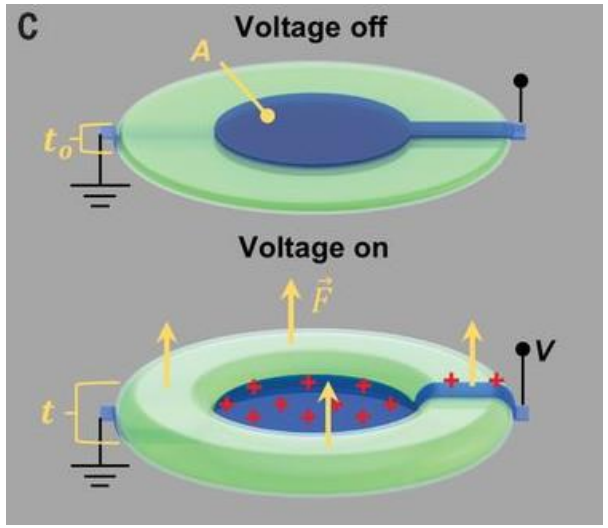
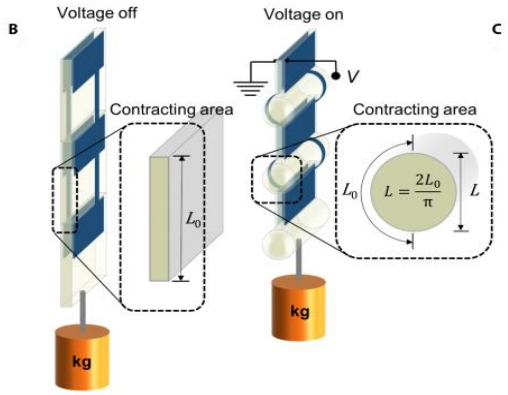
Miniaturized Sensor System for Electrostatic Actuators

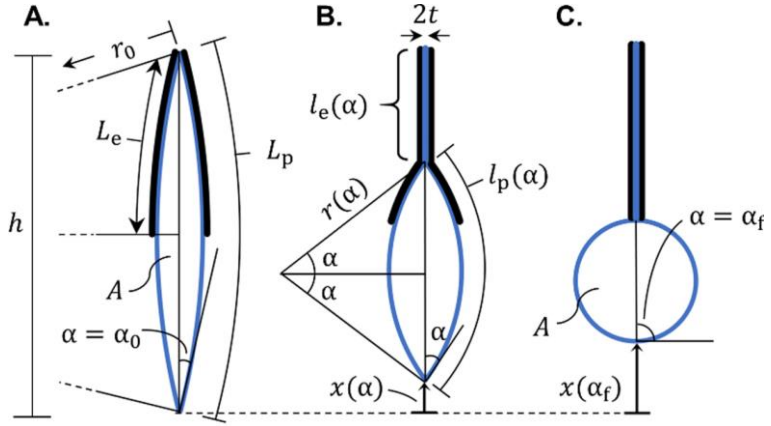
Khoi Ly



$$C = \varepsilon_0 \varepsilon_r \frac{A}{d}$$

$$x = f(A, d)$$

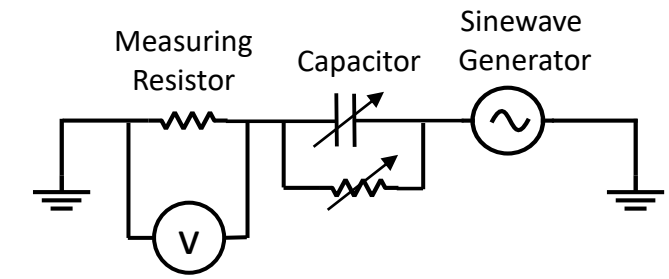




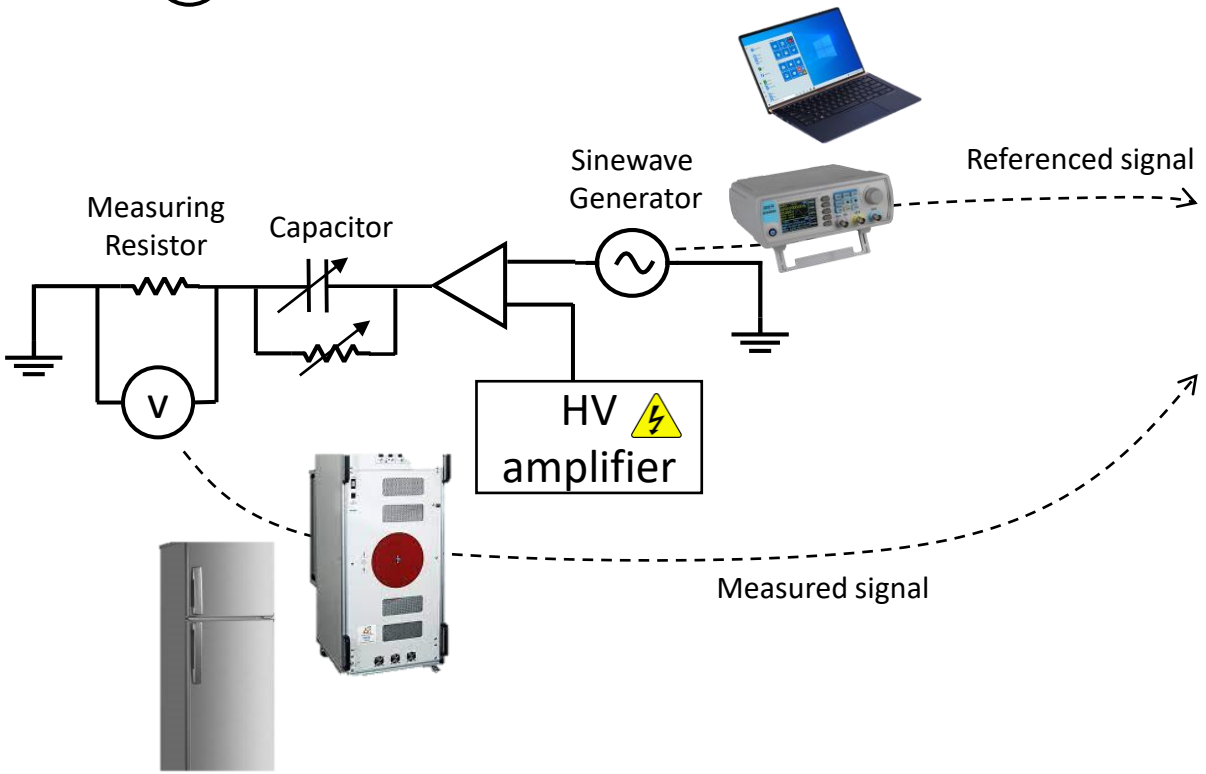
$$C(\alpha) = \varepsilon_0 \varepsilon_r \frac{w}{2t} l_e$$

