Simulation of RF MEMS switching time

Submitted in partial fulfillment of course ME 237

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RF MEMS switches

- Advantages
  - High isolation
  - Low insertion loss
- Disadvantages
  - High driving voltage
  - Low switching speed
- Applications
  - Wireless communication
  - Radar systems

Project Outline

- Analytical solution
- Model
- Results and observations
- Conclusion

Analytical solution-1

- Governing equations (without damping)

$$m\ddot{x} + kx = \in \frac{AV^2}{2(g-x)^2} \rightarrow t = \int_0^{g0} \sqrt{\in \frac{AV^2 x}{m.(g-x)} - \frac{kx^2}{m}}.^{-1}$$

$$g = g0 + td/\in r$$

Ref.2

Analytical solution-2

- Governing equations (with damping)

$$m\ddot{x} + c\dot{x} + kx = F$$
$$c = \alpha m + \beta k \quad (Rayleigh\, damping)$$

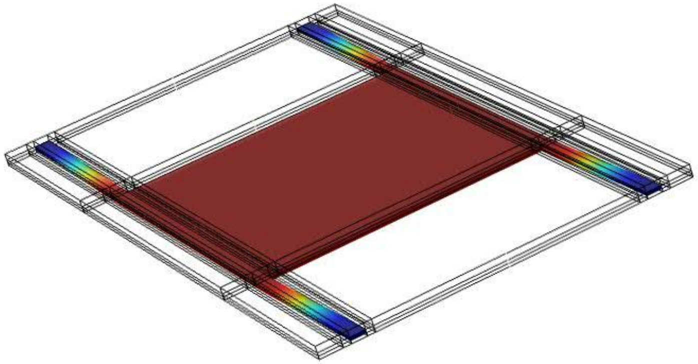
$$m\ddot{x} + \beta k\dot{x} + kx = F, when\, \alpha = 0$$

$$\ddot{u} + \mu\dot{u} + u = \frac{\gamma V^2}{(1+\delta-u)^2};\; u = \frac{x}{g0}, \dot{u} = g0.\sqrt{m/k}.\dot{x}$$
$$\gamma = \frac{\varepsilon A}{2kg0^3}, \mu = \beta\sqrt{k/m}$$

