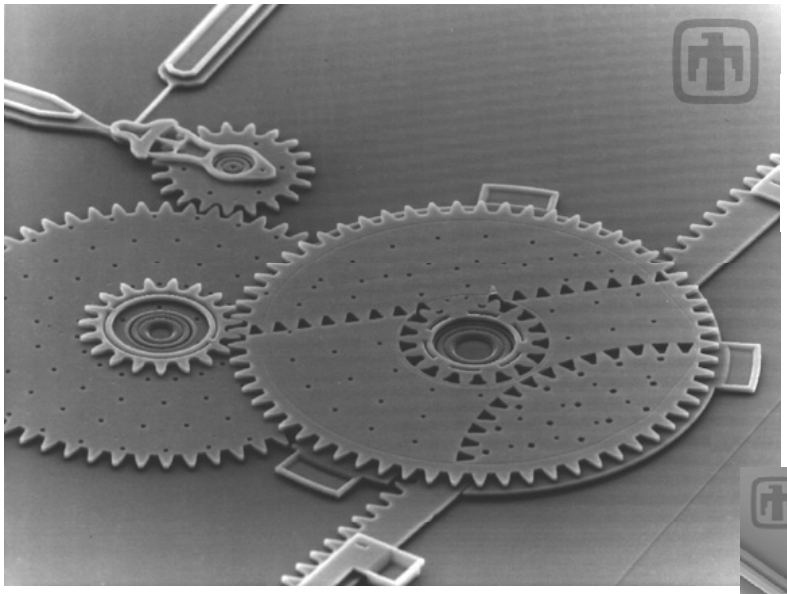
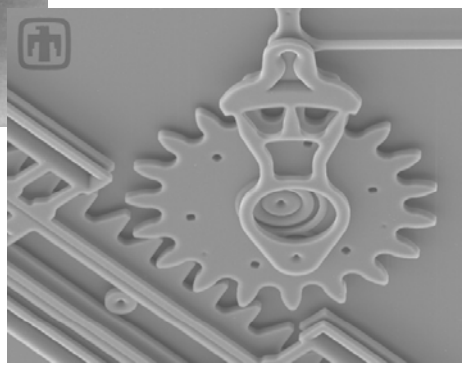


This gear chain converts rotational motion (top left) to linear motion, thereby driving a linear rack (lower right).



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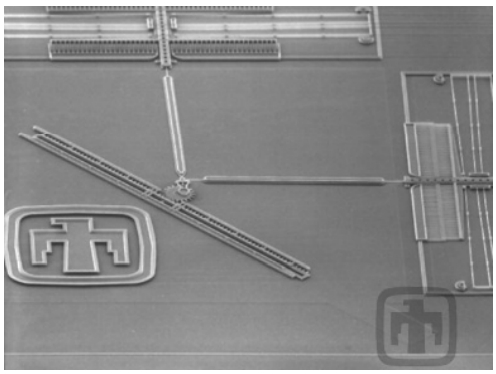
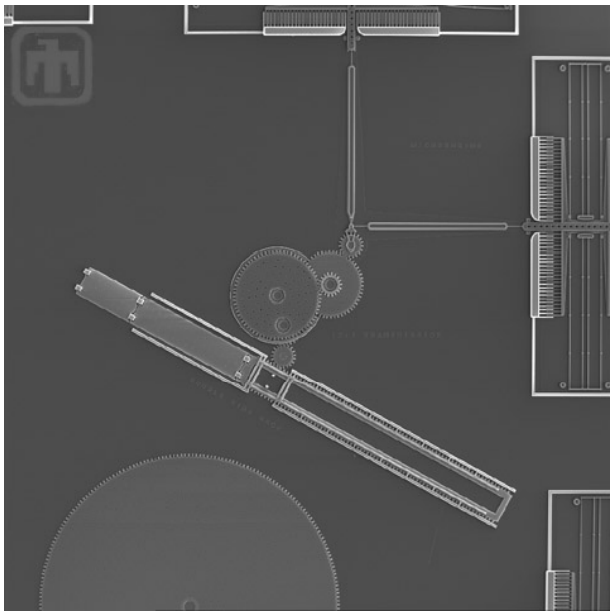
Comb drive actuators

