[SIMULATION OF PULL-IN EFFECT IN MEMS CAPACITOR USING GUI IN MATLAB]

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Report also available on: http://piyushtwri_cap.wordpress.com

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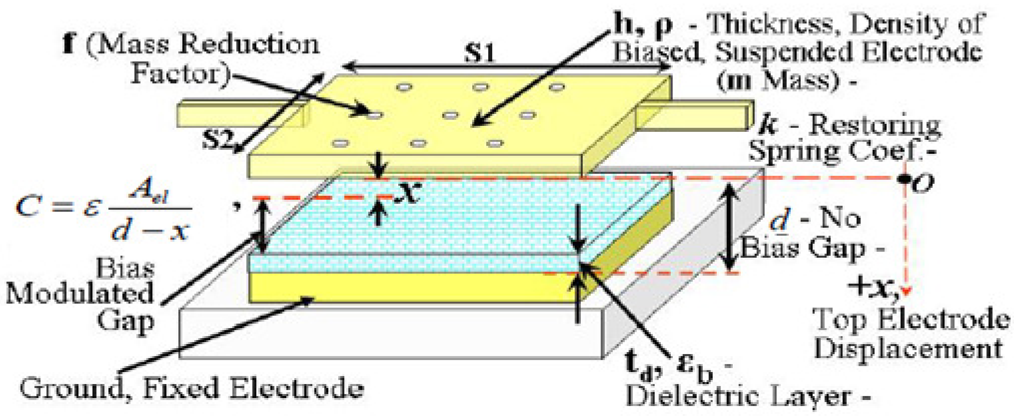
SIMULATION OF PULL-IN EFFECT IN MEMS CAPACITOR USING GUI IN MATLAB

pull-in effect in electrostatic MEMS devices:

Figure shows the schematic of an electrostatic actuator that could be used for example as a tunable RF capacitor. When voltage is applied over the capacitance, electrostatic force will work to reduce the plate separation d –x. At small voltages, the electrostatic voltage is countered by the spring force $F_k = kx$ but as voltage is increased the plates will eventually snap together. Estimating this pull-in voltage U_P and the plate travel distance x before pull-in effect is required for the successful design of electrostatic actuators, switches, varactors, and sensors.



The plate is attached to a spring k. The capacitor capacitance C depends on the plate area Ael and gap d–x.

$$E = -\frac{1}{2}\frac{\varepsilon A_{el}}{d-x}U^2 + \frac{1}{2}kx^2, \quad (1)$$

where the first term is the electrostatic potential of the deformable capacitor and of the voltage source and the second term is due to the mechanical energy stored in the spring. The force acting on the movable plate is obtained by deriving Equation (1):

$$F = -\frac{\partial E}{\partial x} = \frac{1}{2}\frac{\varepsilon A_{el}}{(d-x)^2}U^2 - kx. \quad (2)$$

At equilibrium, the electrostatic force and spring force cancels (F = 0) and Equation (2) gives:

$$kx = \frac{1}{2}\frac{\varepsilon A_{el}}{(d-x)^2}U^2. \quad (3)$$

Equation (3) can be solved for the equilibrium plate position x as a function of applied voltage U as shown
in Figure 2(a). Above the pull-in voltage VP, Equation (3) has no solutions. The solution above the pull-in
displacement (green line) are shown to be unstable in the following. A simple expression for the pull-in point is obtained by deriving Equation (2) to obtain the stiffness of the system:

$$\frac{\partial F}{\partial x} = \frac{\varepsilon A_{el}}{(d-x)^3}U^2 - k. \quad (4)$$

Substituting Equation (3) gives the stiffness around the equilibrium point:

