ECE 145B Homework #7 Solutions

#1

$f_{IF} = 10\,GHz$

$f_{RF} = 60\,GHz$

f_{LO}	f_{image}
50 GHz	40 GHz
or	
70 GHz	80 GHz

#2

a) $f_{LO} = 50\,GHz$

$F_{amp} = 1.5\,dB$
$IIP3_{amp} = 0\,dBm$

$F_{mixer} = 6\,dB$
$G = -6\,dB$
$IIP3_{mixer} = 0\,dBm$

$F_{IFamp} = 4\,dB$
$IIP3_{IFamp} = -10\,dBm$

$$F_{total} = F_{1amp} + \frac{F_{mixer} - 1}{G_{LNA}} + \frac{F_{IFamp} - 1}{G_{LNA} G_{mixer}}$$

$$F_{total} = 1.41 + \frac{9}{G_{LNA}}$$

$$IIP3_{from\ mixer} = \frac{IIP3_{mixer}}{G_{LNA}} = 0\,dBm - G_{LNA}(dB) = \frac{1\,mW}{G_{LNA}(linear)}$$

$$IIP3_{LNA} = 0\,dBm$$

b) $G_{LNA} = 20\,dB$

$$F_{total} = 1.41 + \frac{9}{100} = 1.5$$

$$IIP3_{mixer} = -20\,dBm = IIP3_{rec.}$$

c)

$$P_{min} = KTFBQ^2$$

$$= (300)(1.38 \times 10^{-23})(1.5)(2e9)(10)$$

$$P_{min} = 1.241 \times 10^{-10}\,W = -69.05\,dBm$$

#3

IF filter irrelevant since mixer IIP3 dominates and term will be @ 10 GHz.

$S_{21}(6.1\text{GHz}) = S_{21}(6.2\text{GHz}) = 0\text{dB}$

for $P(f_2 - f_1) = -69.05\text{dBm}$:

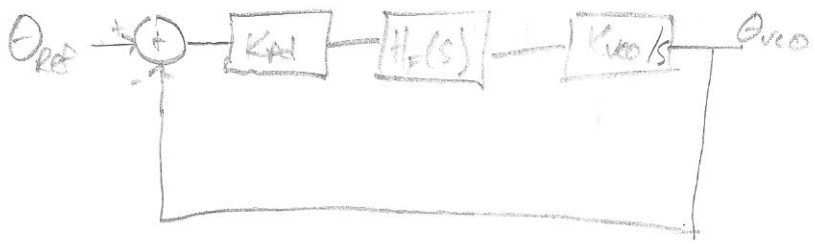
$$P(f_1) = IP3 - \frac{P(f_2) - P(2f_1 - f_2)}{2}$$

$$3P(f_1) = 2IP3 + P(2f_1 - f_2)$$

$$P(f_1) = \frac{2}{3}(-20) + \frac{-69.05}{3} \quad (\text{dBm})$$

$$\boxed{P(f_1) = P(f_2) = -36.3\text{dBm}}$$

#4



$V_o(t) = A_{mixer} \cdot V_{ref}(\sin(\Delta\omega t + \Delta\theta))$

$\Delta\omega = 0$ for small $\Delta\theta$, $V_o(t) = A_{mix} \cdot V_{ref} \cdot \Delta\theta$

$K_{pd} = 200mV$

$K_{vco} = \frac{16Hz}{1V} = 1e9\ Hz/V$

$T(s) = \frac{K_{pd} K_{vco}(1+s\tau_2)}{s^2 \tau_1}$

$\omega_x^2 = \frac{K_{pd} K_{vco}}{\tau_1}$ $\quad \omega_x = 2\pi(100KHz)$

$\boxed{\tau_1 = 5.07 \times 10^{-4}\ s/rad}$

a) $\omega_{zero} = \omega_x = 2\pi(100KHz)$

$$T(s) = \frac{(.2)(1e9)\left(1+s\left(\frac{1}{2\pi \cdot 100KHz}\right)\right)}{s^2(5.07\times10^{-4})}$$

loop BW: $|T(\omega_{loop})| = 1$ $\quad$ phase margin: $180 - \angle T(\omega_{loop})$

b)
$$\frac{\sqrt{(.2\cdot 1e9)^2 + \left(\frac{\omega_{loop}\cdot .2\cdot 1e9}{2\pi\ 100KHz}\right)^2}}{\omega_{loop}^2(5.07\cdot10^{-4})} = 1$$

