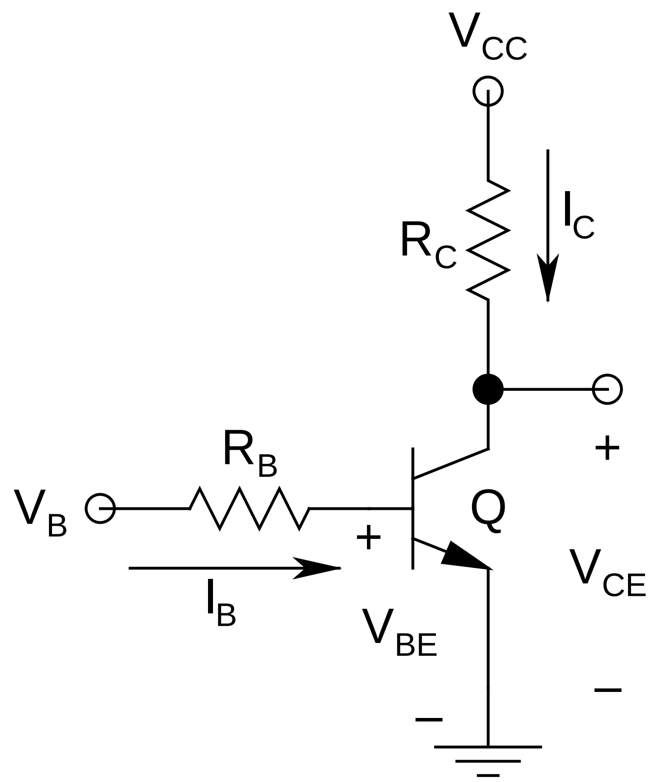
Finding the Operating Point: Load Line Analysis

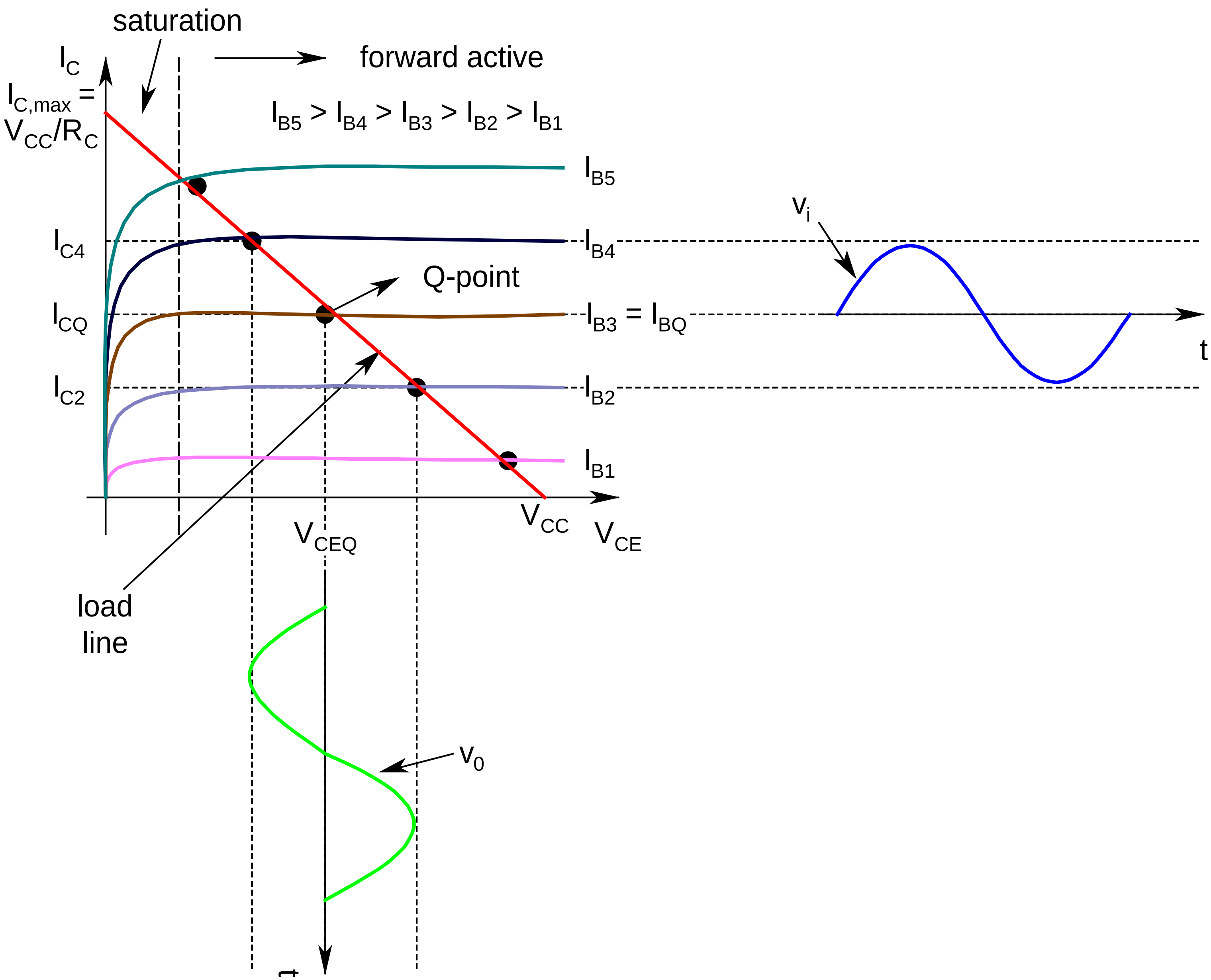
- ***Quick estimate*** in ***FA mode***:
  - $I_B = (V_B - V_{BE})/R_B$
  - $V_{BE} = 0.7$ V
  - $I_C = \beta I_B$
  - ***Independent*** of R_C, so long as ***FA operation*** is ***maintained***



