10-4-12

Lec 39

Fractional BG reference

So far, $V_{ref} = V_{BE} + k \cdot \Delta V_{BE}$

$\simeq 1.25V$

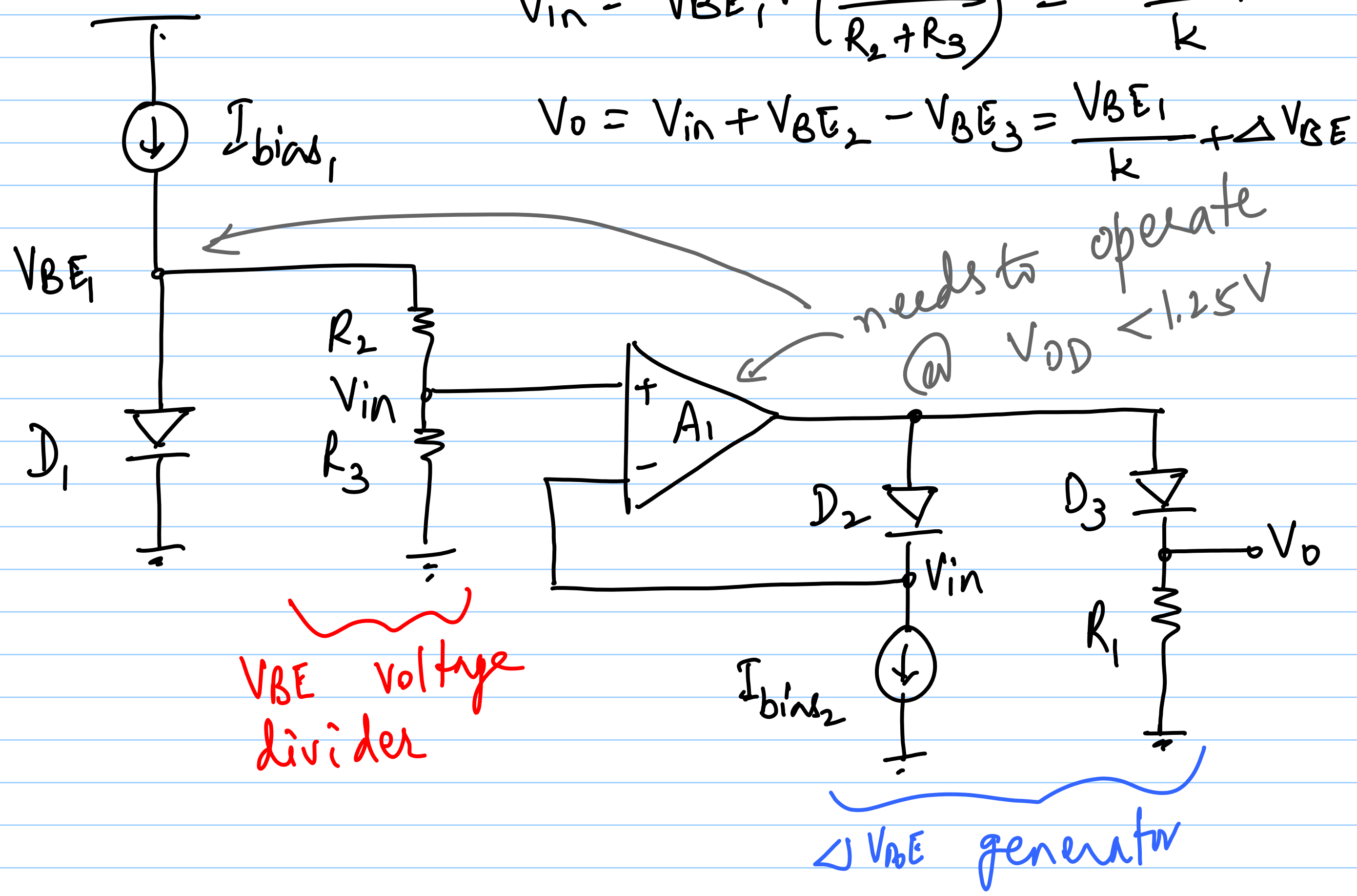
What if $V_{DD} < 1.25V$?

