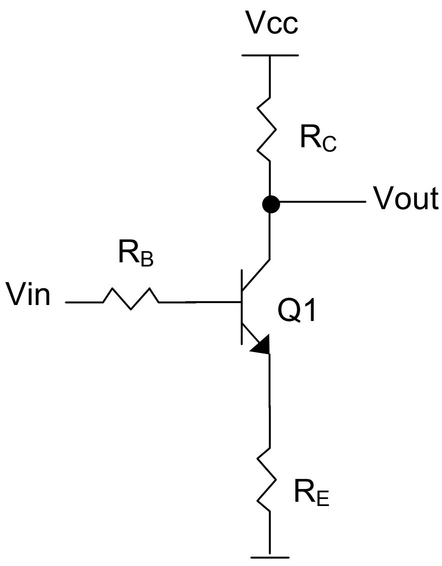
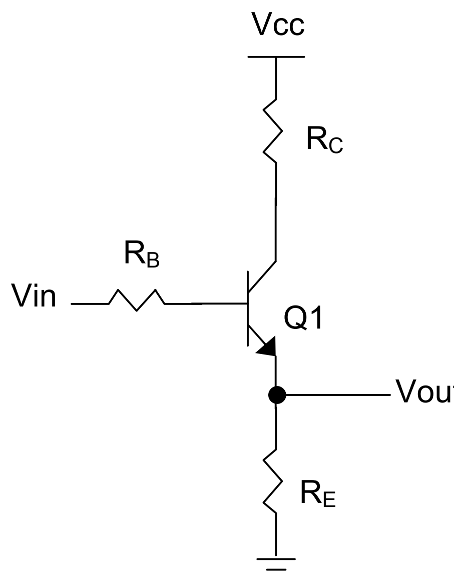
ECE 323 HW # 3

Prob. 1-3: Find the expression for small signal Rin, Gm, Rout and Gain for all the circuits. Assume all the BJTs are biased in forward active region and MOSFETs in saturation. Consider ro = ∞

Prob.1



(a)



(b)

$R_{in} = R_B + r_\pi + R_E(1+\beta)$

$R_{out} = R_C$

$G_m = \frac{-r_\pi}{R_{in}} g_m$

$Gain = G_m \cdot R_{out} = \frac{-\beta R_C}{R_B + r_\pi + R_E(1+\beta)}$

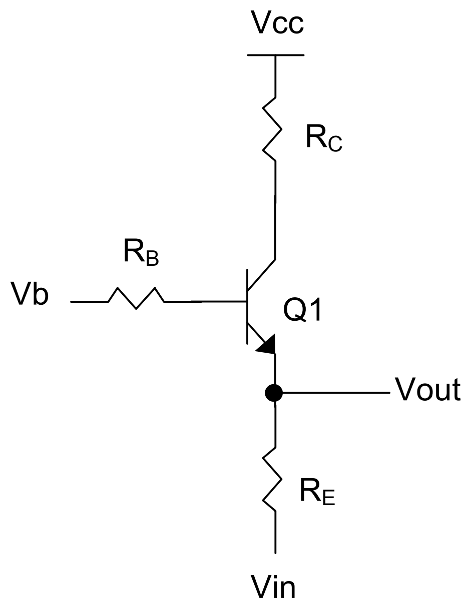
$R_{in} = R_B + r_\pi + R_E(1+\beta)$

$R_{out} = R_E \parallel \frac{R_B + r_\pi}{1+\beta}$

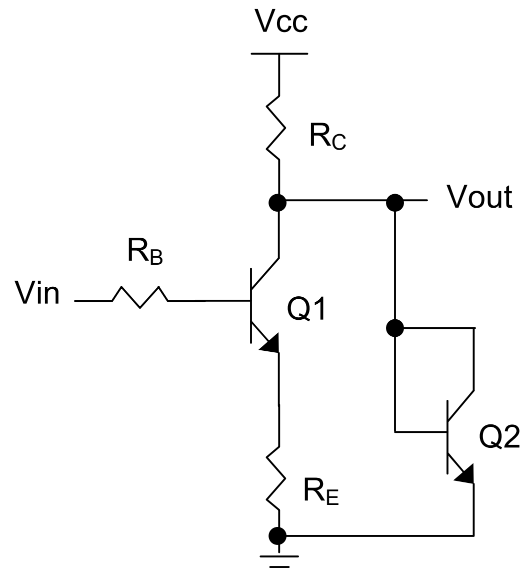
$G_m = \frac{1}{R_B + r_\pi} + \frac{r_\pi}{R_B + r_\pi} g_m = \frac{1+\beta}{R_B + r_\pi}$

$Gain = G_m \cdot R_{out}$

but you can just apply voltage divider to get gain, even without knowing Gm & Rout.