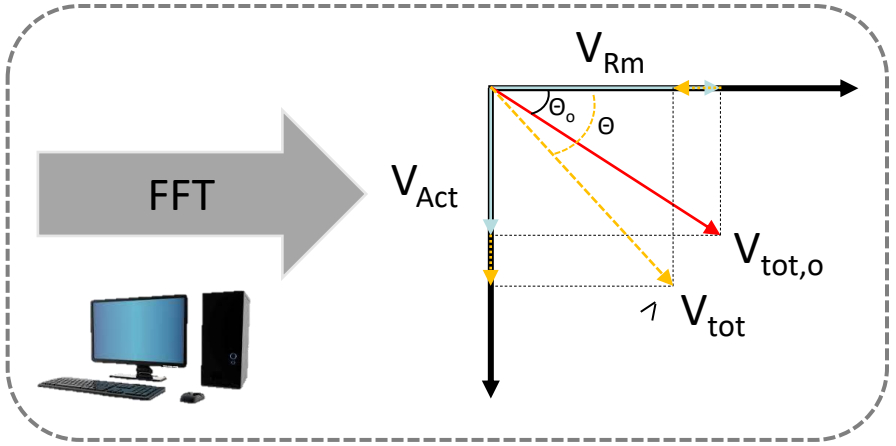
$$x(\alpha) = h - \left(l_p(\alpha) \frac{\sin(\alpha)}{\alpha} + l_e(\alpha) \right)$$

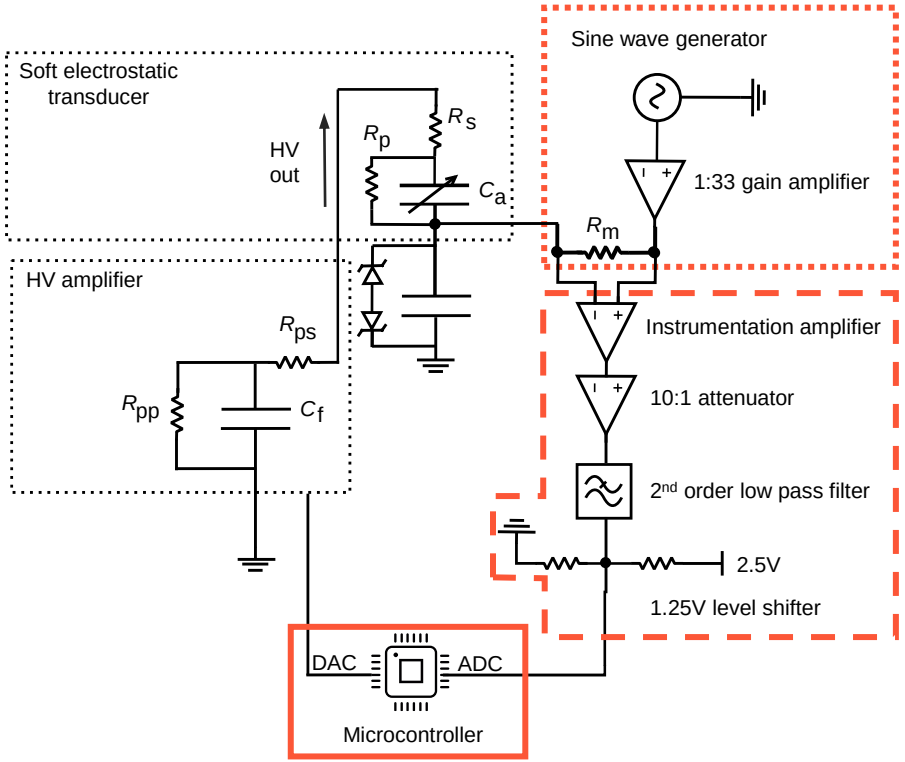
(Kellaris et. al, 2019)