- Solutions are evaluated using oneDdyne.m

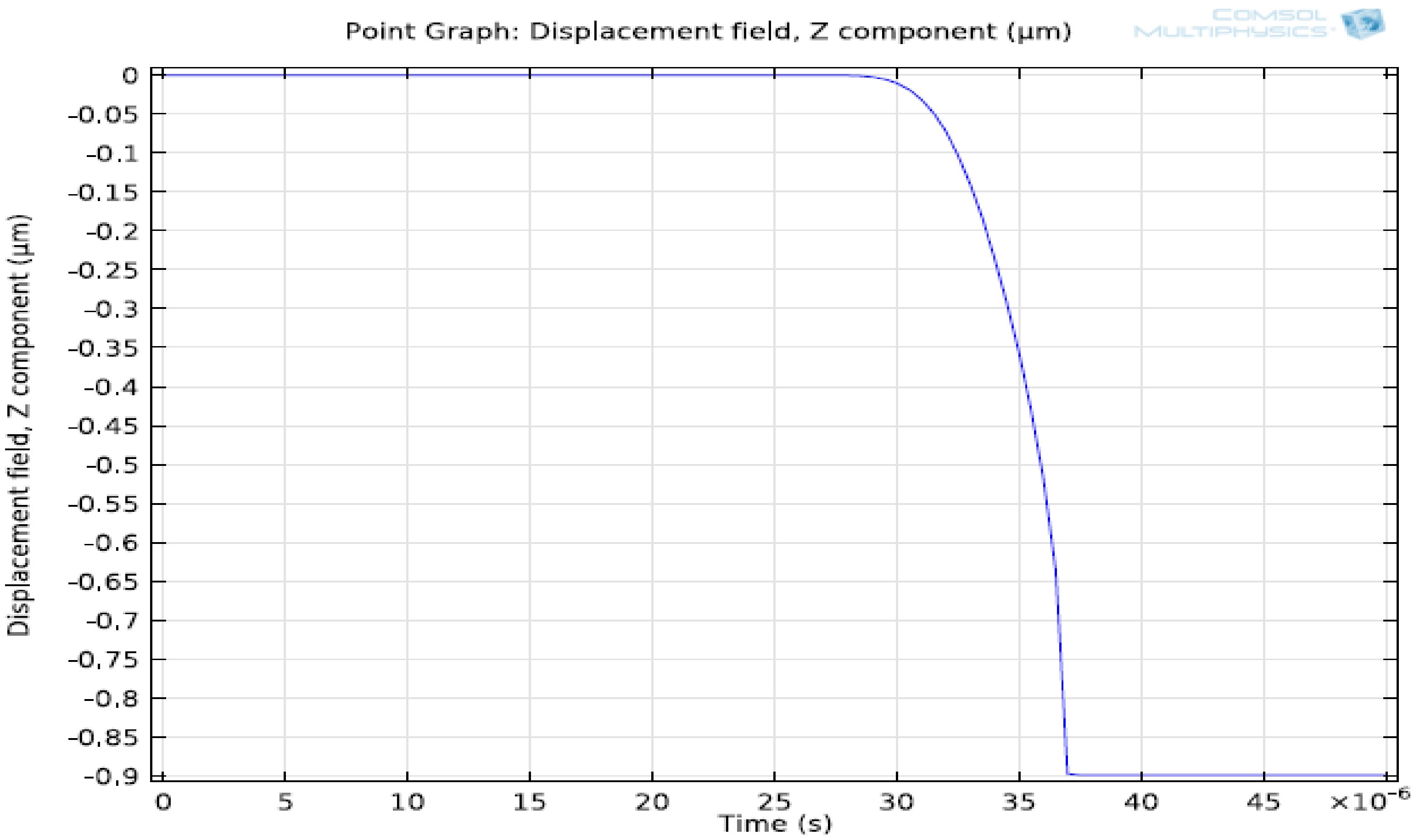
Ref.1,3

Model-1



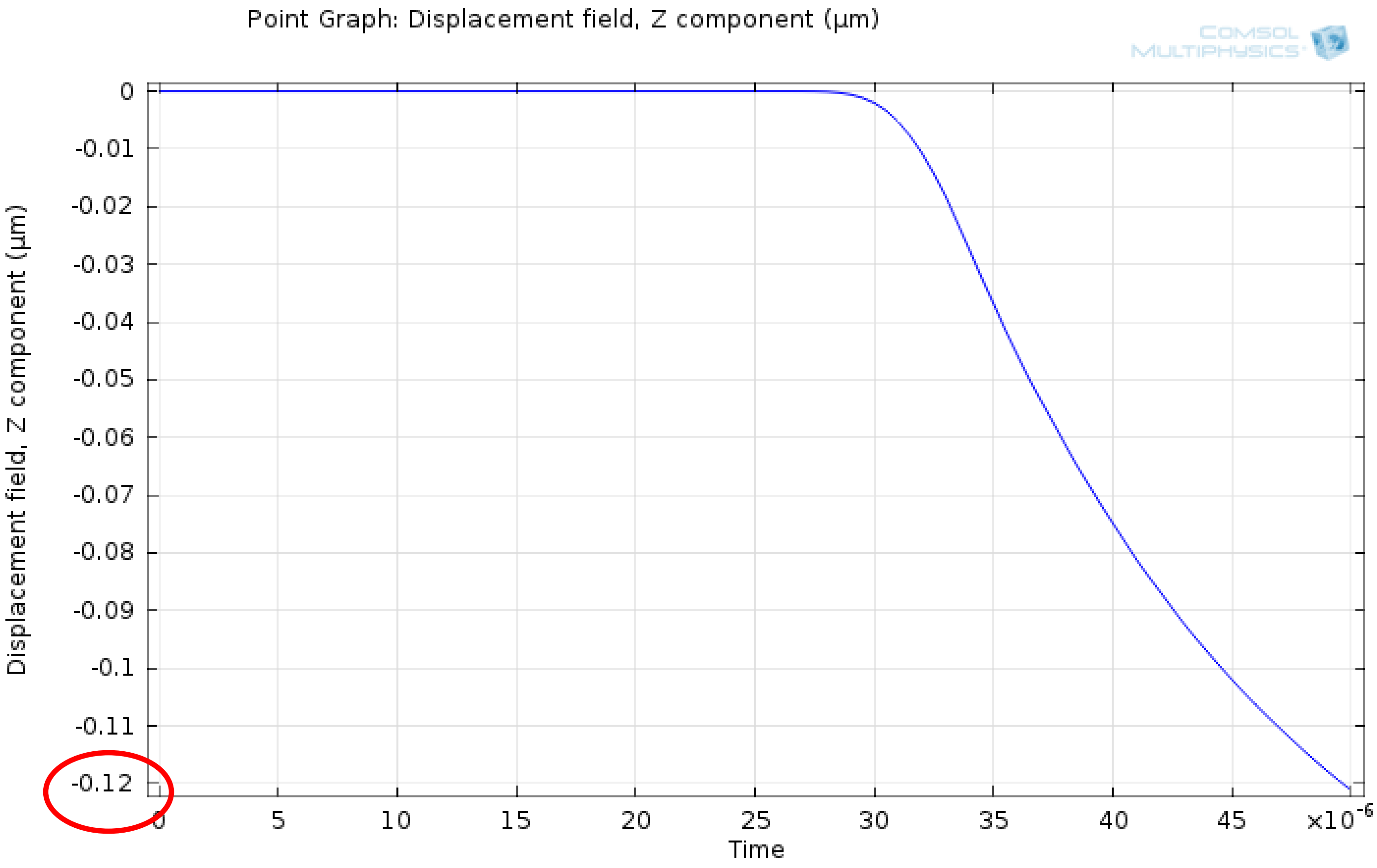
- A thin micromechanical bridge suspended over a dielectric layer (ε_r=7.5)
- Air gap of 0.9µm and a dielectric layer of 0.1µm