(c)



(d)

$R_{in} = R_E + \frac{R_B + r_\pi}{1+\beta}$

$R_{out} = R_E \parallel \frac{R_B + r_\pi}{1+\beta}$

$G_m = \frac{1}{R_E}$

$Gain = G_m \cdot R_{out}$

or just apply voltage divider

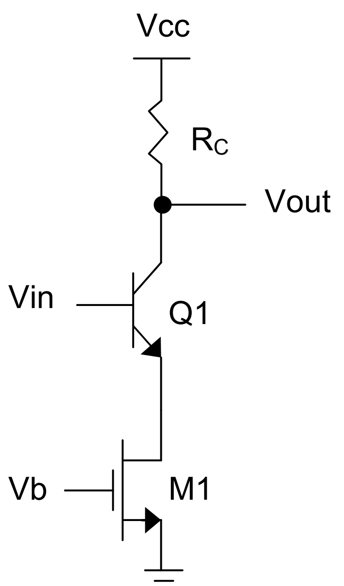
$R_{in} = R_B + r_{\pi 1} + R_E(1+\beta_1)$

$R_{out} = \underbrace{\frac{r_{\pi 2}}{1+\beta_2}}_{\approx \frac{1}{g_{m2}}} \parallel R_C$

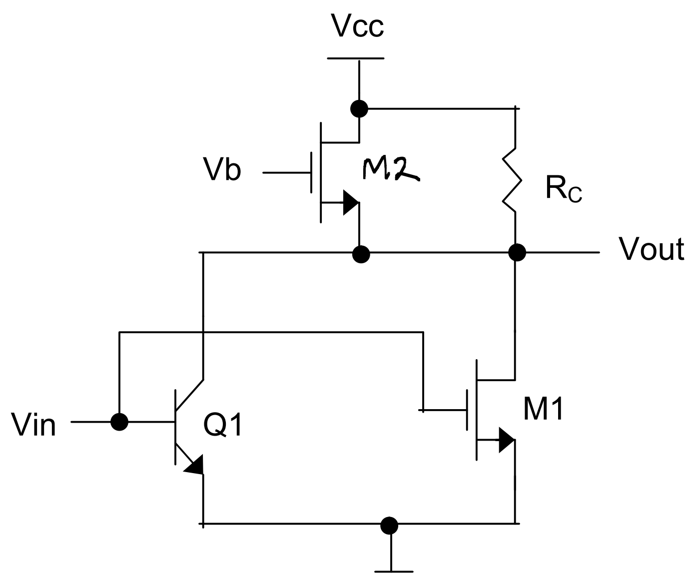
$G_m = \frac{-r_{\pi 1} \cdot g_{m1}}{R_B + r_{\pi 1} + R_E(1+\beta_1)}$

$Gain = G_m \cdot R_{out}$

Prob.2



(a)



(b)

