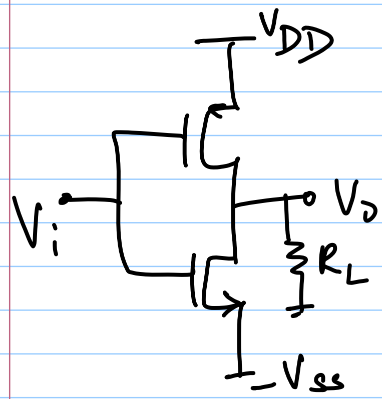
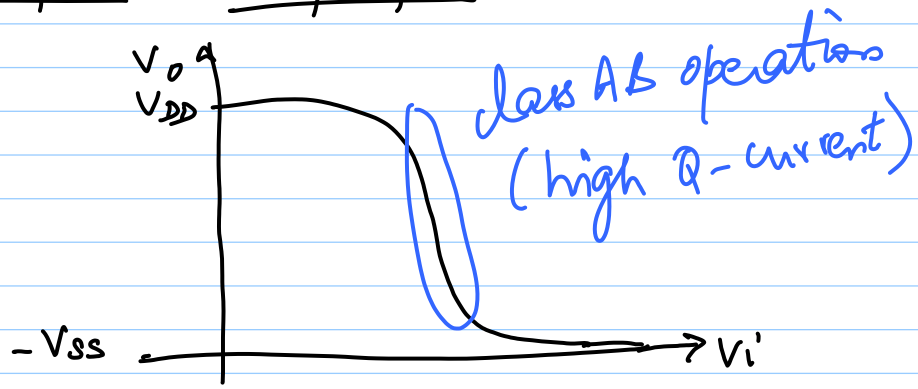
18-4-12

