PROBLEM SET #6

Issued: Tuesday, Oct. 30, 2012

Due (at 7 p.m.): Tuesday Nov. 20, 2012, in the EE C245 HW box near 125 Cory.

Figures PS6.1-6 show a dual-axis *x-y* accelerometer manufactured via the following 3-mask surface micromachining process:

i) Deposit 1.0 µm of SiO_2 on a Silicon wafer
ii) Deposit 300 nm of SiN_3 via LPCVD
iii) Deposit 200 nm of in-situ doped polysilicon
iv) Lithographically define and etch polysilicon interconnects (anisotropic)
v) Deposit 2.0 µm of SiO_2 (LTO)
vi) Lithographically define and then etch anchor openings in SiO_2 (anisotropic)
vii) Deposit 3.0 µm of in-situ doped polysilicon
viii) Lithographically define and then etch the polysilicon structure (anisotropic)
ix) Etch SiO_2 completely using an HF etch, releasing structure (isotropic)

Assume all materials are stress-free at room temperature and have the material properties listed in Table PS6.1.

Table PS6.1

Material	ρ_m kg/m^3	E GPa	ν	α_T µstrain/K	σ_0 MPa	Comment
Polysilicon	2300	150	0.2	2.8	Varies	Random Grains
Silicon Dioxide	2200	69	0.17	0.7	-300	Amorphous
Silicon Nitride	3170	270	0.27	2.3	1100	Stoichiometric

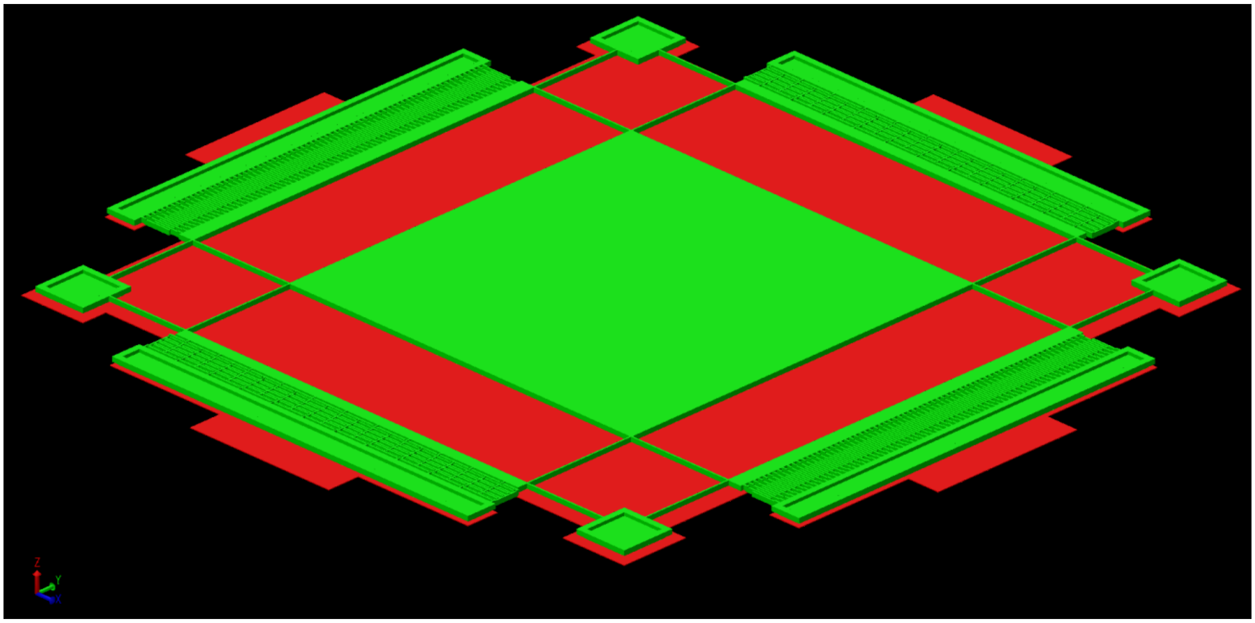

Figure PS6.1 – Perspective view of the accelerometer.