$r_{o(M1)} = \infty$

$\downarrow$

$R_{in} = \infty$

$G_m = 0$

$Gain = 0$

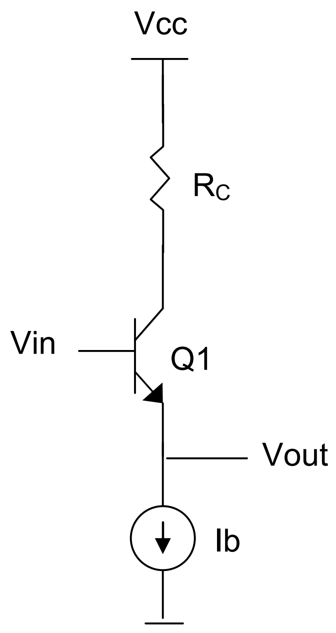
$R_{out} = R_C$

$R_{in} = r_{\pi 1}$

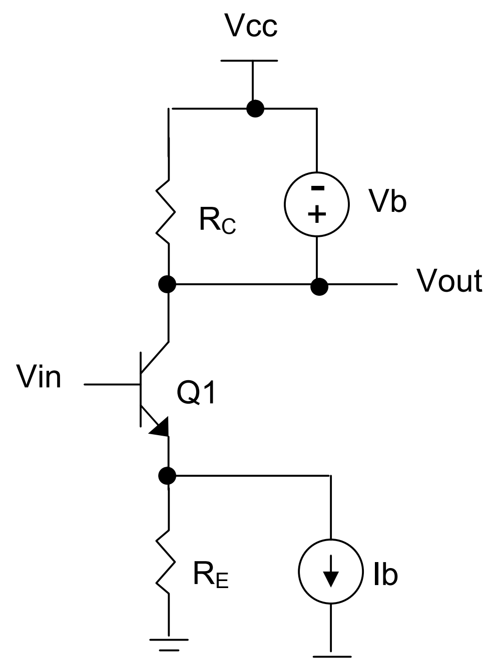
$R_{out} = R_C \parallel \frac{1}{g_{m2}}$

$G_m = -(g_{mQ1} + g_{mM1})$

$Gain = G_m \cdot R_{out}$



(c)



(d)

$R_{in} = \infty$ (current source)

$R_{out} = \frac{r_\pi}{1+\beta}$

$G_m = \frac{1}{r_\pi} + g_m = \frac{1+\beta}{r_\pi}$

Gain $= G_m \cdot R_{out} = 1$

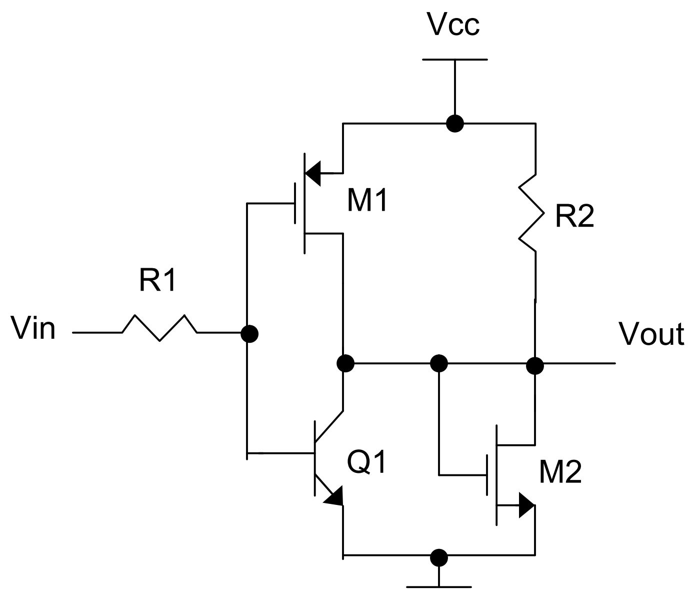
$R_{in} = r_\pi + R_E(1+\beta)$

$R_{out} = 0$ (voltage source)

$G_m = \frac{-r_\pi \cdot g_m}{r_\pi + R_E(1+\beta)}$

Gain $= G_m \cdot R_{out} = 0$

Prob. 3



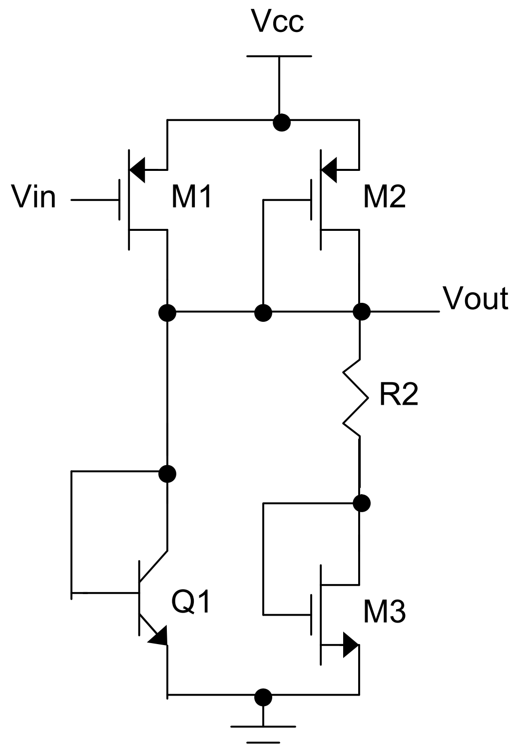
(a)

