Electrical Circuits
Lecture 15: BJT Transistors

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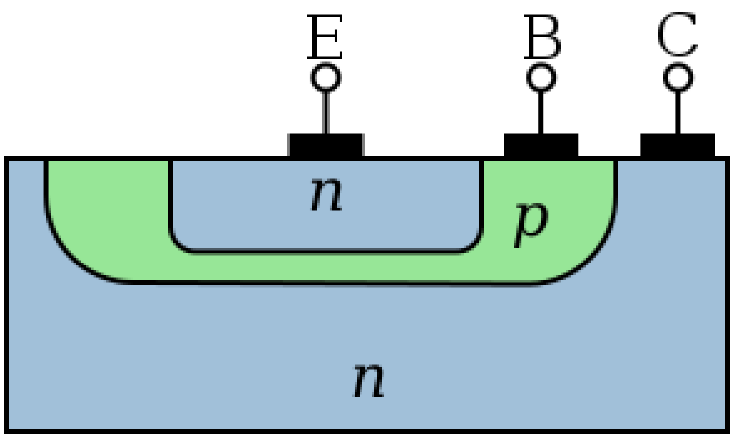
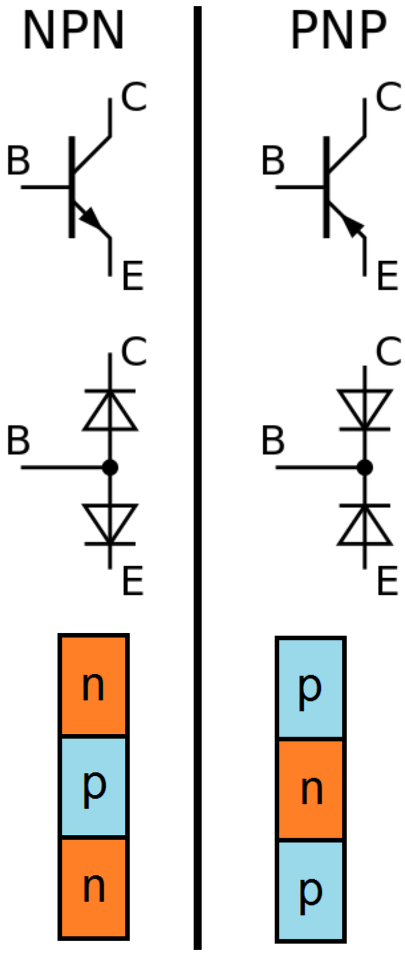
Topic Overview

- BJT Large Signal Model
- BJT Modes of Operations
- BJT DC Analysis
- BJT Small Signal Model
- BJT AC Analysis

