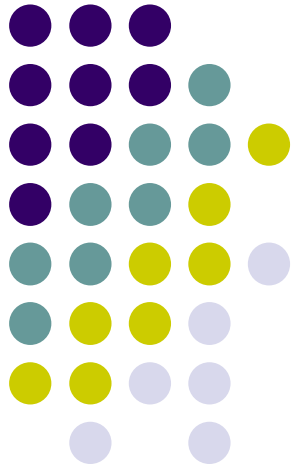
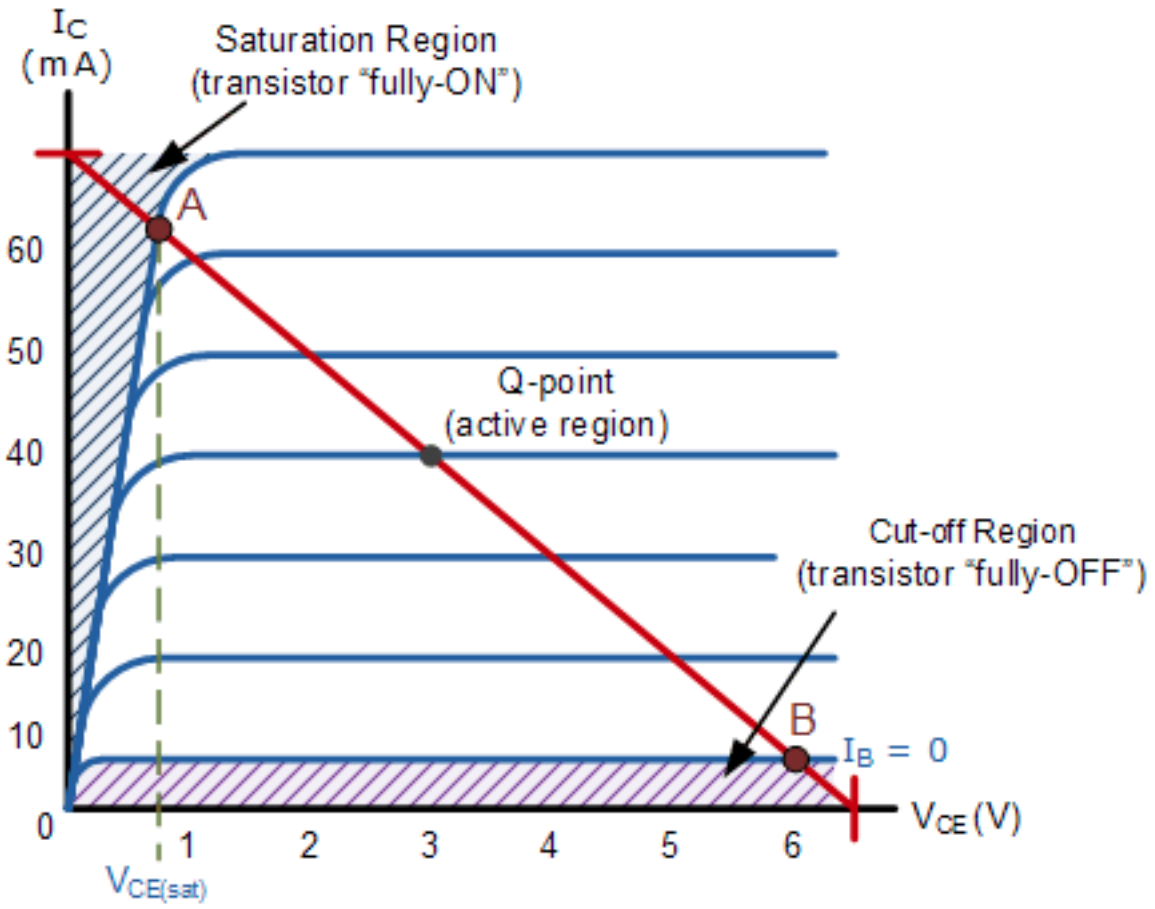
Voltage Transfer Characteristic