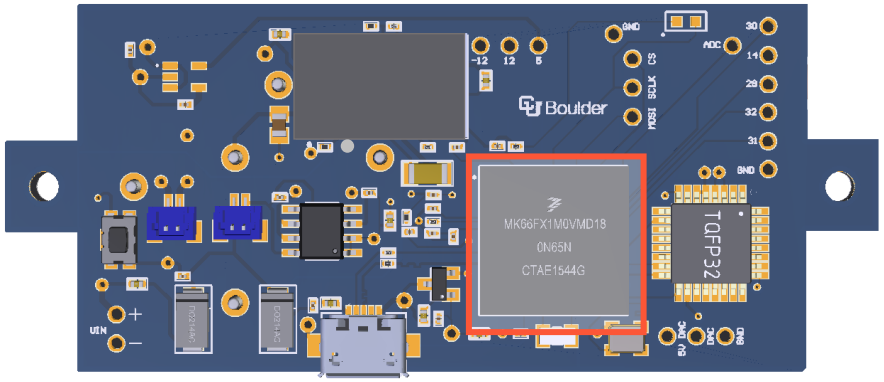


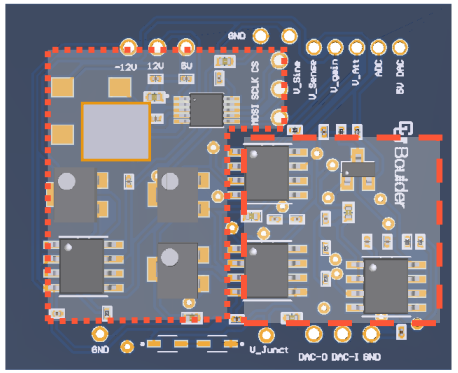
(Keplinger et. al, 2007)











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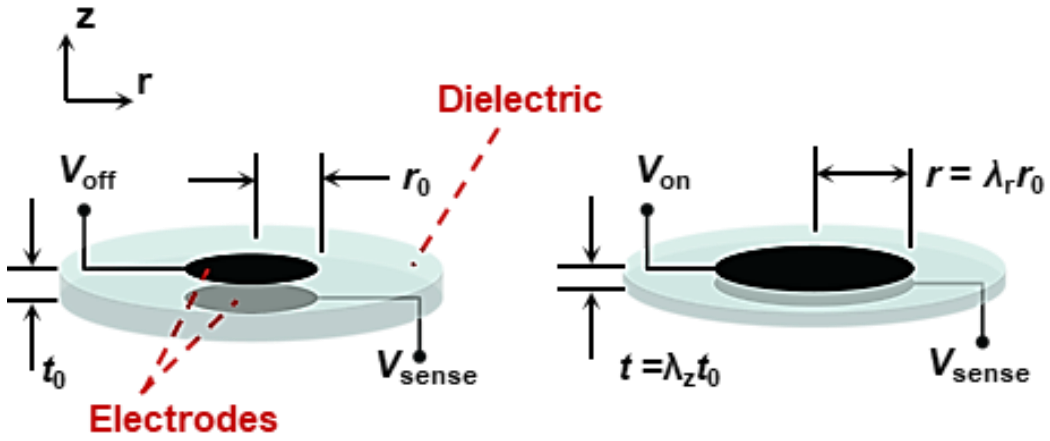
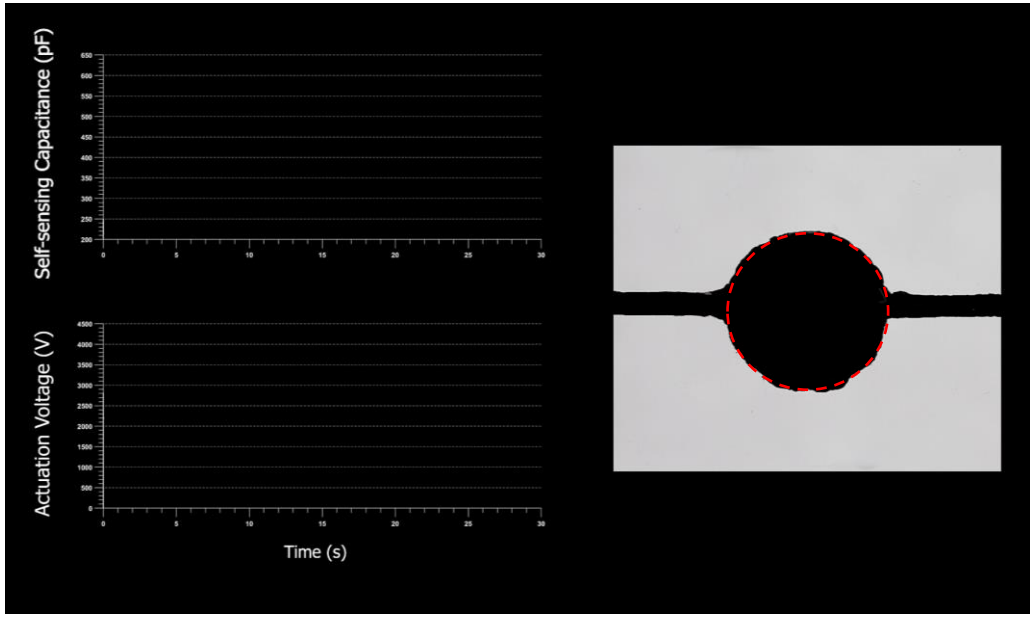
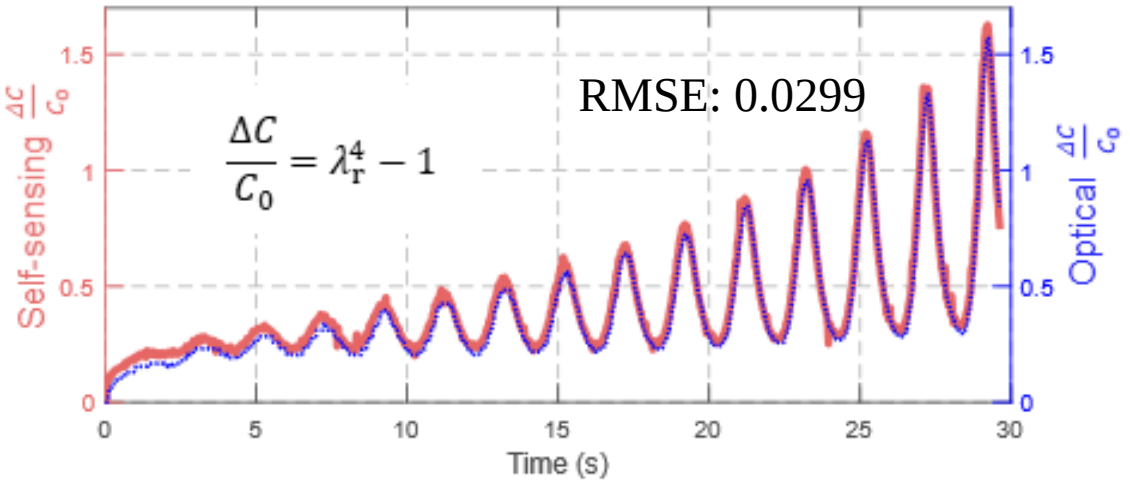


