6.1 (a). $L_{eff} = L - 2\cdot L_D = (2 - 2\times 0.1)\,\mu m = 1.8\,\mu m$

$g_m = \mu_n C_{ox}\frac{W}{L_{eff}}(V_{GS}-V_{Tn})$

$V_{Tn} = V_{T0n} + \gamma_n\left(\sqrt{-2\phi_p - V_{BS}} - \sqrt{-2\phi_p}\right) = 1V + 0.6V^{\frac{1}{2}}\cdot\left(\sqrt{2\times 0.42V+1V} - \sqrt{2\times 0.42V}\right)$

$= 1.264\,V$

$\therefore g_m = 50\times10^{-6}\frac{A}{V^2}\times\frac{14\mu m}{1.8\mu m}\times(3V-1.264V) = \boxed{675\,\mu S = 6.75\times10^{-4}\frac{A}{V}}$

$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L_{eff}}(V_{GS}-V_{Tn})^2(1+\lambda_n V_{DS})$

$= \frac{1}{2}\times 50\times10^{-6}\frac{A}{V^2}\times\frac{14}{1.8}\times(3V-1.264V)^2\left(1+\frac{0.1}{1.8}V^{-1}\cdot 4V\right)$

$= 716\,\mu A$

$r_o = \frac{1}{\frac{1}{2}\mu_n C_{ox}\frac{W}{L_{eff}}(V_{GS}-V_{Tn})^2\cdot\lambda_n} = \boxed{30.7\,k\Omega}$

(b). $C_{GS} = \frac{2}{3}W\cdot L_{eff}C_{ox} + W\cdot C_{ov}$

$C_{ox} = \frac{\varepsilon_{ox}\cdot\varepsilon_0}{T_{ox}} = \frac{3.9\times 8.85\times10^{-14}\,F/cm}{1.5\times10^{-6}\,cm} = 2.3\,fF/\mu m^2$

$C_{ov} = \frac{\varepsilon_{ox}\cdot\varepsilon_0}{T_{ox}}\cdot L_D = 2.3\,fF/\mu m^2\cdot 0.1\,\mu m = 0.23\,fF/\mu m$

$\therefore C_{gs} = \frac{2}{3}\times 14\,\mu m\times 1.8\,\mu m\cdot 2.3\,fF/\mu m^2 + 14\,\mu m\times 0.23\,fF/\mu m$

$= \boxed{41.86\,fF}$

$C_{gd} = W\cdot C_{ov} = \boxed{3.22\,fF}$

$\phi_{n+} = 550\,mV$ (heavily doped n-type silicon)

$\phi_p = -60mV\cdot\log\left(\frac{N_a}{10^{10}}\right) = -60mV\cdot\log\left(\frac{10^{17}}{10^{10}}\right) = -420\,mV$

$\phi_B = \phi_{n+} - \phi_p = 550\,mV - (-420\,mV) = 970\,mV$

$C_{j0} = \varepsilon_s\sqrt{\frac{q}{2\varepsilon_s\phi_B}\left(\frac{1}{N_a}+\frac{1}{N_d}\right)^{-1}} \doteq \sqrt{\frac{q\varepsilon_s N_a}{2\phi_B}}$

$\therefore C_{j0} = \sqrt{\frac{1.6\times10^{-19}C\times 11.7\times 8.85\times10^{-14}\,F/cm\times10^{17}\,cm^{-3}}{2\times 0.97V}} = 0.92\,fF/\mu m^2$

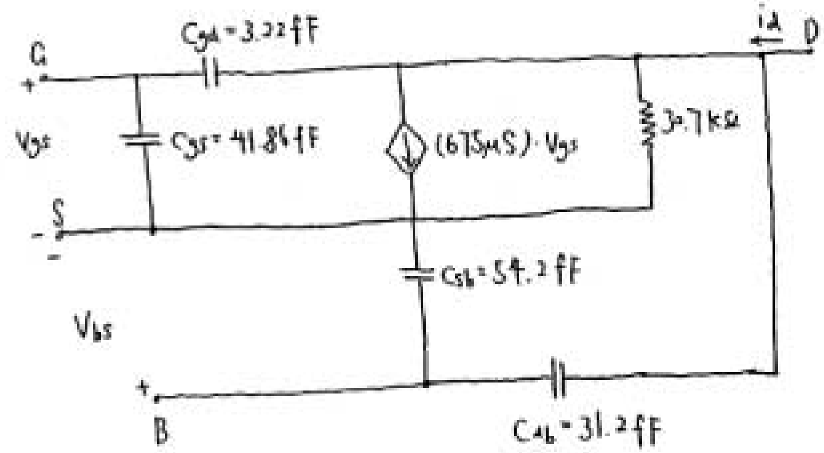
$V_{BS} = -1V$

$C_{sb} = \frac{W\cdot L_{eff}\cdot C_{j0}}{\sqrt{1-V_{BS}/\phi_B}} = \frac{14\,\mu m\times 6\,\mu m\times 0.92\,fF/\mu m^2}{\sqrt{1-(-1V)/0.97V}} = \boxed{54.2\,fF}$

$V_{BD} = -5V$

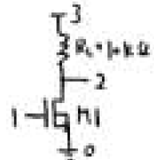
$C_{db} = \frac{W\cdot L_{eff}\cdot C_{j0}}{\sqrt{1-V_{BD}/\phi_B}} = \frac{14\,\mu m\times 6\,\mu m\times 0.92\,fF/\mu m^2}{\sqrt{1-(-5V)/0.97V}} = \boxed{31.2\,fF}$

(c).