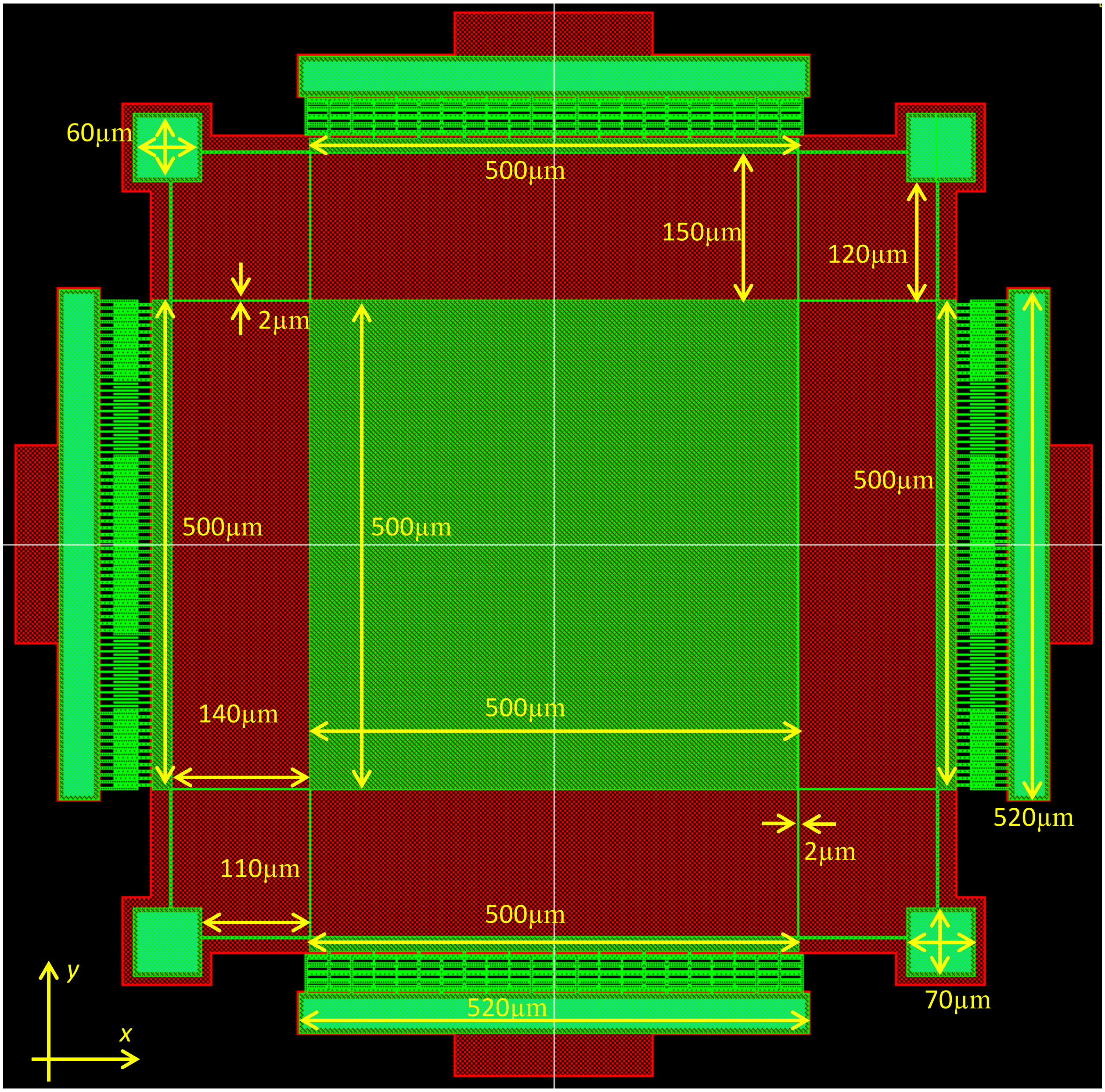

Figure PS6.2 – Top view of the accelerometer.

