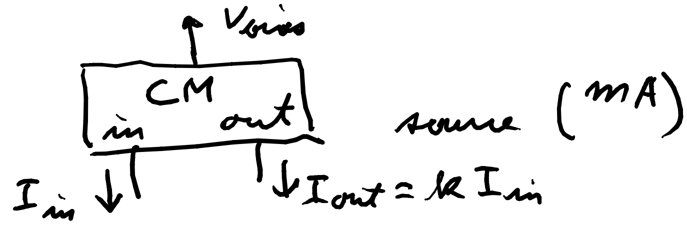
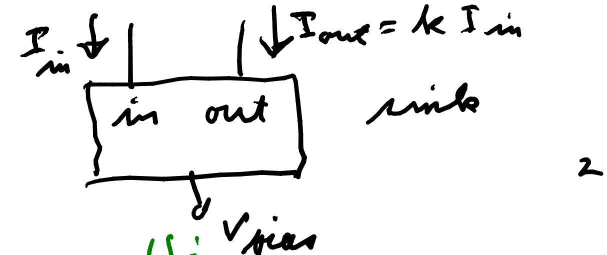
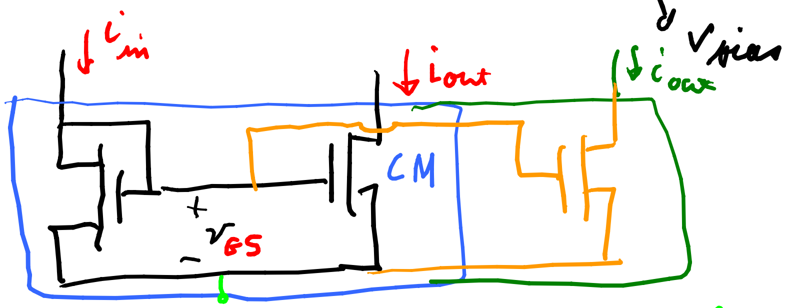
Hmwk due on W.

