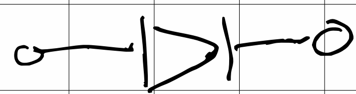
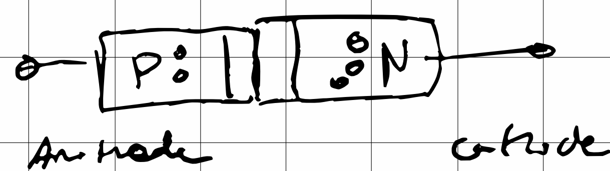
# ME 133 Lecture 6 1/20/2022

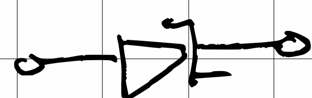
Last time:

- Diodes



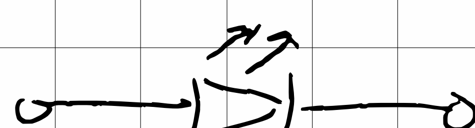



- Zener diodes



→ operates in <u>Breakdown</u>

- optoelectric diodes
  - LEDs

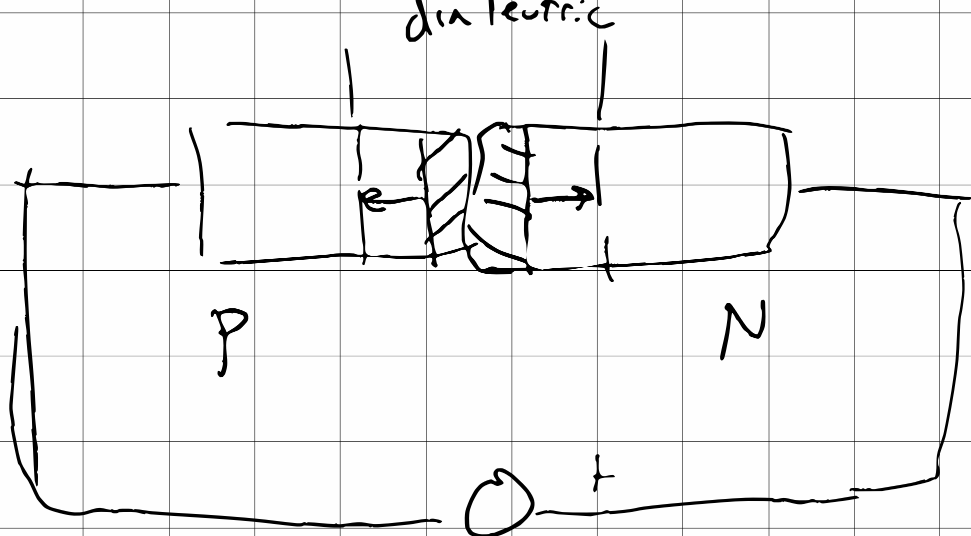


  - photo diode

* <u>Main Point</u>: diodes function to control the flow of current

Correction from last time:

Do diodes act as capacitors?




- junction capacitance
- usually ignore it
- also exploit
  variable capacitance diodes

  varicap diode

  - Variable oscillators

<u>Today:</u>

① Quick note on analyzing diodes on circuits

② Transistors
- Bipolar Junctions
- Field Effect

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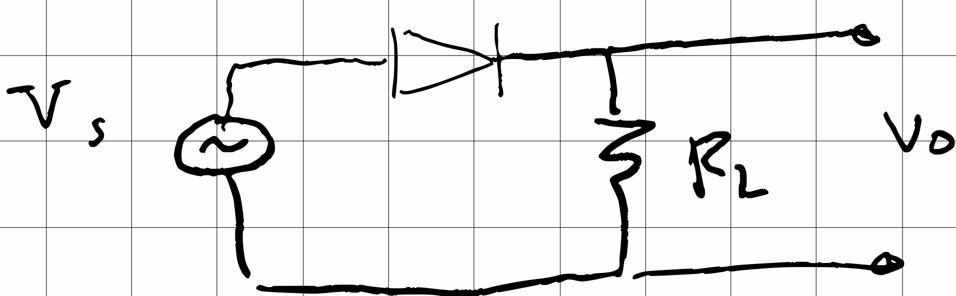
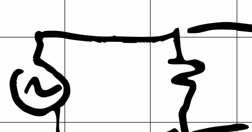
How to analyze diodes in circuits:



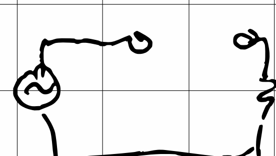

<u>ideal model</u>:

$V_s > 0$ : short circuit



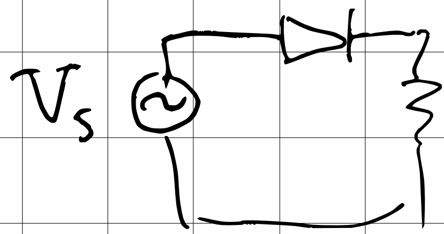
$v_o = v_s$

$V_s < 0$ : open circuit

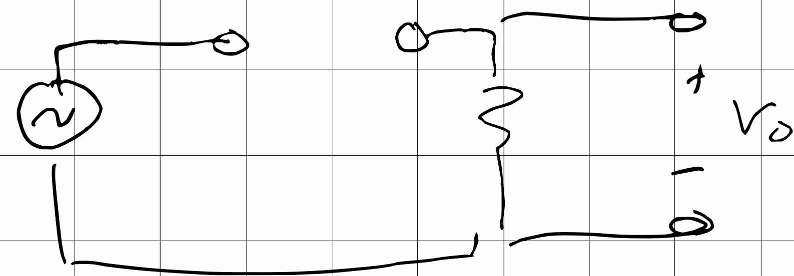


$V_o = 0$

## Approximation model (offset model):

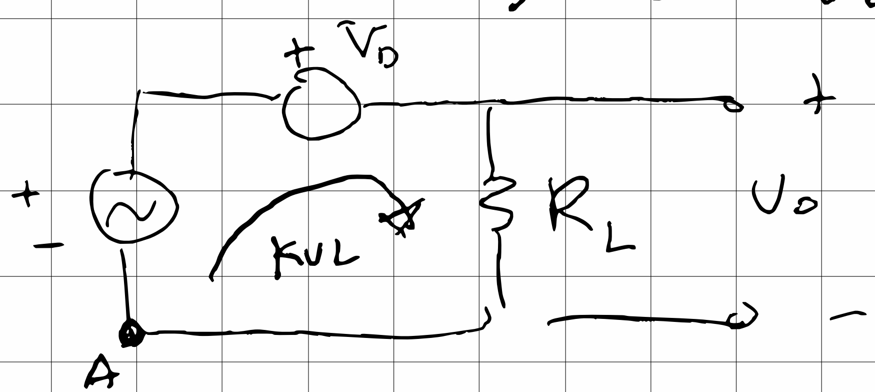



$V_s < V_D$



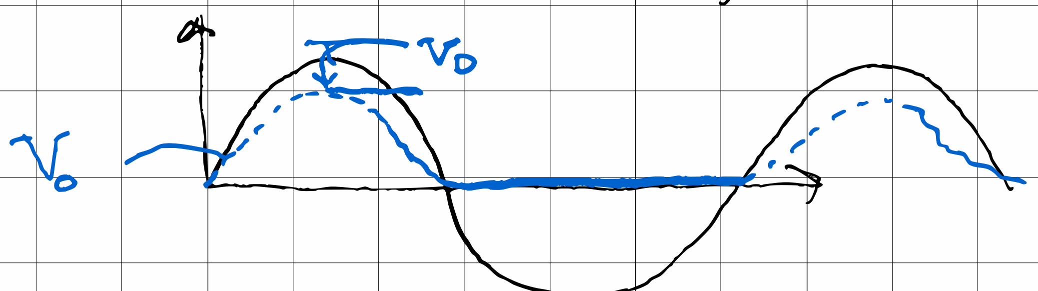

$V_o = 0$

$V_s > V_D$ : replace diode w/ voltage source $= V_D$




$$-V_s + V_D + V_o = 0$$

$$V_o = V_s - V_D$$




All model are wrong, some models are useful!