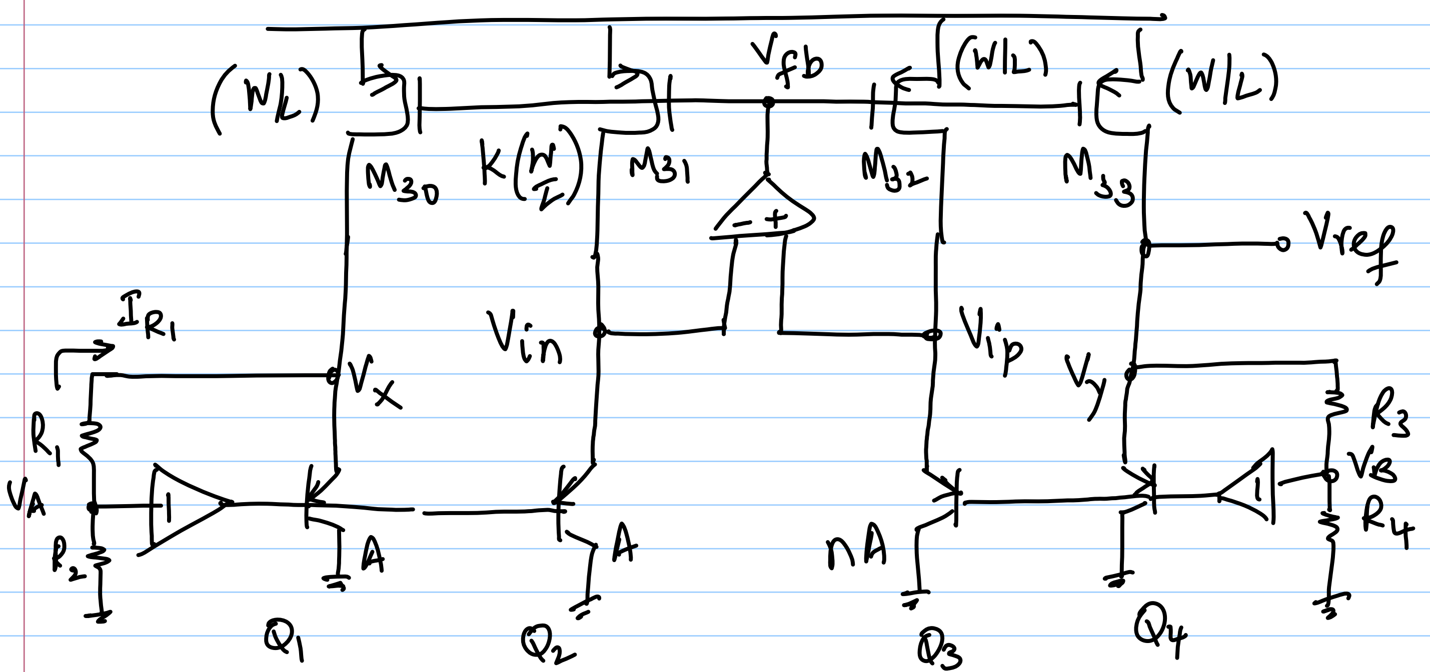
$$V_{ref,fr} = \frac{V_{ref}}{k} = \frac{V_{BE}}{k} + \Delta V_{BE}$$