Vstep= 5V , β=0μs



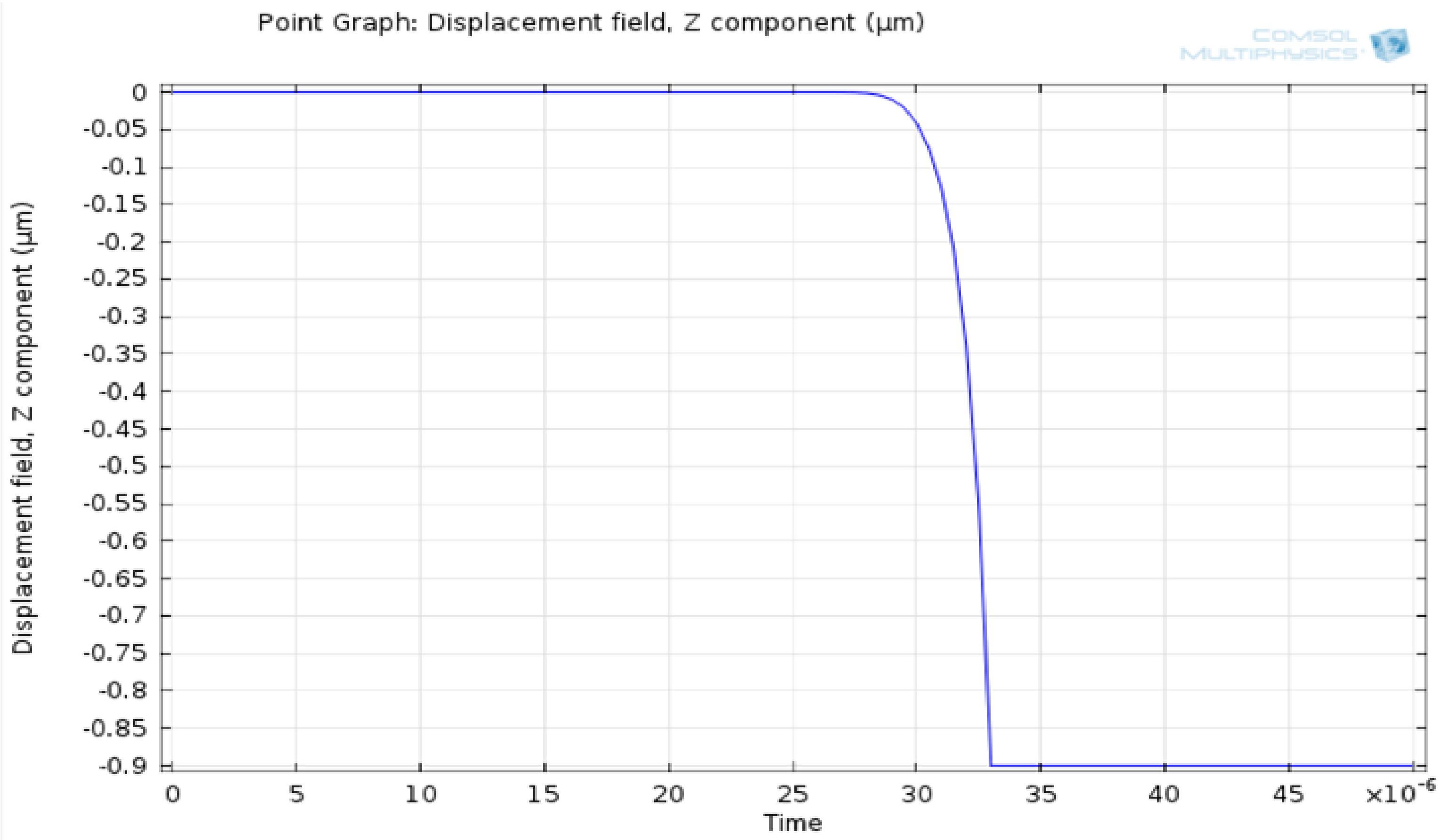
Switching time is observed to be 8μs (analytical value: 3.96 μs)

