Homework Assignment #9 - Due Wed. 4/17/13

A photograph of a MEMS gyroscope, that was fabricated in an SOI wafer, is presented in Figure 1. The proof mass is forced to move along the x-axis and sensing is made along the y-axis. The z-axis is orthogonal to the photograph, i.e. out of the paper. Answer the following questions about it:

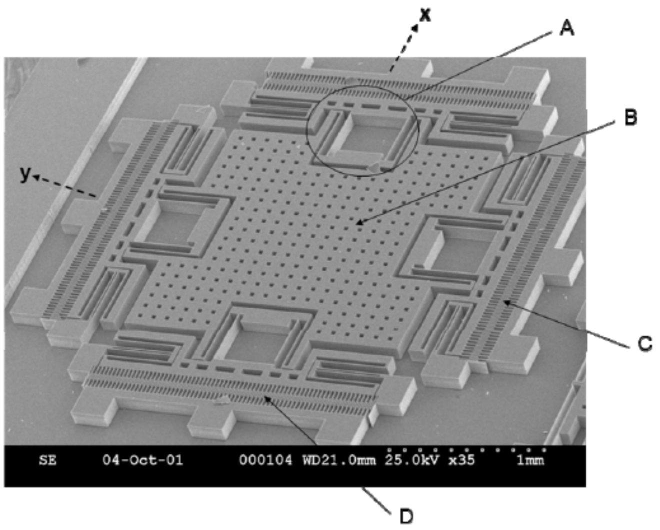

Figure 1: MEMS Gyroscope on SOI wafer. Movement is in the x-axis, while sensing is in the y-axis.

1) What is "A"?
   "A" is part of the suspension system.

2) What is "B"?
   "B" is the proof mass.

3) What are the holes in "B" for?
   The holes in "B" are used for the release etching.

4) What is "C" and what is it used for?
   "C" is a comb-drive actuator. It is used to actuate the proof mass in the x-direction so that the system can detect motion in the y-direction.

5) What is "D" and what is it used for?
   "D" is an interdigitated sense capacitor circuit. It is used to detect movement in the y-direction.

6) About which axis would rotational motion be sensed with this gyroscope?
   Because the actuators are moving the mass along the x-axis, and because the gyroscope sensors detect motion in the y-axis, the gyroscope will sense rotational motion about the z-axis.

7) Does this gyroscope sense angular position, angular rate, or angular acceleration?
   This gyroscope senses angular rate.

8) If the proof mass is $1\mu g$, Q=100, f_n=10KHz, $A_x = 1\mu N$, what is the damping coefficient, c, and the system spring constant, k, for the sensor?

$f_n = 10kHz \rightarrow \omega_n = 2\pi 10krad/s$

k $: {\omega_n}^2 = k/m \rightarrow k = {\omega_n}^2 m$

$: k = (2\pi 10000rad/s)^2(1\times10^{-9}kg)$

$: k = 3.948N/m$

c $: \omega_n/Q = c/m \rightarrow c = \frac{omega_n m}{Q}$

$: c = \frac{2\pi 10000rad/s \times 1\times10^{-9}kg}{100}$

$: c = 628.3\times10^{-9}Ns/m$

9) For the parameters in (8), what is the amplitude of displacement along the y-axis for $\Omega = 300°/s$?

$\Omega = 300°/s = 5.236rad/s$

$Y_d = \frac{2m\Omega A_x}{c^2\omega_n}$

$= \frac{2(1\times10^{-9})(5.236rad/s)(1\times10^{-6}N)}{(628.3\times10^{-9}Ns/m)^2(2\pi 10000rad/s)}$

$= 422.25\times10^{-9}m$

$Y_d = 422.25nm$

10) For the parameters in (8), what angular rate (in °/s), results in an amplitude of displacement along the y-axis of $1\mu m$?

$Y_d = \frac{2m\Omega A_x}{c^2\omega_n} \rightarrow \Omega = \frac{Y_d c^2\omega_n}{2mA_x}$

$\Omega = \frac{(1\times10^{-6}m)(628.3\times10^{-9}Ns/m)^2(2\pi 10000rad/s)}{2(1\times19^{-9}kg)(1\times10^{-6}N)}$

$\Omega = 12.4rad/s \rightarrow \Omega = 710.5°/s$