$< 0.4V$ (typically)

$$V_{in} = V_{BE_1} \cdot \left(\frac{R_3}{R_2+R_3}\right) = \frac{V_{BE_1}}{k}$$

$$V_o = V_{in} + V_{BE_2} - V_{BE_3} = \frac{V_{BE_1}}{k} + \Delta V_{BE}$$





$$\frac{R_1}{R_2} = m > 1$$

$$I_{R_1} = \frac{V_{EB1}}{R_1} \Rightarrow V_A = \frac{V_{EB1}}{R_1} \cdot R_2 = \frac{V_{EB1}}{m}$$

$$V_{in} = \frac{V_{EB1}}{m} + V_{EB2}$$

−ve feedback drives $V_{ip} = V_{in}$

$$\Rightarrow V_B = V_{ip} - V_{EB3}$$

$$= \frac{V_{EB1}}{m} + V_{EB2} - V_{EB3}$$

Since $I_{Q_2} \neq I_{Q_3}$ $\{M_{31} = k\ M_{32}\}$

$$V_{EB2} - V_{EB3} = \Delta V_{EB} \propto T \quad (PTAT)$$

* choose m so that

$$\frac{\partial}{\partial T}\left(\frac{V_{EB1}}{m}\right) + \frac{\partial}{\partial T}(\Delta V_{EB}) = 0$$

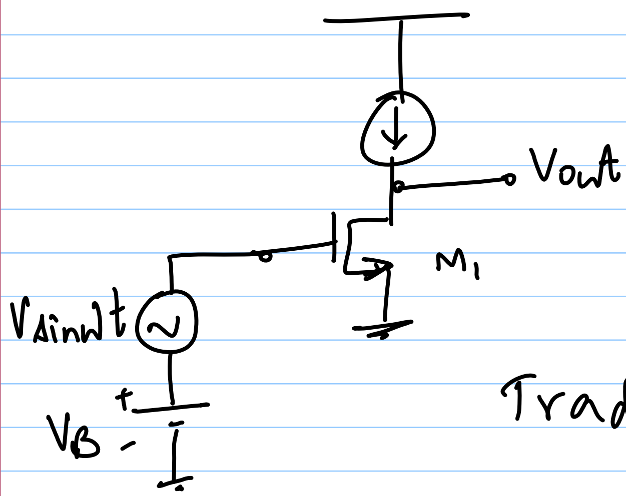
$\Rightarrow$ V_{R4} is temp. insensitive

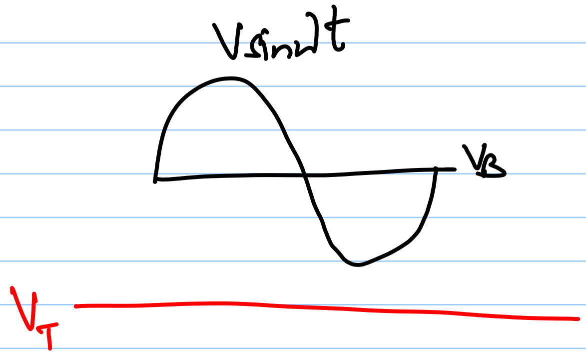
$$V_{R4} = \frac{V_{EB1}}{m} + \Delta V_{EB} = \frac{V_{BG}}{m}$$

$$V_{Ref} = \frac{V_{BG}}{m}\left(1 + \frac{R_3}{R_4}\right) = \frac{V_{BG}}{m}(1+\alpha)$$

can easily get $V_{ref} < 1V$

Output Stages





class A

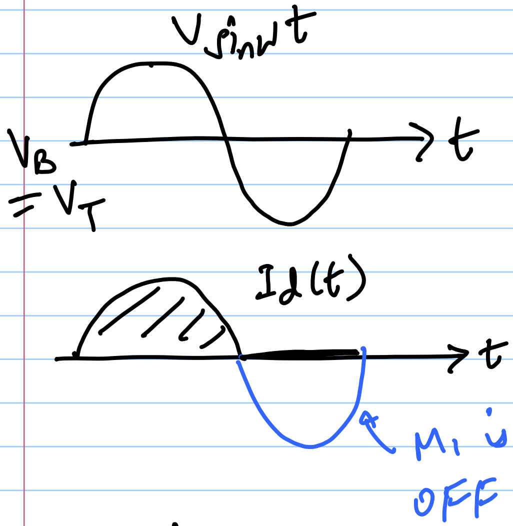
Tradeoffs: Gain, Power efficiency, distortion