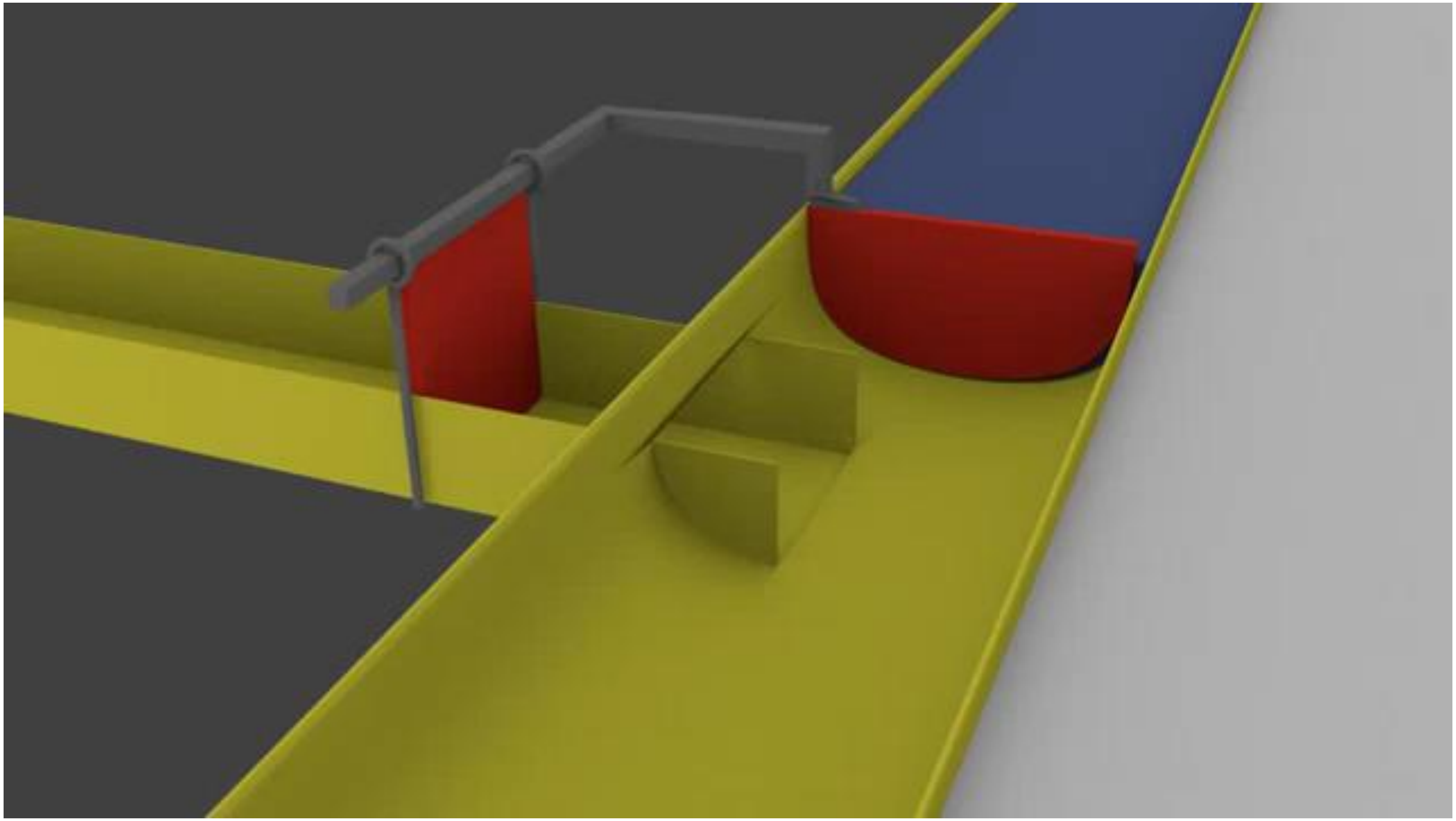
BJT

- B: Base
- C: Collector
- E: Emitter





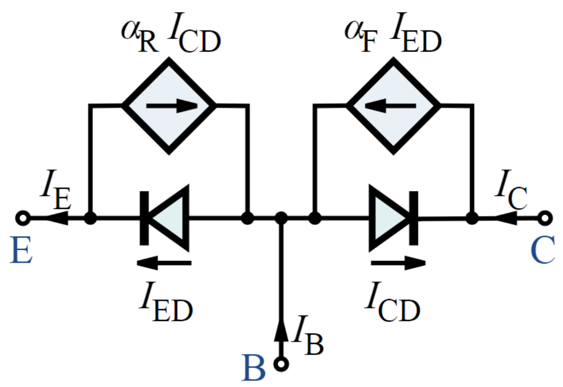
BJT Operation



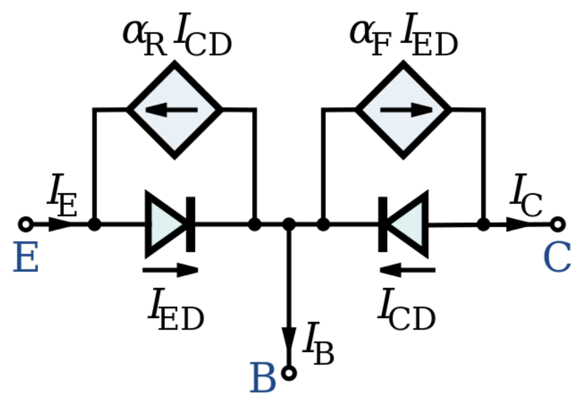
BJT Large Signal Model

- Ebers-Moll Model
- Modes of operation:
  - Cut-off
  - Forward Active
  - Reverse Active
  - Saturation

