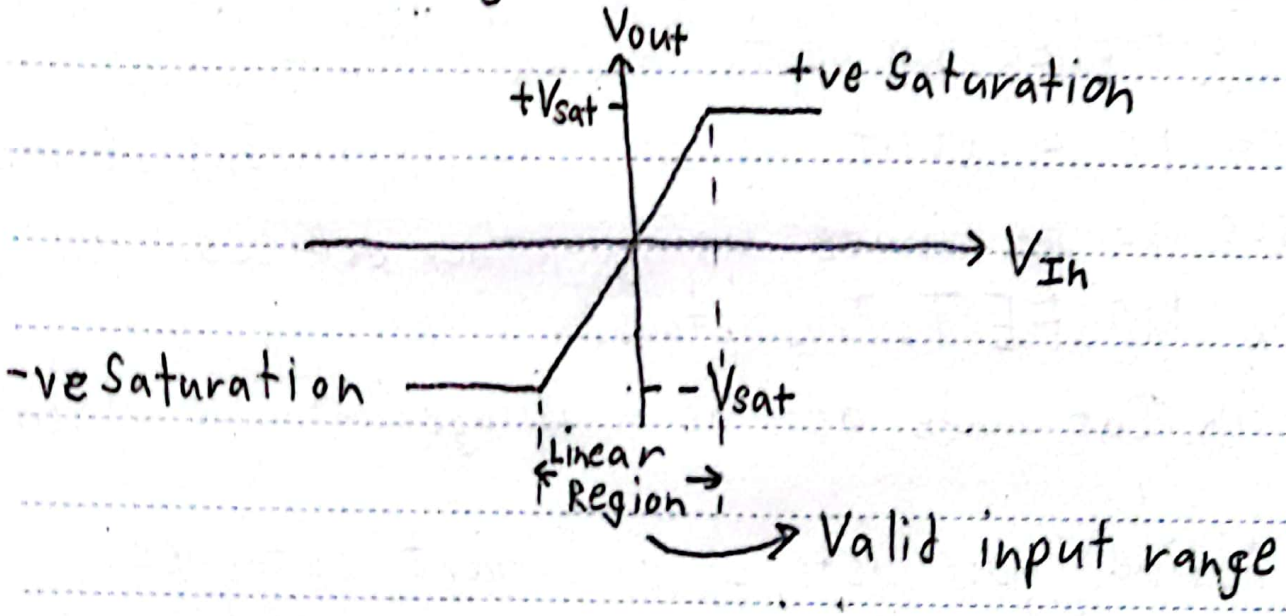
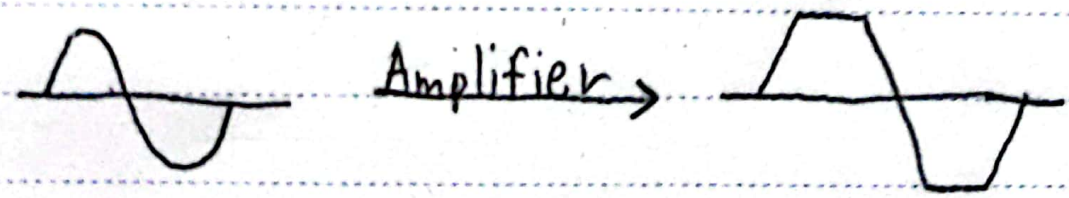
* Liner Amplifier ⇒ Output = k X Input [k = gain]
* Input/Output can be voltage or current.
* $P_{OUT} > P_{IN}$, so power supply is needed.
* Usage: Communication

# Transfer characteristics of Amps:

* Acts as a straight line going through the origin, $y = mx$ [m = k = gain]




* Saturation due to limited power supply
* Input must be in valid input range or the output will be distorted.




