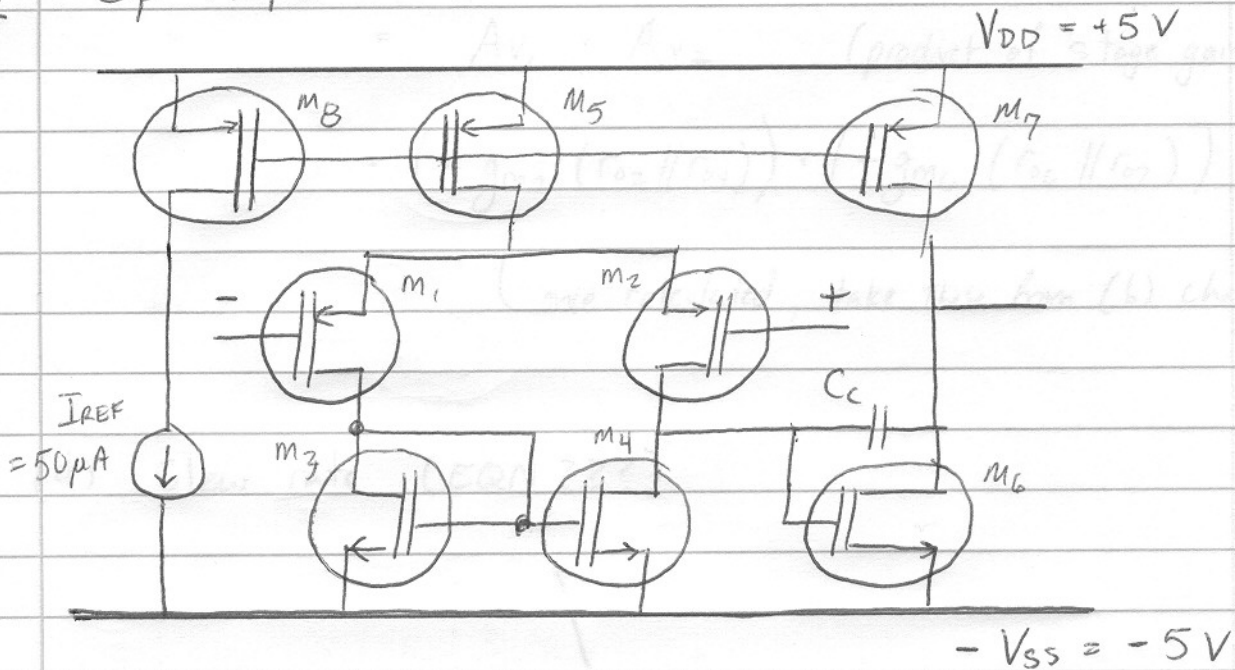


Q6 Op-Amp.



(a) Choose value  $W_7$  such that ckt does not exhibit a systematic offset voltage. ??? what does this mean  
 satisfy  $\frac{(W/L)_6}{(W/L)_4} = 2 \frac{(W/L)_7}{(W/L)_5}$  → how to calc?

(b)	$Q_1$	$Q_2$	$Q_3$	$Q_4$	$Q_5$	$Q_6$	$Q_7$	$Q_8$
$\frac{W}{L}$	$\frac{120}{8}$	$\frac{120}{8}$	$\frac{50}{10}$	$\frac{50}{10}$	$\frac{150}{10}$	$\frac{100}{10}$	$\frac{300}{10}$	$\frac{300}{10}$
$I_D$	$25\mu$	$25\mu$	$25\mu$	$25\mu$	$50\mu$	$50\mu$	$50\mu$	$50\mu$
$V_{GS}$	1.41	1.41	1.582	1.582	1.58	2	2	1.41
$\frac{2I_D}{V_{GS} - V_t} = g_m$	122	122	50	50				
$\frac{V_A}{I_D} = r_o$	<del>1000k</del>	<del>1000k</del>	<del>1000k</del>	<del>1000k</del>	500k	500k	500k	500k

$$V_{GS} = V_t + \sqrt{\frac{2I_D}{\mu C_{ox} (\frac{W}{L})}}; \quad I_D = \frac{1}{2} \mu C_{ox} \left(\frac{W}{L}\right) (|V_{GS}| - |V_t|)^2$$

