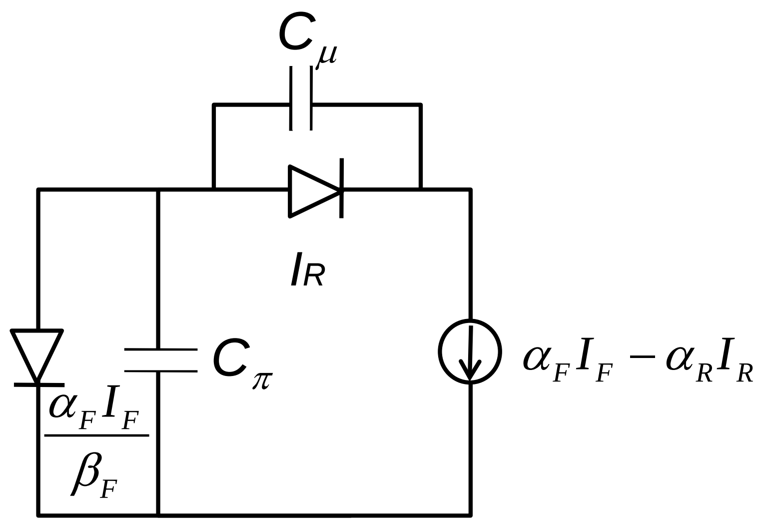
=> Emitter and collector current are identical => no current gain
Common base configuration provides power gain, but no current gain.
=> Collector current I_C can be driven through large resistor => power gain
Is there another configuration that can deliver current gain?

Common Emitter Configuration



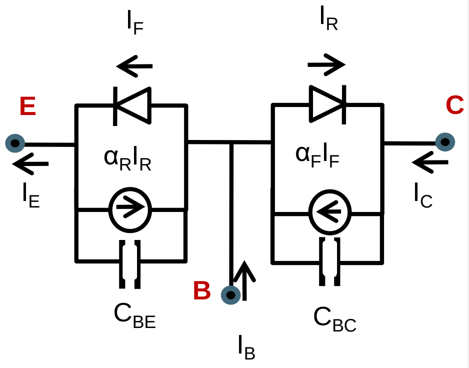




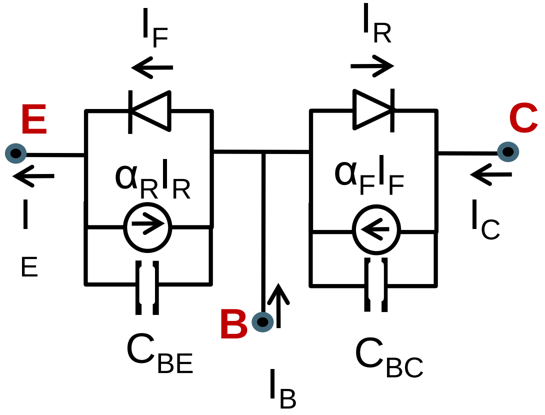


$$\frac{\alpha_F I_F}{\beta_F} = \frac{\alpha_F I_F}{\frac{\alpha_F}{1-\alpha_F}} = \left(1-\alpha_F\right) I_F = I_B$$

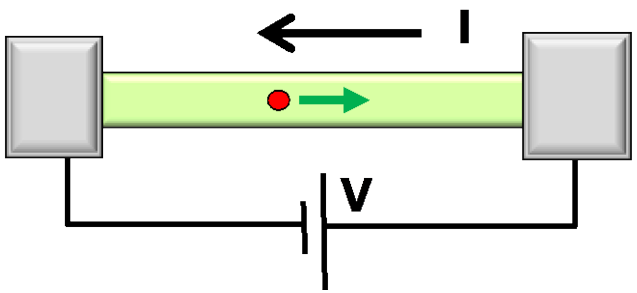
This is a practice problem …



- The physics of BJT is most easily understood with reference to the physics of junction diodes.
- The equations can be encapsulated in simple equivalent circuit appropriate for dc, ac, and large signal applications.
- Design of transistors is far more complicated than this simple model suggests => the next lecture elements
- For a terrific and interesting history of invention of the bipolar transistor, read the book “Crystal Fire”.



Bipolar Junction Transistor - Fundamentals



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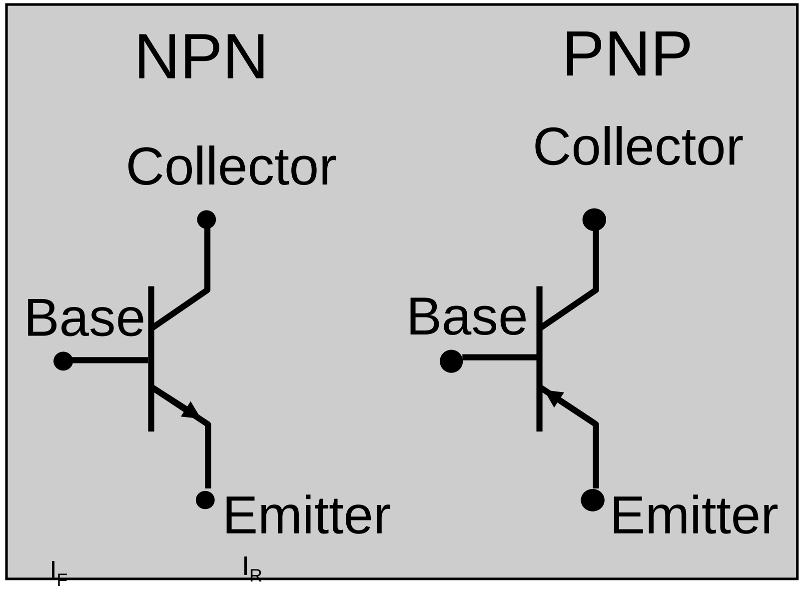