V_O versus V_i



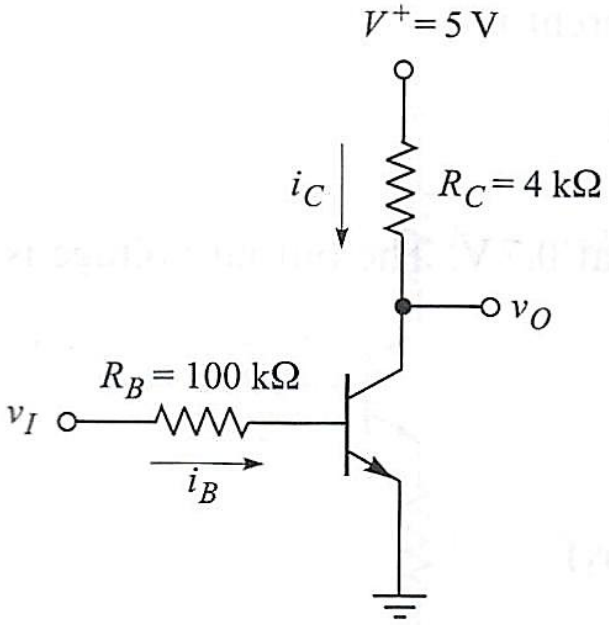

I_C (mA)
Saturation Region
(transistor "fully-ON")
A
60
50
Q-point
(active region)
40
30
Cut-off Region
(transistor "fully-OFF")
20
B
10
I_B = 0
0
1
2
3
4
5
6
V_{CE} (V)
$V_{CE(sat)}$

Voltage Transfer Characteristics - npn

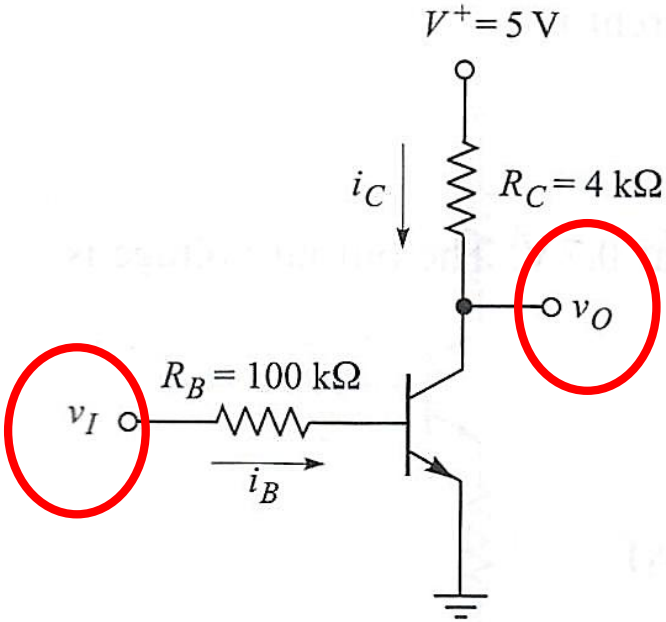
- A plot of the transfer characteristics (output voltage versus input voltage) can also be used to visualize the operation of a circuit or the state of a transistor.

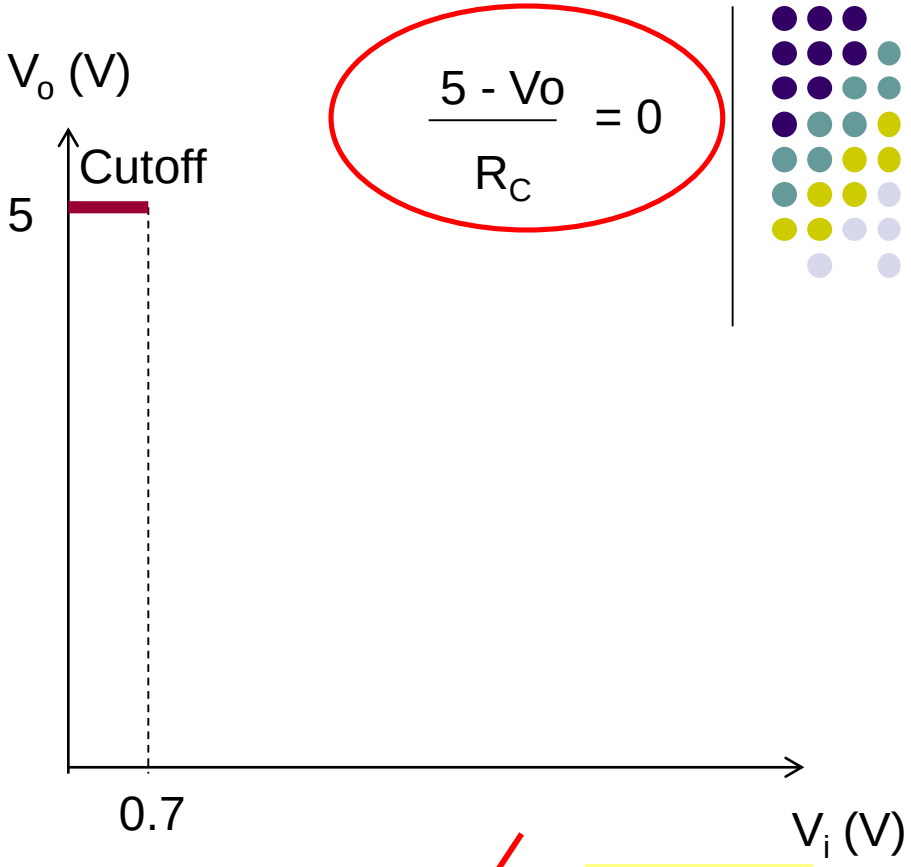
- the input is voltage changed slowly enough that the output can keep up.