$\omega_{loop} = 8e5$ rad/sec $= 127$ KHz

c) matlab: PM $= 51.8°$

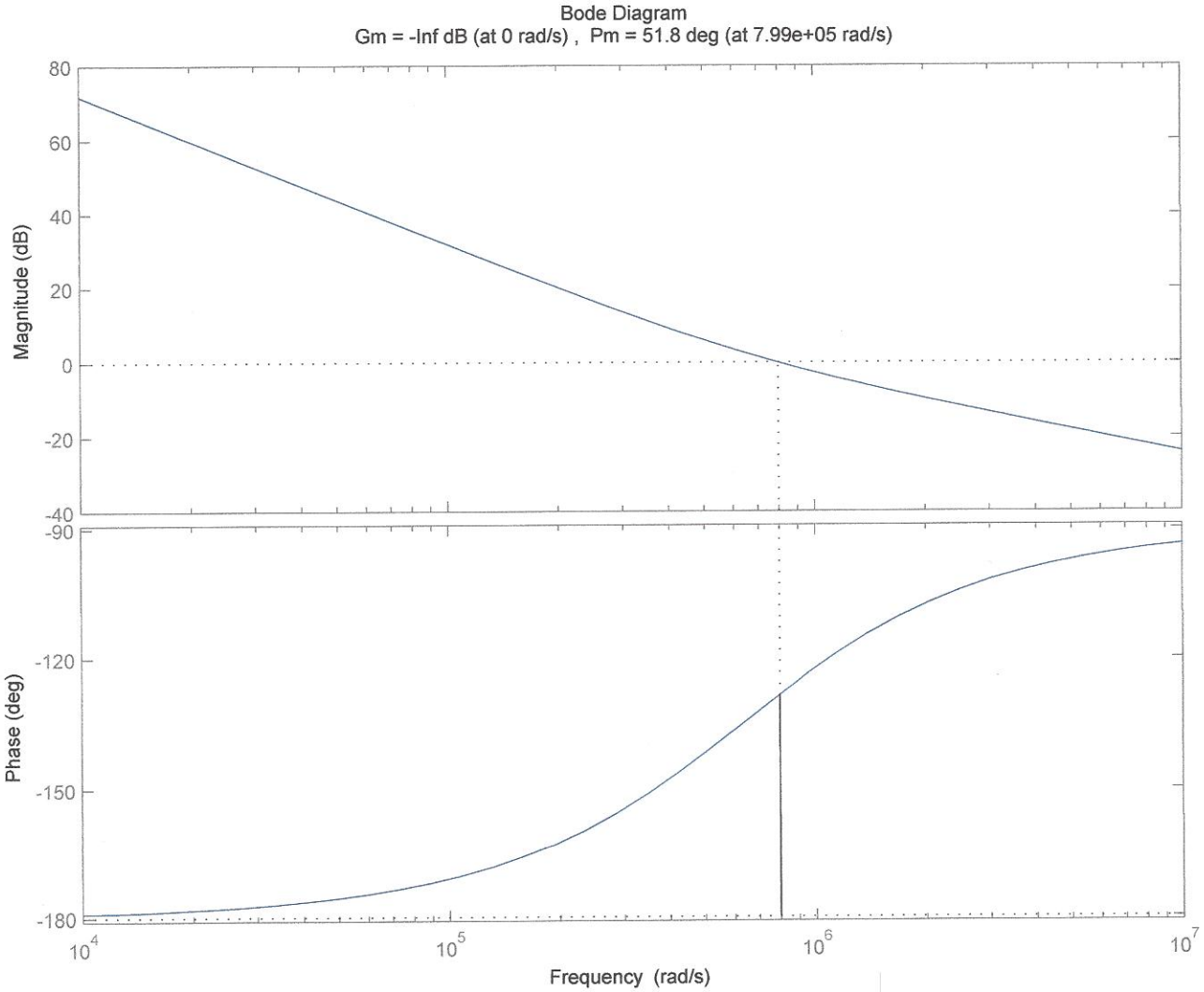
$\left\| \frac{d\omega_{vco}}{dt} \right\|_{max} = \omega_x^2 = 3.948 \times 10^{11}\ rad^2/sec^2$

d) $\theta_{ref} - \theta_{vco} = \left(\frac{d\omega_{vco}}{dt}\right)\left(\frac{\tau_1}{K_{vco}K_{pd}}\right) = \frac{1}{10}\left(\frac{K_{vco}K_{pd}}{\tau_1}\right)\left(\frac{\tau_1}{K_{vco}K_{pd}}\right) = .1$ rad

e) freq eq. BW $\approx \omega_{loop} = 8e5$ rad/sec

#4

T(s)


Bode Diagram
Gm = -Inf dB (at 0 rad/s) , Pm = 51.8 deg (at 7.99e+05 rad/s)
Magnitude (dB)
80
60
40
20
0
-20
-40
Phase (deg)
-90
-120
-150
-180
10^4
10^5
10^6
10^7
Frequency (rad/s)

