- Thus, the ***current can't increase indefinitely***
- Assume $R_1 = 30\ \Omega$ and $V_\gamma = 0.6\ V$

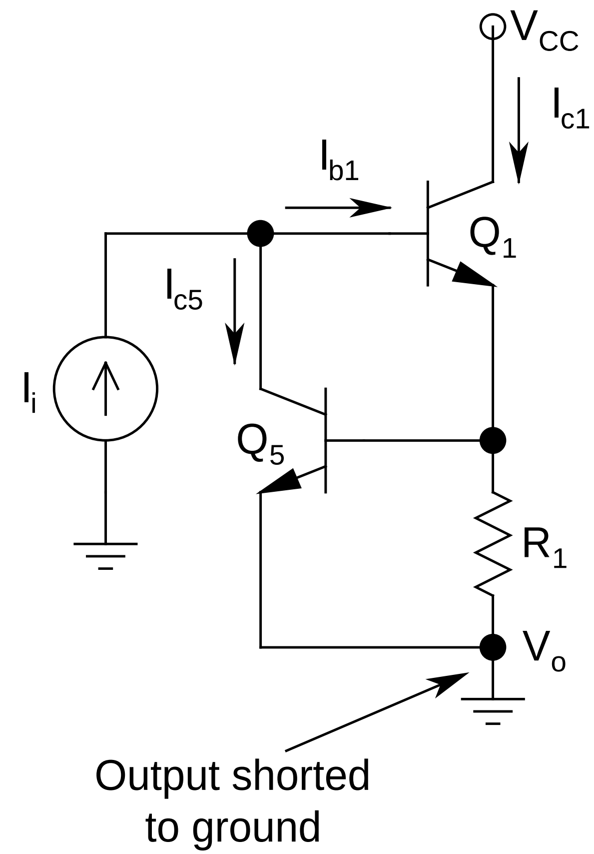
  $\Rightarrow$ As soon as ***I_{c1} reaches about 20 mA***, ***Q_5 cuts in***, ***shunts current away from the base of Q_1***, and ***protects the circuit***
- Due to the ***exponential dependence*** of this ***shunted current*** on V_{be5}, the ***maximum output current*** will ***saturate near around 20 mA itself***
- Thus, under this case, if the output is ***accidentally shorted to ground***, then ***P_1(max) will be around 100 mW***, which is ***well within limit***, and ***protection will be achieved***

- Similarly, for the ***negative half cycle***, this job of ***protection will be achieved by the Q_6-R_2 combination***
- The ***drop across R_2*** will depend on the ***amount of current*** being ***sunk by Q_2***
- Once this drop ***reaches the cut-in voltage*** of Q_6, it will ***turn on***, and ***bypass the drive current of Q_2***, thus ***protecting the circuit***
- This ***protection circuit*** is ***widely used*** due to its ***efficacy***, and the ***most popular analog building block***, the ***op-amp***, ***uses this protection scheme***

➢ *Quantitative Estimate of the Protection Mechanism*:

- Assume ***V_i positive*** and ***supplying drive current*** I_i to Q_1
- ***Output shorted to ground*** $\Rightarrow V_o = 0$
- $I_i = I_{b1} + I_{c5}$

  $I_{c5} = I_{S5}\exp(V_{be5}/V_T)$
- $V_{be5} = I_{c1}R_1$ (***assuming*** ***$\alpha_1 = 1$*** and ***neglecting I_{b5}***)



Protection Scheme

- For ***small values*** of I_{c1}, V_{be5} will be ***small***, and I_{c5} will be ***negligible***
- Also, $I_{c1} = \beta_1 I_{b1} = \beta_1(I_i - I_{c5})$

  $\Rightarrow \beta_1 I_i = I_{c1} + \beta_1 I_{S5}\exp(I_{c1}R_1/V_T)$
- This is the ***final protection expression***
- For ***small*** I_{c1}, the ***second term*** on the ***RHS*** will be ***negligible***