NPN:

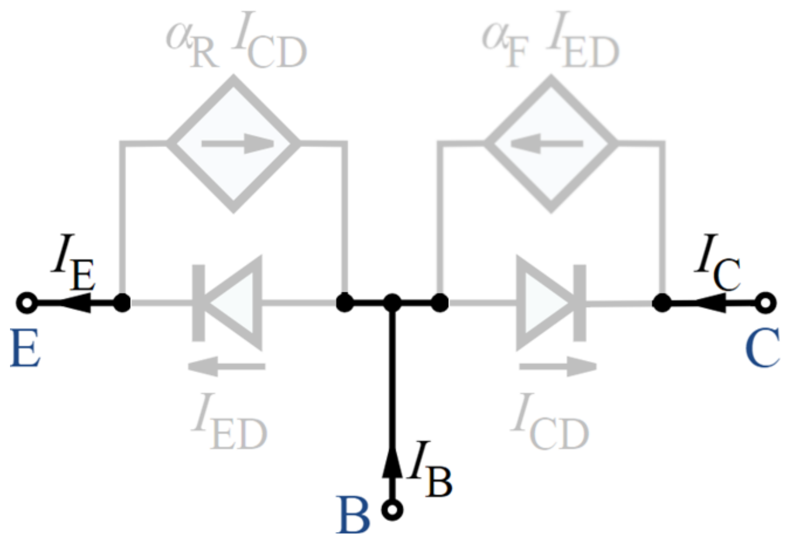


PNP:



NPN BJT Modes of Operation

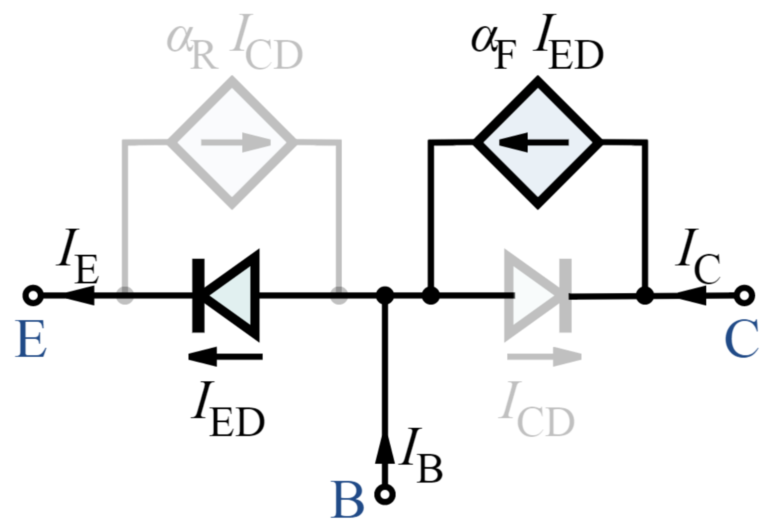
- Cut-off
  - $V_B - V_C < 0.4$
  - $V_B - V_E < 0.6$



