Instructor Manual

Foundations of MEMS

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Chapter 1

Visit http://www.memscentral.com, a companion website of the book for additional teaching materials.

Problem 12: Design

A resistor is made of a suspended, doped polycrystalline silicon beam with the resistance being 5kΩ. Calculate the resistor's Johnson noise when measured in a frequency range of 0 to 100 Hz and 0 to 10 kHz. The temperature of the resistor is 27°C and the bias voltage is 2 V.

Solution:

The magnitude of the Johnson noise for 0-100 Hz is

$$V_{noise} = \sqrt{4kTRB} = \sqrt{4(1.38\times10^{-23})300\cdot5000\cdot100} = 91pV$$

The magnitude of the Johnson noise for 0-1000 Hz is

$$V_{noise} = \sqrt{4kTRB} = \sqrt{4(1.38\times10^{-23})300\cdot5000\cdot1000} = 287.8pV$$

Problem 13: Design

Solution:

The volume of the sphere is $V = \frac{4}{3}\pi r^3$. The total buoyancy force is expressed as

$$f_{buoyancy} = Vg\gamma_s - Vg\gamma = \frac{4}{3}\pi r^3(\gamma - \gamma_s)$$

If we designate the radius to be the characteristic length scale, *L*, we have

$$f_{buoyancy} \propto L^3$$

Problem 14: Design

Solution:

The mass is proportional to the characteristic length scale to the third power. The static displacement due to gravity is

$$d = \frac{mg}{k} \propto \frac{L^3}{L} = L^2$$

The resonant frequency is

$$f \propto \sqrt{\frac{m}{K}} \propto \sqrt{\frac{L^3}{L}} = L$$

Problem 19: Design

Solution:

The magnitude of the Johnson noise for a bandwidth of 1kHz is

$$V_{noise} = \sqrt{4kTRB} = \sqrt{4(1.38\times10^{-23})300\cdot10000\cdot1000} = 407\,pV$$

Problem 21: Design

Answer:

Some candidate principles include:

Resistance chance due to temperature variation;

Thermal electric voltage generation;

Variation of infrared radiation intensity;

Thermal bimetallic bending of mechanical members, detected optically;

Thermal bimetallic bending of mechanical members, detected mechanically;

Thermal expansion, detected optically;

Thermal expansion, resulted changes of dimensions of electric pathways;

Thermal expansion, detected capacitively;

Changes of magnetic characteristics due to temperature variation;

Changes of fluorescent emission characteristics of certain molecules due to temperature change.

Problem 22: Design

Answer:

Candidate methods include thermal expansion, magnetic force and torque, optical induced thermal expansion, light pressure, fluid dynamic pressure, phase change materials, shape memory alloy, molecular interaction (e.g., DNA tweezers), bacteria motility, among others.