

Homework #7

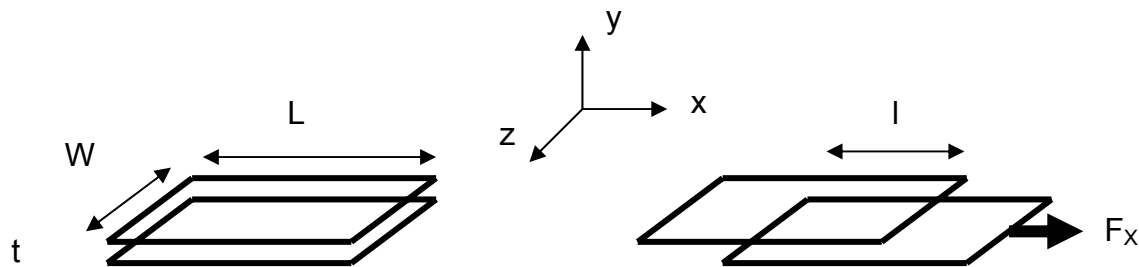
Question 1 (Electrostatic Sensing):

A MEMS accelerometer (similar to Analog Devices ADXL50) has 40 fingers that are 120 microns long and have an airgap of 1.3 microns. The accelerometer has a proof mass made of polysilicon whose effective dimensions is 380 x 40 x 2 microns.

- (i) Calculate the value of the sense capacitor.
- (ii) If the accelerometer is subjected to 1g acceleration, what is the displacement.
- (iii) Given the displacement of the finger structure, what is the change in the capacitance.
- (iv) Assuming that the capacitance is set to a voltage of 5 volts and an external circuit is designed to measure the charge how much charge do we expect to see flow in the external circuit.
- (v) If the 1g acceleration was applied in a time span of 1ms what is the current that will flow in our circuit.
- (vi) Is this easy to measure?

Question 2 (Electrostatic Actuation):

Electrostatic actuators rely on the transformation of the electrostatic energy stored in a capacitor into a displacement  $dx$  with a force  $F_x$ . Assume that all electrostatic actuation occurs in vacuum and ignore fringe field effects.



In the parallel plate capacitors shown above and with the plates at a voltage difference  $V$  (Volts)

- (i) Write the equation for the electrostatic energy in the two capacitance systems shown above.
- (ii) Derive the equations for the force in the  $x$ ,  $y$  and  $z$  directions. When the two parallel plates are slightly displaced, a restoring force develops that tends to align the plates in the parallel plate configuration. MEMS comb actuators rely on differential restoring forces generated along the  $x$  and  $z$  directions for their operation.

- (iii) Show that the restoring force per unit edge of the structure ( $F_x/W$ ) is proportional to the square of the electrostatic field in the capacitance system.
- (iv) Calculate the force  $F_y$  and the restoring force  $F_x$  in a MEMS structure formed by two parallel plates that have square geometry 100 micron on each side, separated by 2 micron at a potential difference of 50 volts.
- (v) To get a little bit more insight on the magnitude of the force that is pulling the plates together, compute the pressure on the plates ( $F_y/A$ ) where  $A$  is the area. How does this compare to typical atmospheric pressures.