- For ***continuous variation*** of V_B, ***continuous variation*** of I_C and I_B
    - The ***output characteristics*** will ***fill up*** the ***entire quadrant***
- The ***operating point*** (***Q-point***) can ***lie anywhere*** in this ***quadrant***
- To find the ***unique*** Q-point, need to ***draw*** the ***load line***
- ***Load line equation***:
    - $I_C = (V_{CC} - V_{CE})/R_C$

- ***2 boundary points***:
  - For $I_C = 0$, $V_{CE} = V_{CC}$
  - For $V_{CE} = 0$, $I_C = V_{CC}/R_C$
- ***Joining*** these ***2 points*** by a ***straight line*** gives the ***load line***
- The ***intersection point*** of the ***load line*** with the ***output characteristic*** gives the ***Q-point***
- Gives ***infinite number*** of ***choices*** for ***possible Q-point***

- The ***best choice*** for the ***Q-point*** is ***right at the center*** of the ***load line***
  - V_{CEQ}(best) = $V_{CC}/2$ and I_{CQ}(best) = $V_{CC}/(2R_C)$
- ***Permits the maximum possible signal swing in both directions***
- If $V_{CEQ} > V_{CC}/2$, it's ***biased more towards cutoff***
- If $V_{CEQ} < V_{CC}/2$, it's ***biased more towards saturation***
- ***Either way***, we will get a ***distorted output***



saturation
forward active
I_C
$I_{C,max}$ =
V_{CC}/R_C
$I_{B5} > I_{B4} > I_{B3} > I_{B2} > I_{B1}$
I_{B5}
I_{C4}
I_{B4}
Q-point
I_{CQ}
$I_{B3} = I_{BQ}$
I_{C2}
I_{B2}
I_{B1}
V_{CC}
V_{CE}
V_{CEQ}
load
line
v_i
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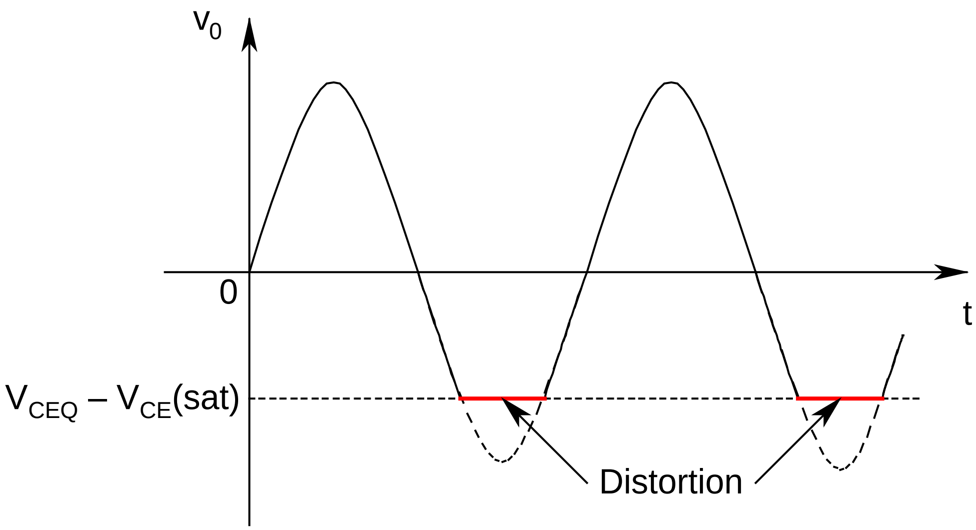
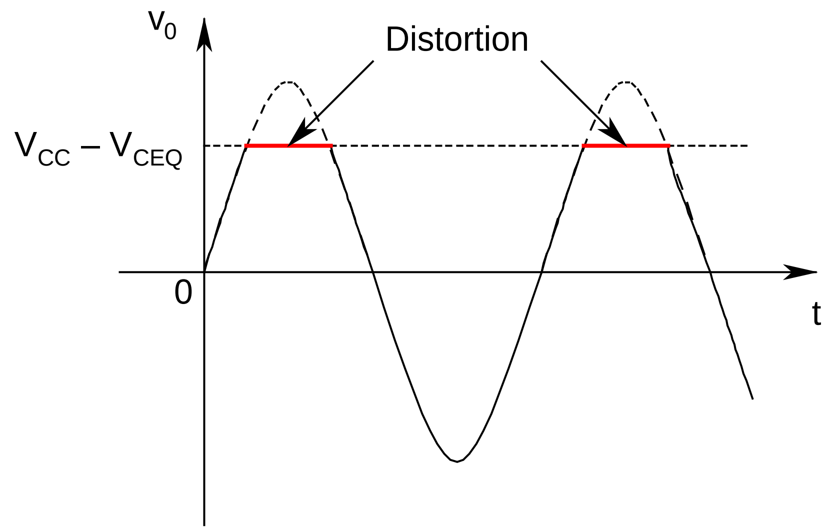


(a) **Negative Clipping**:
Saturation Induced



(b) **Positive Clipping**:
Cutoff Induced

- Under ***application*** of an ***ac signal*** (v_i), the ***dynamic operating point*** (DOP) will ***move along the load line***
- For ***positive*** v_i, the DOP ***will move*** Q ***towards saturation*** ($V_{CE} \rightarrow 0$, $I_C \rightarrow I_{C,max}$)
  - The ***output signal*** (v_0) will be in its ***negative excursion***
  - If Q enters ***saturation***, ***negative peak*** of v_0 will get ***clipped***
  - ***Distorted output***