Example 1



Given V_{BEon} = 0.7V, β = 120, V_{CEsat} = 0.2V, Develop the voltage transfer curve

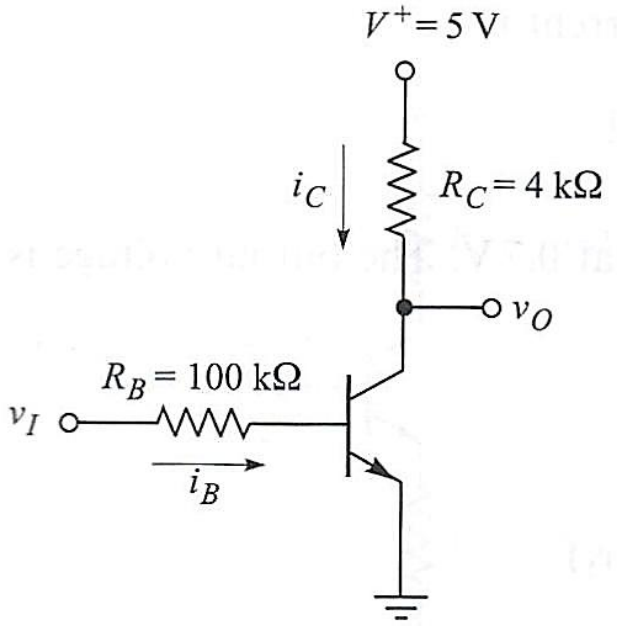




$$\frac{5 - Vo}{R_C} = 0$$

- **In this circuit, Vo = V_C = V_{CE}** $V_{CE} = V_C - V_E$ $V_{CE} = V_C$
- Initially, the transistor is in **cutoff mode** because Vi is too small to turn on the diodes. In cut off mode, there is no current flow.
- Then as Vi starts to be bigger than V_{BEon} the transistor operates in **forward-active mode**.

