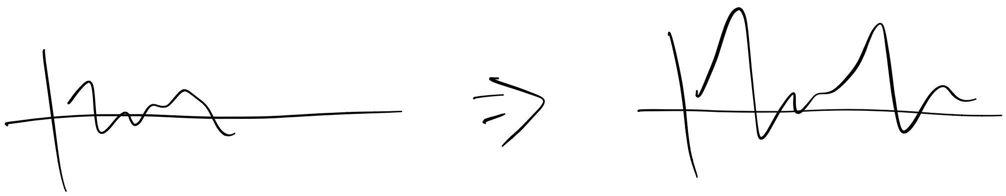
Bipolar Junction Transistors

prior to 1907: no way to amplify small signals!



1883: thermionic emission (Edison)

1904: Fleming diode

1907: Lee DeForest: vacuum tube triode

·· first three-terminal electronic device

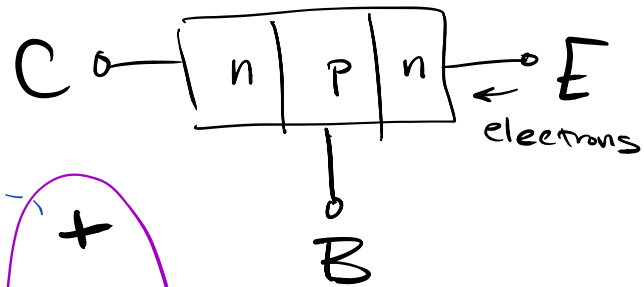
·· grid electrode between cathode and anode could be used to modulate current through the device

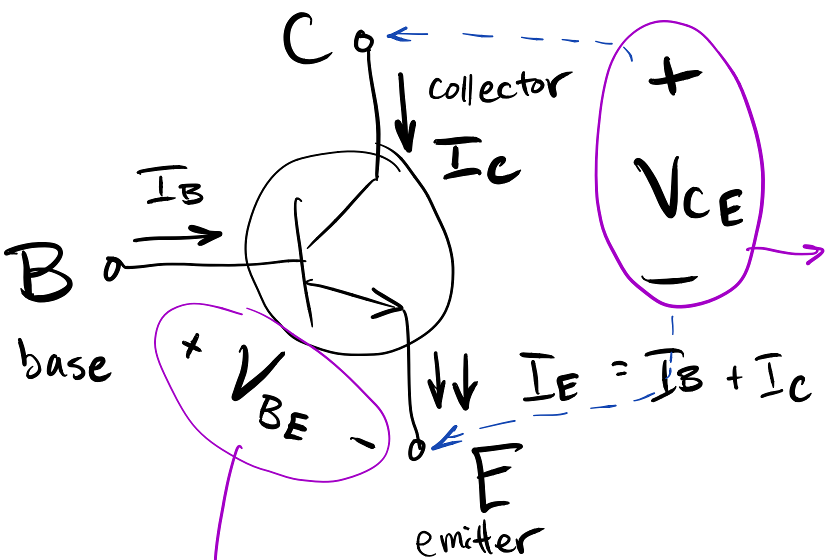
·· now, we have solid-state devices

·· field-effect transistor and bipolar junction transistor are main categories

∴ two types of bipolar junction transistor (BJT)

NPN





"collector-to-emitter voltage"

$$V_{CE} = V_C - V_E$$

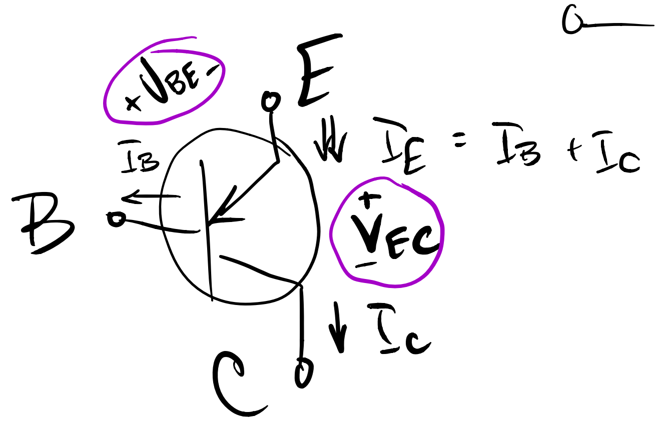
"base-to-emitter voltage"

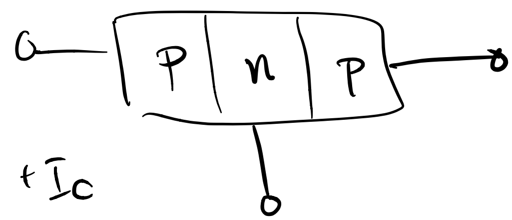
$$V_{BE} = V_B - V_E$$

∴ the base-to-emitter voltage can be used to modulate collector current; and if we're smart enough, we can use this collector current to drop a voltage, and get a large collector-to-emitter voltage

$\Rightarrow$ = amplification!

