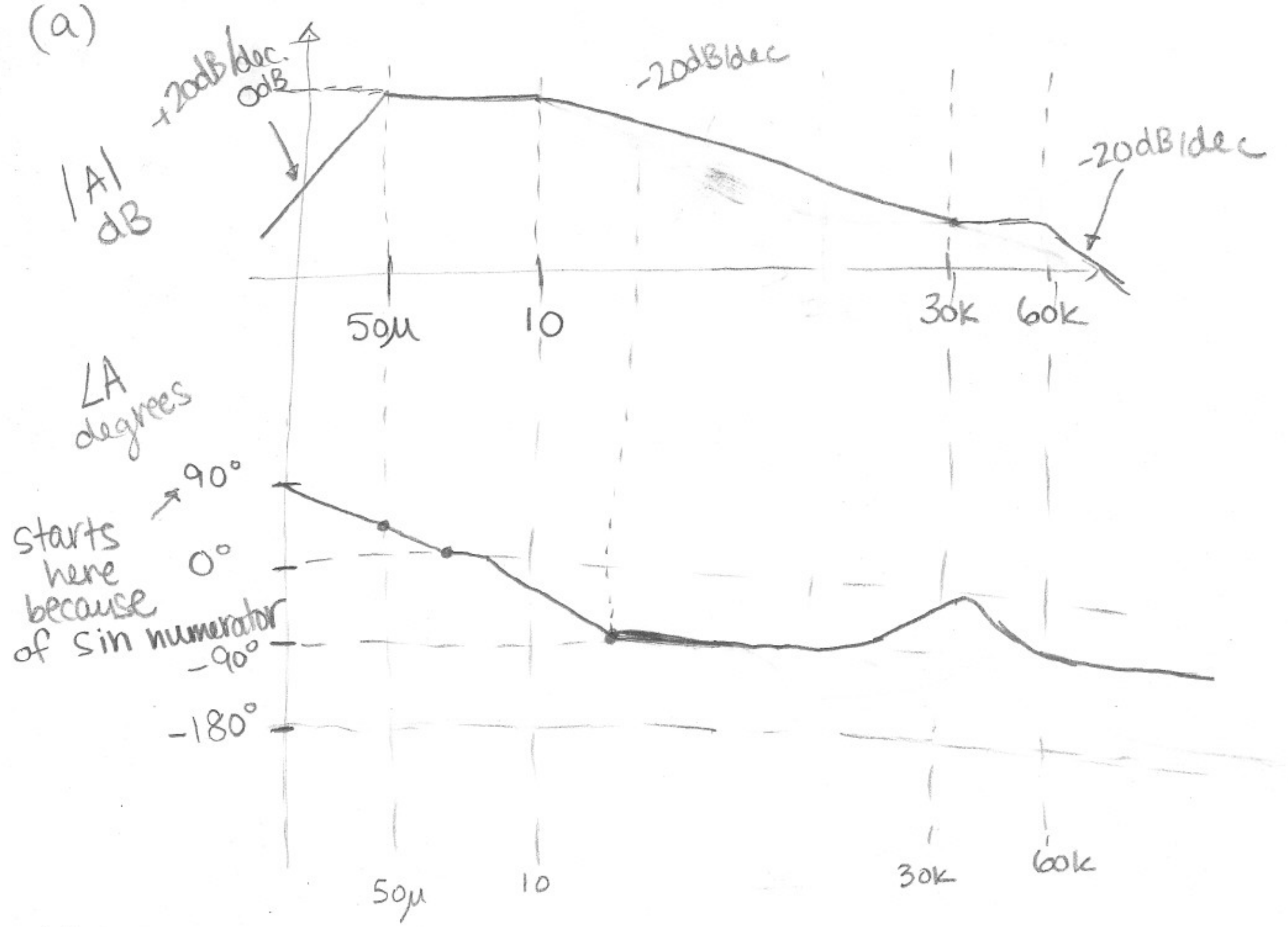
HW #11 Sol'n

1. $$A(s) = \frac{10s\left(\frac{s}{30k}+1\right)}{(s+10)\left(\frac{1}{20k}+s\right)\left(\frac{s}{60k}+1\right)}$$

lowest frequency

$$= \frac{10\cdot s\cdot\left(\frac{s}{30k}+1\right)}{\cancel{10\cdot s}\left(\frac{s}{10}+1\right)\left(\frac{1}{20k\cdot s}+1\right)\left(\frac{s}{60k}+1\right)} = \frac{\left(\frac{s}{30k}+1\right)}{\left(\frac{s}{10}+1\right)\left(\frac{1}{20ks}+1\right)\left(\frac{s}{60k}+1\right)}$$

(a)



(b) $w_L = 50\mu$, $w_H = 10$ rad/sec.