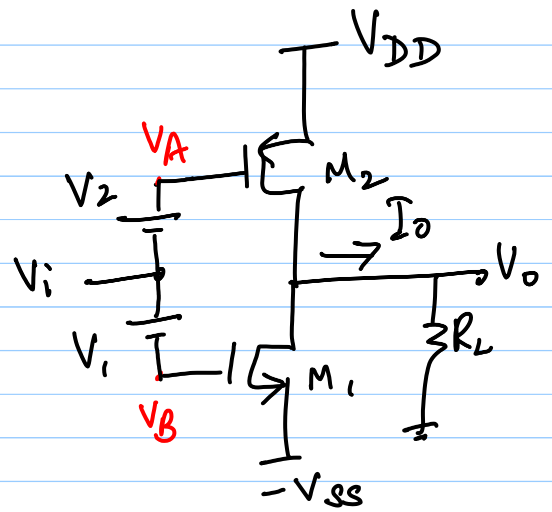
Lec 43

CMOS push-pull amplifier



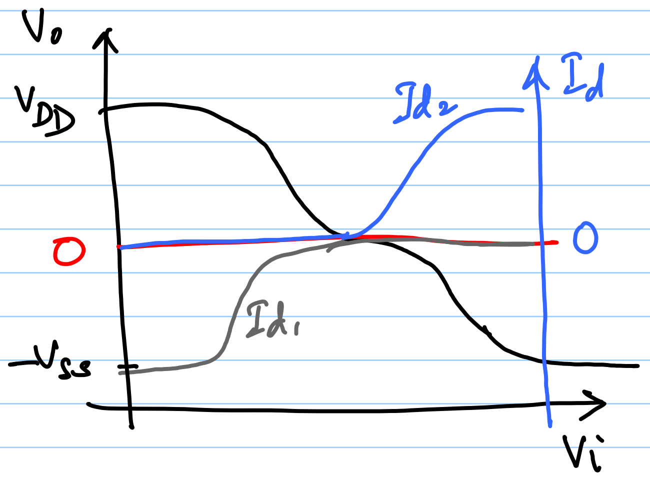


* high $I_Q \Rightarrow$ low η in high gain region

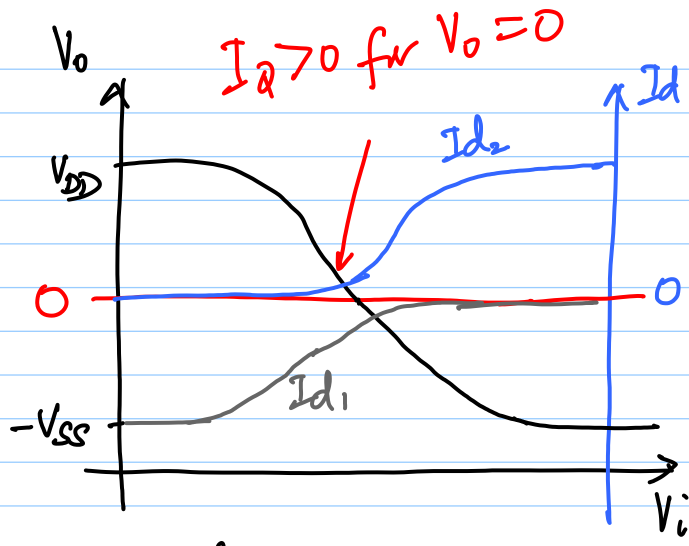


* η is improved by adding V_1, V_2
* $V_i = V_{T_1}$ &
  V_1 & V_2 are such that
  $V_A = V_{DD} - V_{T_2}$

* If V_i is +ve $\Rightarrow$ M_2 OFF, M_1 sinks I_o
* If V_i is −ve $\Rightarrow$ M_1 OFF, M_2 supplies I_o
  → no current is wasted, all I flows thro' R_L
  → R_o is not reduced



class B operation



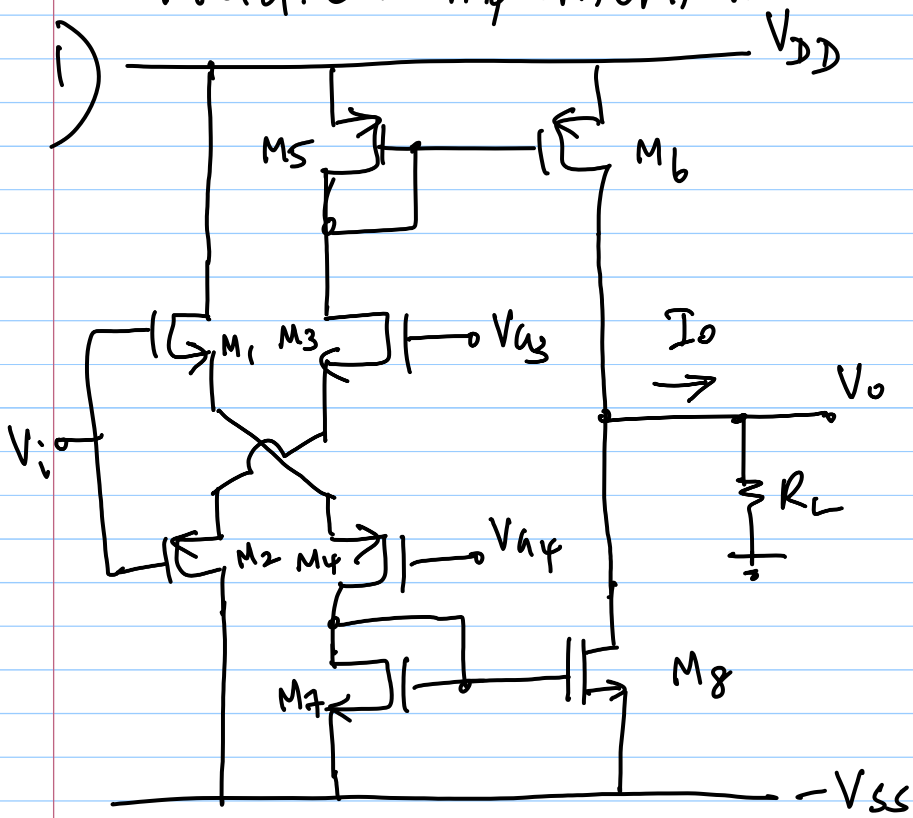
class AB operation
(more linear)