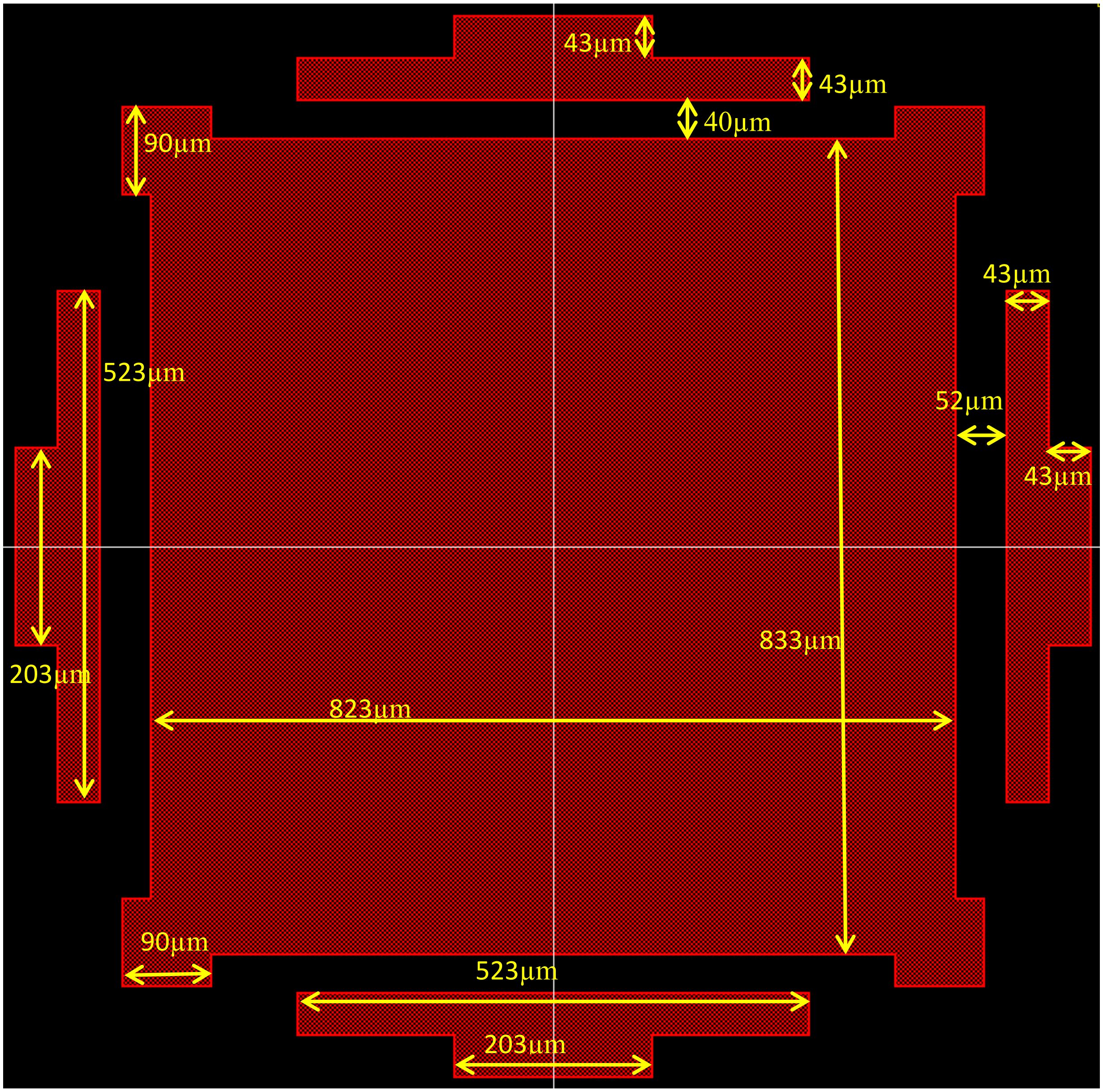

Figure PS6.3 – Top view of accelerometer showing only the interconnect layer.

