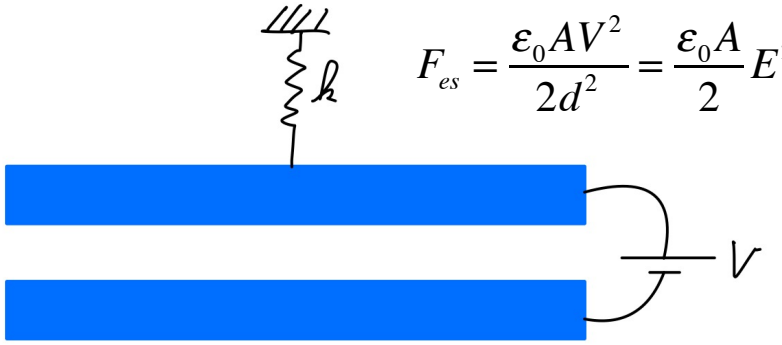
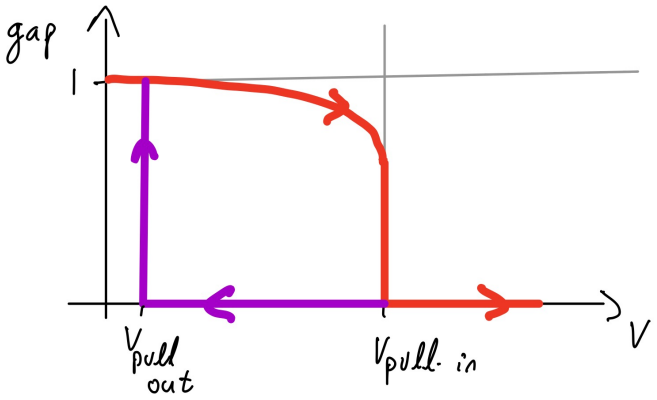
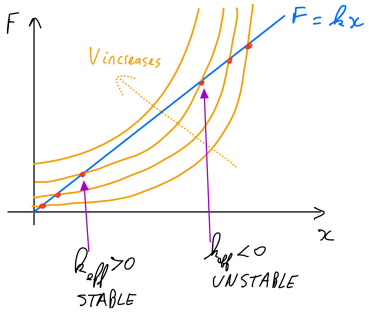
ES actuators
Parallel plate vs. Comb drive

$$F_{es} = \frac{\varepsilon_0 A V^2}{2d^2} = \frac{\varepsilon_0 A}{2} E^2$$

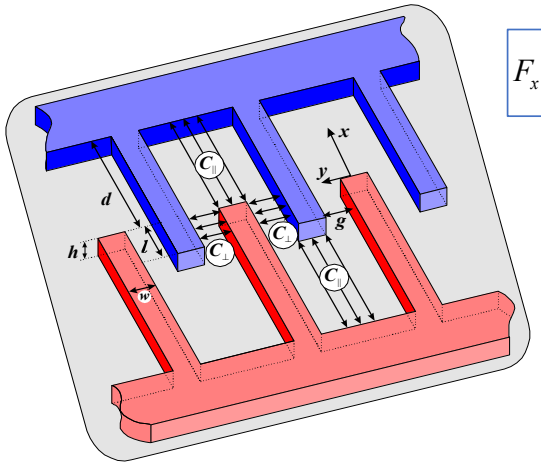




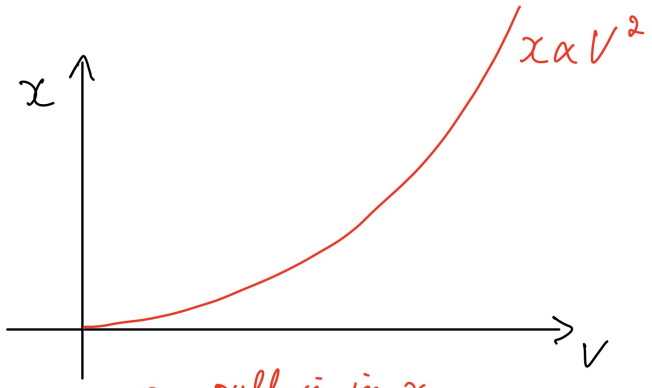


- Max 1/3 gap controlled motion
- Spring softening

Good or bad? When is this helpful?