Input Distorted Output

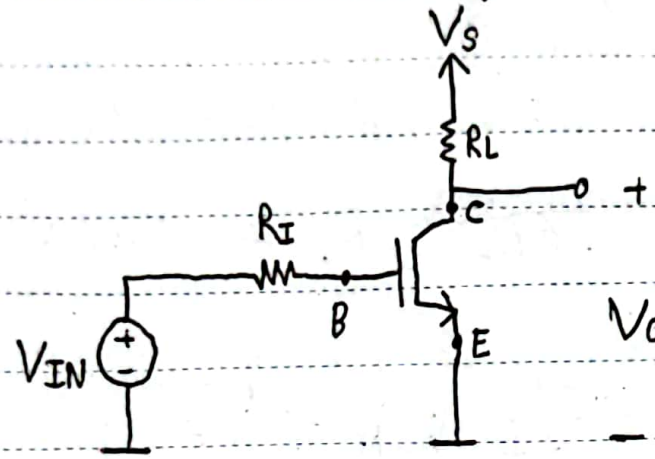
* Inverting amps have negative gain, $y = -mx$.
* Depending on input (V/I) and output (V/I) there can be 4 types of amps:

1) Voltage amplifier ($In = V$, $Out = V$)
2) Current " ($In = I$, $Out = I$)
3) Transconductance amplifier ($In = V$, $Out = I$)
4) Transresistance " ($In = I$, $Out = V$)

* Dependent Sources can be used to make amplifiers.
* E.g., for transconductance amp, $I_{out} = g_m \times V_{in} \Rightarrow$ Voltage Controlled Current Source (VCCS).
* There are no current sources or dependent sources, they need to be made using other devices. Like BJT and MOSFET, Transistors.

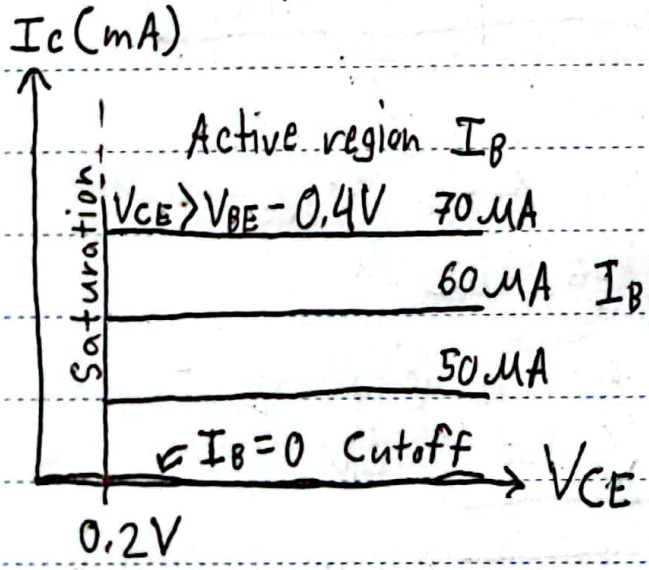
- MOSFET in Sat mode acts as a Voltage Controlled Current Source.
- BJT in Active mode acts as a Current controlled Current Source.
- BJT ~~is~~ in Active mode is preferred as the relation is linear of I/O.

## *BJT Common Emitter Amplifier:




- This circuit is same as BJT inverter.

- In Active Mode, $I_{out} = \beta I_{in}$ [$I_{in} = I_B$ and $I_{out} = I_C$]
- $R_I$ converts input voltage ($V_{IN}$) to $I_B$.
- $R_L$ " output current $I_C$ to $V_O$ (Output Voltage).




* KVL: $V_O = V_{CE} = V_S - I_C \times R_L$ (True for any mode)
* Cutoff: $I_B = 0 \Rightarrow V_{BE} \leq 0.7V \Rightarrow V_{IN} \leq 0.7V$
  $V_O = V_S - 0 \times R_L = V_S$ (since in cutoff $I_B = 0$)
* Active: $V_{CE} = V_O > 0.2V$, $0.7 < V_{IN} < 0.7 + \left(\frac{V_S - 0.2}{\beta R_L}\right) R_I$
  $V_O = \left(V_S + \frac{0.7 \beta R_L}{R_I}\right) - \frac{\beta R_L}{R_I} V_{IN}$