(c) 0dB

(d) poles ⇒ 50μ, 10, 60K

(e) zeros ⇒ 1 at zero, 30K

1. (cont.)

(f) · Need to find freq. when phase $= -90° \Rightarrow \approx 1$ decade after 10 $\therefore$ start at 100

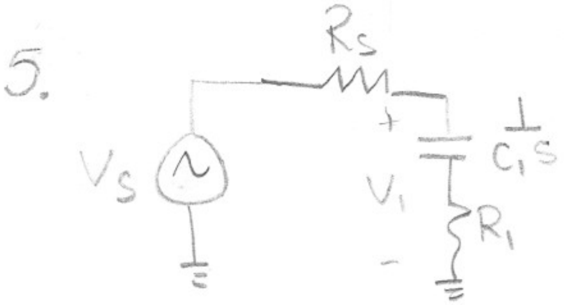
$\left(\tan^{-1}\left(\frac{100}{30k}\right) - \tan^{-1}\left(\frac{100}{10}\right) - \tan^{-1}\left(\frac{100}{60k}\right) \cong -84°\right.$

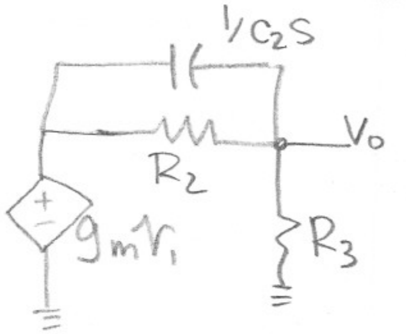
@ 600 rad/sec $\approx -89°$ $\quad \therefore |A\beta| = 1 = \dfrac{\left(\sqrt{\left(\frac{600}{30k}\right)^2+1}\right)\cdot\beta}{\sqrt{\left(\frac{600}{10}\right)^2+1^2}\sqrt{\left(\frac{1}{20k\cdot600}\right)^2+1^2}\sqrt{\left(\frac{600}{60k}\right)^2+1^2}}$

$\boxed{\beta \cong 60}$

(g). $A_f = \dfrac{A}{1+A\beta} = \dfrac{1}{1+(1)(2)} = \boxed{0.33\,V/V} = \boxed{-9.5\,dB}$ [need V/V]

5.





$V_o = \dfrac{g_m V_1 \cdot R_3}{R_3 + \left(R_2 \| \frac{1}{C_2 s}\right)}$ $\qquad R_2 \| \frac{1}{C_2 s} = \dfrac{R_2 \cdot \frac{1}{C_2 s}}{R_2 + \frac{1}{C_2 s}} = \dfrac{R_2}{R_2 C_2 s + 1}$

$= \dfrac{g_m R_3 V_1}{R_3 + \frac{R_2}{(R_2 C_2 s+1)}} = \dfrac{g_m R_3 (R_2 C_2 s+1) V_1}{R_3(R_2 C_2 s+1)+R_2} = \dfrac{g_m R_3 (R_2 C_2 s+1)}{(R_3+R_2)\left[\frac{R_3 R_2 C_2 s}{(R_3+R_2)}+1\right]}$

$V_1 = \dfrac{\left(\frac{1}{C_1 s}+R_1\right)V_s}{\frac{1}{C_1 s}+R_1+R_s} = \dfrac{(1+R_1 C_1 s)V_s}{1+(R_1+R_s)C_1 s}$

$\dfrac{V_o}{V_s} = \dfrac{g_m R_3 (R_2 C_2 s+1)(1+R_1 C_1 s)}{(R_3+R_2)\left[\frac{R_3 R_2 C_2 s}{(R_3+R_2)}+1\right]\left[1+(R_1+R_s)C_1 s\right]}$