# Transistors

- these the <u>heart</u> of nearly every electronic device
  → mechatronic

- the first transistor, bipolar junction, invented in <u>1948</u>
  - William Shockley, Bell Labs
    → most important techological innovation of the 20th century

## Basically Two Functions

① Amplification : magnify voltage/current by transfering energy from another source

② Switching : control large voltage/current using <u>small</u> voltage/current

## Advantages:

1. Amplification: transmit tiny signals then amplify them.

2. switching: Buid logic circuits
   Ch. 6

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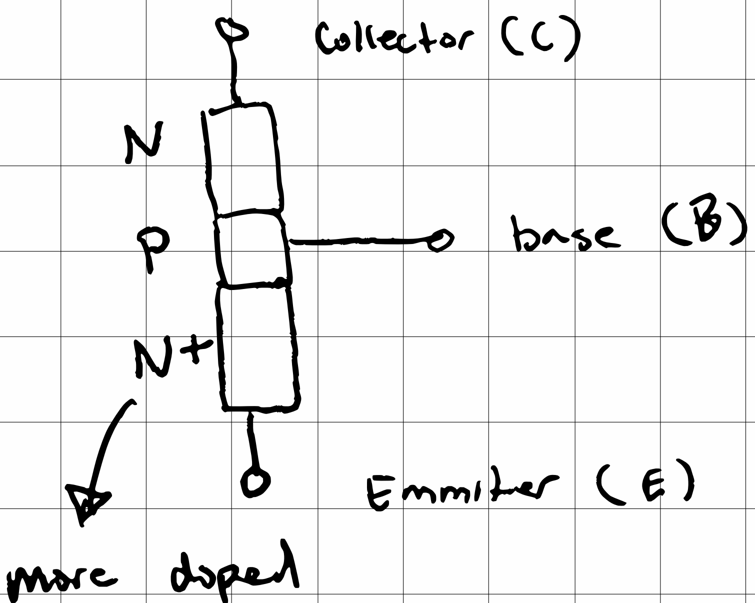
Most Common: BJT, FET

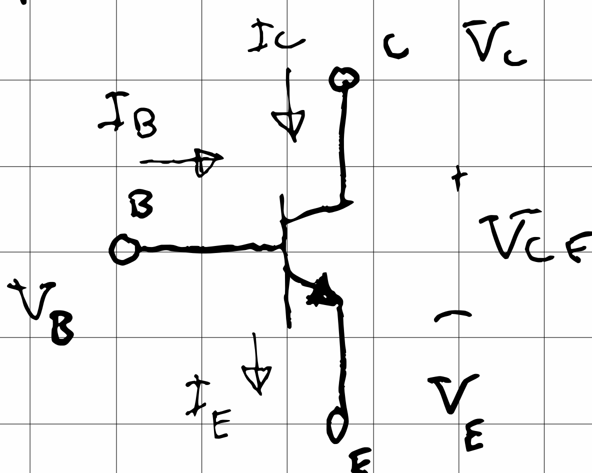
| Bipolar Junction | Field Effect |
|---|---|
| · 3 terminal devices | · 3 terminal Devices |
| · Two PN juctions | · Channel of doped semiconductor through which current flows → conductivity of channel |