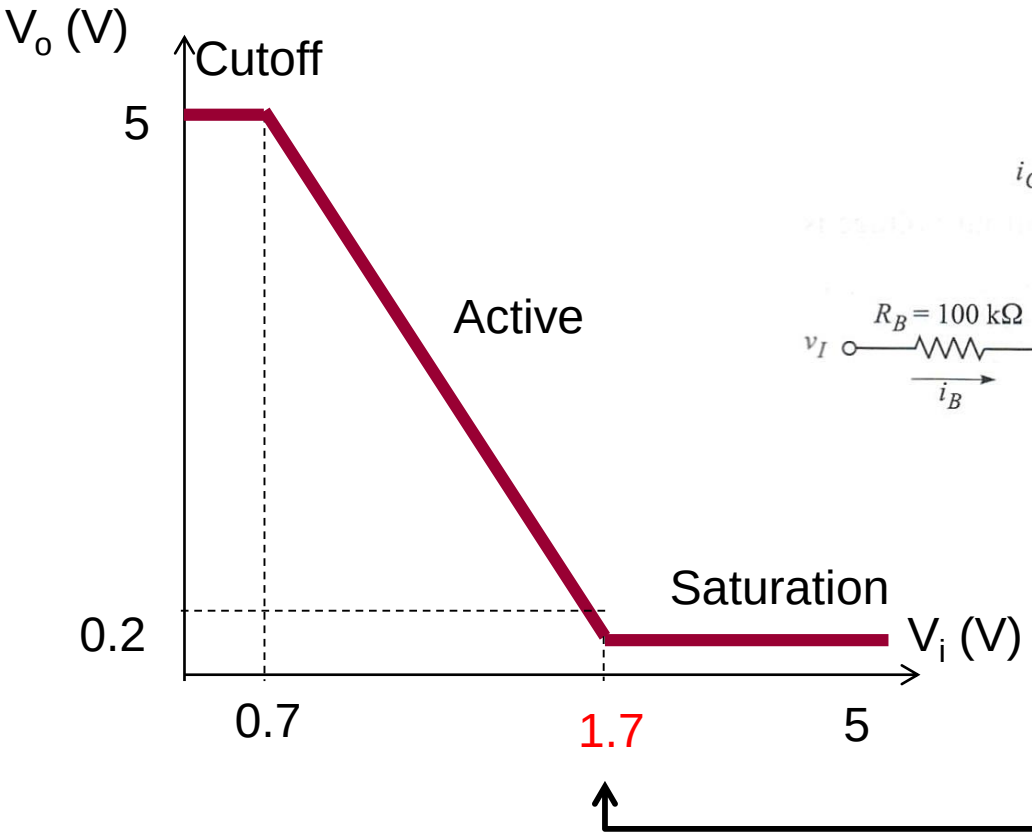
Active Mode



- BE Loop
  - $100I_B + V_{BE} - V_i = 0$
  - $I_B = (V_i - 0.7) / 100$
- CE Loop
  - $I_C R_C + V_O - 5 = 0$
  - $I_C = (5 - V_O) / 4$
  - $\beta I_B = (5 - V_O) / 4$ β = 120
  - $I_B = (5 - V_O) / 480$
- Equate the 2 equations:

$$(V_i - 0.7) / 100 = (5 - V_O) / 480 \Rightarrow Vo = \frac{-480\,Vi + 836}{100}$$

A linear equation with negative slope



To find point x, the coordinate is (x, 0.2)

- However, as you increase Vi even further, it reaches a point where both diodes start to become forward biased – transistor is now in saturation mode.
- In saturation mode, $V_O = V_{CEsat} = 0.2V$. So, what is the starting point, x, of the input voltage, Vi when this occurs?

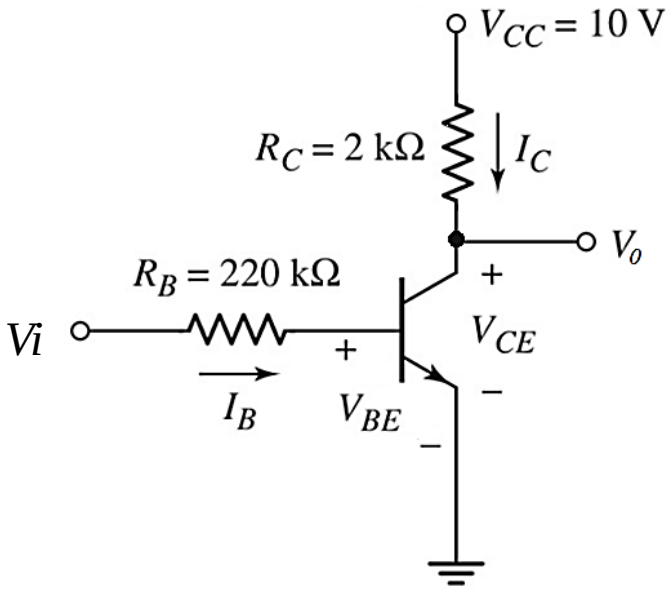
  Need to substitute in the linear equation →