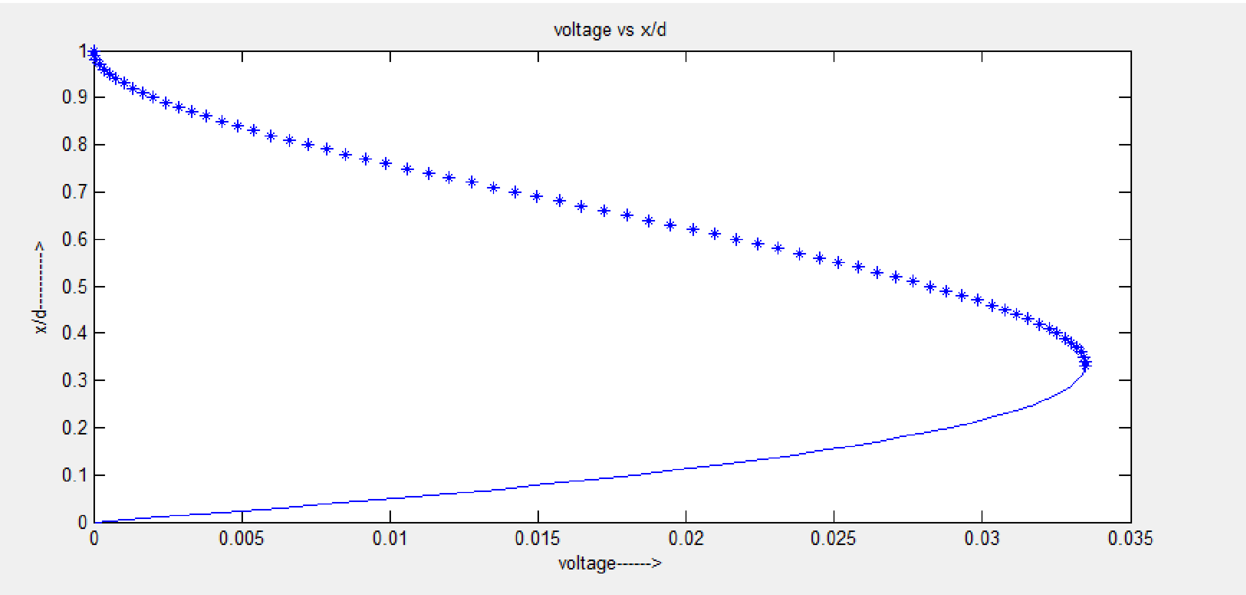
$$\frac{\partial F}{\partial x} = \frac{2kx}{(d-x)} - k. \tag{5}$$

Here near the 2/3rd of total gap between the plates the response of the mems capacitor gets unstable. Beyond this point the stiffness becomes positive and the system is unstable: a small positive movement dx result in positive force that increases x. the pull-in voltage at which the system becomes unstable

The expression for pull –in voltage and gap between plates is given by:

$$U_P = \sqrt{\frac{8}{27}\frac{kd^3}{\varepsilon A_{el}}}.$$

>>Where Up is voltage across the plates of the Mems capacitor.
>>K is the spring stiffness constant.
>>D is the distance b/w plates.
>>Epsilon is the permittivity of the medium.
>>A is the area overlapped.