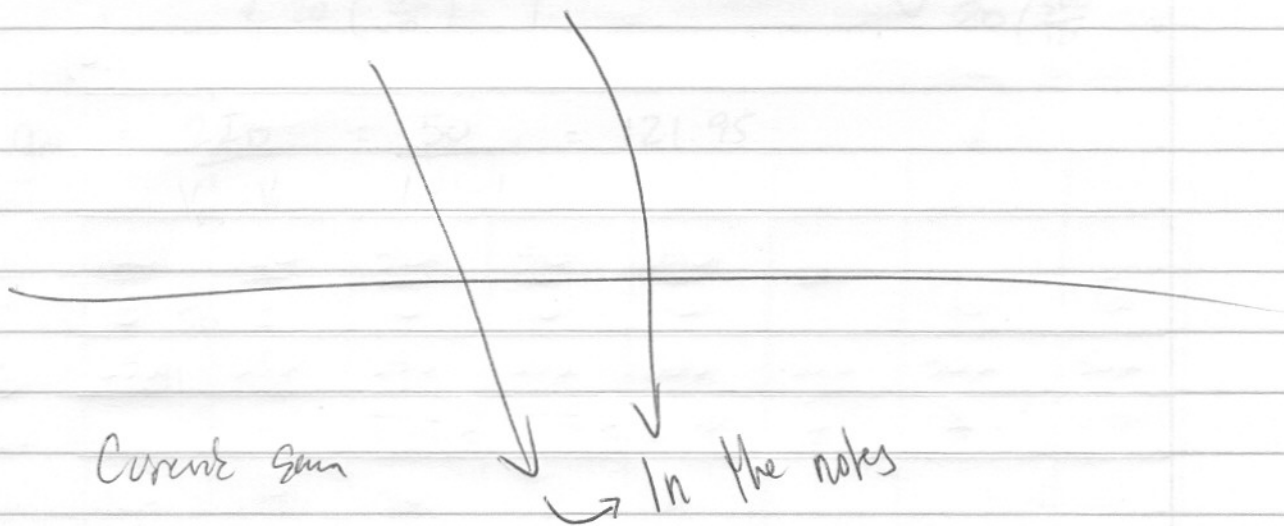
$$A_{v1} = -g_{m2} (r_{o2} \parallel r_{o4}); \quad A_{v2} = -g_{m6} (r_{o6} \parallel r_{o7})$$

$$\begin{aligned}
 \text{(c) } A_{v(\text{total})} &= \overset{\text{GAIN}}{\text{Stage ①}} \cdot \overset{\text{GAIN}}{\text{Stage ②}} \\
 &= A_{v_1} \cdot A_{v_2} \quad (\text{product of stage gains}) \\
 &= \left( -g_{m_2} (r_{o_2} \parallel r_{o_4}) \right) \cdot \left( -g_{m_6} (r_{o_6} \parallel r_{o_7}) \right)
 \end{aligned}$$

↑ once calculated, take these from (b) chart

(d) Slew rate (EQN ???)

(e) -3 dB frequency (EQN for cutoff frequency ???)



Q  $\mu_n C_{ox} = 20 \mu$   $\mu_p C_{ox} = 10 \mu$

Op-Amp

$$V_{GS1} = V_t + \sqrt{\frac{2I_D}{\mu C_{ox} (\frac{W}{L})}} = 1 + \sqrt{\frac{50 \mu A}{20 \mu (\frac{120}{8})}} = 1.415V$$

$$V_{GS3} = (1) + \sqrt{\frac{50}{10 (\frac{120}{8})}} = 1.58$$

$$V_{GS6} = (1) + \sqrt{\frac{100}{10 (\frac{100}{10})}} =$$

$$V_{GS3} = 1 + \sqrt{\frac{50}{10 (\frac{50}{10})}}$$

$$V_{GS5} = 1 + \sqrt{\frac{100}{20 (\frac{150}{10})}} \quad V_{GS8} = 1 + \sqrt{\frac{100}{20 (\frac{300}{10})}}$$

$$g_{m1} = \frac{2I_D}{V_{GS} - V_t} = \frac{50}{1.41 - 1} = 121.95$$

$V_{GS1}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS2}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS3}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS4}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS5}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS6}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS7}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS8}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS9}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS10}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS11}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS12}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS13}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS14}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS15}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS16}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS17}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS18}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS19}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS20}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS21}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS22}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS23}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS24}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS25}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS26}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS27}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS28}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS29}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS30}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS31}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS32}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS33}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS34}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS35}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS36}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS37}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS38}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS39}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS40}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS41}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS42}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS43}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS44}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS45}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS46}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS47}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS48}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS49}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41
$V_{GS50}$	1.41	1.41	1.58	1.58	1.58	1.58	1.41

$$V_{GS} = V_t + \sqrt{\frac{2I_D}{\mu C_{ox} (\frac{W}{L})}} \quad I_D = \frac{1}{2} \mu C_{ox} (\frac{W}{L}) (V_{GS} - V_t)^2$$

$$A_v = -g_{m1} (r_{o1} \parallel r_{o2})$$

$$A_v = -g_{m2} (r_{o1} \parallel r_{o2})$$