$$C_0 = \varepsilon_0 \varepsilon_r \pi \frac{r_0^2}{t_0}$$

$$C = \varepsilon_0 \varepsilon_r \pi \frac{r_0^2}{t_0} \frac{\lambda_r^2}{\lambda_z}.$$





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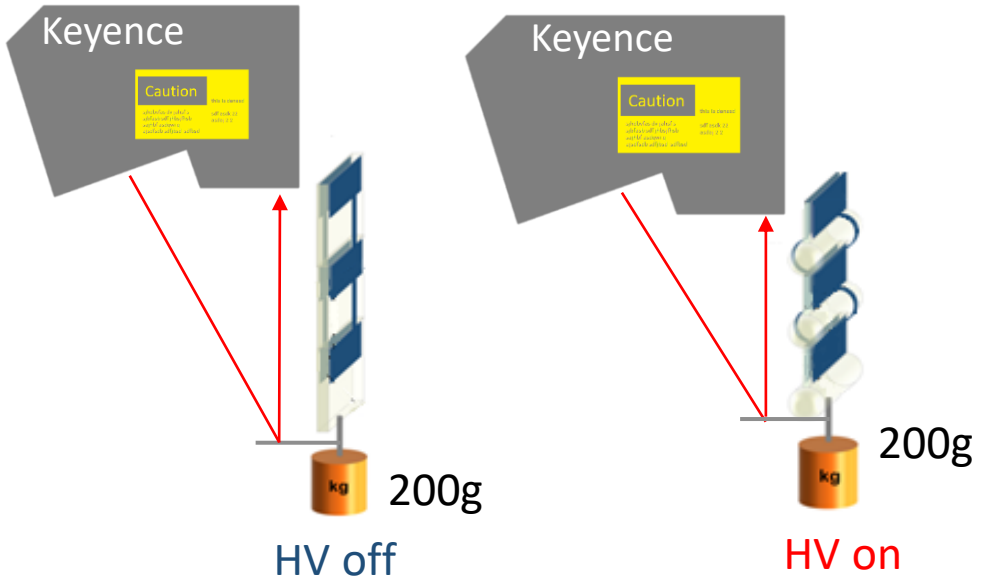
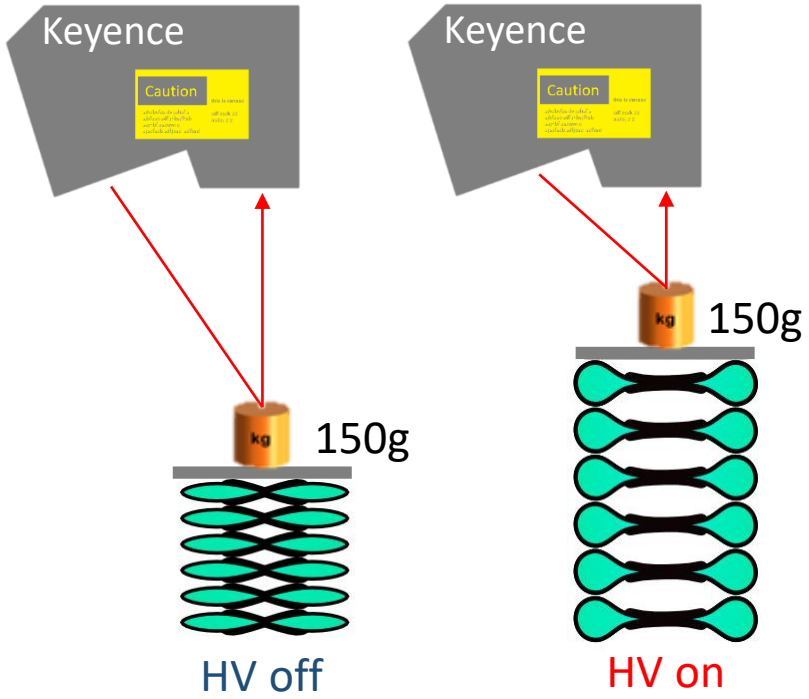
Laser displacement sensor