* η is similar to that of source followers
* V_o < VDD or |Vss| for good linearity

$\Rightarrow \hat{I}_{om}$ < V_{DD}/R_L or V_{SS}/R_L

Practical implementations

1)



* V_i = +ve

$\Rightarrow I_1 \uparrow, I_2 \downarrow$

in class B $\Rightarrow$ M_2 is OFF

as $I_1 \uparrow$, $I_8 \uparrow$

* V_i = −ve

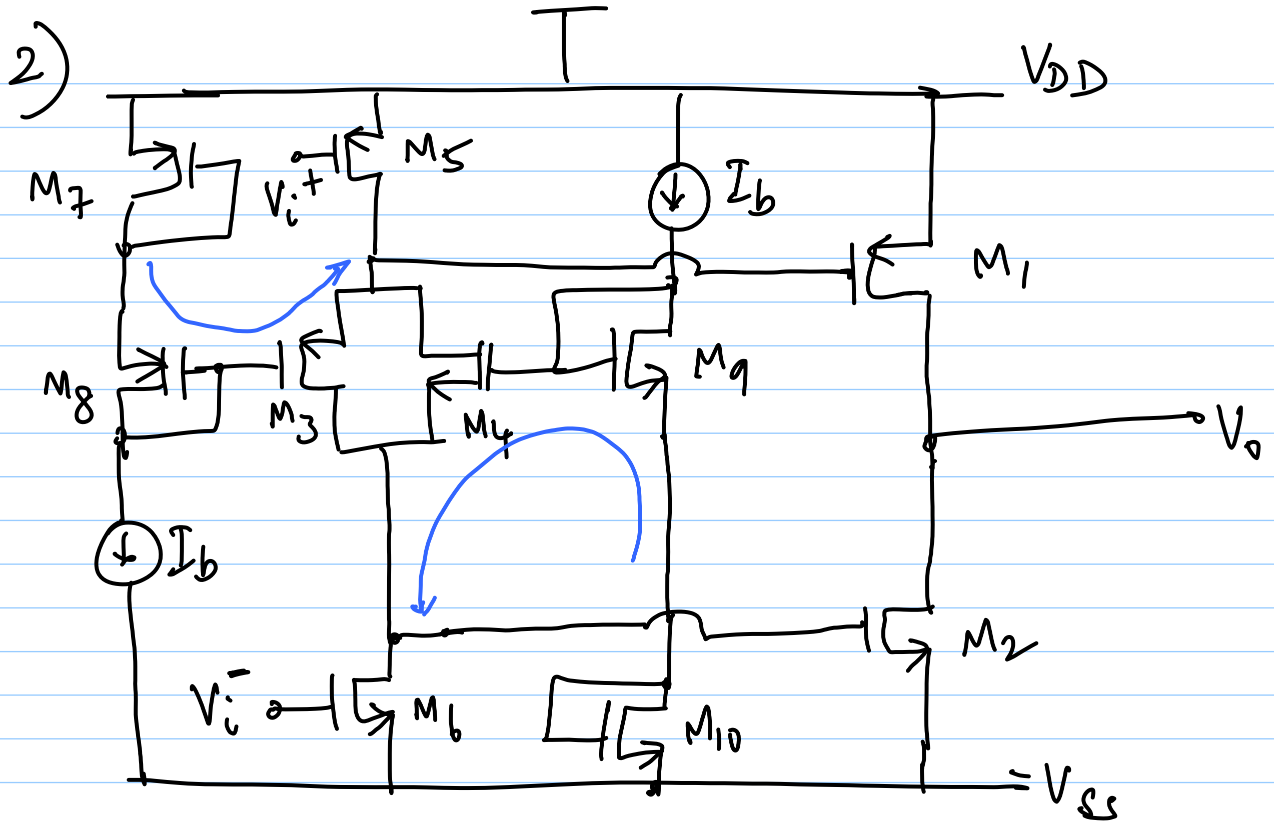
$\Rightarrow I_2 \uparrow, I_1 \downarrow$