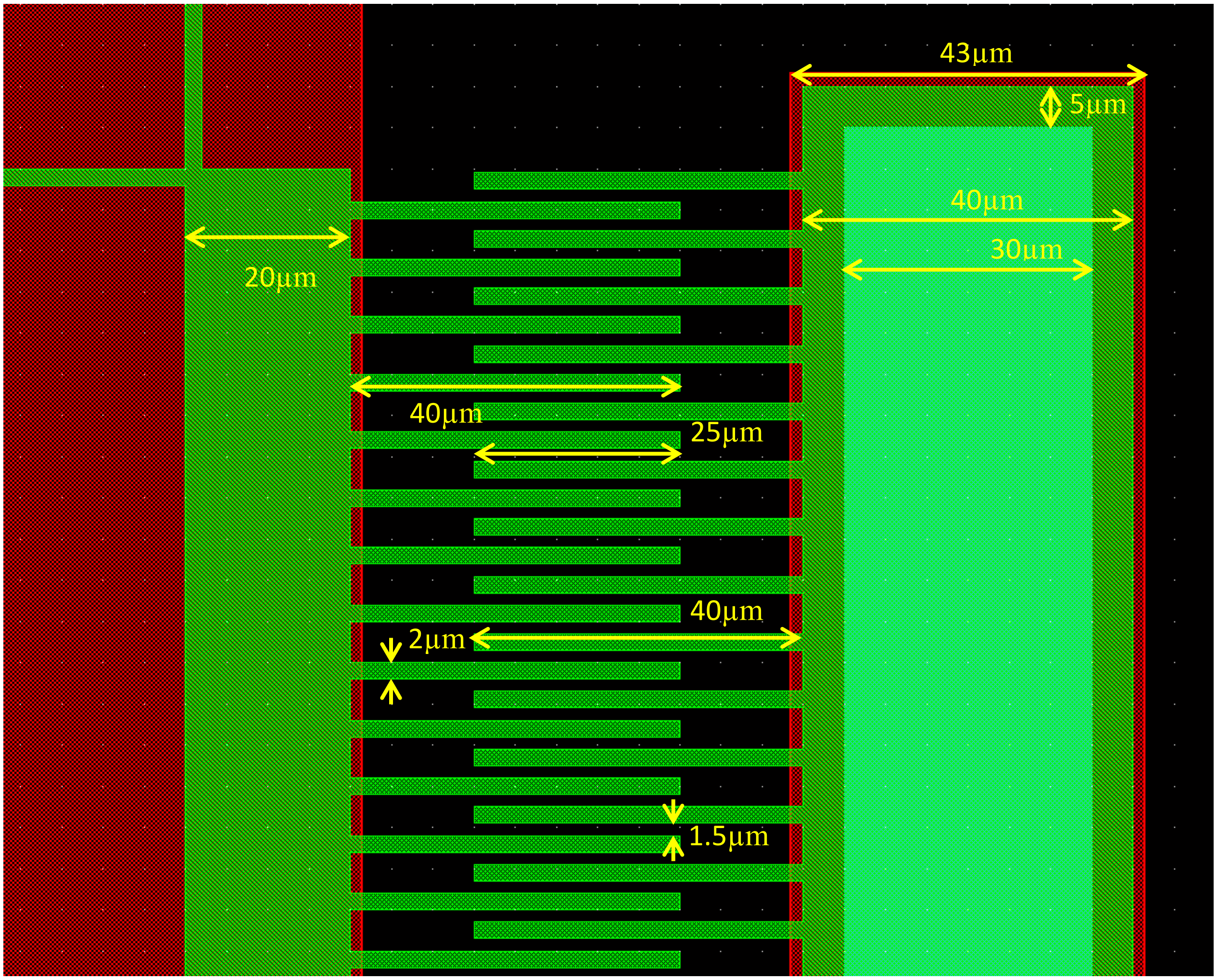

Figure PS6.4 – Zoom-in view of the *x*-direction interdigital comb finger structure. There are 71 fingers on each side of the proof mass.

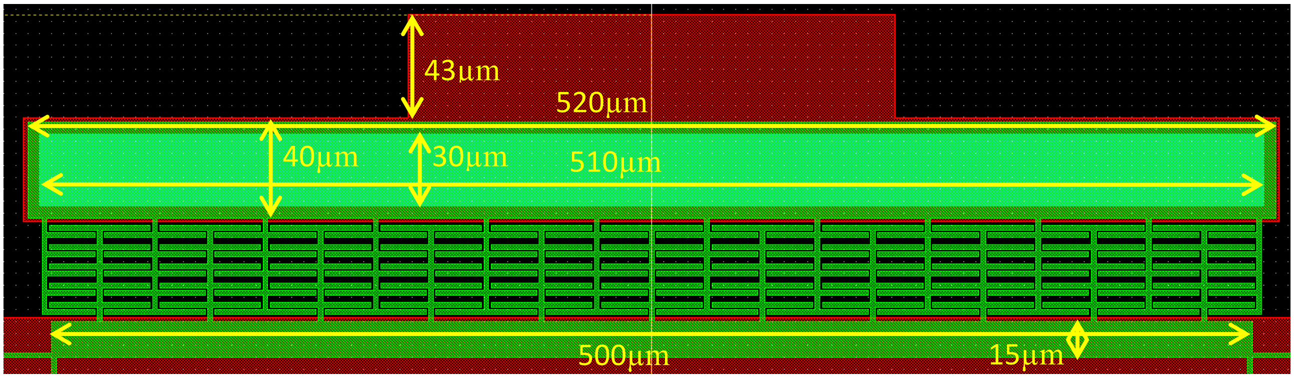

Figure PS6.5 – Top view showing the *y*-direction capacitor structure.