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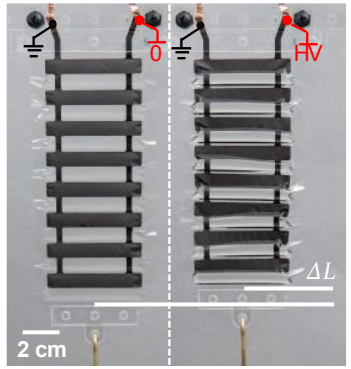
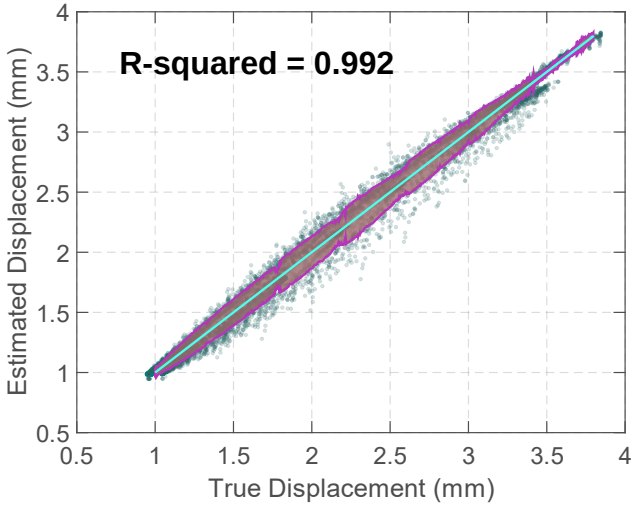
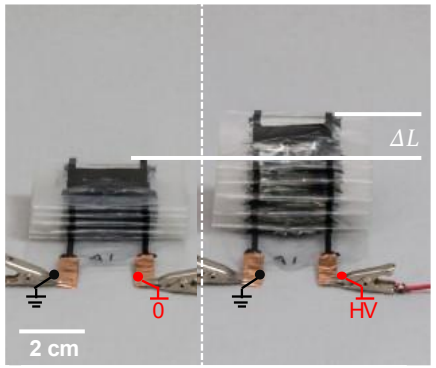
a Peano HASEL



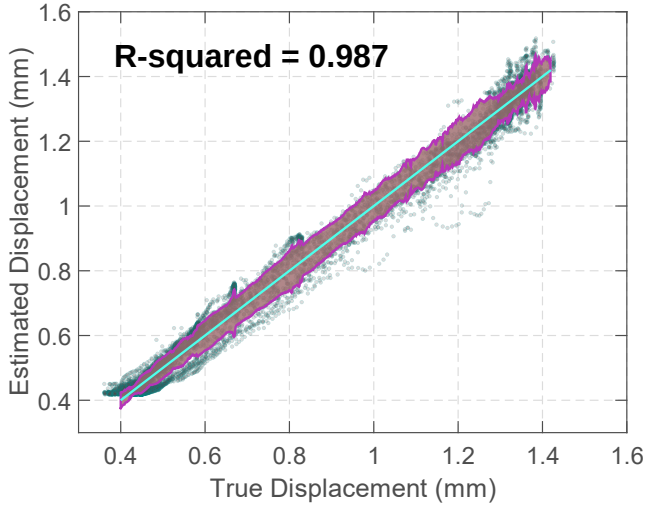
$$z\ (mm) = (1.13 \times 10^{-8})C^2 + (4.97 \times 10^{-4})C + 0.908$$