$R_{in} = R_1 + r_\pi$

$R_{out} = R_2 \parallel \frac{1}{g_{m2}}$

$G_m = \frac{-r_\pi}{R_1 + r_\pi}\left(g_{mQ1} + g_{mM1}\right)$

$Gain = G_m \cdot R_{out}$



(b)

$R_{in} = \infty$

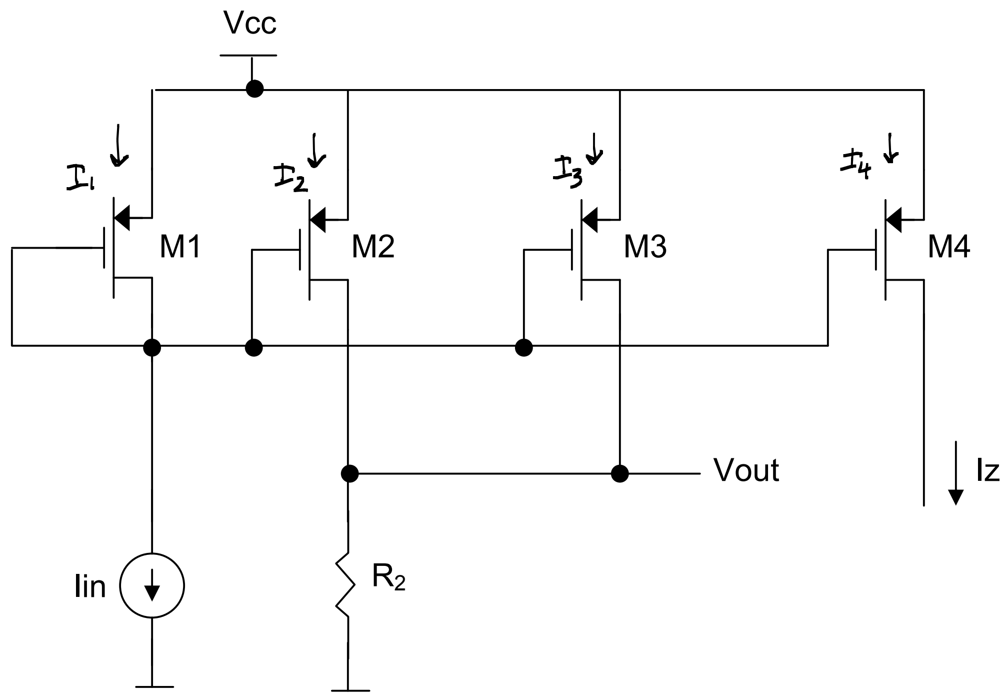
$R_{out} = \frac{1}{g_{m2}} \| \left(R_2 + \frac{1}{g_{m3}}\right) \| \frac{r_\pi}{1+\beta}$

$G_m = -g_{mM1}$

$Gain = G_m \cdot R_{out}$

Prob. 4

For the circuit given below, find the expression for output resistance Rout, transimpedance Vout/Iin and current gain Iz/Iin. Assume all the MOSFETs having same W/L and operating in saturation region. Consider ro = ∞



all same $\frac{W}{L}$ → $I_{in} = I_1 = I_2 = I_3 = I_4 = I_Z$ → $\frac{I_Z}{I_{in}} = 1$

$R_{out} = R_2$ $(r_o = \infty)$

$\frac{V_{out}}{I_{in}} = 2 \cdot R_2$

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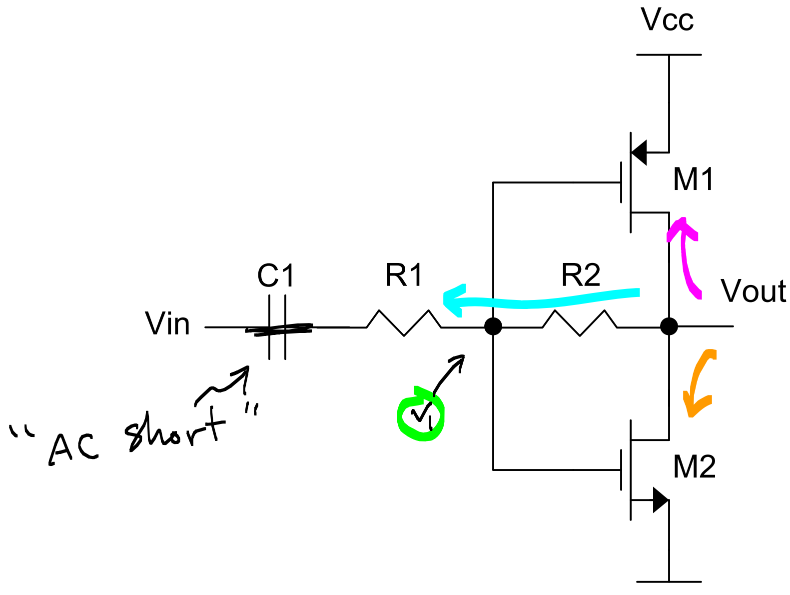
Prob. 5