$\therefore$ Midband gain, $A_m \Rightarrow$

$$\boxed{A_m = \frac{g_m R_3}{(R_3 + R_2)}}$$

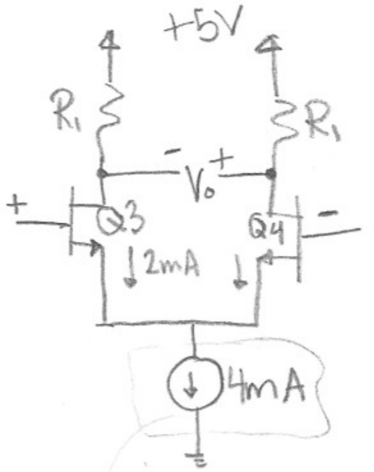
Low-freq. poles: None

Low-freq. zeros: None

high-freq. poles: $\frac{(R_2+R_3)}{R_2 R_3 C_2}$, $\frac{1}{(R_1+R_S)C_1}$

high-freq. zeros: $\frac{1}{R_2 C_2}$, $\frac{1}{R_1 C_1}$

6.



$A_d = 100\,V/V = g_m \cdot R_D$

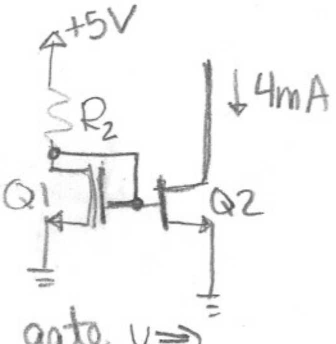
$g_m = \sqrt{2(k'(\frac{W}{L}))I_D} = \sqrt{2(4m)(2m)}$

$g_m = 4m\ A/V$

$\therefore\ R_D = \frac{100}{4m} = \boxed{25K}$

$g_m = 4m = \frac{2I_D}{V_{OV}}$

$\therefore\ V_{GS} = \frac{2(2m)}{4m} + 1 = \boxed{2V}$



· Need $2V = V_{GS}$

$\therefore V_{Q1_D} = 2V$

$R_2 = \frac{5-2}{4m} = \boxed{750\Omega}$

OR $4m = \frac{1}{2}(4m)(V_{GS}-V_t)^2$

$\Rightarrow V_{GS} = 2V$

$\therefore R_2 = \frac{5-2}{4m}$ (same)

minimum gate $V \Rightarrow$

saturation condition (min.)

for Q2 $\Rightarrow V_{DS} = V_{GS} - V_t = 2-1 = 1V$

$\therefore\ V_{S_{Q4,Q3}} = 1V$

$V_{G_{Q4,Q3}} = \boxed{3V}$

(2) .differential (not single-ended) gain for MOSFET $= 50\,V/V = g_m \cdot (10K)$

$\therefore g_m = 5m$

$g_m = \sqrt{2K'\left(\frac{W}{L}\right) I_D}$

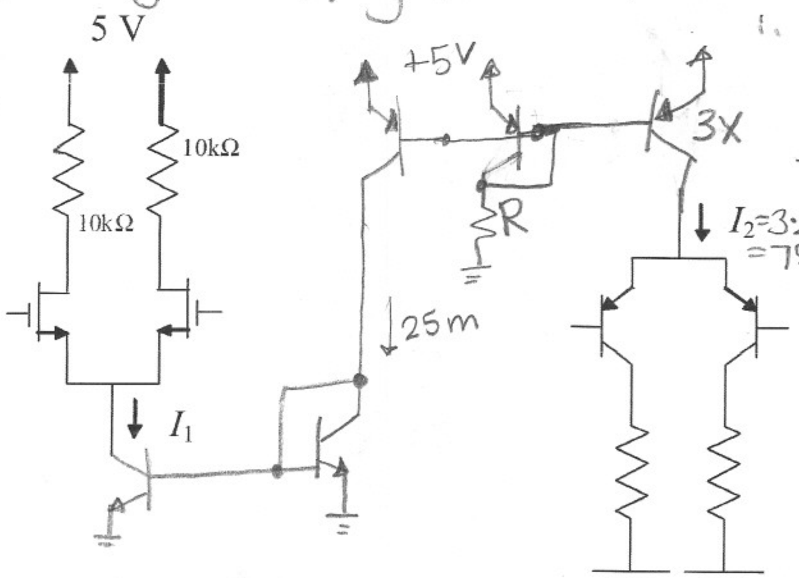
$\Rightarrow \frac{(5m)^2}{2(1m)} = I_D$