$$Vo = \frac{-480\,Vi + 836}{100}$$

→ $V_i = 1.7$ V

  and V_O stays constant at 0.2V until $V_i = 5V$

Example 2

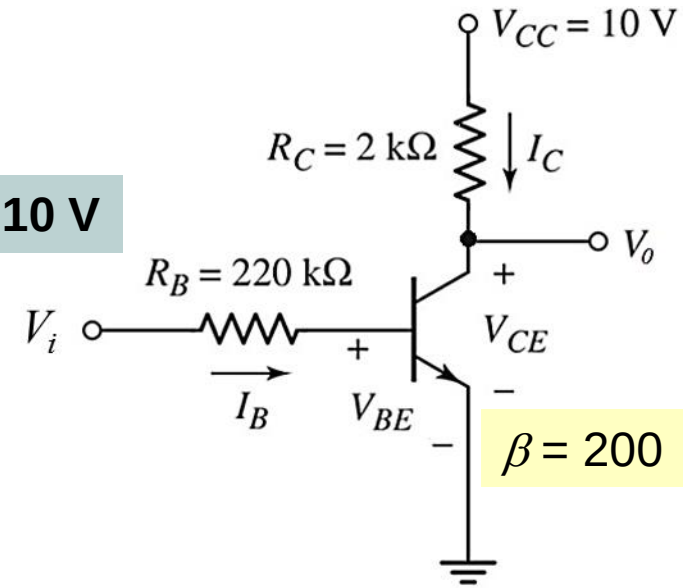


Develop the voltage transfer curve given V_{CE} at saturation = 0.25 V.

What happen to Vo when Vin < 0.7V?

CUTOFF

Vo = V_{CC} = 10 V



What happen to Vo when Vin > 0.7V?

ACTIVE

Vo = V_C = V_{CE}

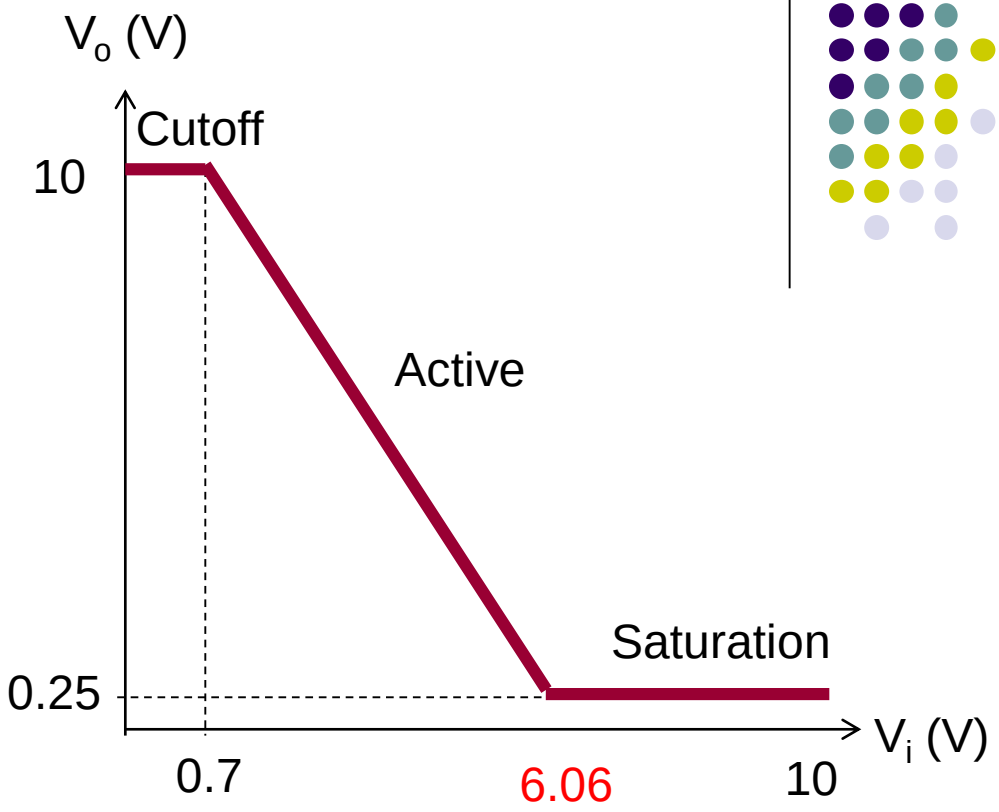
BE LOOP & CE LOOP EQUATION

Vo = V_{CEsat} = 0.25 V

What happen to Vi when Vo reach saturation V_{CEsat} = 0.25V?

SATURATION

- BE Loop
  - $220I_B + V_{BE} – V_i = 0$
  - $I_B = (V_i – 0.7) / 220$
- CE Loop
  - $I_CR_C + V_O – 10 = 0$
  - $I_C = (10 – V_O) / 2$
  - $200I_B = (10 – V_O) / 2$
  - $I_B = (10 – V_O) / 400$



- Equate the 2 equations:

$$(V_i – 0.7) / 220 = (10 – V_O) / 400$$

$$Vo = - 1.82\ Vi + 11.274$$