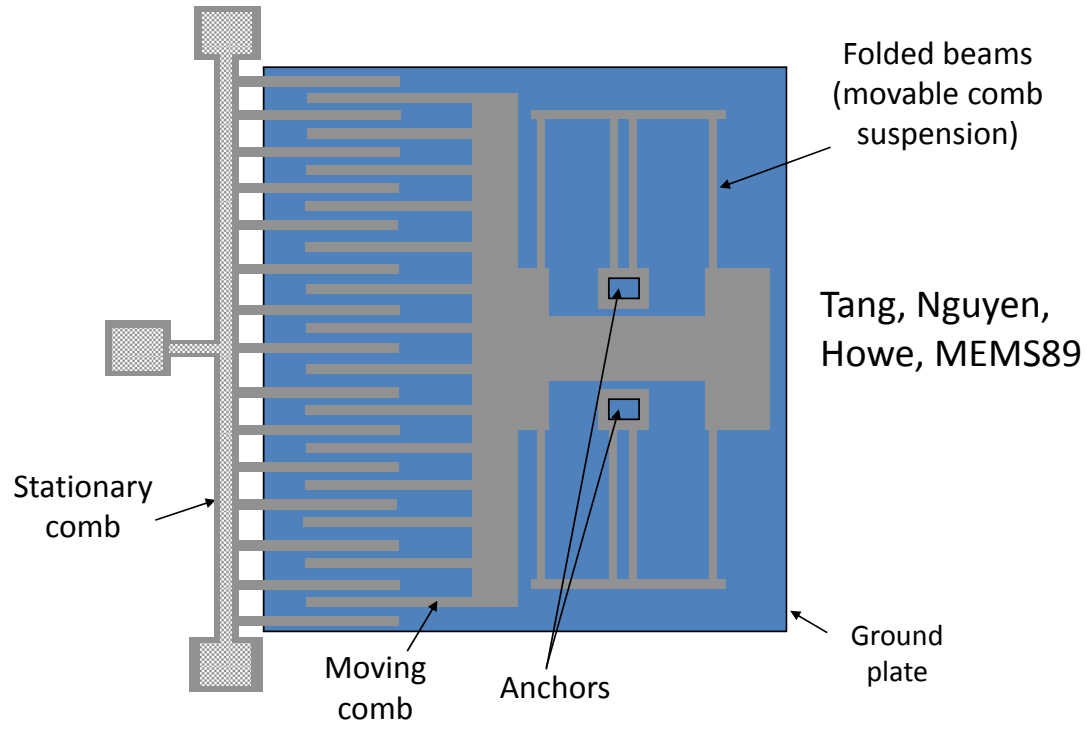


The comb drives (top and right) rotate the main drive gear, which is meshed with a linear rack. This mechanism converts rotational motion into linear motion to perform work.



Courtesy of Sandia National Laboratories, SUMMiT™ Technologies, www.mems.sandia.gov

Layout of electrostatic combdrive



Interdigitated Finger Capacitors

Opposite walls of comb fingers in the overlapped region form a parallel-plate capacitor with capacitance C. The magnitude of C between two immediate neighboring finger is

$$C = \varepsilon \frac{l_0 t}{x}$$

The electric energy U stored by a given capacitor is

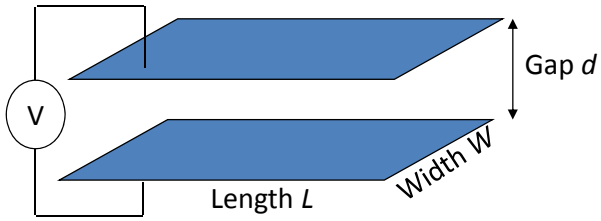
$$U = \frac{1}{2} C V^2$$

As a differential voltage is applied between two parallel plates, an electrostatic attraction force will develop. The magnitude of the force is given by

$$F = \left| \frac{\partial U}{\partial x} \right| = \frac{1}{2} \frac{C V^2}{d}$$