PNP

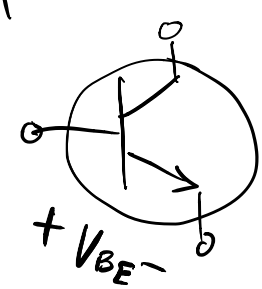




- PNP transistor is the mirror image of NPN;
  all voltages and currents <u>reversed</u>.

- we'll <u>usually</u> refer to NPN transistors
  - PNP amplify the same way

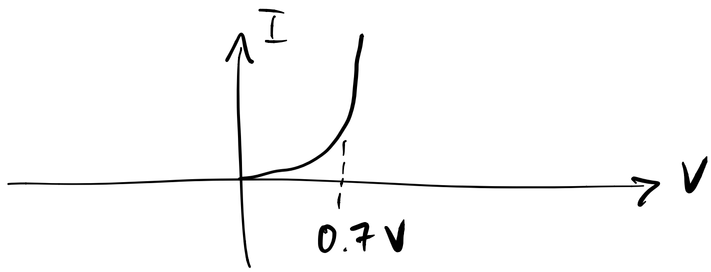
- the base-to-emitter junction is the key input port on a transistor amplifier.



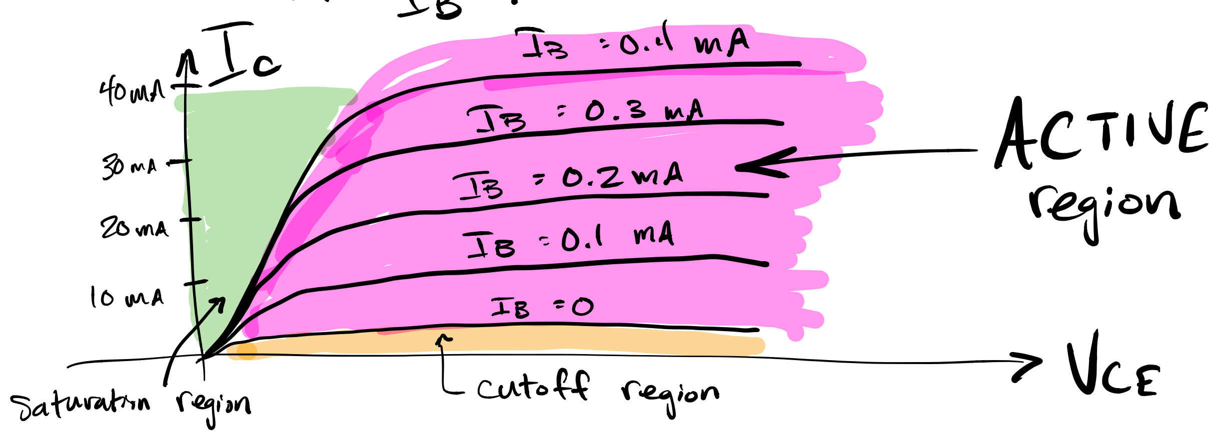
∴ for Si transistors, V_{BE} acts like a Si diode and drops ~ 0.7V when ON.

∴ also allows base current I_B to flow, as long as $V_{CE} \geq 0.2V$ (roughly)

∴ unlike a diode, which has <u>one</u> current-to-voltage relationship:



∴ bipolar transistors have a <u>family</u> of curves that relate V_{CE} to I_C for different values of I_B:



- in fact, when used as switches, transistors are operated in saturation and cutoff regions

- when used to amplify small signals (linearly), we are interested only in the active region.

- in the active region, base and collector currents are roughly proportional by a parameter called β (current gain)

a/k/a h_{FE}

$$I_C = \beta I_B$$

- we know by KCL that $I_E = I_C + I_B$

$\therefore I_E = I_B(1+\beta)$

∴ if β is "sufficiently high",

$$I_E \approx \beta I_B \quad \text{and} \quad I_E \approx I_C$$