* class A: M_1 is always ON

$(V_B - V) > V_T$ or $(V_B - V_T) > V$

"conduction angle" = 360°

* **class B :** M_1 ON for half cycle

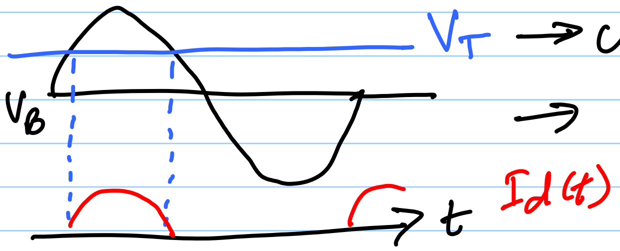


$\rightarrow V_B = V_T$

$\rightarrow$ conduction angle $= 180°$

$\rightarrow$ filtering may be required

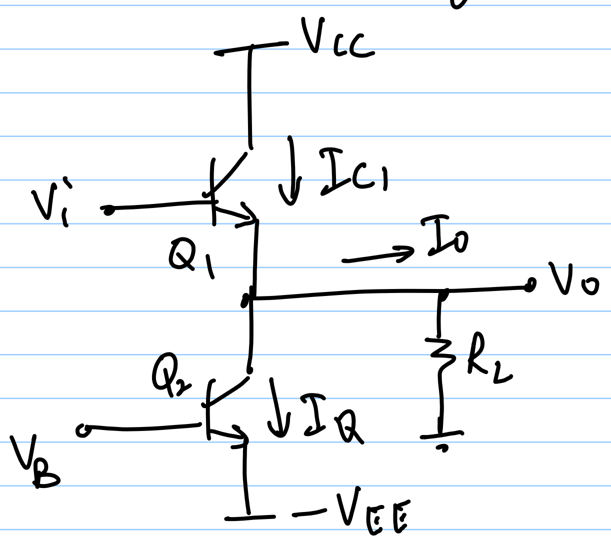
* **class C :** $V_B < V_T < V_B + V$



$\rightarrow$ conduction angle $< 180°$

$\rightarrow$ filtering may be required

Class A stage (Emitter follower)



