

**Prepare to present your solutions during the exercise session on 14.4.**

### Piezo scanner

1. (1p) Piezo-based z-scanner has a nominal maximum range of 100 $\mu\text{m}$  with voltage range from -20 to 140V. How many bits controller is required to achieve movement accuracy of 5nm?
2. (2p) Consider the same piezo scanner. Its actuator's structure is illustrated below. If there is no thermal correction in the controller, what is the acceptable operating temperature range around room temperature if movement accuracy of  $\pm 2\mu\text{m}$  is required? For multilayer low voltage piezo element, you can use expansion coefficient of  $\alpha_{\text{piezo}} = -6 \cdot 10^{-6} \text{K}^{-1}$ .



3. (1p) The piezo scanner uses only voltage range from -20 to 140V. Piezo stack's travel range could be much more if using the whole negative voltage range down to -140V as well. Why it is not used? Name and explain the phenomena behind it.

### Ultrasonic knife

(2p) What is an ultrasonic knife? What benefits, and conversely disadvantages, does it offer compared to a conventional knife? Describe potential applications for an ultrasonic knife.

### Cavitation

- 1) (1p) Explain inertial (transient) and non-inertial (stable) cavitation.
- 2) (1p) Calculate the duty cycle of the following ultrasonic pulse: Center frequency of transducer  $f=2\text{MHz}$ , 40 cycles, pulse repetition frequency PRF=1 kHz.
- 3) (2p) Calculate the resonance bubble size of air bubbles in water using Minnaert's formula for the driving frequency  $f=2.5\text{ MHz}$ .

(M. Minnaert, "XVI. On musical air-bubbles and the sounds of running water," *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science*, vol. 16, no. 104, pp. 235-248, 1933. or find some other (simpler) source).