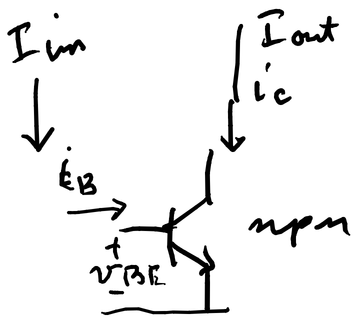
# Current mirror CM

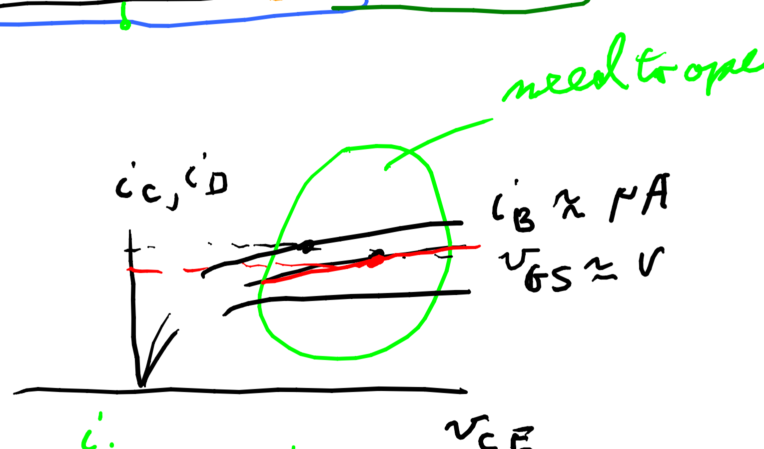


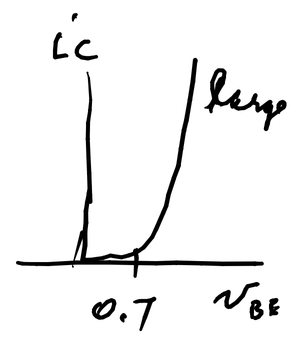



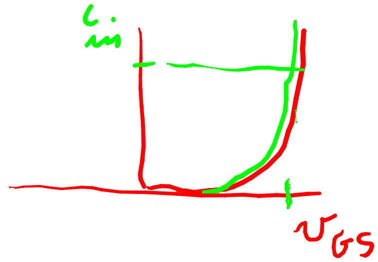

for MOS
sink
NMOS



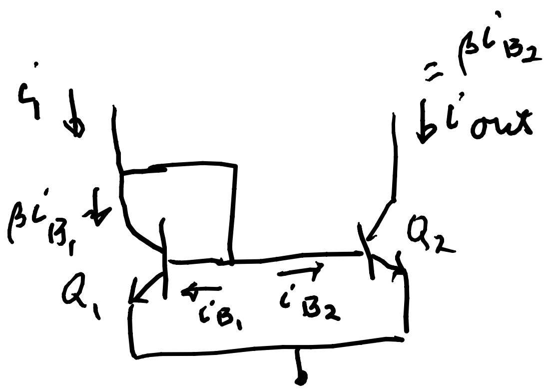




BJT
sink

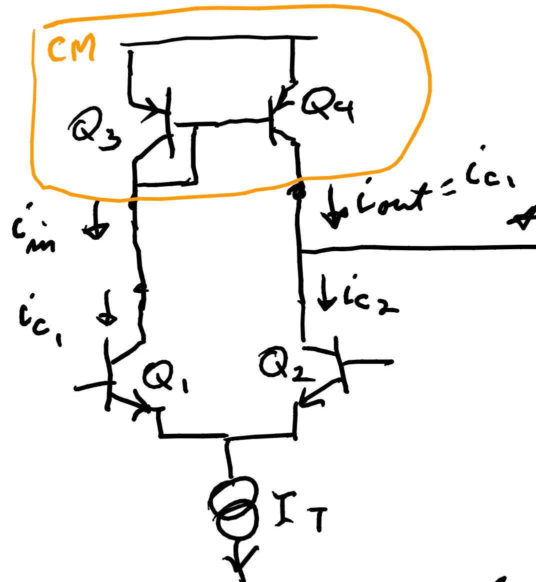



$i_{in} = i_1 = \beta i_{B_1} + i_{B_1} + i_{B_2}$

if $Q_2 = Q_1$ $\quad i_{B_2} = i_{B_1}$, $\beta_1 = \beta_2 = \beta$

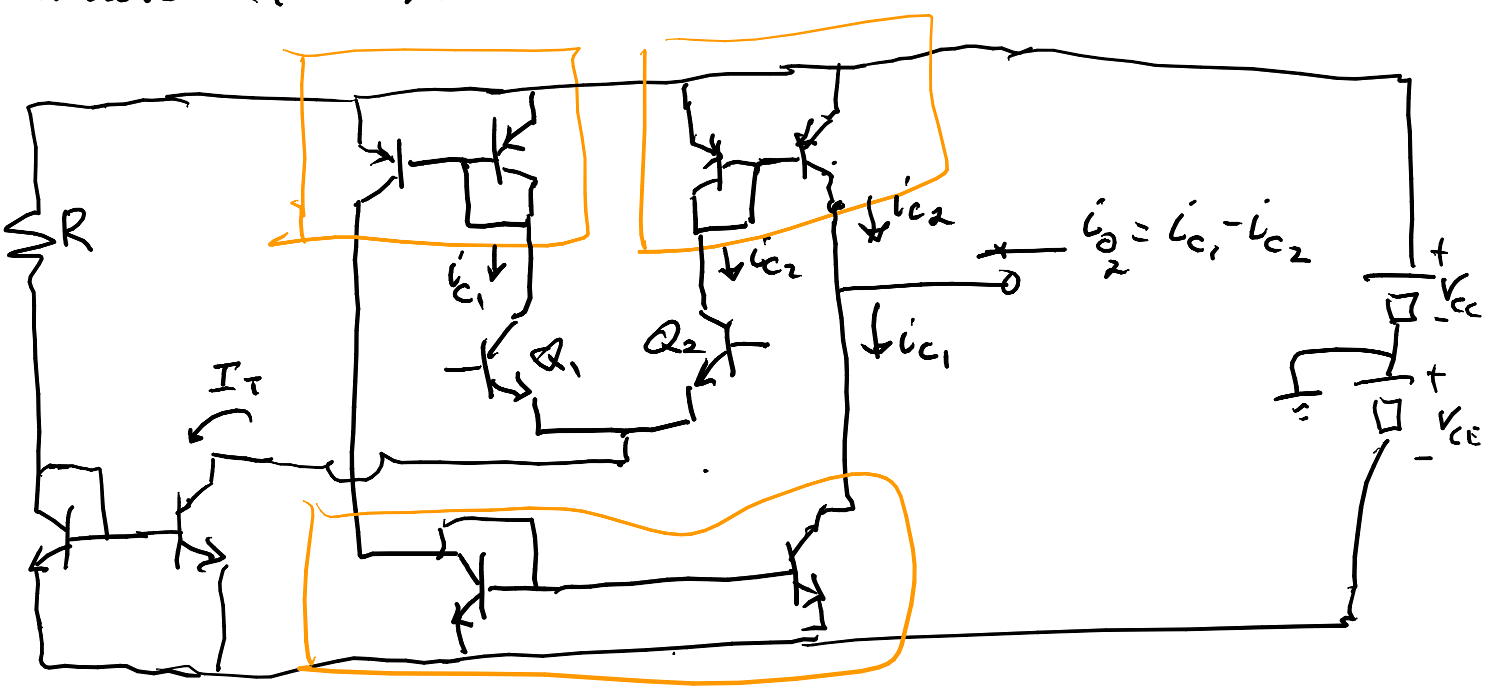
$$\left.\begin{aligned} i_{in} &= (2+\beta)\, i_{B_2} \\ i_{out} &= \beta\, i_{B_2} \end{aligned}\right\} \quad \frac{i_{out}}{i_{in}} = \frac{\beta}{2+\beta}$$