$\Rightarrow I_6 \uparrow$

* R_o is still large

* V_{a3} & V_{a4} determine class B/AB mode

2)



* steady state: $I_5 = I_6 = 2I_b$

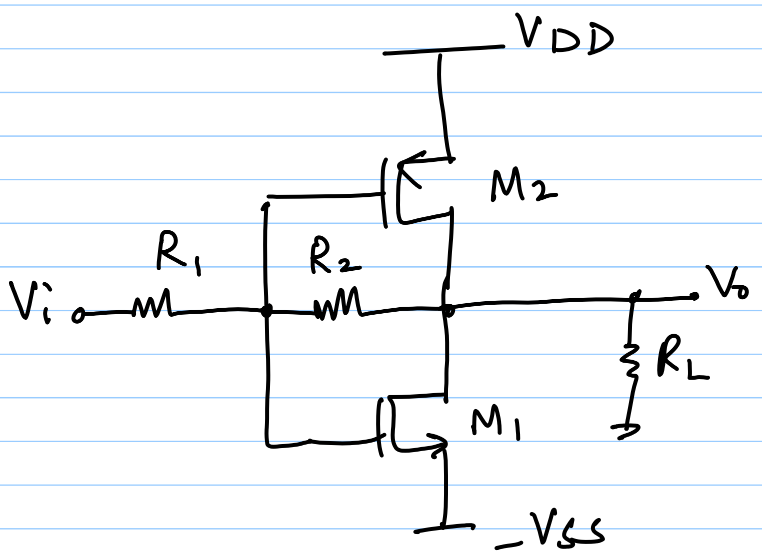
$\{M_4 = M_9 \;\&\; M_3 = M_8\}$

$$I_1 = I_2 = I_b \cdot \frac{(W/L)_1}{(W/L)_7} = I_b \cdot \frac{(W/L)_2}{(W/L)_{10}}$$

* $V_i^+ \downarrow \Rightarrow$ M_5 pulls V_{a1} & V_{a2} high
  - $\rightarrow$ M4 turns OFF
  - $\rightarrow$ $2I_b$ flows through M_3
  - $\Rightarrow$ M_1 turns OFF & M_2 is strongly ON
* $V_i^- \uparrow \Rightarrow$ M_6 pulls V_{a1} & V_{a2} low
  - $\Rightarrow$ M_2 OFF & M_1 is ON

Reducing R_o (-ve feedback)

* Use of error amps (last class)
* can also use resistive f.b.

