Homework Assignment 03

Question 1 Consider a sinusoidal oscillator consisting of an amplifier having a frequency-independent gain $A$ (where $A$ is positive) and a second-order bandpass filter with a pole frequency $\omega_0$, a pole $Q$ denoted $Q$, and a center-frequency gain $K$.

a) Find the frequency of oscillation and the condition that $A$ and $K$ must satisfy for sustained oscillation.

b) Derive an expression for $d\phi/d\omega$, evaluated at $\omega = \omega_0$, where $\phi$ is the phase of $A\beta(j\omega)$.

c) Use the result from (b) to find an expression for the per unit change in frequency of oscillation resulting from a phase angle change of $\Delta\phi$, in the amplifier transfer function.

Hints

$$\frac{d \tan^{-1} y}{dx} = \frac{1}{1 + y^2} \frac{dy}{dx}$$

The transfer function for a second-order BPF is

$$H(s) = \frac{s(\omega_0/Q)}{s^2 + s(\omega_0/Q) + \omega_0^2}$$

Where $K$ is the gain at resonance and all the other symbol have their usual meaning.

(25 points)

Question 2 Shown is a variation of the so-called “Bubba” oscillator we covered in class and in the homework. One can view the oscillator as consisting of 4 identical phase shift blocks, each block consisting of an amplifier with unity gain and an $RC$ network. Additionally, there is an inverting amplifier $A_1$ with gain $G$. All the amplifiers are ideal with $R_{out} = 0$ and $R_{in} \to \infty$.

a) Explain briefly (1-2 sentences) the purpose of $D_1$ and $D_2$. (2 points)
b) Ignoring $D_1$ and $D_2$, determine the transfer function $H(j\omega)$ for a phase shift block. (4 points)
c) Show/argue/explain that the oscillation frequency is $\omega = 1/RC$ rad/s. (4 points)
d) Consider the purity of the output, where would be the best place to take the output: $A$, $B$, $C$, $D$, or $E$? Explain briefly. (2 points)
e) Ignoring $D_1$ and $D_2$, determine an expression for the magnitude of the loop gain. (4 points)
f) Determine the minimum magnitude of the gain for the inverting amplifier to ensure oscillation. (4 points)
g) Predict the peak-to-peak voltage at $C$ assuming $A_1$ has gain $-5$. Assume $D_1$ and $D_2$ are Si diodes with turn on voltage 0.65 V. (5 points)
Question 3 Consider the two back-to-back diodes in the Wien bridge oscillator below. For these diodes one can define a large-signal resistance $R_{LS}$ for a symmetric voltage excursion with amplitude $V$ as

$$R_{LS} = \frac{\Delta V}{\Delta i} = \frac{V - (-V)}{2I_s \sinh \left( \frac{V}{V_T} \right) - 2I_s \sinh \left( - \frac{V}{V_T} \right)}$$

Determine the frequency of oscillation. Plot of $R_{LS}$ for $0.4 \leq V \leq 0.5$. Use this information and estimate the amplitude at which the oscillations stabilize. Assume that $I_s = 1 \times 10^{-14} \text{ A}$. (25 points)