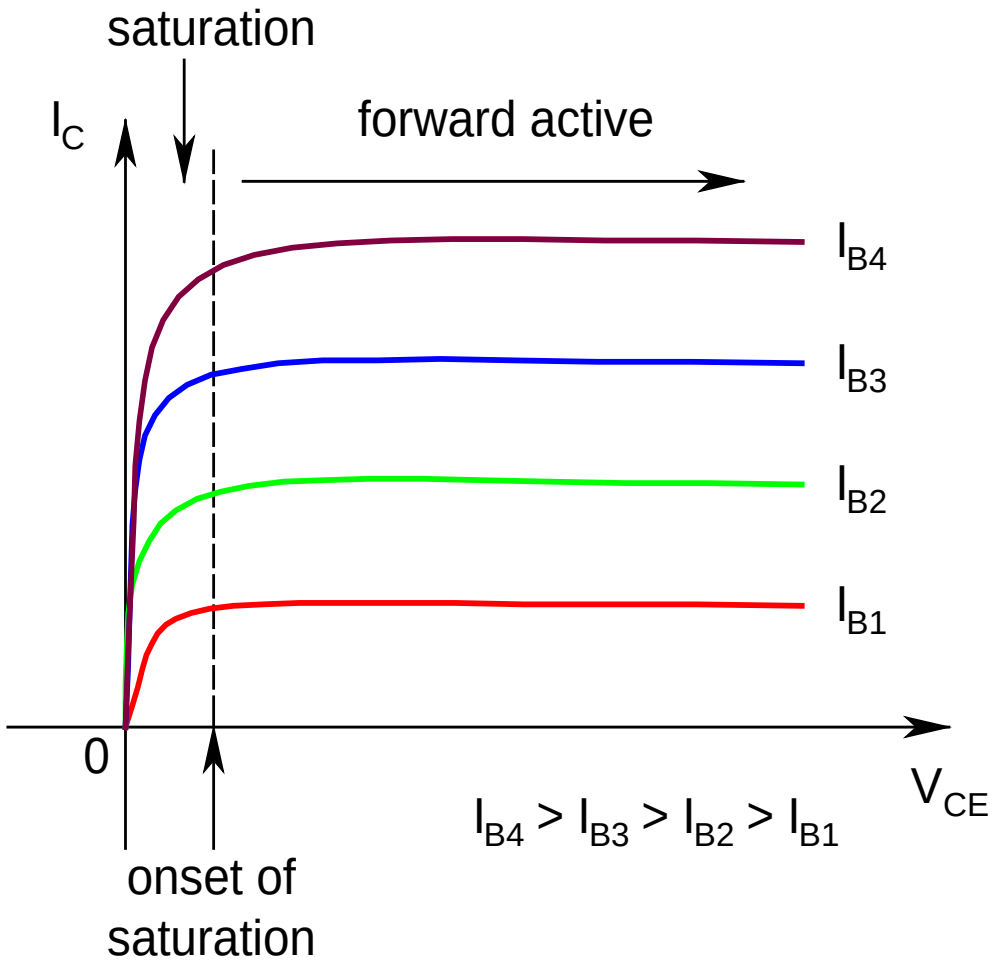
Current-Voltage Relation

- ***BE junction*** basically a ***diode***
  - $I_E = I_{ES}\exp(V_{BE}/V_T)$ $(V_{BE} > 4V_T)$
    - I_{ES}: ***Reverse Saturation Current of BE junction***
- A ***fraction*** α of I_E reaches ***collector***
  - $I_C = \alpha I_E = I_S\exp(V_{BE}/V_T)$
    - I_S $(= \alpha I_{ES})$: ***Saturation current of the BJT***
- The ***difference*** between I_E and I_C is I_B
  - $I_B = I_E - I_C$

Output Characteristic



- ***Quick Estimate***:
  - Under ***forward bias***, $V_{BE} \sim 0.7$ V
  - ***Justification***:
    - $V_\gamma \sim 0.6$ V
    - 0.7 V is 100 mV above $V_\gamma \Rightarrow$ ***junction sufficiently forward biased***
    - I_C-V_{BE} relation ***exponential*** $\Rightarrow$ A ***little change*** in V_{BE} can cause a ***large change*** in I_C
  - ***Heuristic estimate***: ***not accurate***, however, ***extremely useful*** for a ***quick hand-calculation***
- $V_{CE} = V_{BE} - V_{BC}$ (***applying chain rule***)

- Thus, for $V_{CE} > 0.7$ V, V_{BC} ***negative***
  - BC junction ***reverse biased*** and FA operation is ***maintained***
- As $V_{CE} \rightarrow 0.7$ V, $V_{BC} \rightarrow 0$
  - BC junction ***losing its reverse bias***
- At $V_{CE} = 0.7$ V, $V_{BC} = 0$
  - BC junction ***under zero bias***
- For $V_{CE} < 0.7$ V, V_{BC} turns ***positive***
  - Both BE and BC junctions become ***forward biased*** $\Rightarrow$ ***saturation***

- $V_{CE} = 0.7$ V is known as ***onset of saturation*** (OS)
- ***Saturation***:
  - For $V_{CE} < 0.7$ V
  - CB junction becomes ***forward biased***
  - Collector also starts to ***inject*** electrons to base
  - ***Two effects***:
    - ***Net electrons reaching collector*** $\downarrow \Rightarrow I_C \downarrow$
    - ***Base gets flooded with electrons***

      $\Rightarrow$ ***Recombination increases manyfold*** $\Rightarrow I_B \uparrow$
    - Thus, $\beta \downarrow \Rightarrow$ Defined as β_{sat} $(= I_{C,sat}/I_{B,sat})$