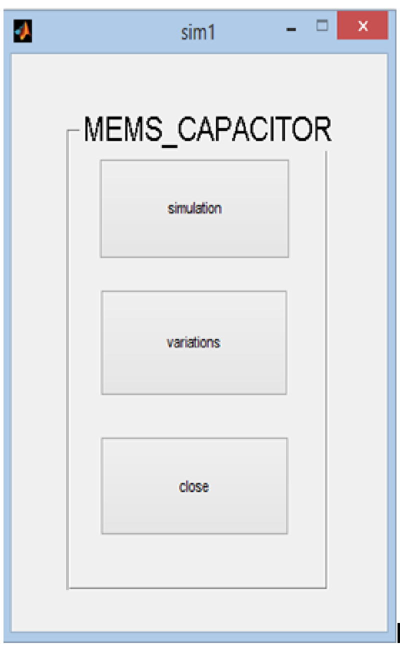


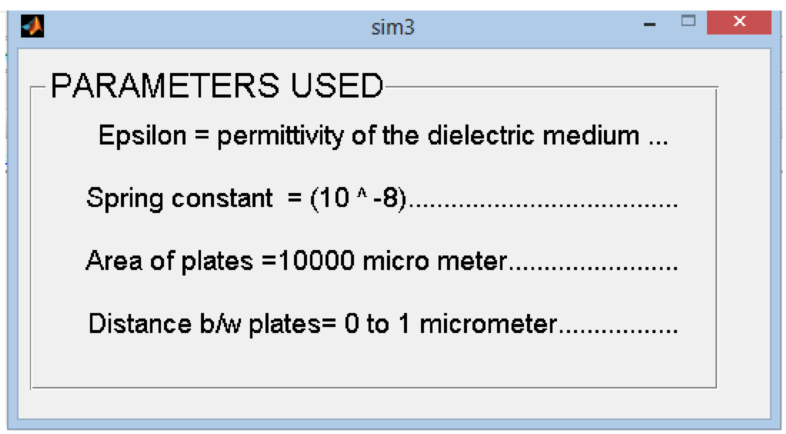
The equilibrium relationship between plate displacement x and voltage V.

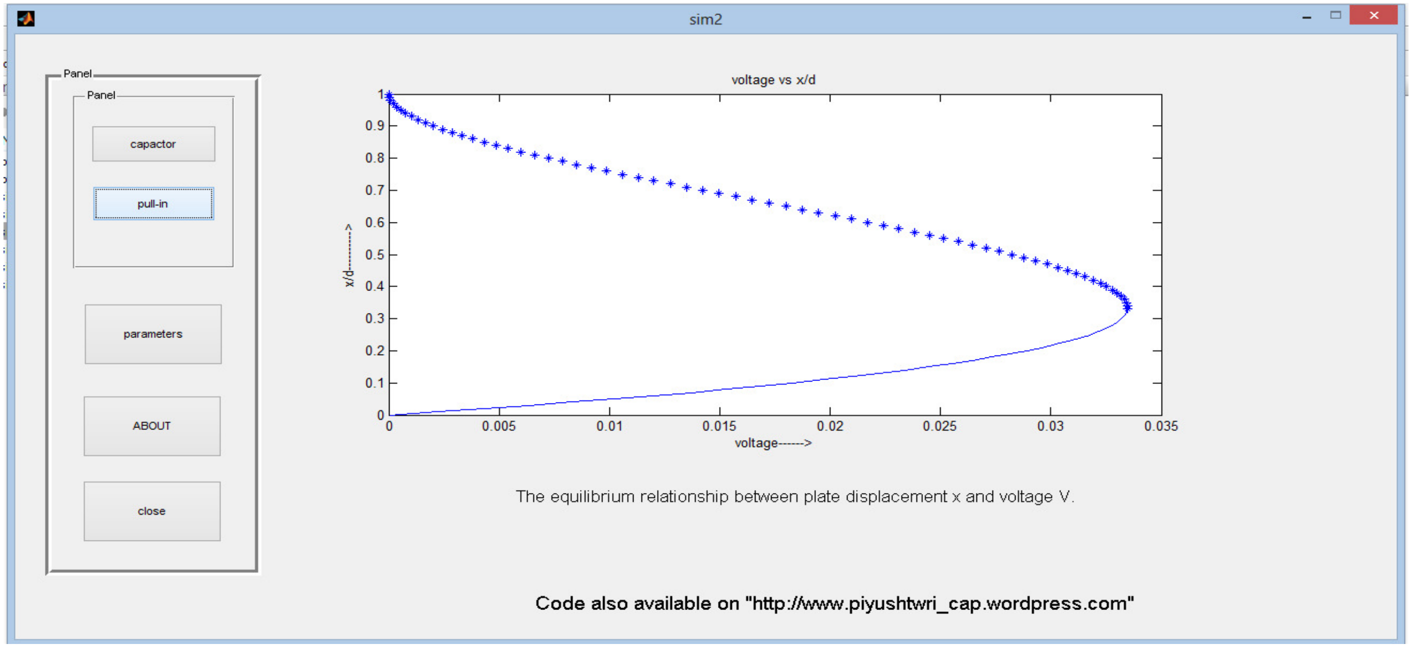
Matlab code to generate the plot and simulation of MEMS device pull-in effect.