* assume β_o is large

$\Rightarrow I_C = I_E$

$$V_i = V_{be_1} + V_o$$

$$V_{be_1} = V_T \ln\left(\frac{I_{C1}}{I_{S1}}\right)$$

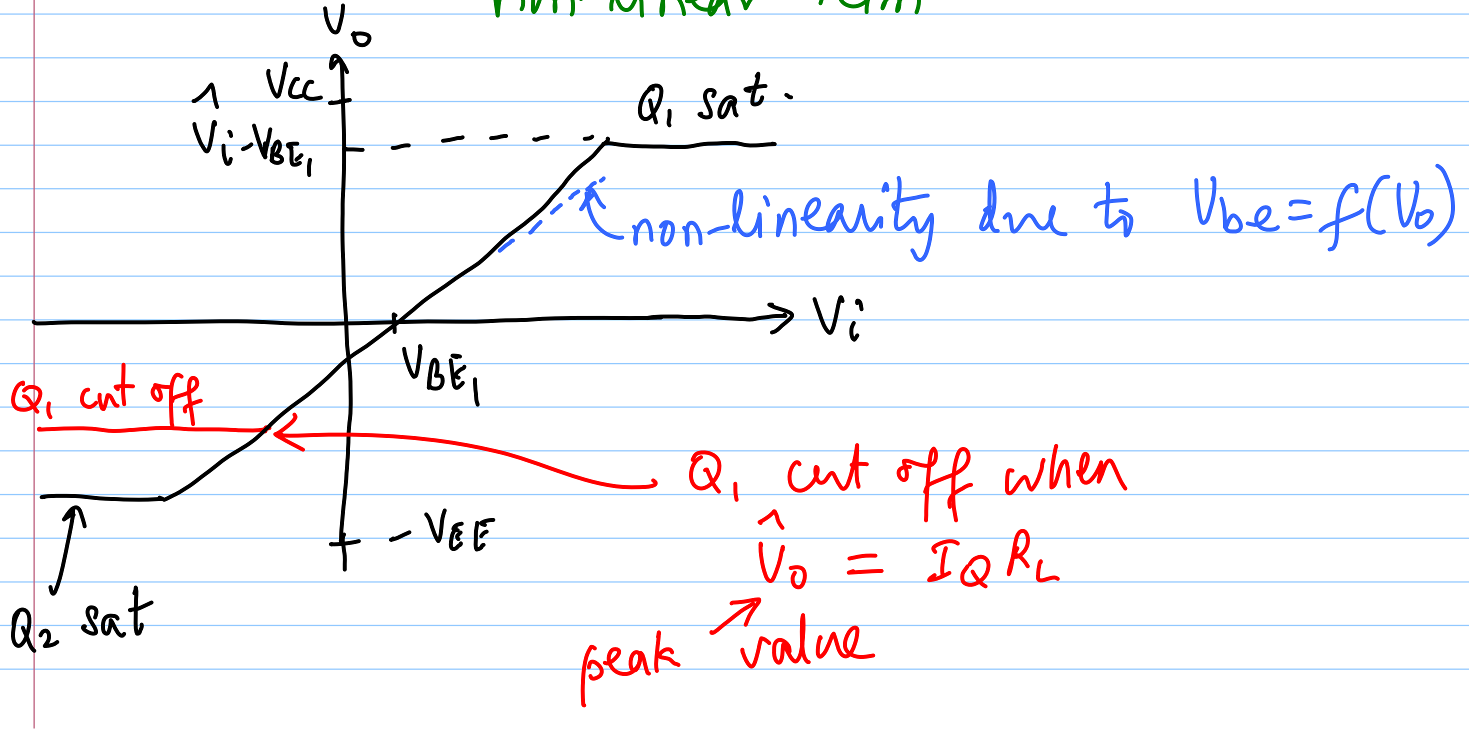
$$I_{C_1} = I_Q + I_o$$

$$= I_Q + \frac{V_o}{R_L}$$

* $I_{C_1} = f(V_o) \Rightarrow V_{be_1} = f(V_o)$

$\Rightarrow$ weak non-linearity

$$V_i = \underbrace{V_T \ln\left[\frac{I_Q + V_o/R_L}{I_{S_1}}\right]}_{\text{non-linear term}} + V_o$$



<u>Output range:</u>

* $V_o > 0 \Rightarrow Q_1$ always ON

$$V_{i\,max} - V_{BE_1} = V_{cc} - V_{SAT_1}$$

$$V_{i\,max} = V_{cc} + \underbrace{V_{BE_1}}_{\sim 0.7V} - \underbrace{V_{SAT_1}}_{\sim 0.2V}$$

$\rightarrow V_i$ can exceed V_{cc}

* $V_o < 0 \Rightarrow$ 3 cases ;

R_L large , R_L small , R_L/I_Q for max. range

$$I_{C_1} = I_Q + \frac{V_o}{R_L}$$

(i) R_L very large $\Rightarrow I_o \approx 0$

$\Rightarrow I_{C_1} \approx I_Q$

$V_{i_{min}} - V_{BE_1} = -V_{EE} + V_{SAT_2}$

$\Rightarrow V_{i_{min.}} = -V_{EE} + V_{BE_1} + V_{SAT_2}$

(ii) R_L small $\Rightarrow I_{C_1} = 0$ is possible

this happens @

$$\frac{V_o}{R_L} = -I_Q \Rightarrow V_o = -I_Q R_L$$

$$\Rightarrow V_i = V_{BE_1} - I_Q R_L$$

(iii) For max. o/p range $\Rightarrow -I_Q R_L = -V_{EE} + V_{SAT_2}$

$$\therefore I_Q = \frac{V_{EE} - V_{SAT_2}}{R_L}$$ {optimum design case}