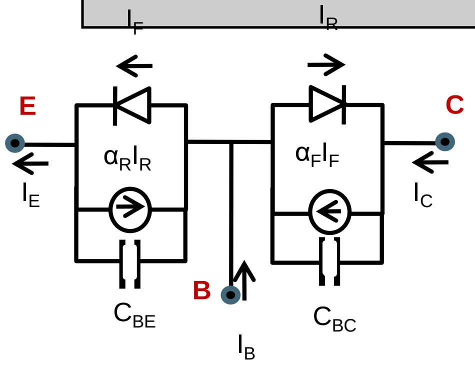

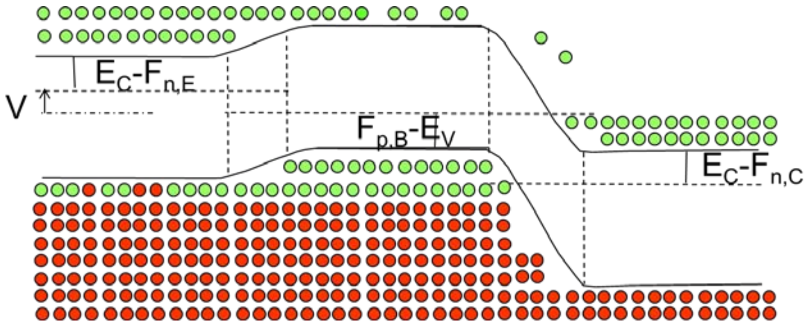

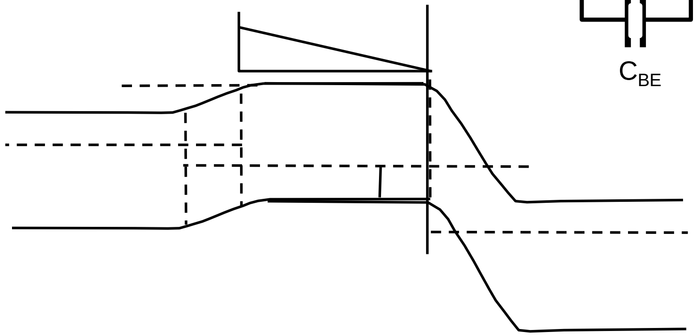

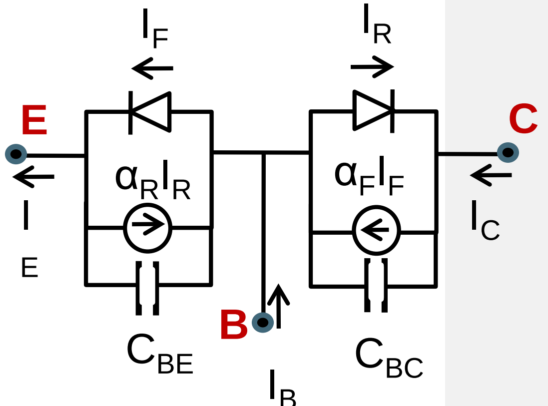

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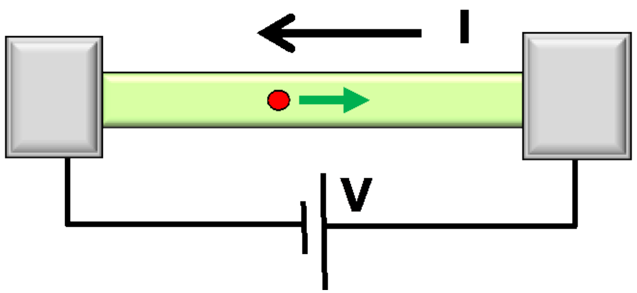

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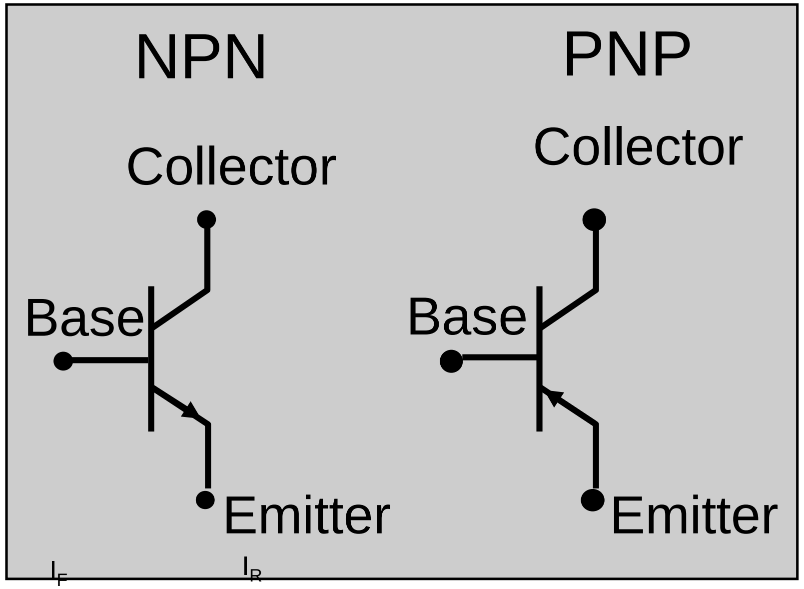

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- 24.2 Band Diagram in Equilibrium
- 24.3 Currents in BJTs
- 24.4 Ebers Moll Model
- 25 BJT Design
- 26 BJT High Frequency Response
- 27 HBT – Heterojunction Bipolar Transistor