Electrostatic forces in parallel plates

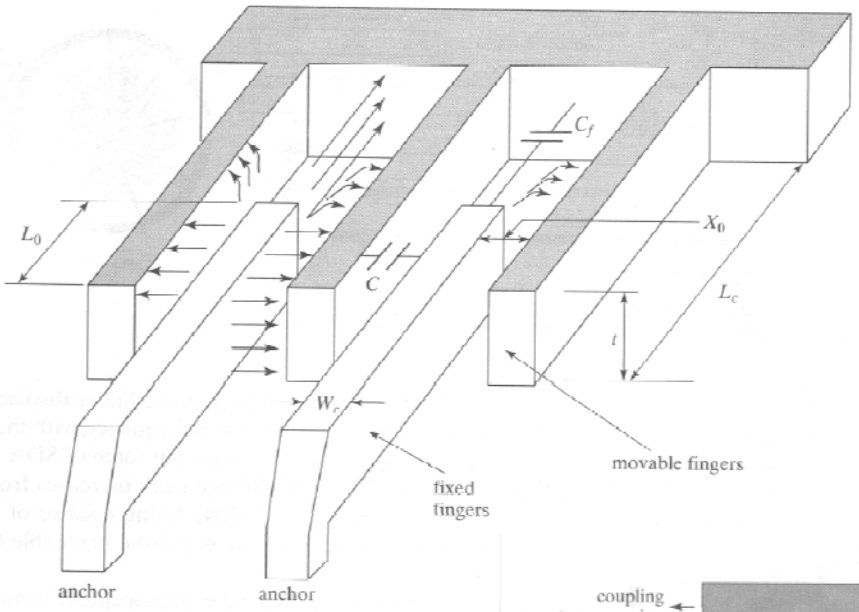
A capacitor stores electrical charge on its plates. It contains energy that depends on the amount of stored charge or on the electric field between the two plates.

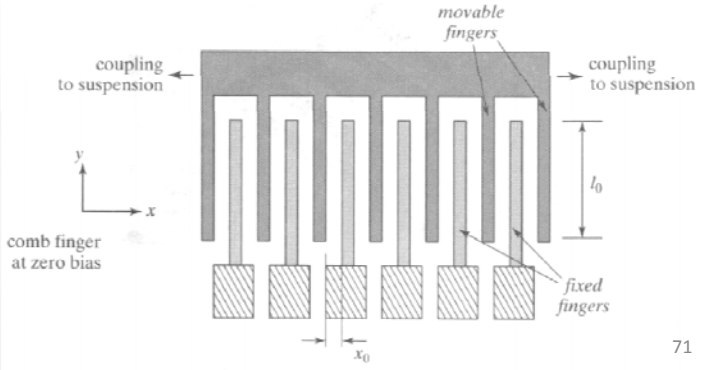


Given a parallel plate capacitor with plate area A and plate separation d, the capacitance is given as

The energy associated with this electric potential is:

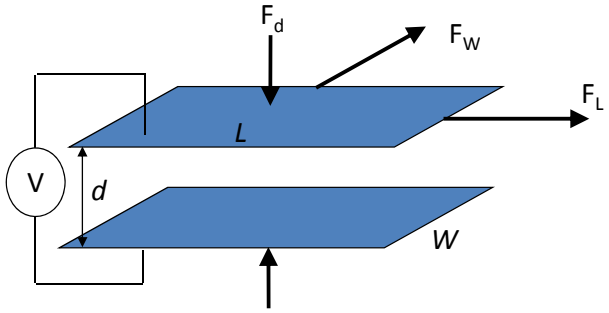
The electrostatic force that is normal to the plates (in the *d* direction) is:





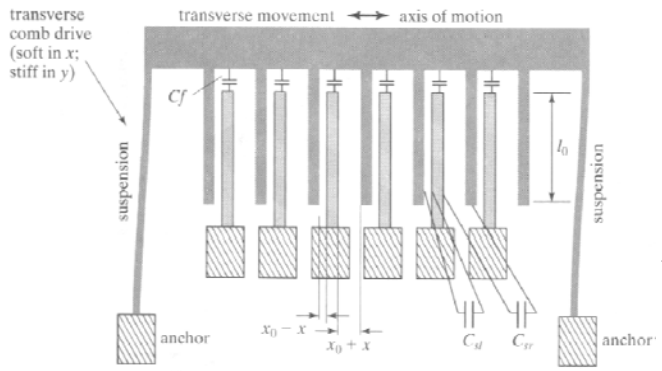
Electrostatic forces in parallel plates

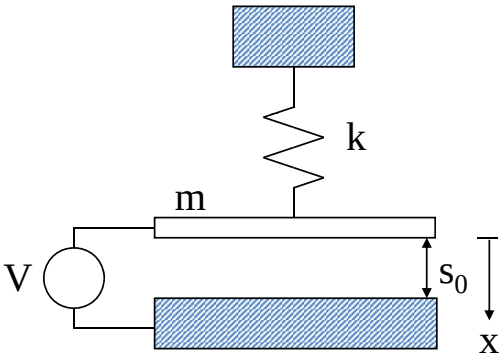
We can also derive expressions for electrostatic forces in the width *W* and length *L* directions.