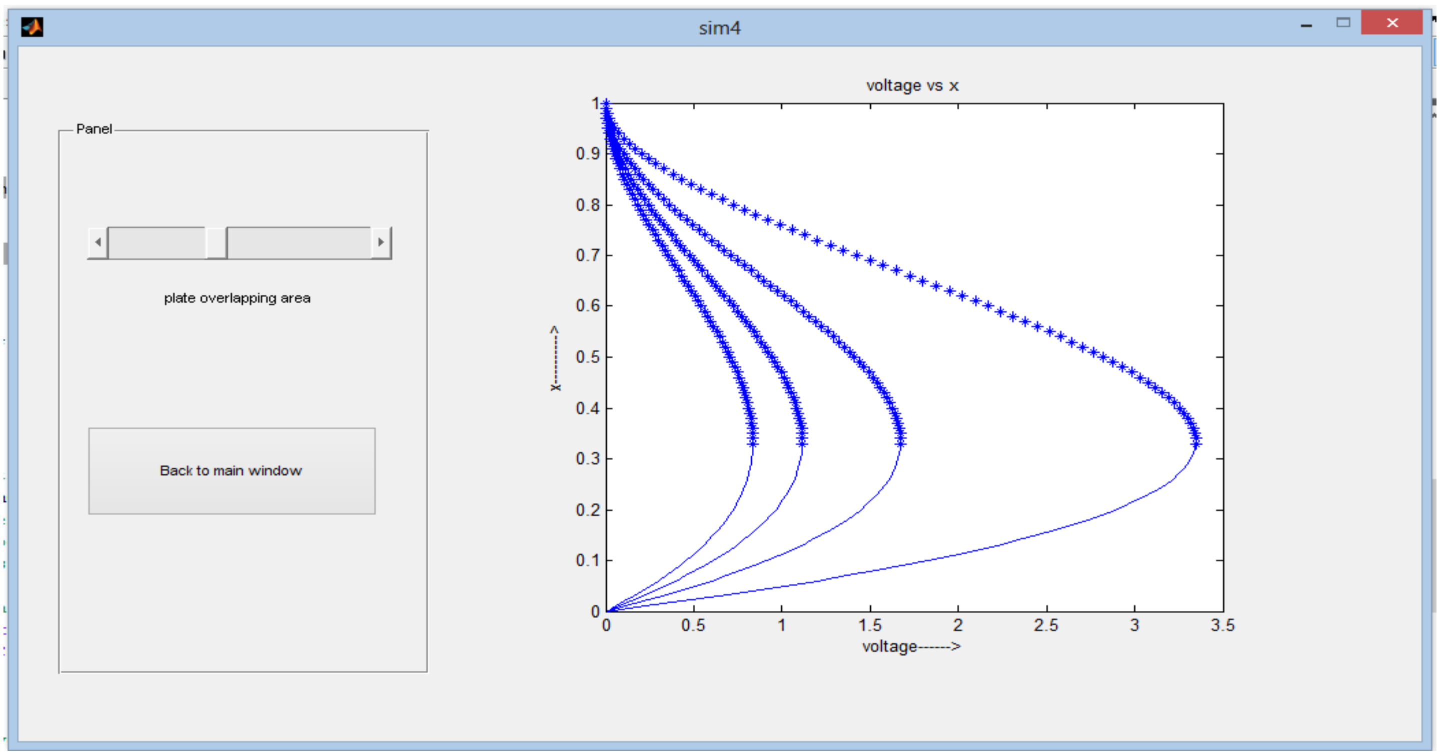
```
k=1e-8;
e = 8.854 * 10 ^ -12;
d = 1;                     % in mm
 % in mm
% a = input('Enter the value of a: ');
a=10000;
x = 1: -0.01 : .33; % in mm
V = (2/(e*a)) * k * x .* ((d - x).^2);
plot(V,x/d,'*')
hold on;
x = .33: -0.01 : 0;
V = (2/(e*a)) * k * x .* ((d - x).^2);
plot(V,x/d)
ylabel('x/d---------->');
xlabel('voltage------>');
title('voltage vs x/d');
```

GRAPHICAL USER INTERFACE:






sim2
Panel
Panel
capactor
pull-in
parameters
ABOUT
close
voltage vs x/d
x/d------->
voltage------>
The equilibrium relationship between plate displacement x and voltage V.
Code also available on "http://www.piyushtwri_cap.wordpress.com"


sim4
Panel
plate overlapping area
Back to main window
voltage vs x
x------->
voltage------>