# Bipolar Junction

## NPN transistor

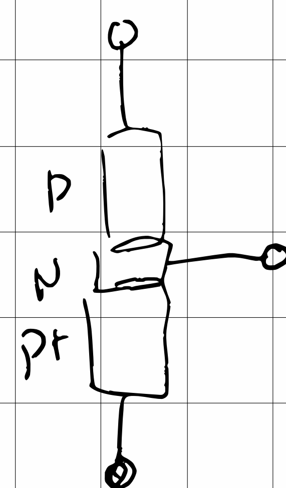
~~(n-channel)~~

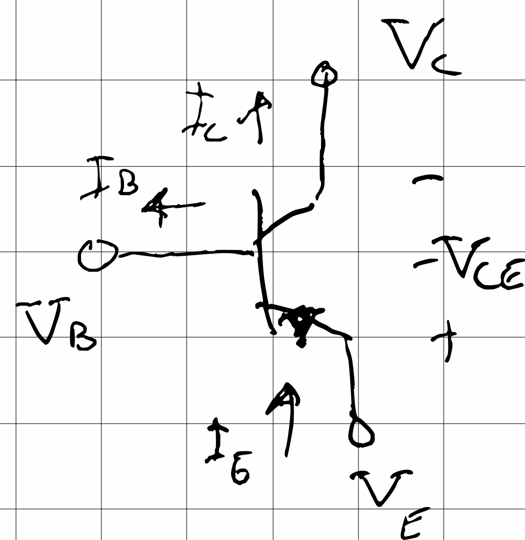


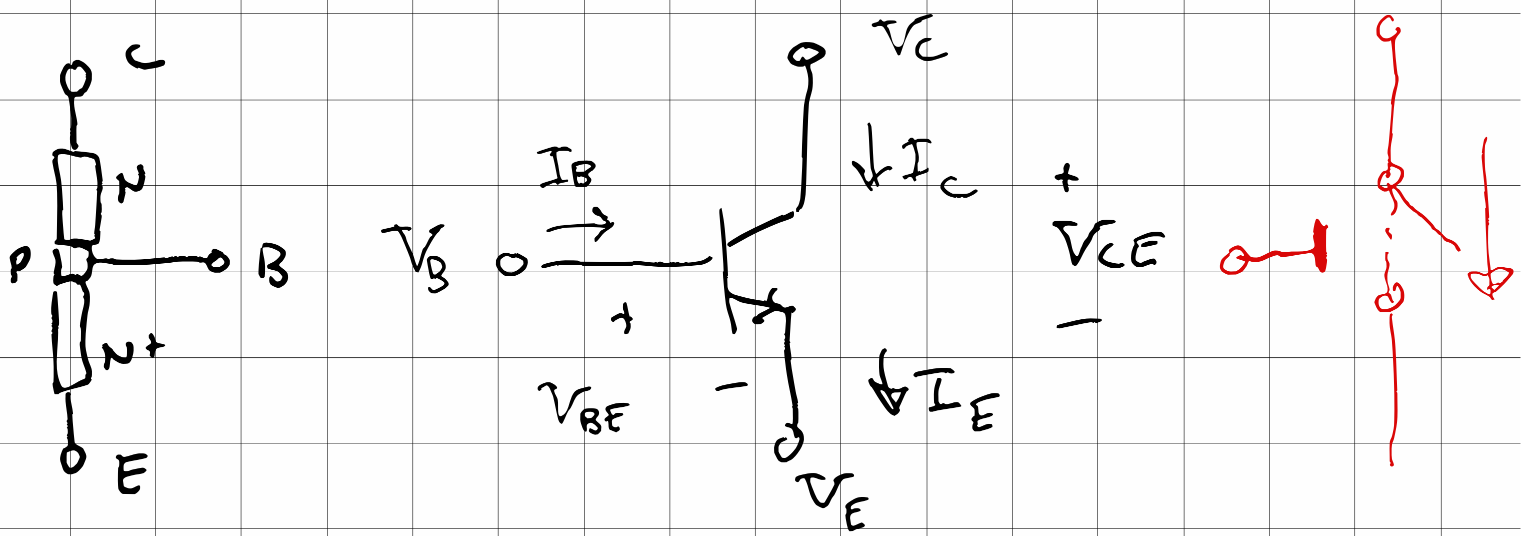

## PNP - transistor

~~(P-channel)~~



# NPN Working Principle



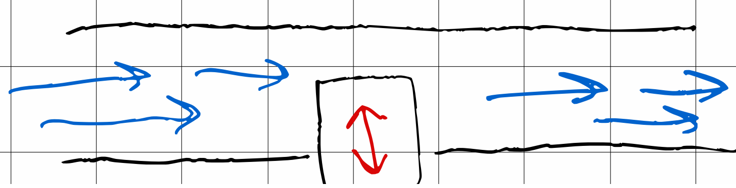

$$I_E = I_C + I_B$$
$$V_{BE} = V_B - V_E$$