*Saturation: $V_{IN} > 0.7 + \left(\frac{V_S - 0.2}{\beta R_L}\right) R_I$

$V_O = V_{CE} = 0.2V$

# VTC of BJT/CE Amplifier:

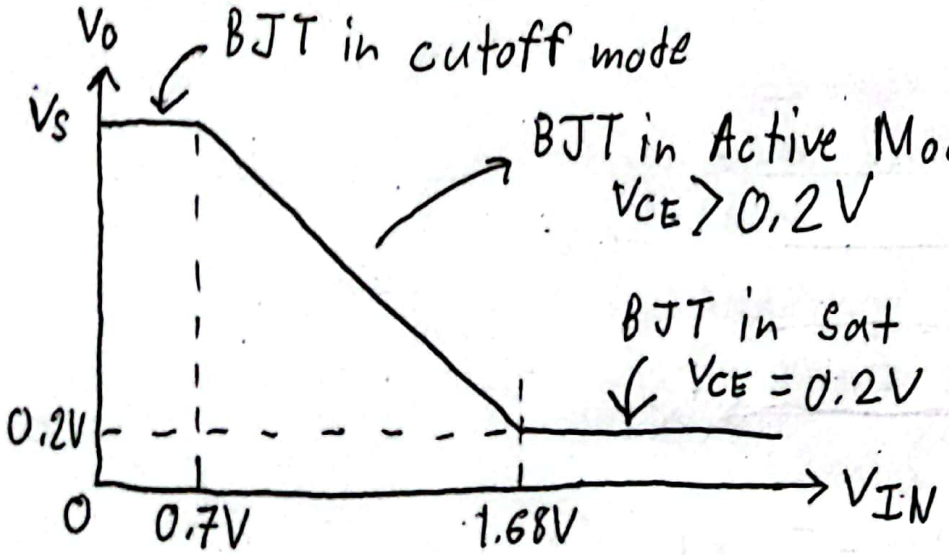
Let $R_I = 100k\Omega$, $R_L = 10k\Omega$, $\beta = 100$, $V_S = 10V$

Threshold Voltage $= 0.7 + \left(\frac{V_S - 0.2}{\beta R_L}\right) R_I = 0.7 + \left(\frac{10 - 0.2}{100 \times 10}\right) 100$

$= 1.68V$

$V_O = \left(V_S + \frac{0.7 \beta R_L}{R_I}\right) - \frac{\beta R_L}{R_I} V_{IN} \Rightarrow \boxed{V_O = 17 - 10 V_{IN}}$

| | | |
|---|---|---|
| $V_{IN} \leq 0.7$ | $V_O = 10$ | Cutoff |
| $0.7 < V_{IN} < 1.68$ | $V_O = 17 - 10V_{IN}$ | Active |
| $V_{IN} \geq 1.68$ | $V_O = 0.2$ | Saturation |



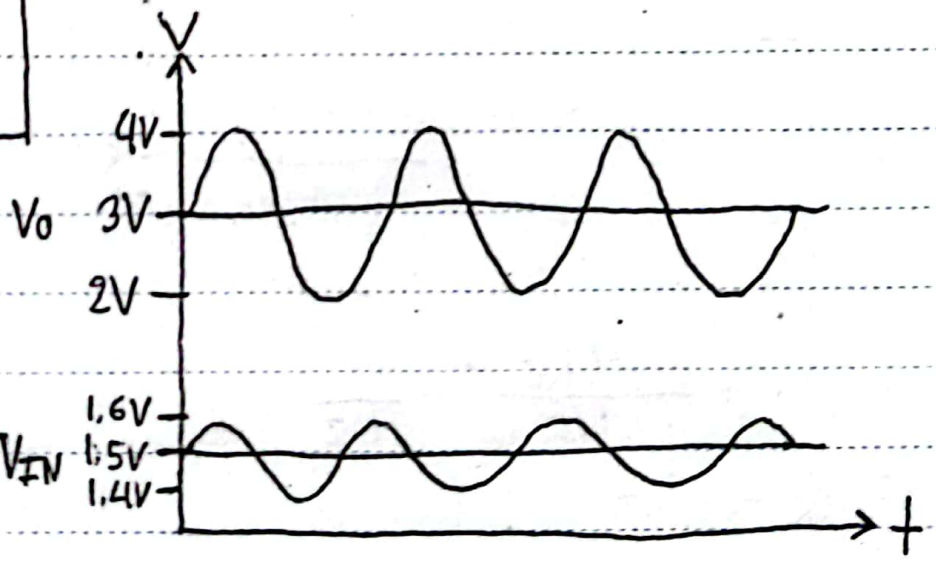

* If $V_{IN} = 1 \sin \omega t$, output will be distorted since for $V_{IN} \leq 0.7V$ in cutoff and $0.7 < V_{IN} < 1$ in ~~active~~ active. Hence does not amplify "Large" Signals.