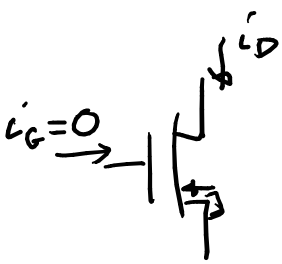
BJT current "source"




here $Q_1$ is loaded differently than $Q_2$

∴ make $Q_1$ & $Q_2$ see the same load (ie on the diff. pair)



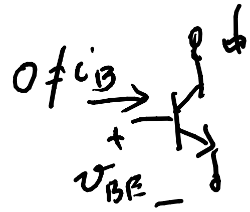

subthreshold

$i_G = 0$ @ DC

$i_D = \frac{KP}{2} \frac{W}{L} e^{(v_{GS} - VTO)/V_T}$

$v_{GS} > VTO$

$v_{GS} - V_{TO} < v_{DS}$




$i_C = \alpha I_S e^{v_{BE}/V_T}$

means an OTA operating in subthreshold ($I_T \sim 10^{-12}$ A) has $i_o = I_T \tanh(v_d/2V_T)$

For small signals $\tanh x = \frac{e^x - e^{-x}}{e^x + e^{-x}} \approx \frac{(1+x)-(1-x)}{(1+x)+(1-x)} = \frac{2x}{2} = x$

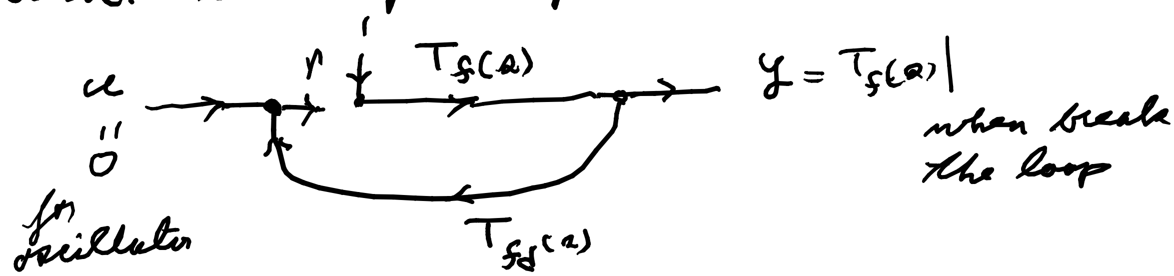
(≈: small signal)

acts as a resistor

$i_o \sim I_T \cdot v_d / 2V_T = \frac{I_T}{2V_T} \cdot v_d \approx G_m \sim 10^{-10}$

Oscillators:

Feedback: via signal graph



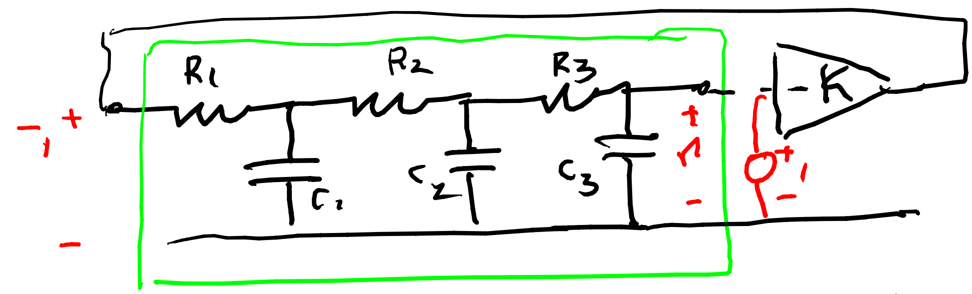

$r$ = return ratio = $T_{fd} \cdot T_f(s)$ = loop gain

close the loop and then $1 = r = T_{fd} \cdot T_f(s)$

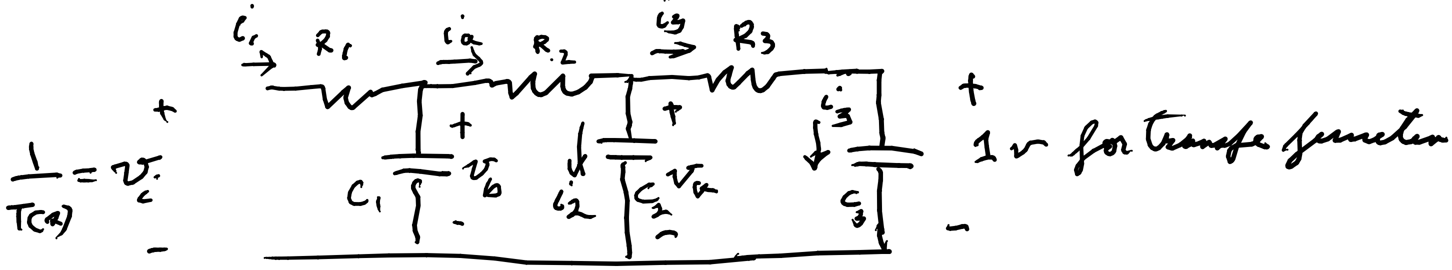
∴ desire 1 − loop gain = 0 = $1 - T_{fd}(s) \cdot T_f(s)$

we want those s which satisfy this

look at the RC phase shift oscillator




∴ want the voltage transfer function of the ladder




$i_3 = sC_3$

$v_a = R_3 i_3 + 1 = sR_3C_3 + 1$

$i_2 = sC_2 v_a = s^2 R_3 C_3 C_2 + sC_2$

$$i_a = i_2 + i_3 = s^2 R_3 C_3 C_2 + s C_2 + s C_3$$

$$v_b = R_2 i_a + v_a = s^2 R_3 C_3 R_2 C_2 + s R_2 C_2 + s R_2 C_3 + s R_3 C_3 + 1$$

$$i_1 = i_a + s C_1 v_b = s^2 R_3 C_3 C_2 + s(C_2 + C_3) + s^3 R_3 C_3 R_2 C_2 C_1$$
$$+ s^2 R_2 C_2 C_1 + s^2 R_2 C_3 C_1 + s^2 R_3 C_3 C_1 + s C_1$$

$$v_{in} = R_1 i_1 + v_b = s^2 R_1 R_3 C_3 C_2 + s(C_2 R_1 + C_3 R_1) + s^3 R_3 C_3 R_2 C_2 R_1 C_1$$
$$+ s^2 R_2 C_2 R_1 C_1 + s^2 R_2 C_3 R_1 C_1 + s^2 R_3 C_3 R_1 C_1 + s C_1 R_1$$
$$+ s^2 R_3 C_3 R_2 C_2 + s R_2 C_2 + s R_2 C_3 + s R_3 C_3 + 1$$

$$\therefore \; v_{in}(s) = \frac{1}{T(s)} = (R_1 C_1 R_2 C_2 R_3 C_3) s^3 + (R_1 C_2 R_3 C_3 + R_1 C_1 R_2 C_2 + R_1 C_1 R_2 C_3 + R_1 C_1 R_3 C_3$$
$$+ R_2 C_2 R_3 C_3) s^2$$
$$+ (R_1 C_2 + R_1 C_3 + R_1 C_1 + R_2 C_2 + R_2 C_3 + R_3 C_3) s + 1$$

$= -K$ for oscillations (when close the loop)