$I_D = 12.5mA$

$I_1 = 2I_D = \boxed{25m}$

$I_2 = 2I_C = \boxed{75m}$

$\therefore I_2 = 3 \cdot I_1$

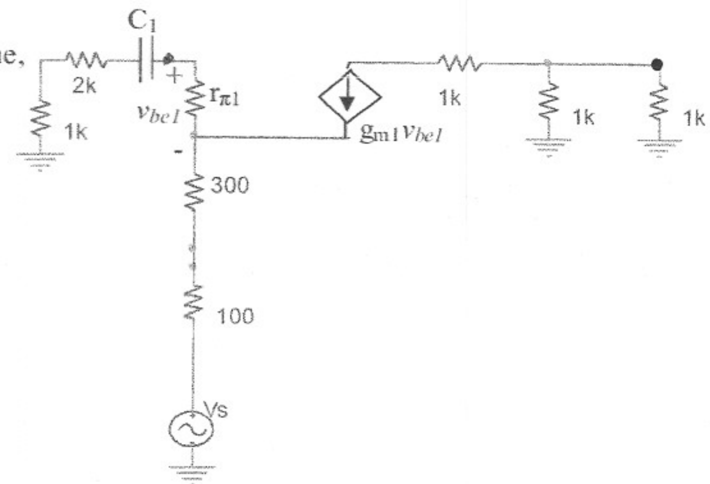


$R = \frac{(5-.7)}{25m} = \boxed{172\Omega}$

BJT: $g_m = \frac{I_C}{V_T} = 1.5A \Rightarrow I_C = 37.5mA$

3. (a) Using the short-circuit time constant technique, what is the resistance seen by C_1?

$\boxed{R = r_{\pi 1} + 400(\beta+1) + 3K}$



(b) Describe in your own words the Miller Effect.

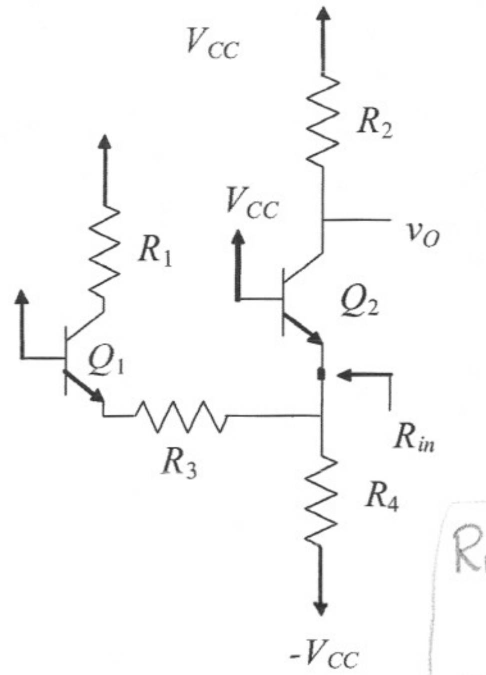
(c) As a general rule of thumb (discussed in lecture), if your low frequency poles are 4 and 9 rad/sec and your low frequency zeros are 16 rad/sec, find ω_L. $W_L = \sqrt{4^2 + 9^2 - 2(16)^2} \approx$ Does not exist $\therefore$ Not an amplifier