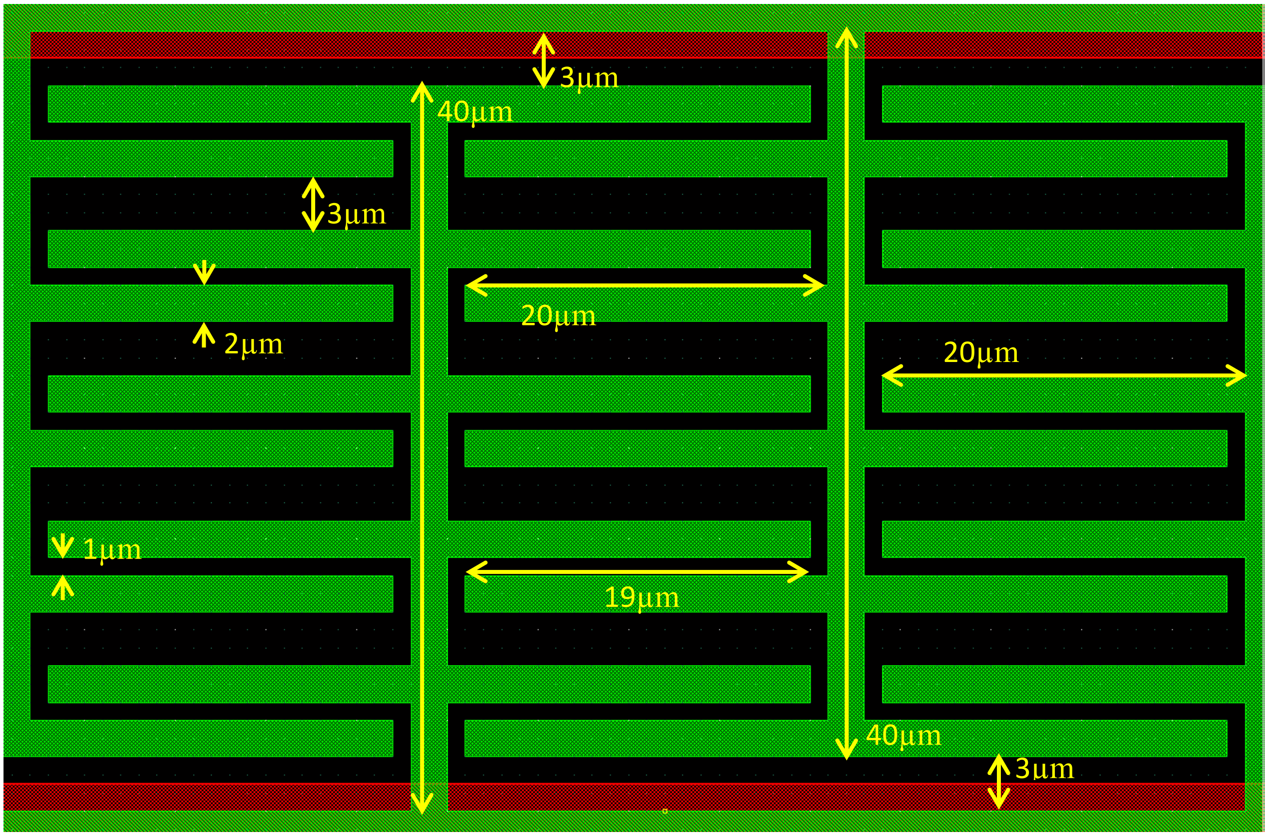

Figure PS6.6 – Zoom-in view of the *y*-direction capacitor structure.

1. Calculate the *x*- and *y*-directed resonance frequencies of the accelerometer structure with no applied DC bias, making simplifying assumptions as necessary. Do NOT neglect the beam masses in these calculations. Assuming a quality-factor Q of 5 in both directions, draw the frequency response for the accelerometer in both the *x*- and *y*-directions.
2. Derive an expression for the capacitance between port *A* and *B* shown in Figure PS6.7 as a function of displacement x using a parallel-plate approximation. Also, calculate the overlap capacitance between these two ports at rest.
3. Derive an expression for the capacitance between port *A* and *C* shown in Figure PS6.7 as a function of displacement y using a parallel-plate approximation. Also calculate the overlap capacitance between these two ports at rest.
4. Suppose the accelerometer is now hooked up as shown in Figure PS6.7, with a DC bias V_{bias} of 10V applied to the structure.
   - **(a)** Calculate the new *x*- and *y*-directed resonance frequencies with this DC bias.
   - **(b)** If a sinusoidal force signal is applied to the structure in the *x*-direction with a magnitude of 1g, what will be the magnitude and phase of the resulting output current i_B as a function of frequency?