#5

$$\frac{\theta_{VCO}(s)}{\theta_{REF}(s)} = \frac{NT(s)}{1+T(s)} \qquad \frac{\theta_{VCO}(s)}{\theta_{n,VCO}(s)} = \frac{1}{1+T(s)}$$

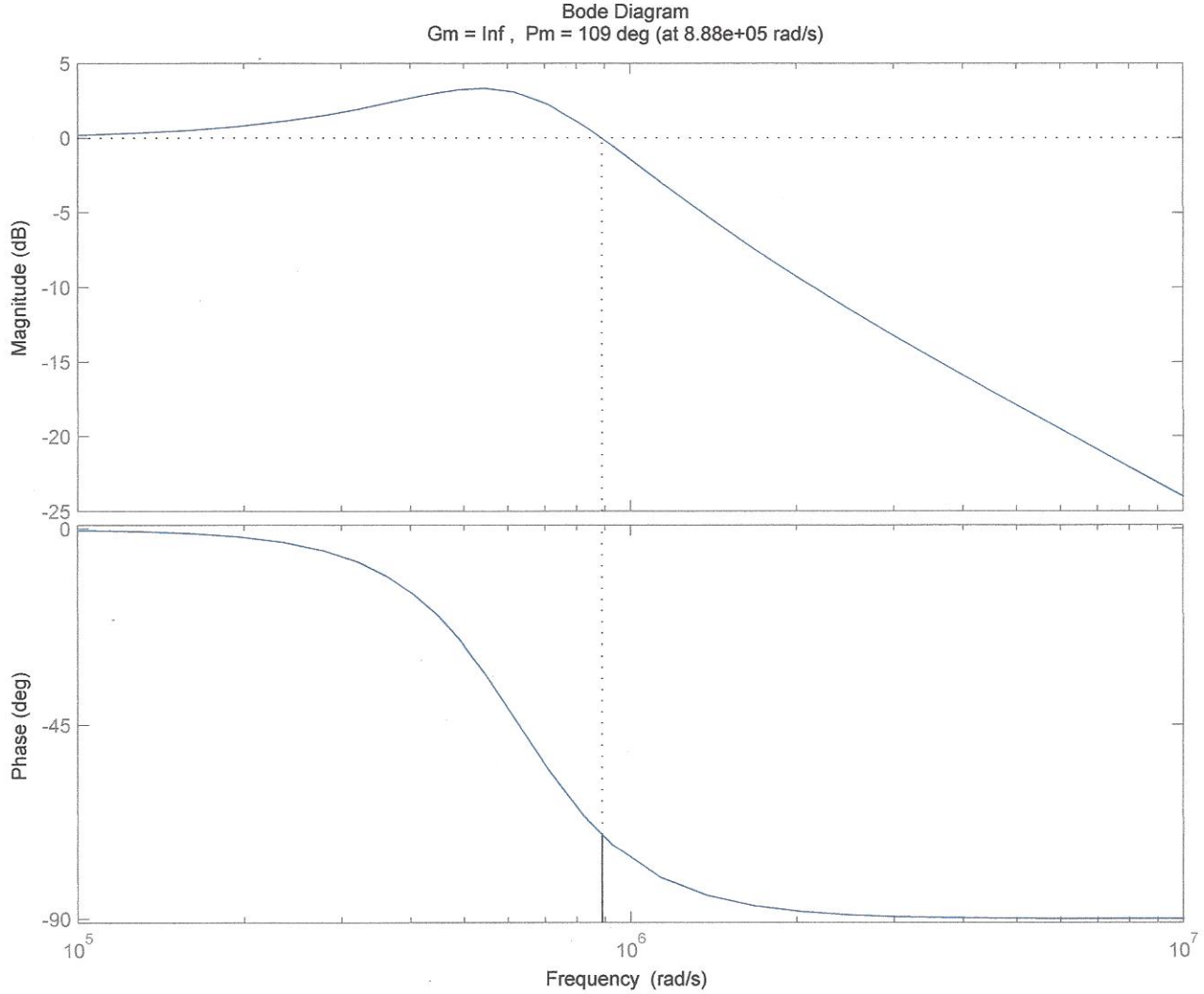
plots attached

$$\frac{\theta_{VCO}}{\theta_{REF}}(100Hz) \approx 1 \Rightarrow -100dBc \text{ @ } 100Hz \text{ offset at output}$$

$$\frac{\theta_{VCO}}{\theta_{n,VCO}}(10KHz) \approx -40dB \qquad -90-40 \Rightarrow -130dBc \text{ @ } 10KHz \text{ offset at output}$$

#5

$$\frac{\theta_{VCO}(s)}{\theta_{REF}(s)}$$



#5

$$\frac{\theta_{vco}(s)}{\theta_{n,vco}(s)}$$