$$V_{CE} = V_C - V_E$$

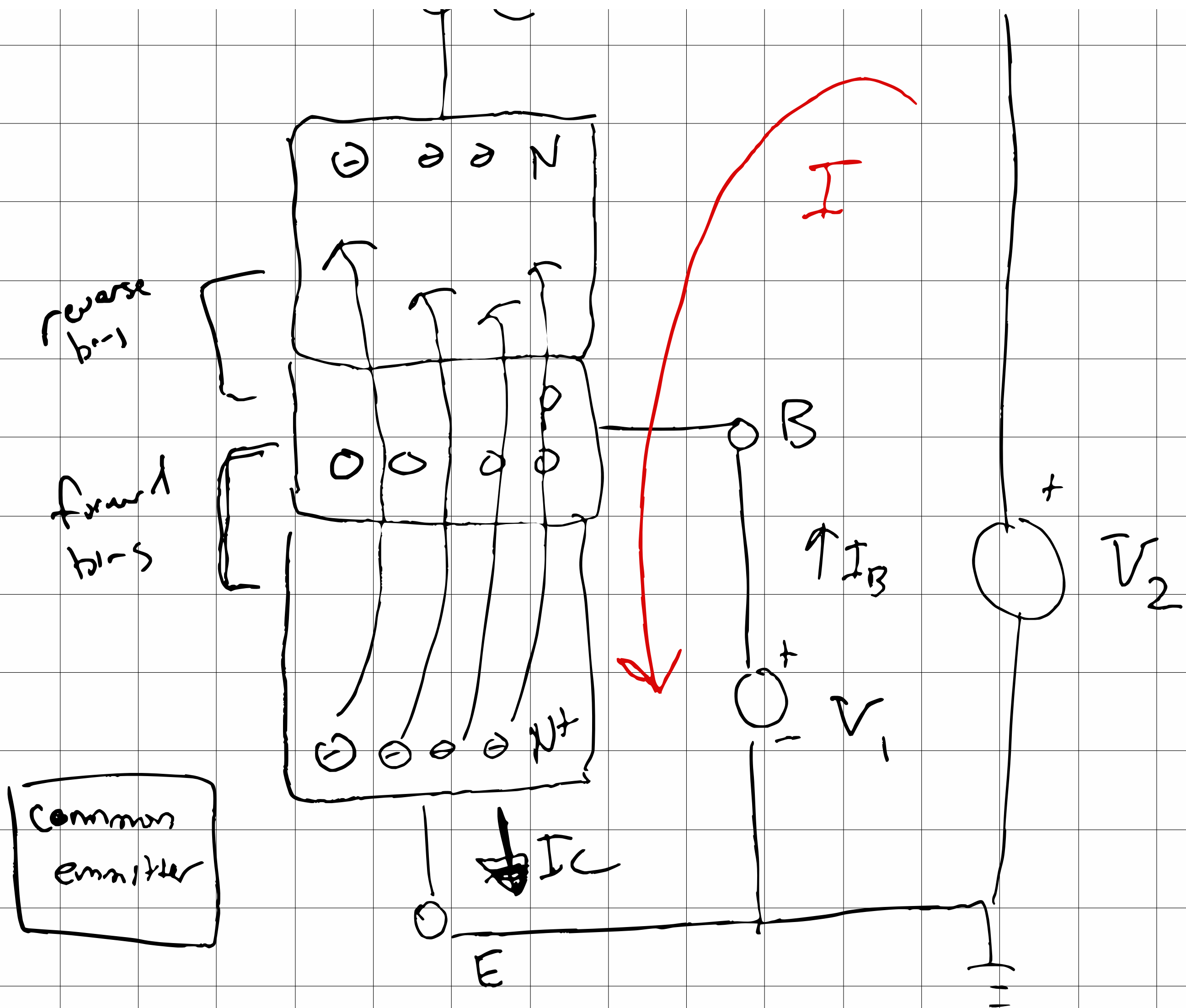
For the transistor to be <u>on</u> base-to-emitter must forward bias

$$V_{BE} = 0.7\,V$$

$$V_B = V_E + 0.7\,V$$

- When this is the case, large collector current ($I_C$) flows, with small base ($I_B \ll I_C$)
- small voltage drop $V_{CE}$