b Folded HASEL



$$z\ (mm) = (2.053 \times 10^{-7})C^2 - (2.56 \times 10^{-4})C + 0.498$$



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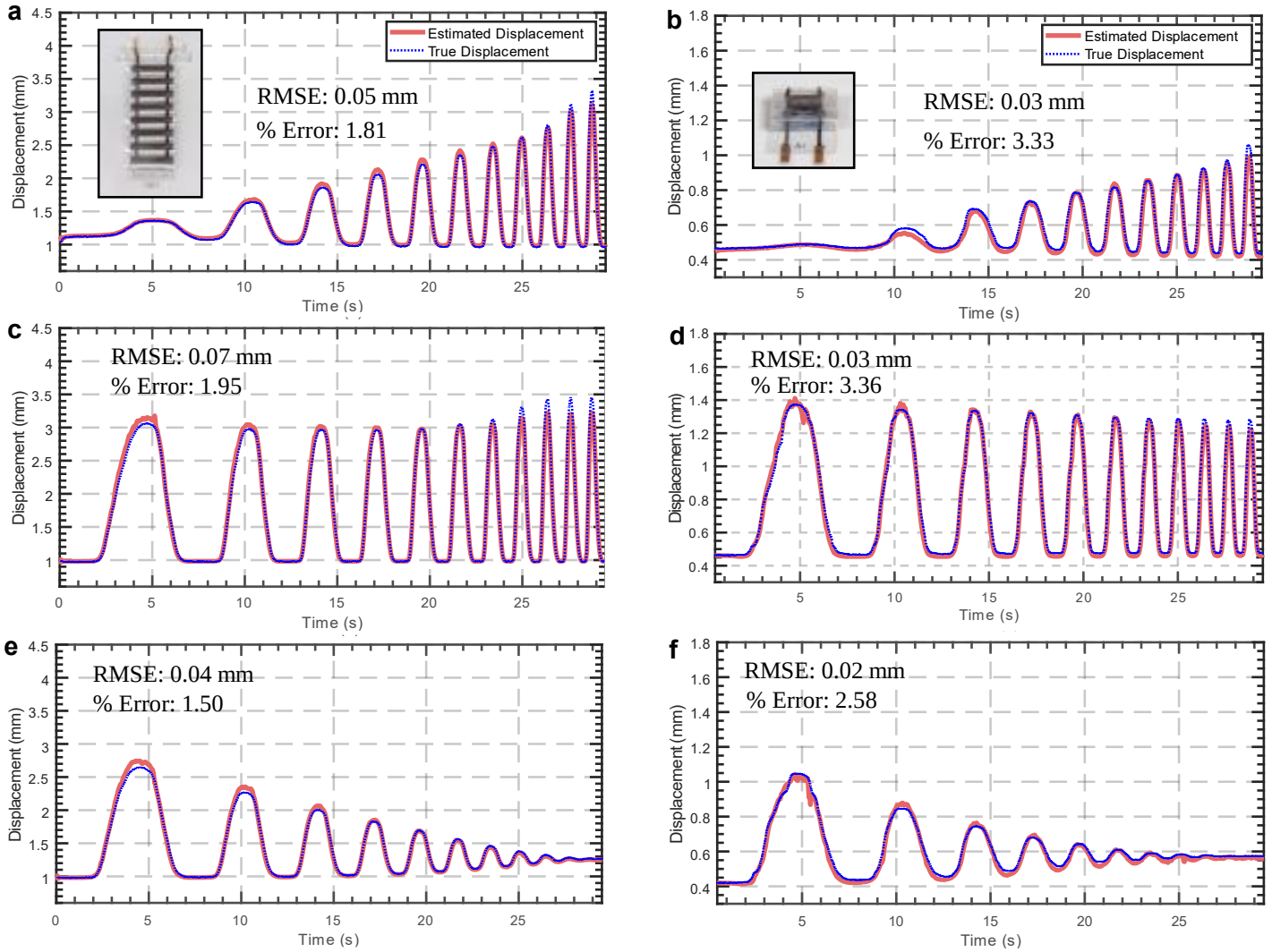
Input Signal

3.25-kV-offset sinusoidal HV

+ Increasing amplitudes (0.5 kV to 2.25 kV)
+ Increasing frequencies (0.1 Hz to 2 Hz)

+ Constant amplitude (2.25 kV)
+ Increasing frequencies (0.1 Hz to 2 Hz)

+ Decreasing amplitudes (2.25 kV to 0.5 kV)
+ Increasing frequencies (0.1 Hz to 2 Hz)



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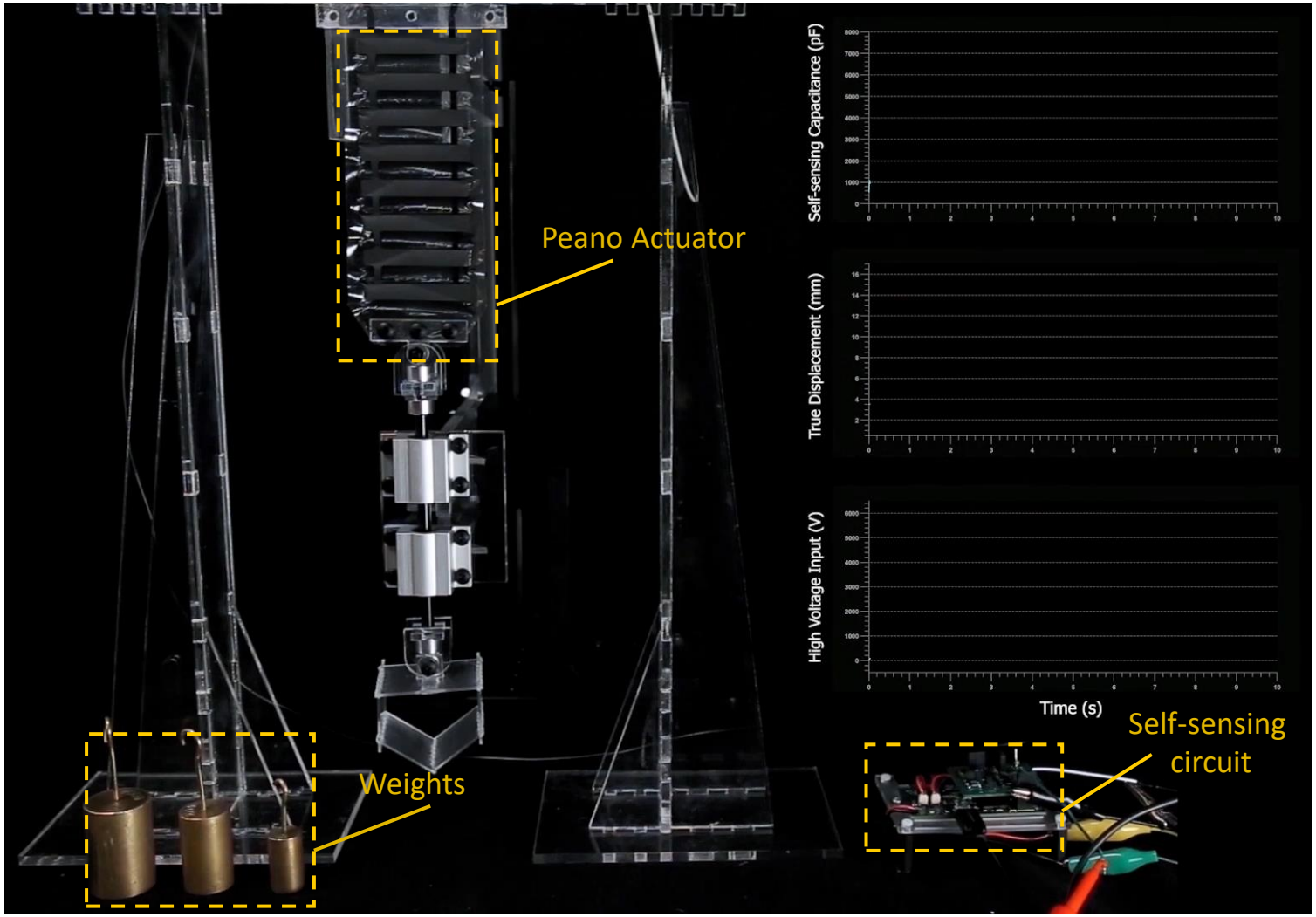
Input Signal