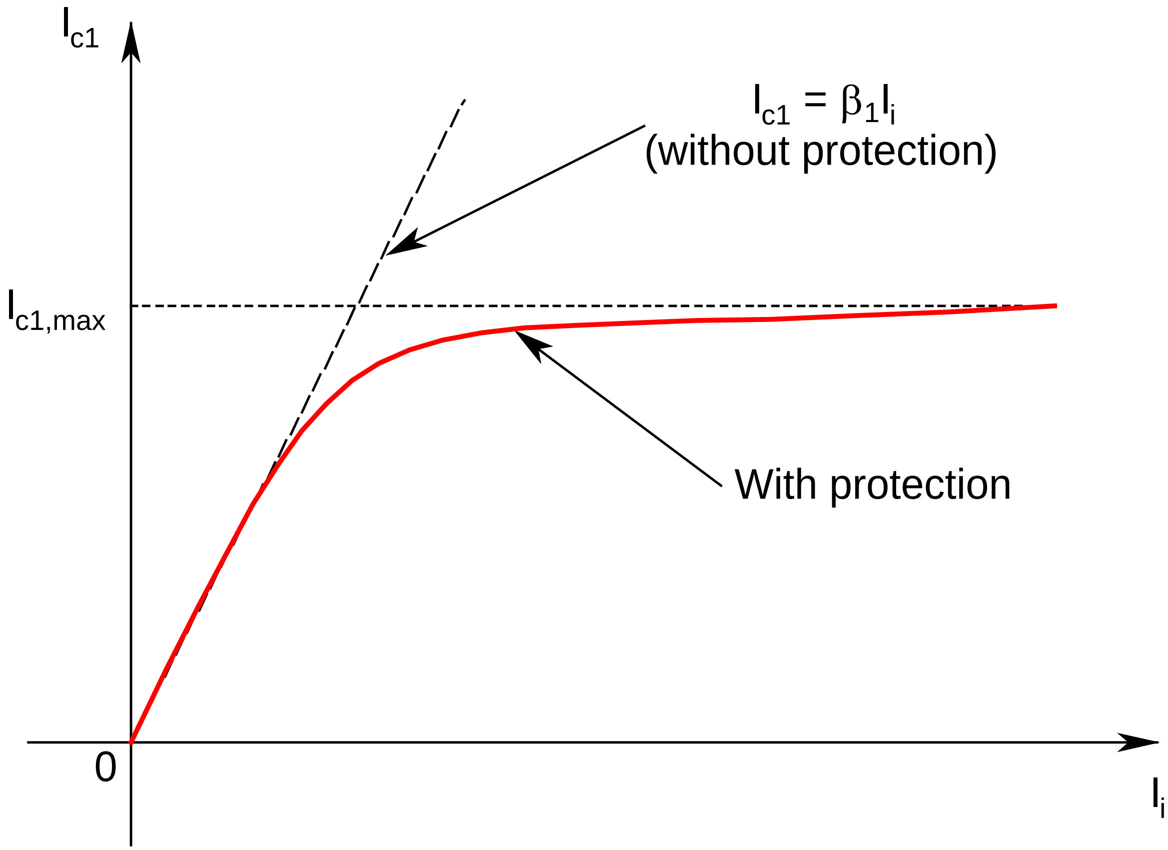
  $\Rightarrow$ ***I_{c1} would follow I_i linearly with proportionality constant β_1***
- As ***I_{c1}*** $\uparrow$, the ***second term*** on the RHS ***increases at a much more rapid rate*** than the ***first term***

- Once it starts to become ***comparable*** to the first term, a ***very little change*** in I_{c1} can ***counter a large change*** in I_i

  $\Rightarrow$ ***I_{c1} gets clamped to almost a constant value of $I_{c1,max}$***

- Note that the ***protection equation*** is ***transcendental***

  $\Rightarrow$ ***Needs numerical or iterative solution***



Protection Characteristic