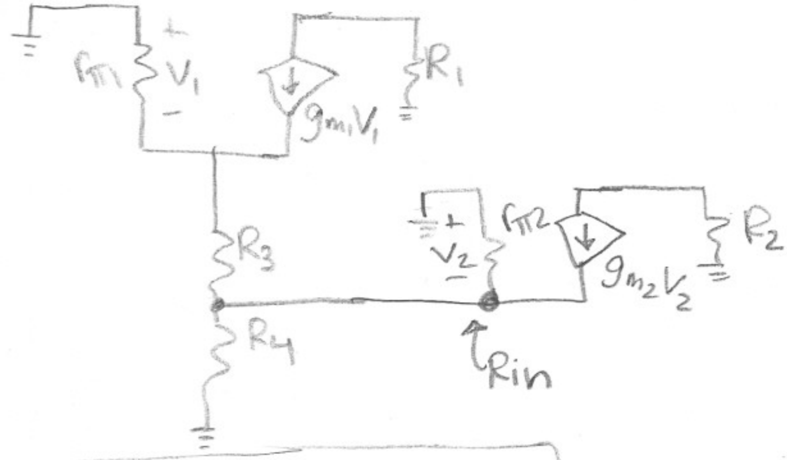
4. Assume the transistors below have a finite β and an infinite Early voltage.

Write an expression for the input resistance R_{in} in the circuit shown below. Your expression should include *only* real resistances (R_1, R_2, R_3, R_4, or a subset of these) and possibly β, r_{e1} or $r_{\pi 1}$, and r_{e2} or $r_{\pi 2}$. (Assume both transistors have the same β.) Circle your answer.

(2). Short and open γ
- Miller Effect
- Resistance Reflection Rule
- Circuit Analysis for gain
- Current Mirror design

- Class A, B, AB output stages
- feedback topologies
  - β, A-circuit, A_f
- Data Converters
- Multivibrators
- Digital logic → power implementation





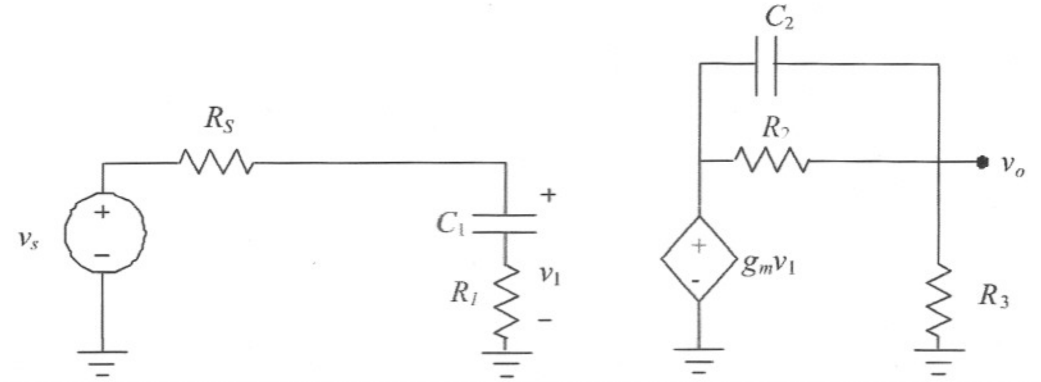
$$R_{in} = \frac{r_{\pi 2}}{(\beta+1)} \| R_4 \| \left[R_3 + \frac{r_{\pi 1}}{(\beta+1)}\right]$$

OR

$$R_{in} = r_{e_2} \| R_4 \| (R_3 + r_{e_1})$$

5. For the circuit shown below, derive expressions for:

- the midband gain A_M, the low-frequency poles and/or zeros (if any; state if none), and the high-frequency poles and/or zeros (if any; state if none)