6.2 (a)

```
.MODEL NMOS NMOS LEVEL=1 VTO=1
+ KP=50U LAMBDA=0.056 GAMMA=0.6
+ PHI=0.42 CGDO=2.3E-10 CGSO=2.3E-10
+ CJ=9.2E-4
```



where VTO $= V_{TO n}$, KP $= \mu_n C_{ox}$, LAMBDA $= \lambda_n (L_{eff}) = \frac{0.1}{1.8} = 0.056$

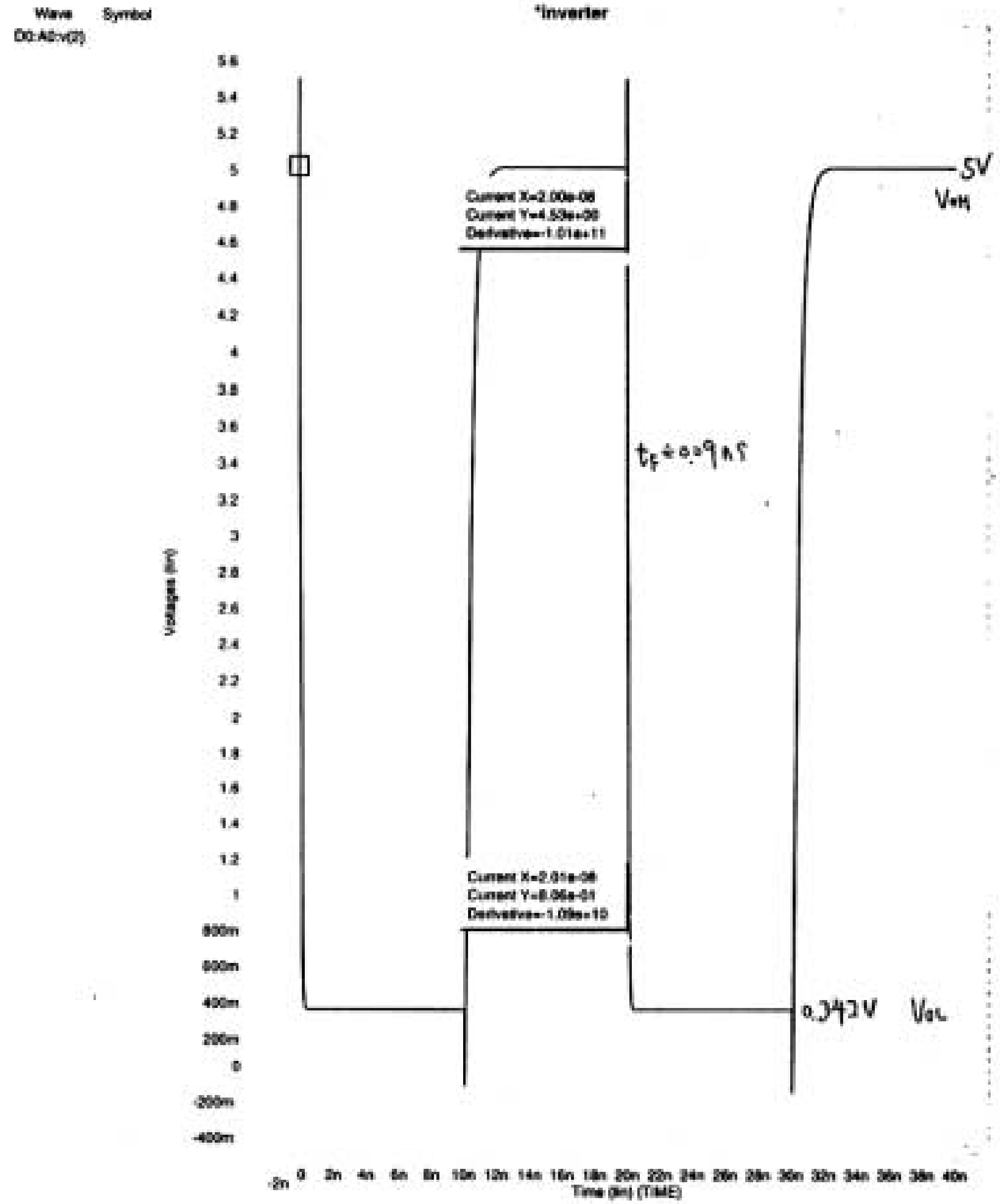
GAMMA $= \gamma_n$, PHI $= -\phi_p$, CGDO $= C_{ov}$, CGSO $= C_{ov}$, CJ $= C_{jo}$