Collector : collects $e^-$ } When transistor on
emitter : emits $e^-$

P-section is <u>small</u>, $e^-$ have enough momentum to cross

<u>Take away</u>: small current $I_B$ allows a larger current $I_C$ to flow

$I_C = \beta I_B$ amplification factor

# BJT's have 3 modes

**Active** :
- Increase $I_B \rightarrow$ Increase $I_C$
- proportional currents

$$I_C = \beta I_B \quad \text{(linear growth)}$$

- amplifier

**Saturation** :

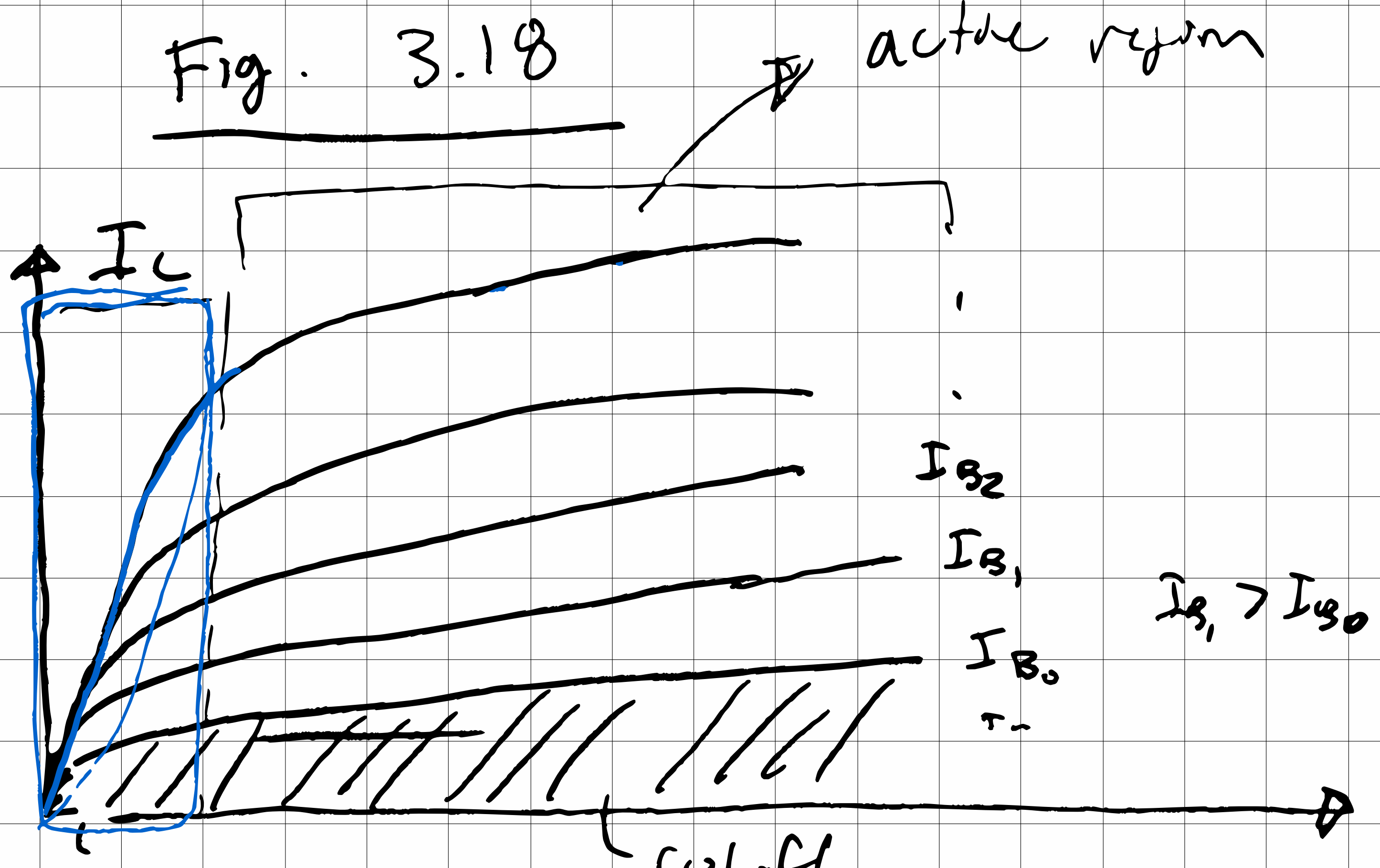
$V_{CE} \approx 0$ ; max current flows

- $I_E >> I_B \quad I_B \approx I_C$
- both junctions are forward bias
- like a short circuit

(switching behavior)