- $I_B = I_C = I_E = 0$

NPN BJT Modes of Operation

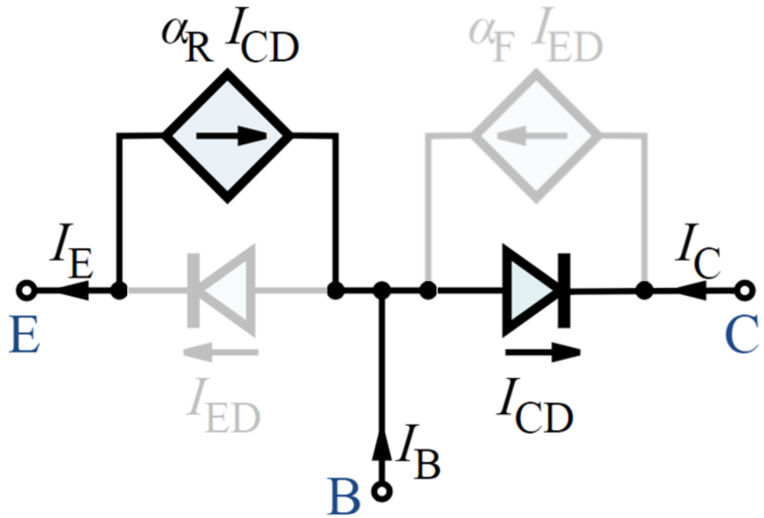
- Forward Active
  - $V_B - V_C < 0.4$
  - $V_B - V_E > 0.6$



- Acts as an amplifier!
  - $I_C = \alpha I_E \qquad (0.98 < \alpha < 0.998)$
  - $I_E = I_B + I_C$
  - $I_C = \beta I_B$
  - $\beta = \frac{\alpha}{1-\alpha}$

NPN BJT Modes of Operation

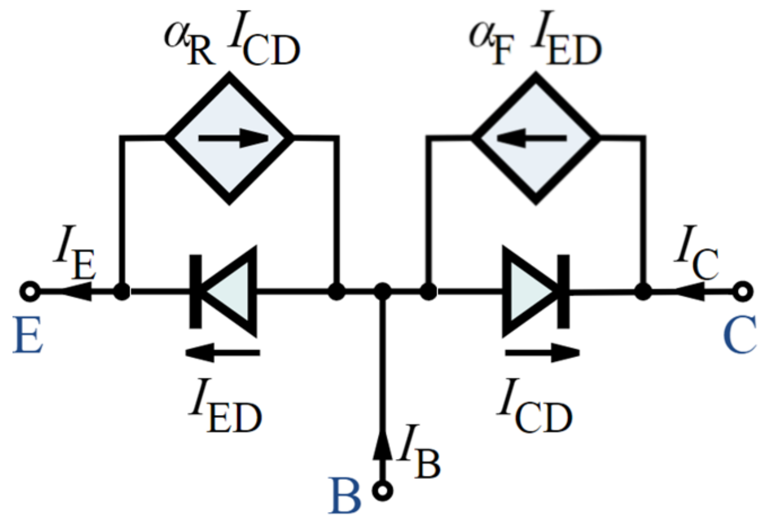
- Reverse Active
  - $V_B - V_C > 0.4$
  - $V_B - V_E < 0.6$



- The collector diode is built in a way that it can tolerate large reverse biases, but emitter diode can’t.
- It also has poor β.
- So, we usually don’t use BJTs in this mode…

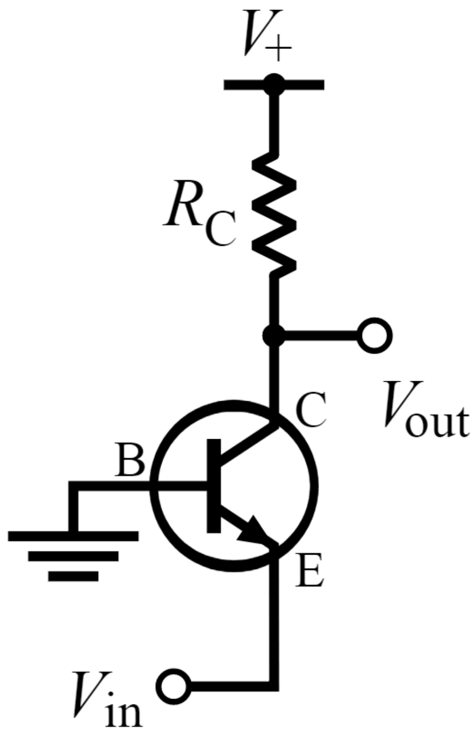
NPN BJT Modes of Operation

- Saturation
  - $V_B - V_C > 0.4$
  - $V_B - V_E > 0.6$
  - $V_C - V_E \approx 0.2$