(b)

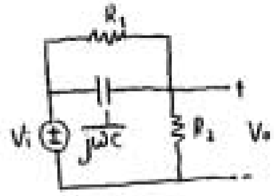
```
     D G S B
M1   3 1 0 0  NMOS W=14U L=2U AD=8.4E-11 AS=8.4E-11
+ PD=2.6E-5 PS=2.6E-5
```

(c). From SPICE, $V_{OH} = 5V$, $V_{OL} = 0.34V$

(d). From SPICE, $t_F = 0.09\,nS$



6.3. (a)



$$\frac{V_o(j\omega)}{V_i(j\omega)} = \frac{R_2}{R_2 + (R_1 \| \frac{1}{j\omega C})} = \frac{R_2}{R_2 + \frac{R_1 \frac{1}{j\omega C}}{R_1 + \frac{1}{j\omega C}}} = \frac{R_2(1+j\omega R_1 C)}{R_1 + R_2 + j\omega R_1 R_2 C}$$

$$= \boxed{\underbrace{\frac{R_2}{R_1+R_2}}_{\text{DC gain}} \cdot \frac{1+j\omega C R_1}{1+j\omega C \frac{R_1 R_2}{R_1+R_2}}}$$

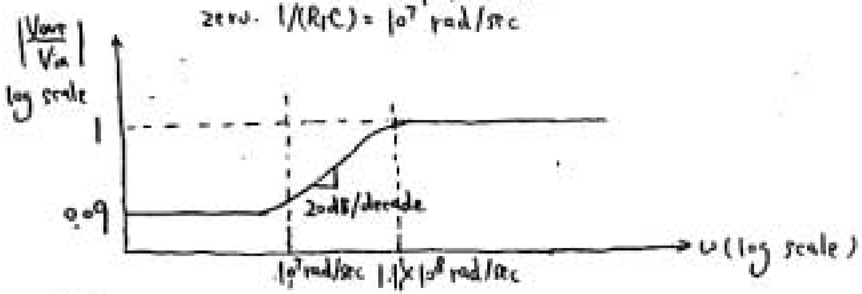
pole $1/(\frac{R_1 R_2}{R_1+R_2} \cdot C)$

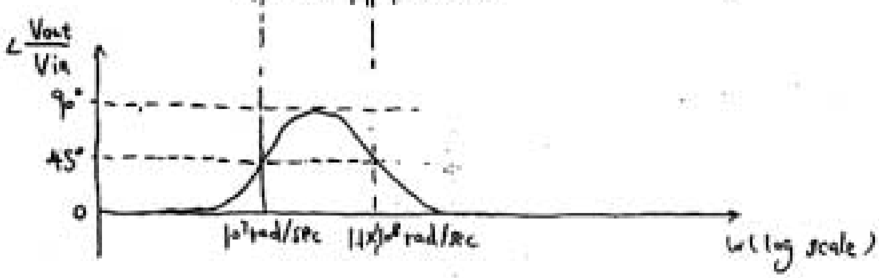
zero: $\frac{1}{R_1 C}$

(b). DC gain $= \frac{R_2}{R_1+R_2} = 0.09$

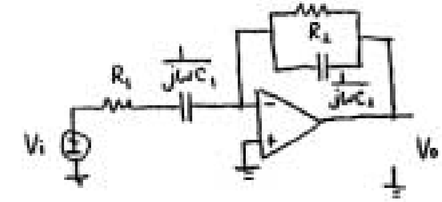
pole $1/(\frac{R_1 R_2}{R_1+R_2} \cdot C) = \frac{1}{\frac{100k\Omega \times 10k\Omega}{100k\Omega + 10k\Omega} \cdot 1pF} = 1.1 \times 10^8$ rad/sec

zero. $1/(R_1 C) = 10^7$ rad/sec





6.4 (a)



$$\frac{V_i}{R_1 + \frac{1}{j\omega C_1}} = -\frac{V_o}{R_2 \| \frac{1}{j\omega C_2}}$$

$$\therefore \frac{V_o(j\omega)}{V_i(j\omega)} = -\frac{R_2 \| \frac{1}{j\omega C_2}}{R_1 + \frac{1}{j\omega C_1}} = -\frac{j\omega R_2 C_1}{(1+j\omega R_1 C_1)(1+j\omega R_2 C_2)}$$

$\omega = 0$, $\frac{V_o(j\omega)}{V_i(j\omega)} = 0$, $\omega \to \infty$, $\frac{V_o(j\omega)}{V_i(j\omega)} = 0$

pole 1: $\frac{1}{R_1 C_1} = 10^7$ rad/sec , pole 2: $\frac{1}{R_2 C_2} = 10^8$ rad/sec