**Cutoff** :
- $V_{BE} << 0.7$ no current flows
- open circuit

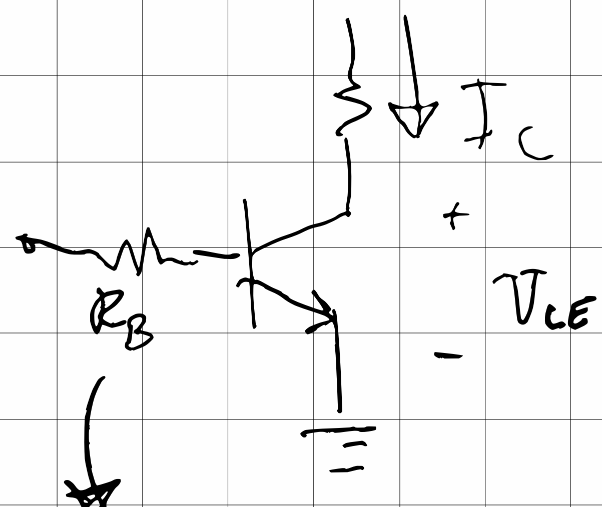
# Fig. 3.18




$I_{B_1} > I_{B_0}$

Saturation region

$I_C$ doesn't depend on $I_B$




tune $R_B$ to ensure saturation

# BJT as a switch

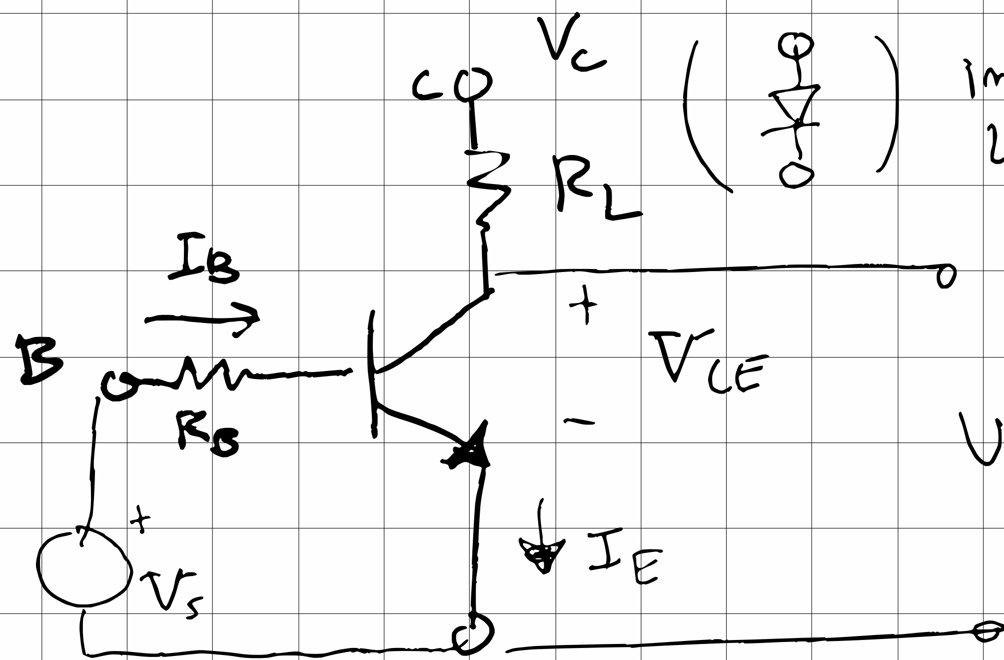
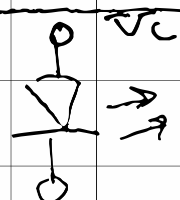
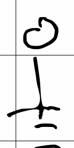



image as LED.