# Small Signal Amplification:

| $V_{IN}$ | $V_O$ | |
|---|---|---|
| 0.5 | 10 | |
| 0.7 | 10 | |
| 1 | 7 | Active |
| 1.3 | 4 | Active |
| 1.4 | 3 | Active |
| 1.5 | 2 | Active |
| 1.6 | 1 | Active |
| 1.7 | 0.2 | |
| 1.8 | 0.2 | |

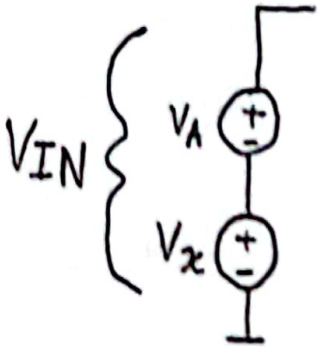
- Overall gain, 1.3V Δ in inp, 9.8V Δ in out.
- But non-linear overall.
- Linear in Active Region.
- 0.1V change in inp ⇒ 1V change in out
- ~~Output~~ 10-fold change ⇒ Amplification!

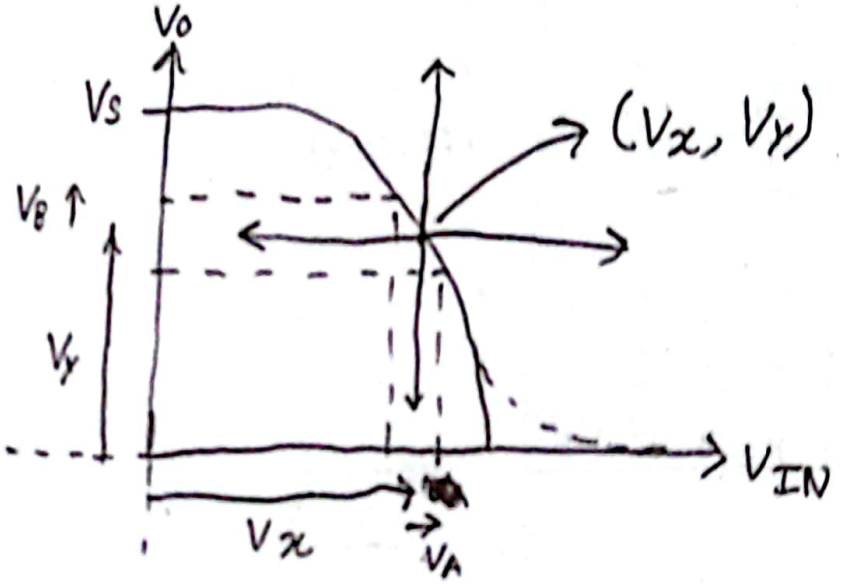
* Say $V_{IN} = 1.5 \pm 0.1V$, then $V_O = 2 \mp 1V$




* Here a 'small' signal of 0.1V amp with input offset 1.5V will have a 1V amp for the small signal output with an output offset 2V, and gain $k = -10$.
* Small signal = an AC signal with small amplitude.

- In general $V_{IN} = V_x + V_A \Rightarrow V_o = V_y + V_B$
- $V_A$ and $V_B$ are I/O small signals of interest and $V_B = k V_A$, where $k = -\frac{\beta R_L}{R_I}$ = gain.
- $V_x$ and $V_y$ are I/O bias, called the operating bias or bias point or Q-point.
- Biasing is used to ensure BJT stays in Active region.




TC of amp with Bias point

* $V_y = \left(V_s + \frac{0.7\beta R_L}{R_I}\right) - \frac{\beta R_L}{R_I} V_x$ //
* Select Q-point in such a way that input is within valid voltage range.
* Valid voltage range: $0.7 < V_{IN} < 0.7 + \left(\frac{V_s - 0.2}{\beta R_L}\right) R_I$
* Best Q-point is middle of active region, which gives max swing (peak-to-peak) for $V_A$.