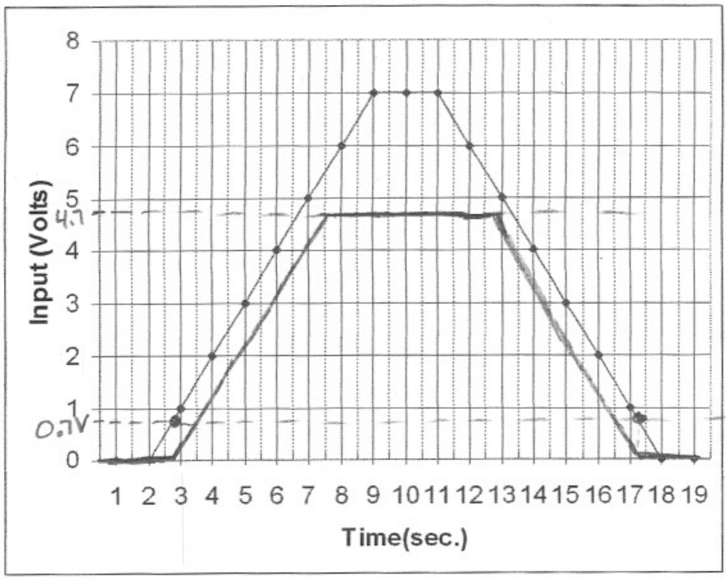


6. Design a MosFet differential amplifier to operate with a dc current bias of 2mA through each transistor and to provide a differential gain equal to 100V/V. The transistors have k'_nW/L=4ma/V^2 , V_t=1V.

- State the required dc bias voltage (V_{GS}) needed for the amplifier to work correctly.
- Design a current mirror to supply the needed current bias. Draw the schematic and all values. Any value of R can be used.
- After choosing your current mirror configuration, state the minimum value for the gate voltage in order for the amplifier to operate correctly.

7

Class A:



max:

$V_{CC} - V_{CESAT}$

$= 5 - 0.3$

$= 4.7V$

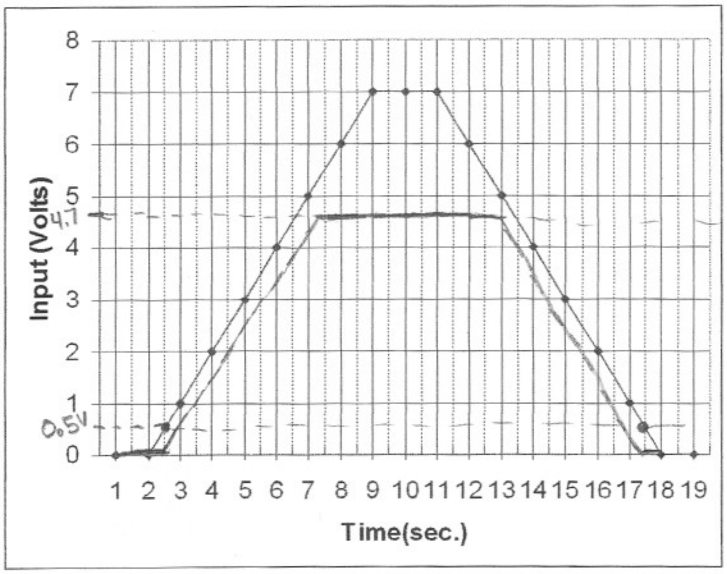
min:

$-V_{CC} + V_{CESAT}$

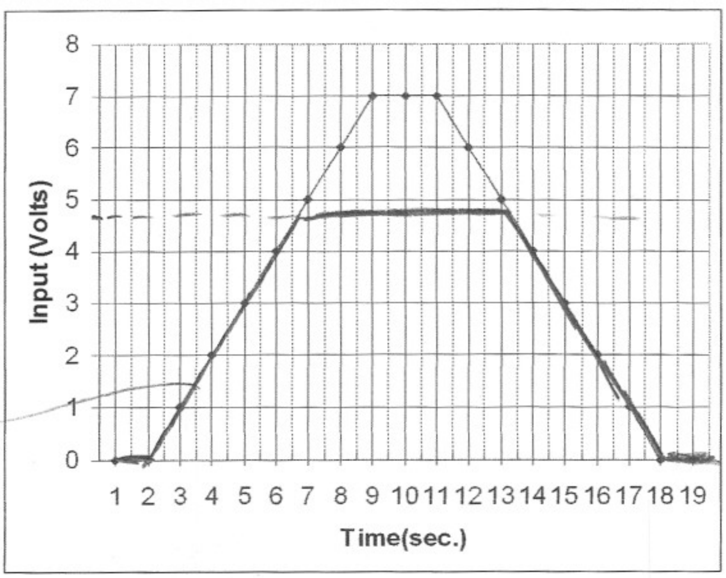
$= -5 + 0.3$

$= -4.7V$

Class B:



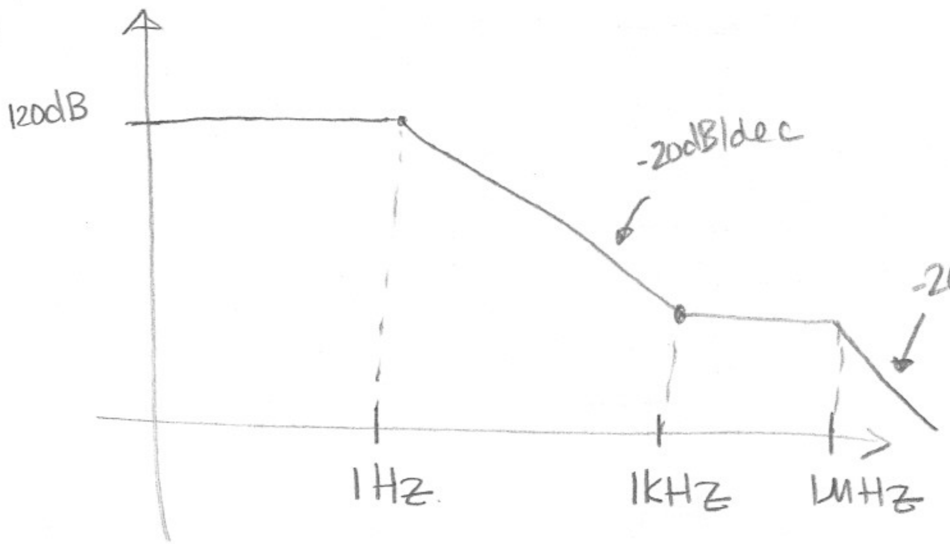
class AB:



Vout

8. (i) series-shunt (ii) shunt-shunt

9.



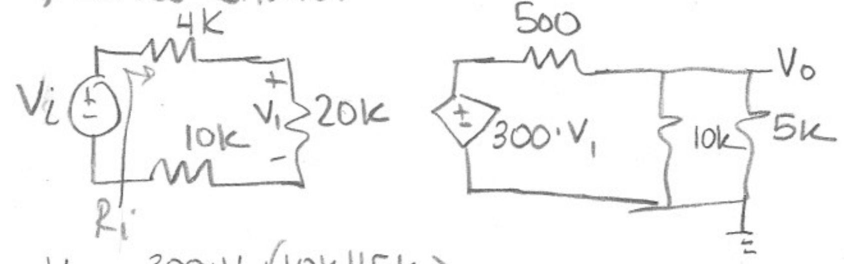
- starting at 0° means no pole/zero at origin.
- each −45° slope/2dec. means pole
- " +45° " " " zero

∴ Since the gain is 120dB at a very low freq. we have all poles/zeros at high-freq. ⇒

$$A(s) = \frac{1\text{Meg}\left(\frac{s}{1k}+1\right)}{(s+1)\left(\frac{s}{1\text{Meg}}+1\right)}$$

10. (a) series-shunt

(b)



$$V_o = \frac{300 \cdot V_1 (10k \| 5k)}{(10k \| 5k) + 500} \approx 261 V_1$$

$$V_1 = \frac{V_i \cdot 20K}{34K}$$

$$\frac{V_o}{V_i} = 261 \cdot \frac{20k}{34k} \simeq \boxed{154\, V/V = A}$$

10. (c) $A_f = \dfrac{154}{1+(154)(0.2)} = \boxed{4.8\ V/V}$

(d) $R_i = 4k + 20k + 10k = 34k$

$R_{if} = R_i(1+A\beta) \cong 1\,Meg\,\Omega$

$R_{in} = R_{if} - R_s \cong \boxed{1\,Meg\,\Omega}$

11. (a) $I_{B1} = I_{B2} = \dfrac{I_E}{\beta+1}$

$I_{E3} = \dfrac{2I_E}{\beta+1}$

$I_{B3} = \dfrac{2I_E}{(\beta+1)^2}$

$I_o = I_{C1} = \left(\dfrac{\beta}{\beta+1}\right) I_E$

(b) $I_{REF} = I_{C1} + I_{B3} = \dfrac{\beta}{\beta+1} I_E + \dfrac{2I_E}{(\beta+1)^2} = \dfrac{[\beta(\beta+1)+2]I_E}{(\beta+1)^2}$