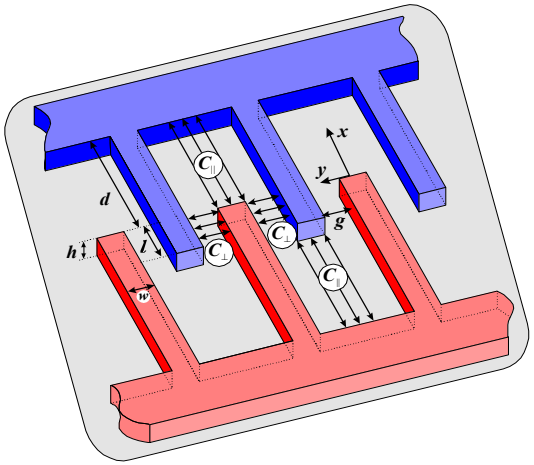
$$F_x = \frac{1}{2}\frac{dC}{dx}V^2 = N \cdot \frac{\varepsilon_0 h}{g}V^2$$



no pull-in in x
but pull-in in y

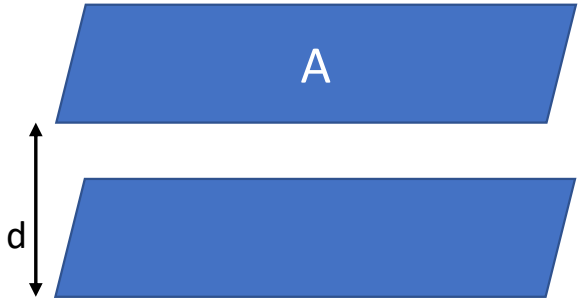
Actuator sizing for 1 mN force at 100 v

- Comb drive actuator:
  - How big should initial overlap be?
  - What h/g can we realistically get?
  - Design a comb-drive to get 1mN force:
    - how much area do you need? (assume 100 µm stroke)



$$F_x = \frac{1}{2}\frac{dC}{dx}V^2 = N \cdot \frac{\varepsilon_0 h}{g}V^2$$

- Parallel plate actuator
  - Design to get 1 mN force.
  - How much area do you need? Compute for gap d= 30 µm, 100 µm, 300 µm.



COMB DRIVE

$$F = \frac{N \varepsilon_0 h V^2}{g} = N \varepsilon_0 20 V^2$$

choose 100 V

$$h = 20\, g$$

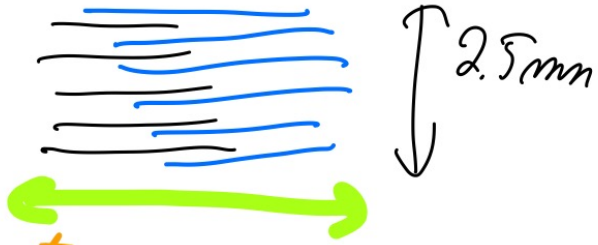
$$N = \frac{F}{20 \varepsilon_0 V^2} = \frac{10^{-3}}{20 \cdot 10^{-11} \cdot 10^{4}}$$

$$= 500$$

$h = 50\,\mu m \quad g = \frac{50}{20} = 2.5\,\mu m$

$w = 2.5\,\mu m$

$500 \times (5\,\mu m) = 2500\,\mu m$

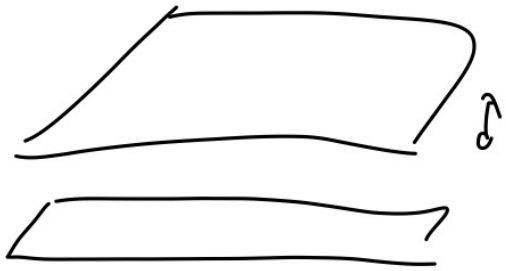


finger length depends on motion range

e.g. 100 µm, $L \approx 400\,\mu m$

$A = 2.5\,mm \times 0.4\,mm$

$A = 1\,mm^2$



$$F = \varepsilon_0 V^2 \frac{A}{d^2}$$

$30\,\mu m \rightarrow 10\,\mu m$
$d = 100\,\mu m \rightarrow 30\,\mu m$
$300\,\mu m \rightarrow 100\,\mu m$

$$A = \frac{d^2 F}{\varepsilon_0 V^2} = \frac{(10^{-4})^2 \cdot 10^{-3}}{10^{-11} \cdot 10^4}$$

$$= 10^{-8-3+11-4} = 10^{-4}\ m^2$$

$A = 100\ mm^2 = 10\,mm \times 10\,mm$

if $d = 300\,\mu m$
$A = 30 \times 30\ mm$!!

if $d = 30\,\mu m$ $A = 3 \times 3\ mm^2$

d= 30 µm, A= 3x3 mm^2
d= 100 µm, A= 10x10 mm^2
d= 30 µm, A= 30x30 mm^2