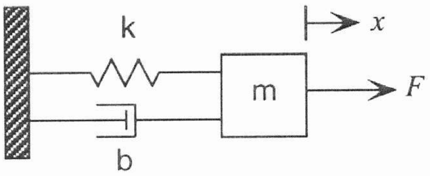
MIT-4057 Design of silicon sensors

Examination, May 10, 2011

1. Explain the system, device, physical and process level models for microsensors. What requirements each level sets for the modeling, and what kind of modeling methods are used in them?

2. What means piezoresistivity? What should be taken into account when modeling piezoresistive properties of silicon? Describe shortly the principle of some silicon microsensor based on piezoresistivity.

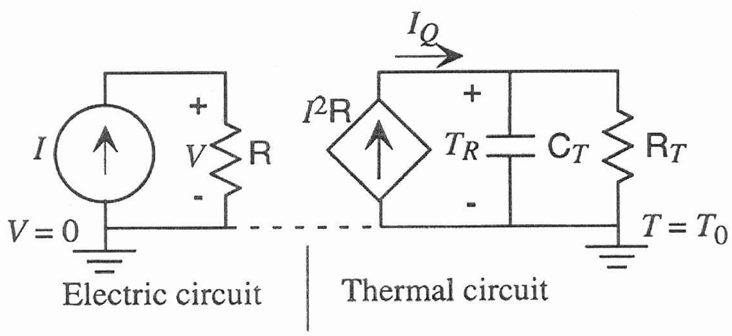
3. Present the impedance and admittance models of the mass-spring-damper system (figure below) in two cases:
a) force is the effort variable and velocity is the flow variable, and
b) velocity is the effort variable and force is the flow variable.



Spring-mass-dashpot system

4. Dimensions of a silicon cantilever are: length 50 μm, width 10 μm and thickness 5 μm. The cantilever is supported rigidly on one end. Calculate the strain of the cantilever for the 1 mN axial force acting on the free end. How much is the cross section area of the cantilever decreasing by the force. What is the resonance frequency of the mechanical axial vibration of the cantilever. Young's modulus of silicon E = 160 GPa, Poisson's ratio $\upsilon = 0.27$ and density $\rho = 2331\ \mathrm{kgm^{-3}}$.
$\omega = \sqrt{k/m}$.

5. In the figure below is the circuit model for self-heating of a resistive sensor. The sensor is heated up when an electric current I flows through it. Derive a differential equation for the temperature (T_R) of the sensor (Hint: write Kirchoff's current law for the thermal circuit node and formulate a state equation). The resistance of the sensor in the temperature T_0 is R_0 and the resistance temperature coefficient is α_R. What is the time constant for the temperature change of the sensor? Suppose that $T_0 = 0$.



6. A 200 nm thick silicon nitride membrane can be made in different ways. Which of the processes shown below are possible to use? Where the successful processes are based on, and why some of the shown processes are impossible?