$\therefore I_E = \dfrac{I_{REF}(\beta+1)^2}{\beta(\beta+1)+2} = \dfrac{I_{REF}\ (\beta+1)^2}{\left[1+\frac{2}{\beta(\beta+1)}\right]\beta\cancel{(\beta+1)}}$

$= \dfrac{I_{REF}\ (\beta+1)}{\beta\left(1+\frac{2}{\beta(\beta+1)}\right)}$

$\therefore I_o = \left(\dfrac{\cancel{\beta}}{\cancel{\beta+1}}\right)\left(\dfrac{\cancel{\beta+1}}{\cancel{\beta}}\right)\boxed{\left[\dfrac{I_{REF}}{1+\frac{2}{\beta(\beta+1)}}\right]}$

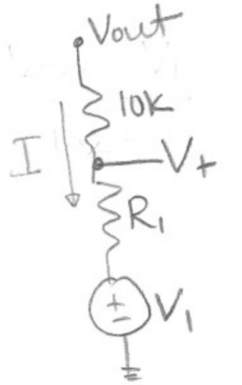
(c) $\dfrac{I_o}{I_{REF}} = \boxed{0.99980}$

(d) $V_{B3} = V_{C1} = \boxed{1.4V}$

12. (a) $V_+ = 2V$

(b) $V_+ = 0V$

(c)



$V_{out} = +2,\ V_+ = 2V$

$V_+ = \frac{2 - V_1}{R_1} = \frac{2-2}{10K} = 0$

$\therefore\ V_1 = \boxed{2V}$

$V_{out} = -2,\ V_+ = 0V$

$\frac{0-2}{R_1} = \frac{0-2}{10K}$

$\frac{2 \cdot 10K}{+2} = R_1 = \boxed{10K}$

Check:

$I = \frac{V_{out} - V_1}{20K} \Rightarrow$ If $V_{out} = 2V \Rightarrow I = 0,\ V_+ = 2V$

when $V_{IN} = 2$ or larger, the output goes to negative rail. $\Rightarrow -2V.$ ✓

If $V_{out} = -2 \Rightarrow I = \frac{-4}{20K} = -200\mu A$

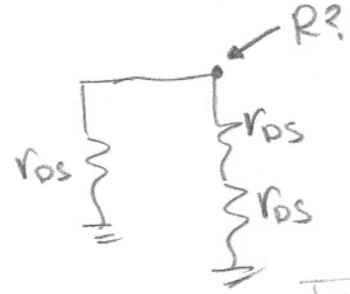
$V_+ \Rightarrow -V_{out} + 10K(I) + V_+$

$V_+ = V_{out} - 10K(I) = -2 - 10K(-200\mu) = 0V.$

13. (a)

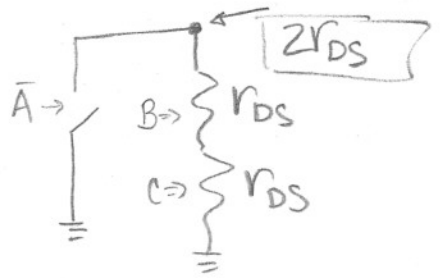
A	B	C	Y
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0

(b)



$r_{DS} \| 2r_{DS} = \boxed{\frac{2}{3} r_{DS}}$

13. (c) $A = B = C = 1$



(d.) $r_{DS} = \dfrac{1}{k'\left(\frac{W}{L}\right)(V_{GS}-V_t)} = \dfrac{1}{80\mu\left(\frac{5\mu}{0.5\mu}\right)(5-0.5)}$

$\cong \boxed{278\Omega}$

14. $P_{tot.} = P_D + P_S$

$$\begin{array}{r} 100mW = P_S + (100M)C(5)^2 \\ -\quad 40mW = P_S + (100M)C(2.5)^2 \\ \hline 60mW = (100MC)(18.75) \end{array}$$

$\therefore\ C = 32pF$

$(100m) = P_S + 100M(32p)(25) \Rightarrow P_S = 20mW$

(a) $P_{tot.} = 20m + (100M)(32p)(4)^2 = \boxed{71.2mW}$

(b) $P_{tot.} = 20m + (50M)(32p)(5)^2 = \boxed{60mW}$

(c) $P_{tot.} = \boxed{20m}$