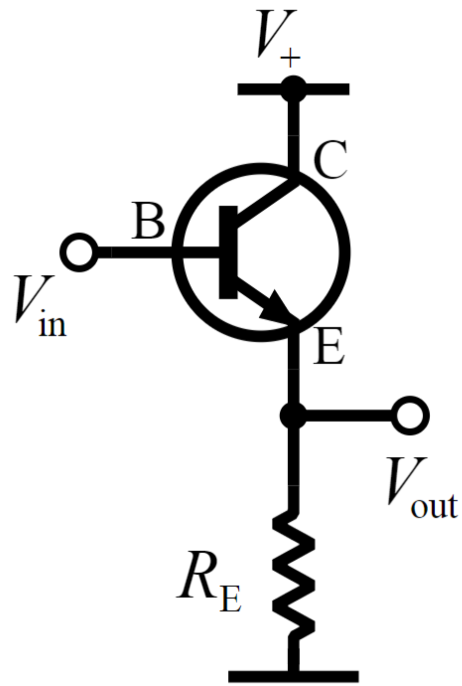


- Acts as a switch!
- 0.2 is called V_{sat}
- $I_C < \beta I_B$ (I_C is set by the circuit, not by I_B)

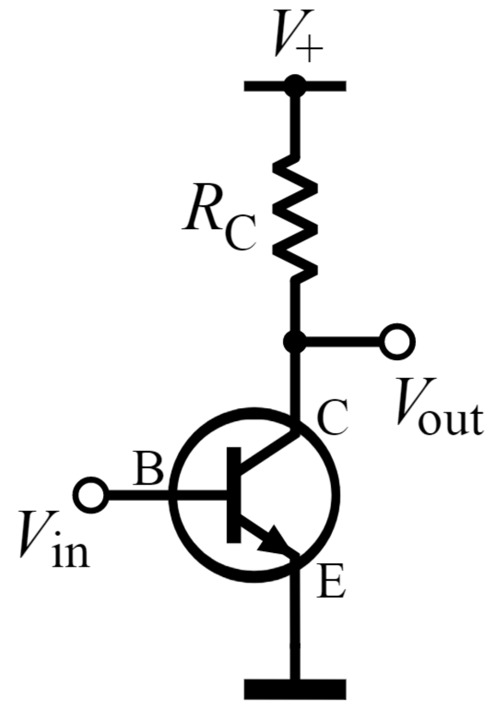
BJT Configurations



Common Base



Common Collector



Common Emitter

BJT DC Analysis

- Write BE and CE KVLs
- Assume Cut-off ($I_B = 0$), use BE-KVL to find V_{BE}:
  - If $V_{BE} < 0.6$, OK! $I_C = 0$, Use CE-KVL to find V_{CE}.
  - If $V_{BE} > 0.6$, assumption is not true…
- Assume Active ($V_{BE} > 0.6$), assume $V_{BE} = 0.6$, use BE-KVL to find I_B. Find $I_C = \beta I_B$. Use CE-KVL to find V_{CE}.
  - If $V_{CE} > 0.2$, OK! Otherwise, assumption is not true
- Assume Saturation ($V_{CE} = 0.2$). Use CE-KVL to find I_C. Double Check $I_C < \beta I_B$

Example

- Find i_C $\quad (\beta = 100)$
- Write BE and CE KVLs:
  - $-4 + 40000 i_B + v_{BE} = 0$
  - $-12 + 1000 i_C + v_{CE} = 0$
- Assume Cut-off
  - $i_B = 0 \ \rightarrow v_{BE} = 4 > 0.6$
- Assume Active
  - $v_{BE} = 0.6 \ \rightarrow i_B = \frac{4-0.6}{40000} = 85\mu A > 0$
  - $i_C = 100 \times 85\mu = 8.5mA \rightarrow v_{CE} = 3.5 > 0.2$