5 cycles of a 0.05 Hz trapezoidal HV waveform from 0 kV to 5.5 kV



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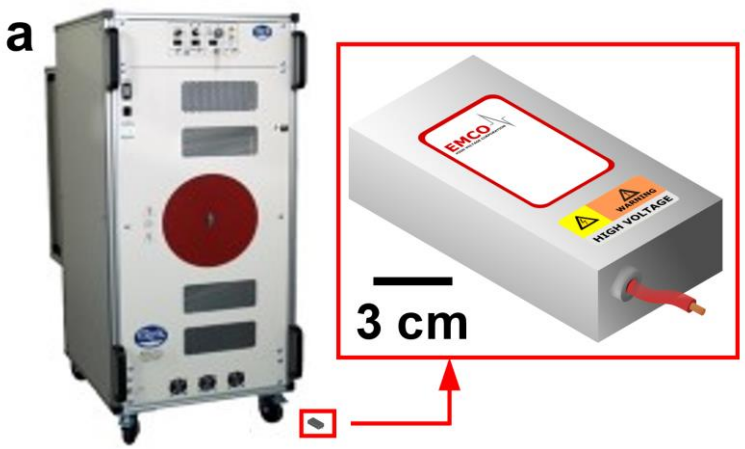
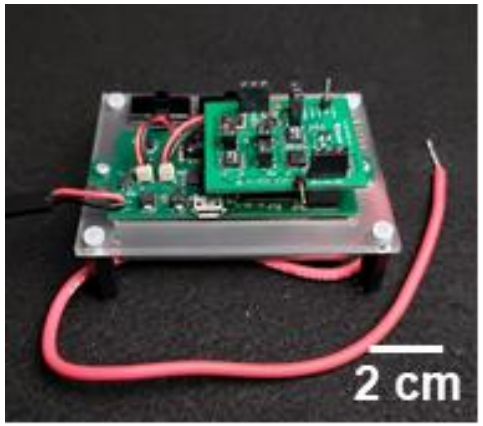
2.3 kV offset sinusoidal HV at 0.1 Hz

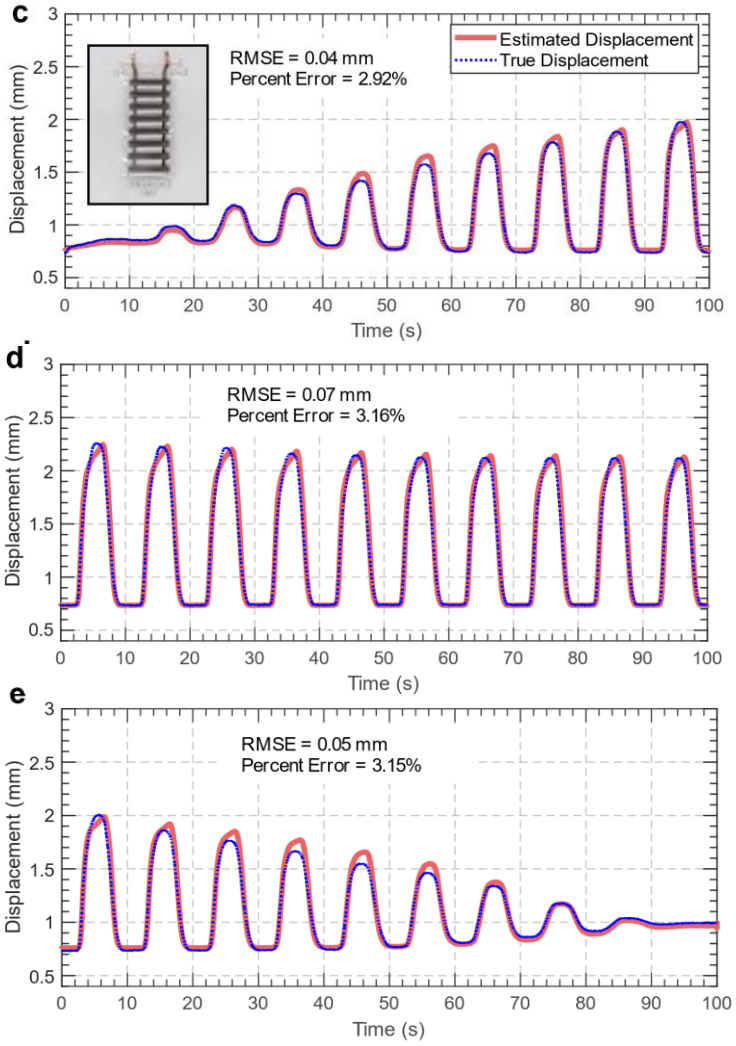




+ Increasing amplitude (0 kV to 1.5 kV)