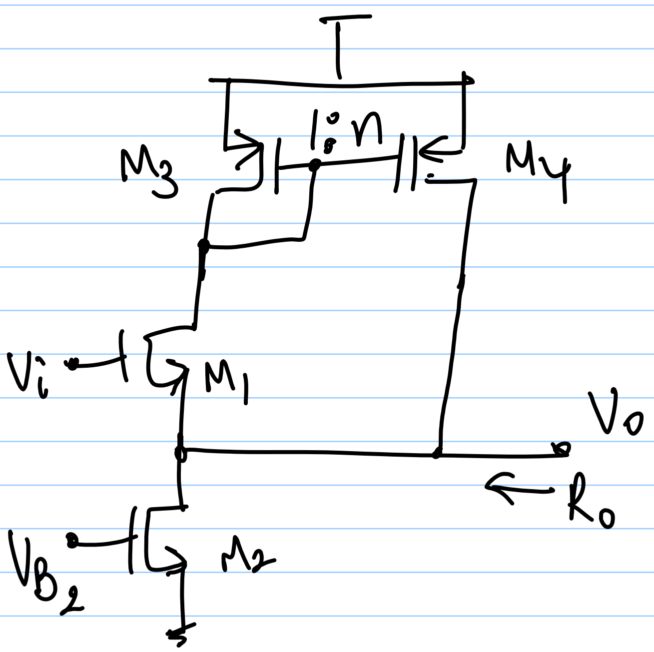


$$R_o \approx \frac{R_{o\,original}}{(g_m R_L/2)}$$

when $R_1 = R_2$

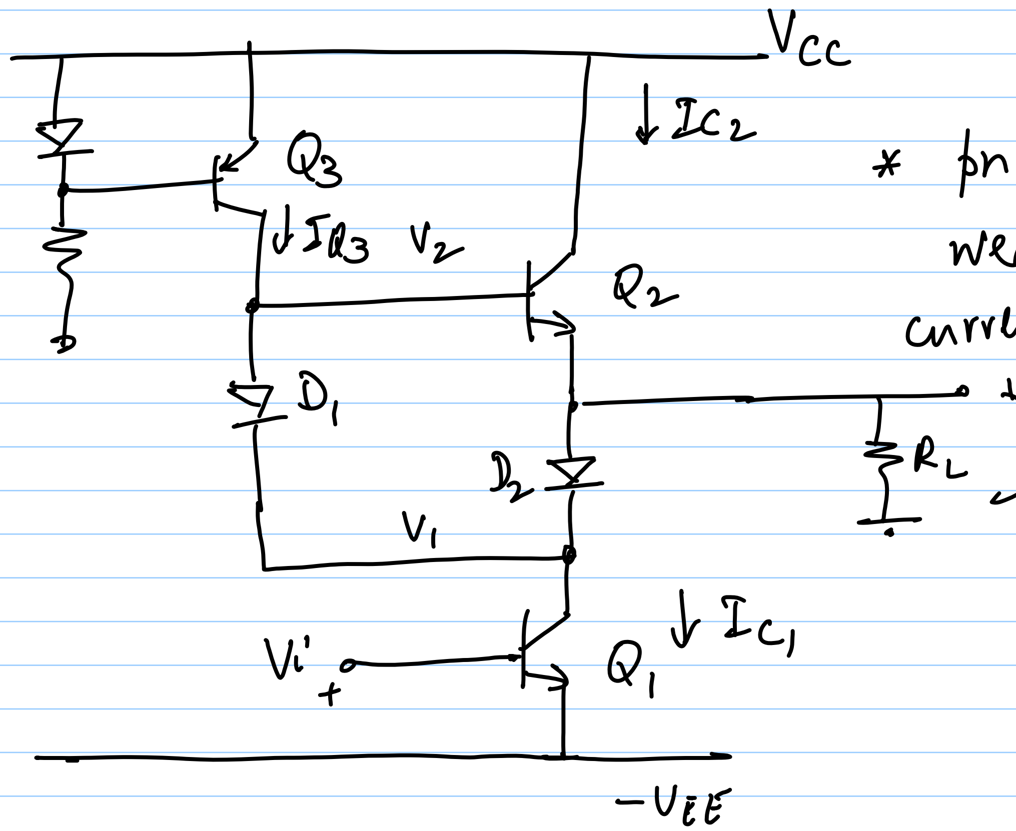
(HW)

For Source follower:



$$R_o = \frac{1}{g_{m_1} \cdot n}$$

All-npn class B output stage



* pnps are weak (limited current carrying capability)

* pnps have low current-carrying capability $\Rightarrow$ Use npn in both halves of class B ckt

* $V_i < V_{iQ} \Rightarrow Q_1$ OFF, $I_{C_1} = 0$
  - $\rightarrow D_1$ & D_2 OFF
  - $\rightarrow I_{Q3} = I_{b_2}$
  - $\rightarrow V_o = V_{o(max.)}$

  Q_2 in emitter follower config.