Vstep= 5V , β=0.1µs



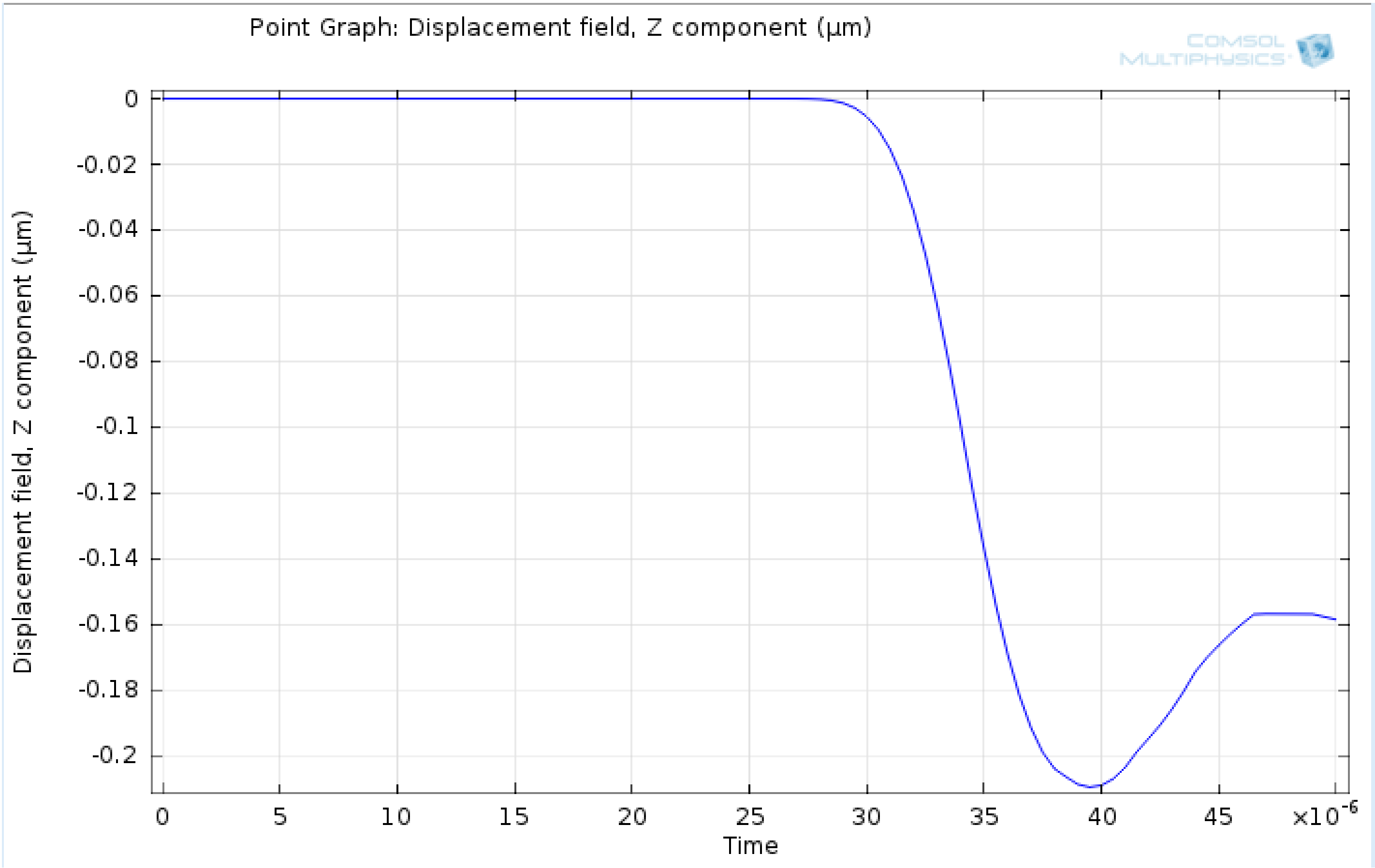
Switching has not occurred with 50µs.