$\boxed{V_s < 0.7\,V}$ collector - emitter → open circuit

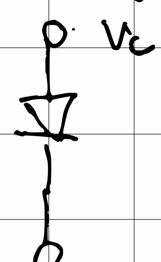



LED off



cutoff

$V_s > 0.7\,V$ collector – emitter → short circuit



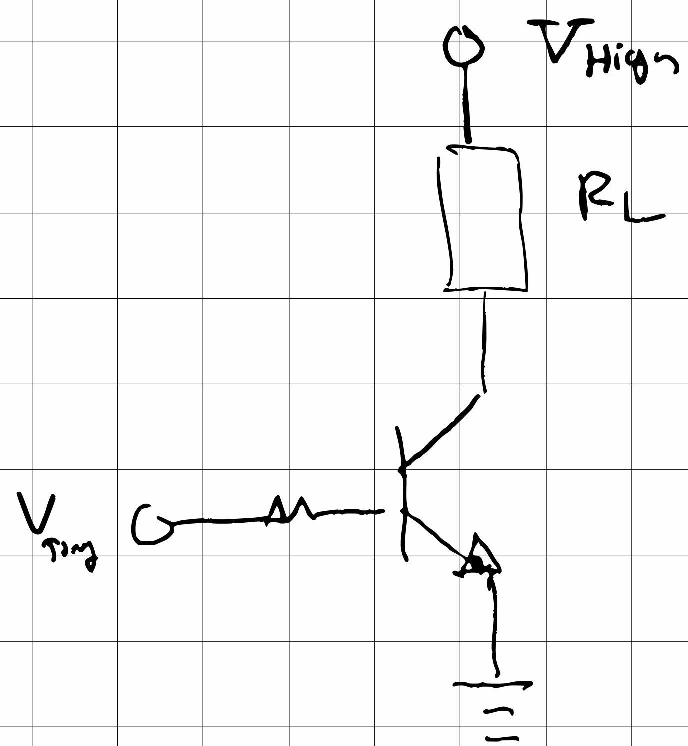

$$I_B = \frac{V_s - V_{BE}}{R_B}$$

$R_B$ → to ensure saturation.

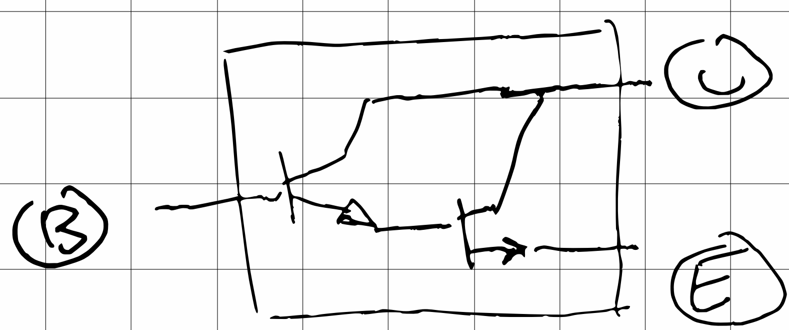
saturation

# Application

- power transistors



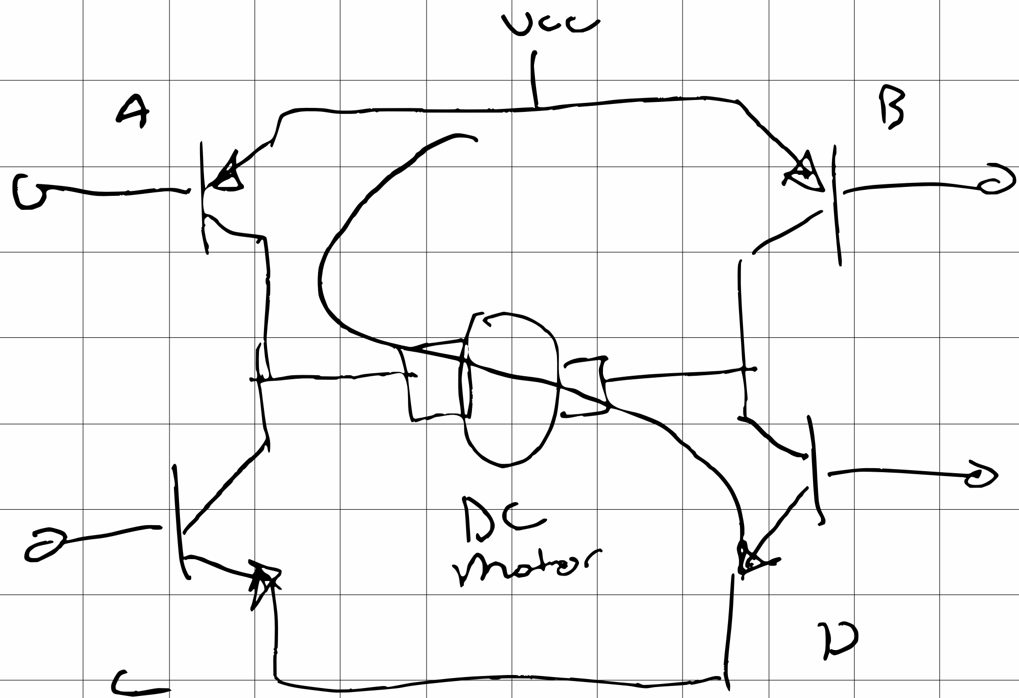

- Darlington Pair




Very large current gain

power amplification

- Motor control (H-Bridge)




- optoisolators ; photo transistor