PROBLEM SET #9

Issued: Wednesday, April 14, 2021
Due: Wednesday, April 21, 2021, 12:00 noon via Gradescope

1. Continuing from Problem Set #8, using the same structures and figures, answer the following questions.

   (a) Suppose you apply an electrical potential $V_{PI}$ at Port 3 while still maintaining Port 1, 2 & 4 at 0V. Calculate the minimum voltage $V_{PI}$ that will pull the structure into Port 3.

   (b) Calculate the $x$-directed resonant frequency of the structure at room temperature ($20^\circ C$), assuming Port 2 is biased at 5V while Port 1, 3 and 4 are biased at 0V. Account for the velocity distribution when determining resonance frequency.

   (c) The suspended comb-drive structure’s resonance frequency varies with environmental temperature fluctuations due to Young’s Modulus temperature dependence, which creates issues in applications such as timing. The electrical stiffness can be used to stabilize the resonant frequency when temperature changes. For example, the right electric potential $V_{tune}$ applied at Port 4 can cancel the intrinsic frequency variation due to temperature change. Fig. PS9.1-1 presents a test configuration that drives the suspended comb-drive structure into resonance, with Port 1 driven by a small-signal ac voltage $v_i$ and Port 2, 3 & 4 biased at 5V, 0V, and $V_{tune}$, respectively. Derive the expression for $V_{tune}$ in terms of temperature $T$ that stabilizes the resonance frequency and plot $V_{tune}$ versus $T$ over a temperature range of $0^\circ C$ to $70^\circ C$. What value of $V_{tune}$ is needed at $0^\circ C$ and $70^\circ C$? (Assume the temperature coefficient of the structure’s resonance frequency ($TCF$) due to intrinsic Young’s Modulus change is $-30$ ppm/°C.)

Fig. PS9.1-1