For the circuit given below, find the expression for Rin, Rout, Gm and gain. Assume all the MOSFETs operating in saturation region and consider ro = ∞. Plot the behavior of output gain vs R2.



V_1 controls V_{gs} of M1 and M2, in parallel.

$$R_{in} = R_1 + \frac{1}{g_{m1} + g_{m2}}$$

$$R_{out} = (R_1 + R_2) \,\Big|\Big|\, \left[\frac{R_1}{R_1+R_2}(g_{m1}+g_{m2})\right]^{-1} = \frac{R_1+R_2}{R_1(g_{m1}+g_{m2})+1}$$

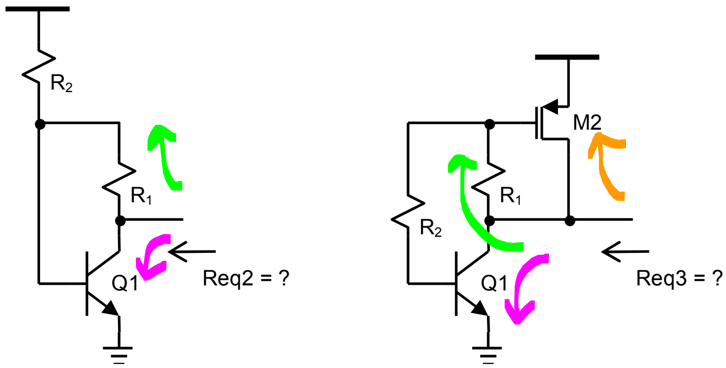
($V_{in}=0$)

$$G_m = \frac{1}{R_1+R_2} - \frac{R_2}{R_1+R_2}(g_{m1}+g_{m2}) = \frac{1 - R_2(g_{m1}+g_{m2})}{R_1+R_2}$$

(V_{out} shorted)

$$\text{Gain} = G_m \cdot R_{out} = \frac{1 - R_2(g_{m1}+g_{m2})}{1 + R_1(g_{m1}+g_{m2})}$$

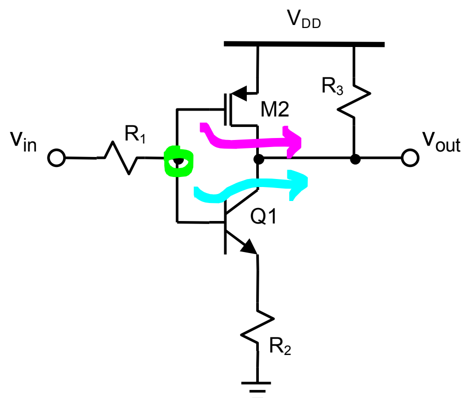
Prob. 6
Find Req2 and Req3



$$R_{eq2} = \left[R_1 + (R_2 \| r_{\pi 1})\right] \Bigg\| \left[\frac{(R_2 \| r_{\pi 1}) \cdot g_{m1}}{R_1 + (R_2 \| r_{\pi 1})}\right]^{-1}$$

$$R_{eq3} = (R_1 + R_2 + r_{\pi 1}) \Bigg\| \left(\frac{r_{\pi 1} \cdot g_{m1}}{R_1 + R_2 + r_{\pi 1}}\right)^{-1} \Bigg\| \left(\frac{(R_2 + r_{\pi 1}) \cdot g_{m2}}{R_1 + R_2 + r_{\pi 1}}\right)^{-1}$$

Prob. 7
Find the input-to-output small-signal gain.



$$\text{Gain} = -\frac{r_{\pi 1} + R_2(1+\beta_1)}{R_1 + r_{\pi 1} + R_2(1+\beta_1)}\left(\frac{r_{\pi 1}\cdot g_{m1}}{r_{\pi 1} + R_2(1+\beta_1)} + g_{m2}\right)\cdot R_3$$