Vstep= 10V , β=0µs

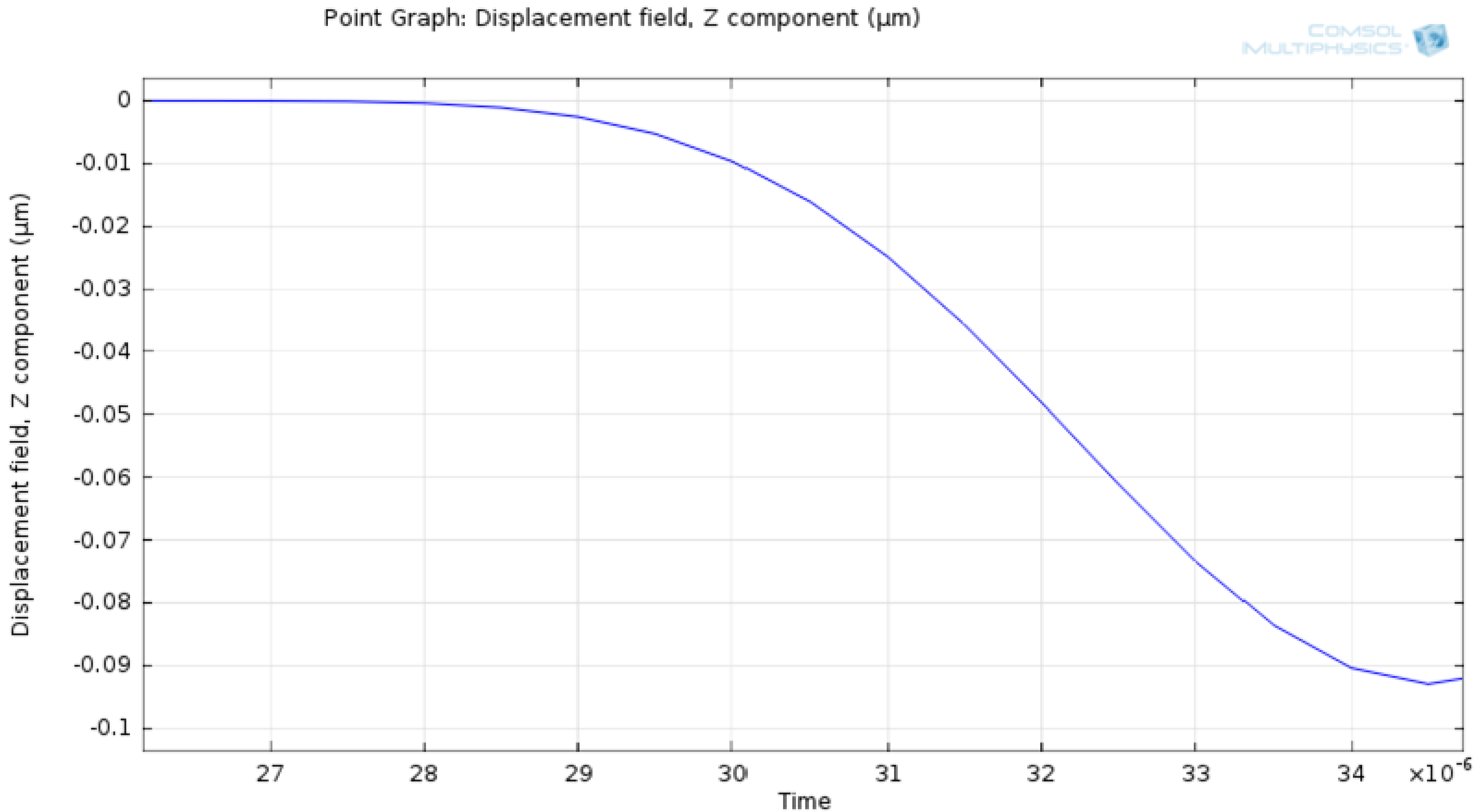


Switching time is observed to be 5 µs(analytical 2.4 µs)

Vstep= 10V , β=0.1μs



Model 2 : Vstep= 5V , β=0μs



Switching time is observed to be 6 μs (with half thickness)

Observations

- Damping parameter (β)
  - As β increases, switching time increases
- Applied voltage (V_{step})
  - As V_{step} increases, switching time decreases

Conclusion

- One degree of freedom model of capacitive switch is solved analytically.
- Results obtained from COMSOL have been compared against the analytical solutions.
- Variation of switching time with respect to damping parameter, input step voltage and beam configuration has been studied.

References

1. MEMS Linear and Non-linear Statics and Dynamics, Mohammad I Younis, Springer,2011
2. Micro and Smart Systems, Ananthsuresh,Vinoy,Gopalakrishnan,Bhat K.N, Aatre V.K, Wiley-India ,2014
3. ME Thesis report, Gaurav Nair, IISc