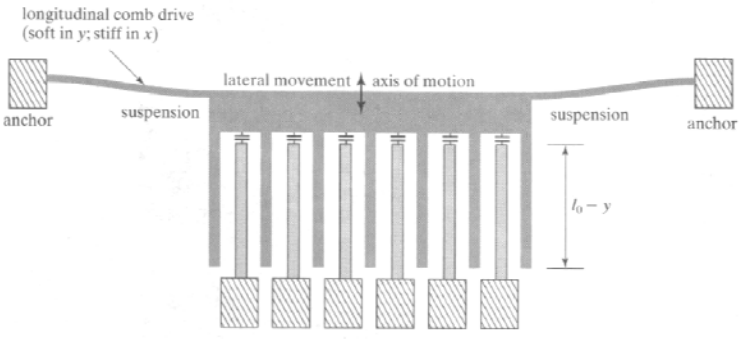


These forces are induced with partial alignment of the plates in the respective directions.

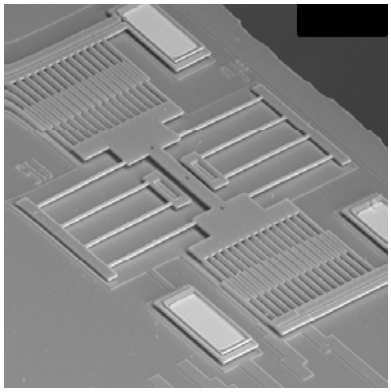
Parallel-Plate Electrostatic Actuator



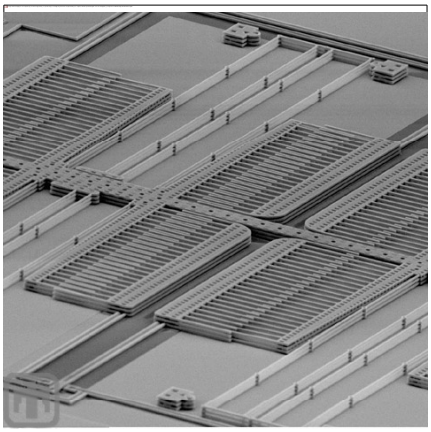




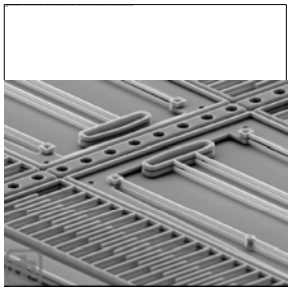
Comb Drives



Tang/Nguyen/Howe



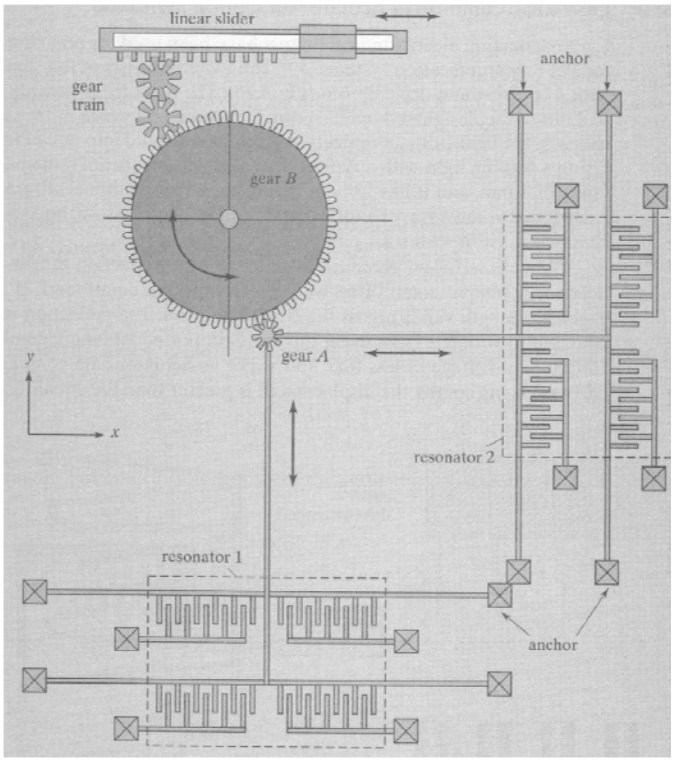
Sandia cascaded comb drive
(High force)