* If R_L is large, Q_3 goes into SAT.

$$V_{om}^{+} = V_{CC} - V_{SAT_3} - V_{be_2}$$

$Q_2 \rightarrow$ cannot saturate

$$V_{om}^{+} = -I_{e_2} R_L = (\beta_2+1) I_{b_2} R_L$$

for Q_3 to be saturated,

$$I_{Q_3} \,(Q_3 \text{ not in SAT}) > I_{b_2}$$

$$\Rightarrow \quad I_{Q_3} > \frac{V_{CC} - V_{SAT_3} - V_{be_2}}{(\beta_2+1) R_L}$$ optimum point

* $V_i > V_{iQ}$ (+ve) $\Rightarrow Q_1$ ON, $I_{C_1} > 0$

→ D_1 turns ON first

$V_{D_1} = V_{be_2} + V_{D_2}$

→ $V_2 \downarrow \Rightarrow V_o$ follows V_2 (emitter follower)

⇒ Q_1 acts as driver & Q_2 is o/p device

* $V_o = 0 \Rightarrow I_o = 0 \Rightarrow I_{e_2} = 0$

$\Rightarrow I_{C_1} = I_{Q_3}$

as $I_{C_1} \uparrow$, V_o stays @ 0 till $V_2 = 0$

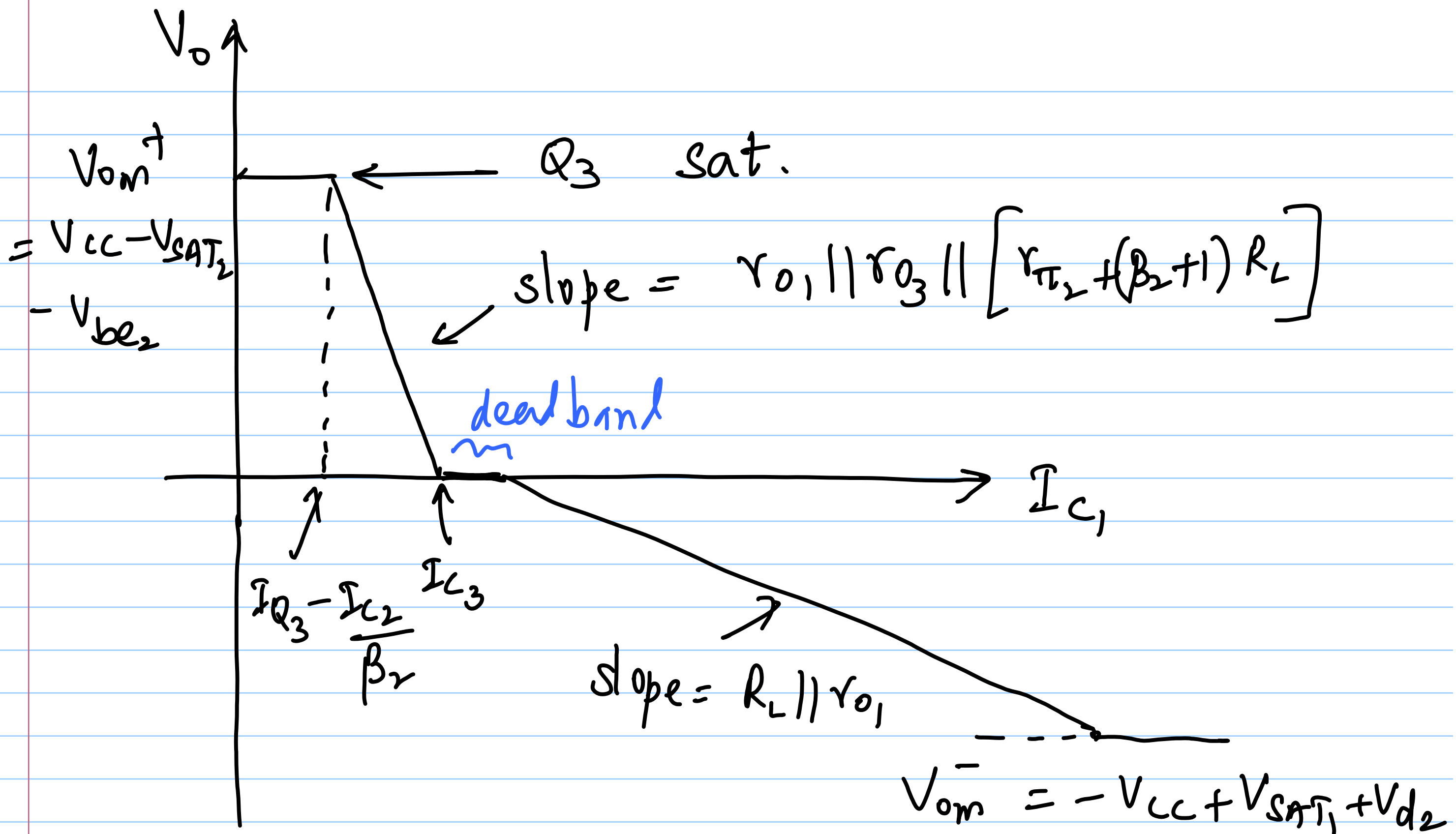
→ D_2 turns ON

* $V_o < 0 \Rightarrow I_{D_1} = I_{Q_3}$

⇒ $I_{C_1} - I_{Q_3}$ flows through D_2 & R_L

Q_1 acts as o/p device

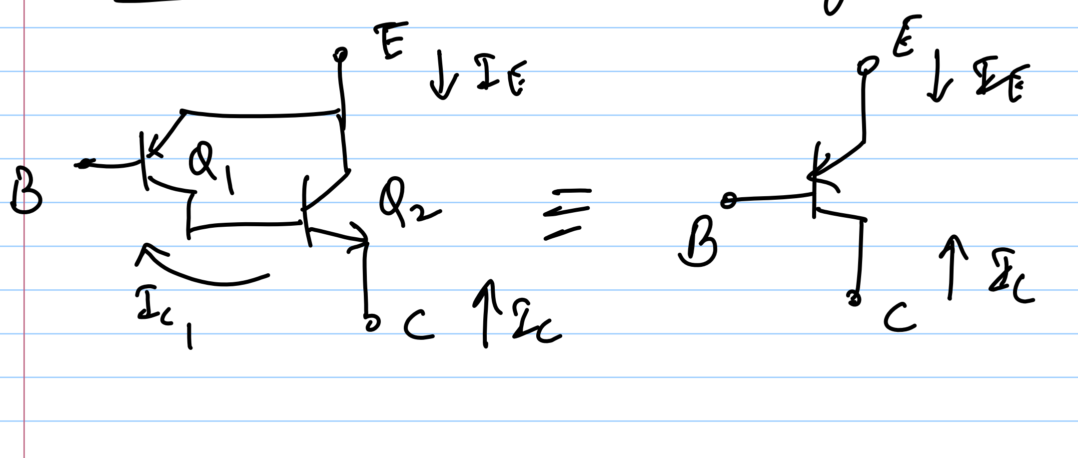
$$V_{om}^{-} = -V_{CC} + V_{SAT_1} + V_{d_2}$$



* eliminate deadband → add another diode in series with D_1

* highly non-linear
  → use feedback to linearize
* $V_i - V_o$ is even more non-linear (exponential relation I_{C_1} to V_{be_1})

Quasi-complementary



$$I_{e_1} = -I_S \exp\left(-\frac{V_{BE}}{V_T}\right)$$

$$I_C = (\beta_2+1) I_{C_1}$$

$$= -(\beta_2+1) I_S \exp\left(-\frac{V_{BE}}{V_T}\right)$$

* high current is sourced by npn
* $V_{SAT} = |V_{SAT_1}| + V_{BE_2}$
* local f.b. can cause instability with cap loads