- 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} $(= I_{C,sat}/I_{B,sat})$

- Noting that $V_\gamma = 0.6$ V, for $V_{BC} \leq 0.5$ V, ***injection*** of electrons from ***collector to base*** will be ***negligible***
  - It can be ***assumed*** that ***FA operation*** is ***maintained*** till this point, with β ***retaining*** its ***nominal (FA) value***
  - $V_{CE} = 0.2$ V at this point, and is known as the ***point of soft saturation*** (SS)
- Beyond this point, BJT enters the ***operating domain*** known as ***hard saturation*** (HS)

- In ***hard saturation***, $V_{BC} \approx 0.7$ V, and collector ***injects*** electrons ***vigorously*** into the base
- To ***counter*** this effect, V_{BE} automatically ***increases*** to about 0.8 V
- At this point, $V_{CE} = 0.1$ V, and is known as the ***point of hard saturation*** (HS)
- Note that all these numbers are for ***quick estimates***, and ***actual values*** can be a ***little different*** from these

- ***Degree of Saturation*** (DoS):
  - DoS = β/β_{sat} (≥ 1)
  - Portrays how ***deeply*** the BJT is driven into ***saturation***
- ***Commonly used values*** of ***parameters*** for ***quick estimate***:
  - V_{BE}(FA) = V_{BE}(SS) = 0.7 V
  - V_{BE}(HS) = 0.8 V
  - V_{CE}(OS) = 0.7 V, V_{CE}(SS) = 0.2 V
  - DoS(FA,OS,SS) = 1, DoS(HS) > 1

- BJTs in ***analog circuits*** are used as ***amplifiers***, and should ***never*** be pushed to ***hard saturation*** (***β drops significantly***)
  - ***Lowest limit*** of V_{CE} = 0.2 V (***soft saturation***)
- On the other hand, BJTs used in ***digital circuits***, while ***on***, are always pushed to ***hard saturation***, since they act basically as ***switches***
  - V_{CE} = 0.1 V (***hard saturation***)

Finding the Operating Point: Load Line Analysis

- ***Quick estimate*** in ***FA mode***:
  - $I_B = (V_B - V_{BE})/R_B$
  - $V_{BE} = 0.7$ V
  - $I_C = \beta I_B$
  - ***Independent*** of R_C, so long as ***FA operation*** is ***maintained***