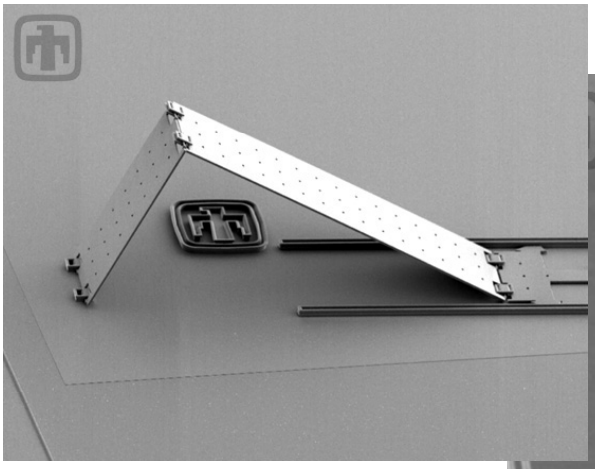


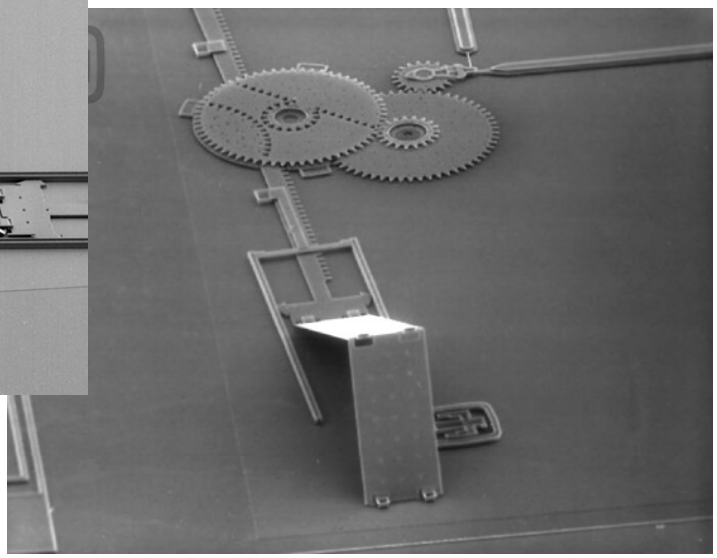
Close-up

Comb drive actuator with large displacement

A gear-train mechanism made by researchers at Sandia National Laboratories.
The gear train receives driving power from two sets of lateral comb drivers. The movement in the *x* and *y* axes is phase locked, so that gear *A* follows an elliptical path. Gear *A* engages gear *B* intermittently, causing gear *B* to continuously rotate in one direction. The motion of gear *B* is further translated through the gear train to achieve linear movement of a linear slider.



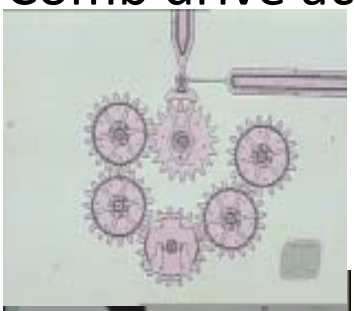




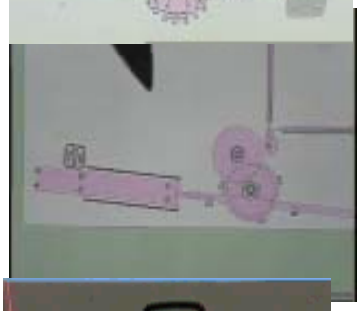
A mirror system design; in this system the mirror is elevated by a three-gear torque-multiplying system. The mirror is shown in the upright position.

Courtesy of Sandia National Laboratories, SUMMiT™ Technologies, www.mems.sandia.gov

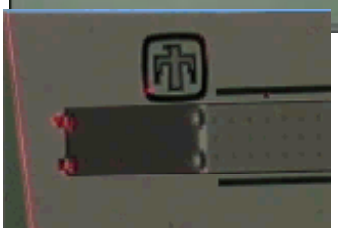
Comb drive actuator



This video shows the six-gear planar train operating at variable working speeds.



Force provided by a comb drive actuator moves a linear rack, which drives a hinged sheet of silicon back and forth. A HeNe optical-band (red) laser is focused at an angle such that as the mirror is elevated, the coherent light is reflected into the microscope's camera.



Here a mirror is slowly raised and lowered to show the deflection of laser light.

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