+ Constant amplitude (1.5 kV)

+ Decreasing amplitude (1.5 V to 0 kV)



RMSE: 0.04 mm
% error: 2.92

RMSE: 0.07 mm
% error : 3.16

RMSE: 0.05 mm
% error: 3.15

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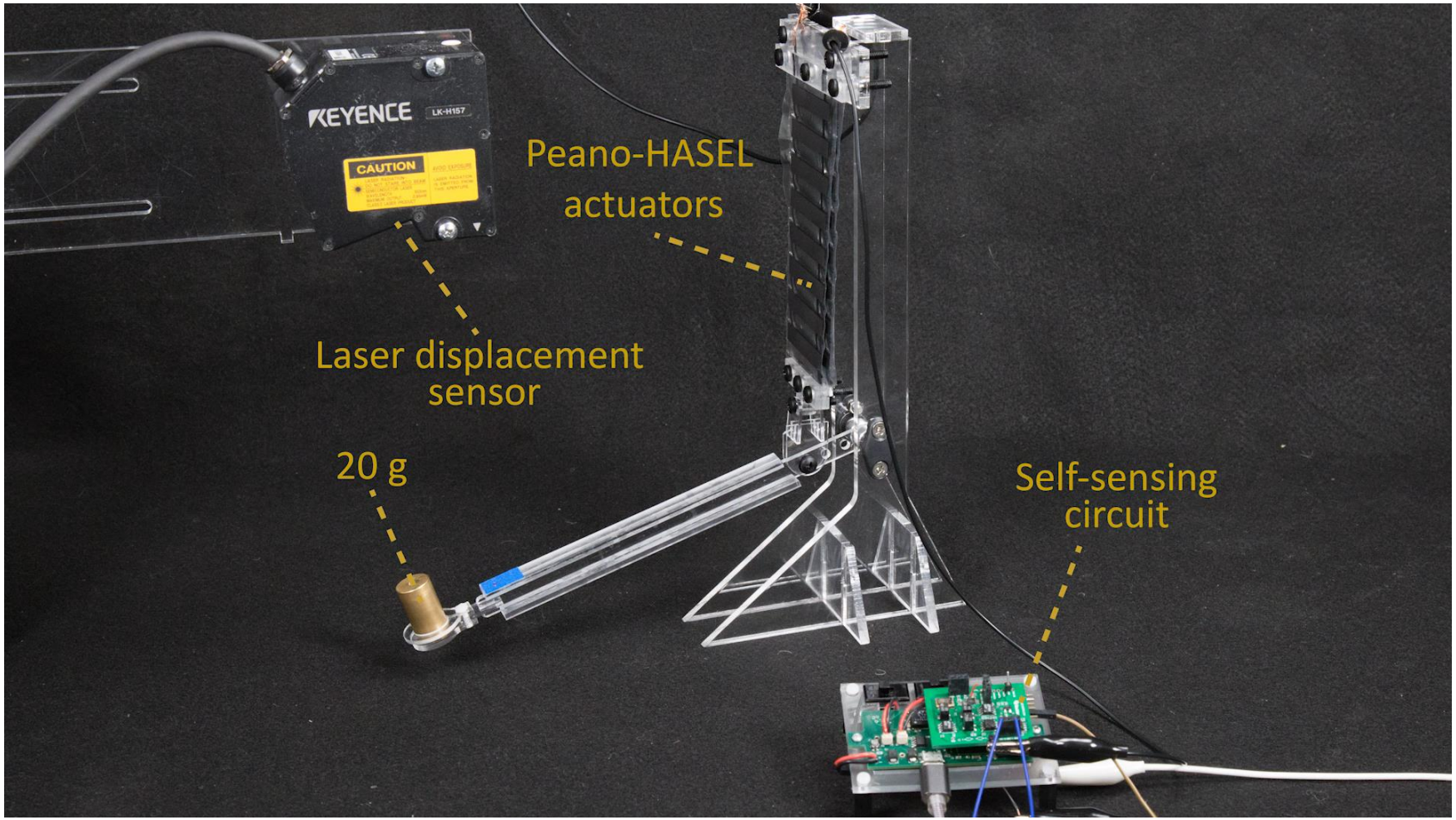
- PID controller
- The closed-loop frequency: 90 Hz
- Estimated low-pass digital filter for self-sensing displacement 5 Hz corner frequency



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- The **first** miniaturized capacitive self-sensing circuit with no high-voltage-tolerated external components
- Demonstrating of the circuit's sensing capabilities with a **wide range of variable capacitors**
- The **first** embedded controller that uses **miniaturized** self-sensing method for an electro-hydraulic actuator

Advantages

- **Tolerating High-voltage** and electric-field noises
- **Low-cost** and can be mass-produced
- **Not relying on external soft sensors**

Disadvantages

- Currently operating at low sensing rate (up to 5Hz)
- Sensing resolution is dependent on the transducers
- Faulty transducers can result in noisy data

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Thank you