(c) If a sinusoidal force signal is applied to the structure in the *y*-direction with a magnitude of 1g, what will be the magnitude and phase of the resulting output current i_C as a function of frequency?

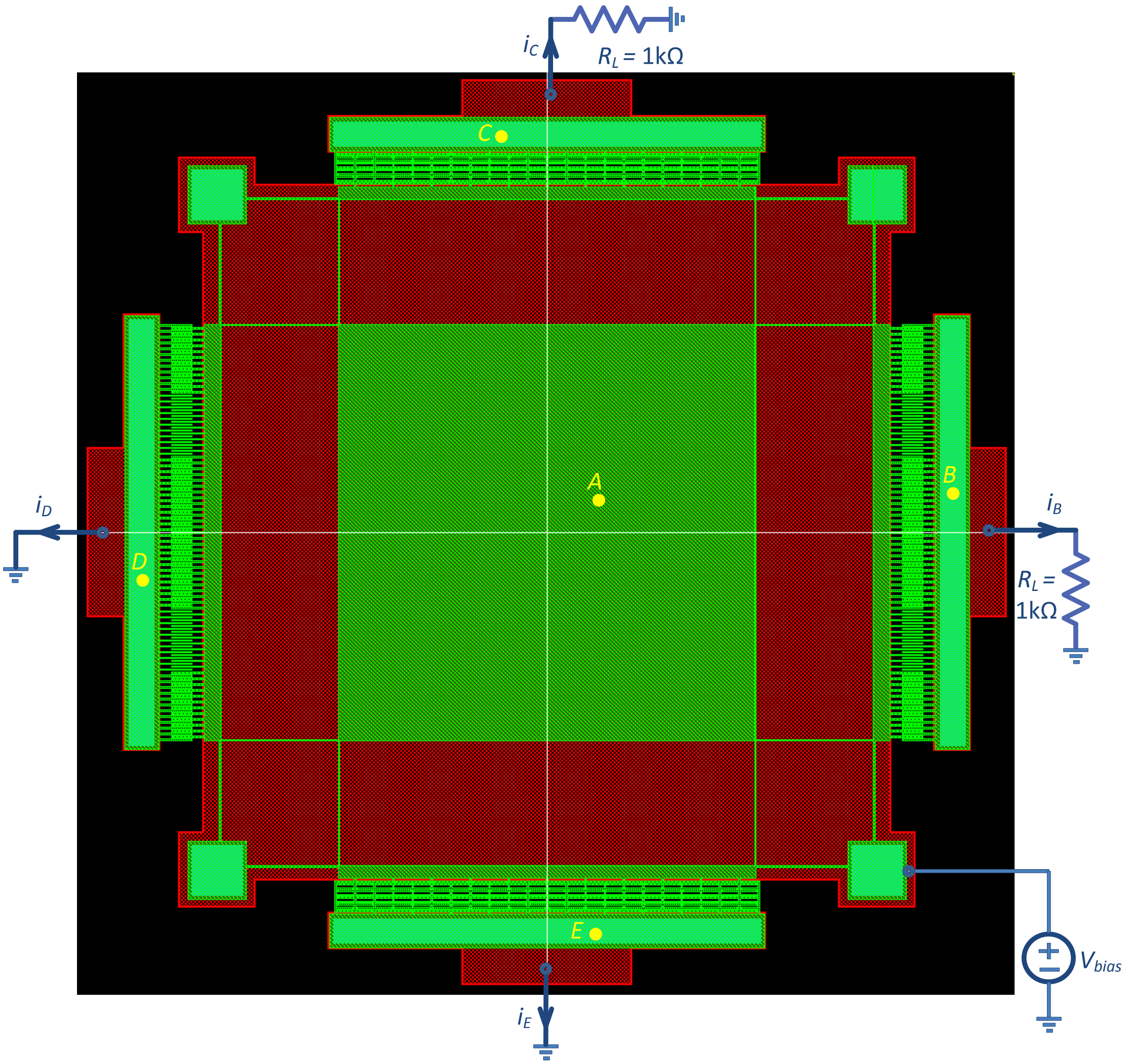

Figure PS6.7 – Top view of the accelerometer with circuit connections for problem 4.