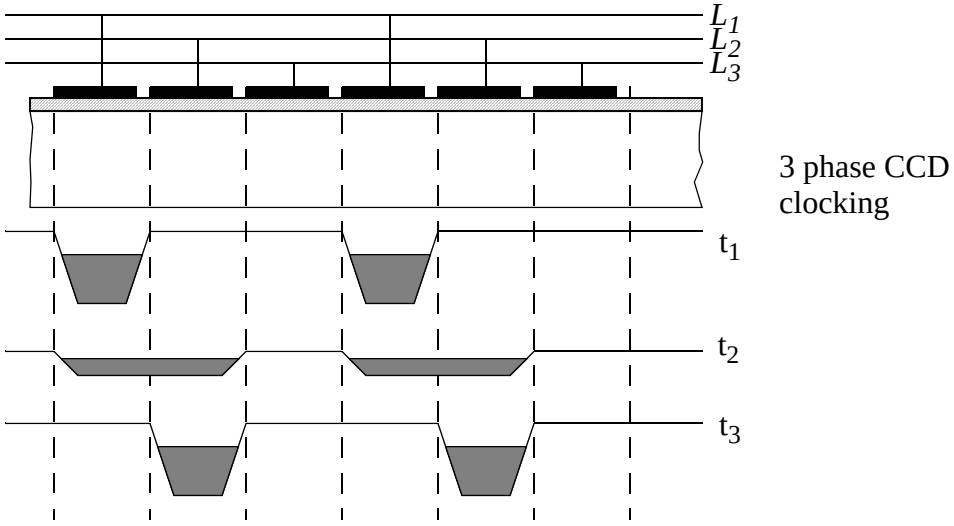
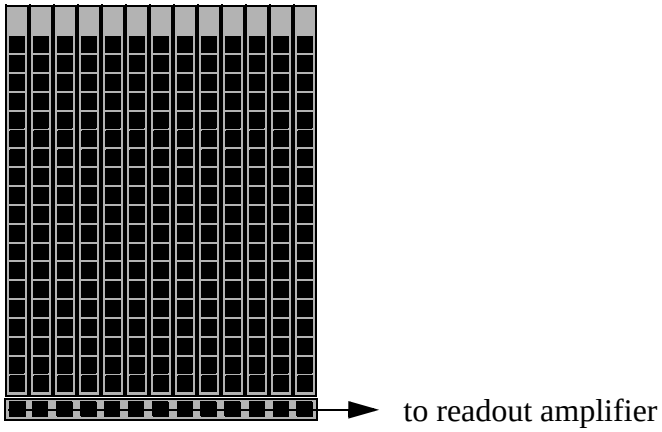
Lecture 15

Charge coupled device (CCD)

The basic CCD is composed of a linear array of MOS capacitors. It functions as an analog memory and shift register. The operation is indicated in the diagram below:



In the fashion indicated, charge is transferred down the line. In the modern CCD image sensor, there is one such CCD transfer line for each column of the array. During the image exposure, one phase in each column is biased in deep depletion. Light passes through the gate electrodes, which are made thin enough so that most of the light creates electron-hole pairs in the substrate, which are then collected under the gates. To read out the array, each column is clocked down by one. At the bottom, there is one extra CCD line oriented in the horizontal direction. The columns deposit their charge in this horizontal array, which then clocks out to a charge sensitive amplifier and then off-chip. In turn, the array is read out one line at a time in this fashion.



Spatial Light Modulator (SLM)

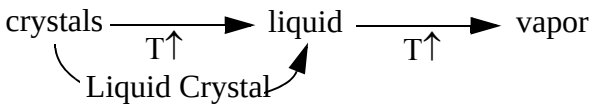
Electro-optic devices that can modulate certain properties of an optical wavefront: amplitude, intensity, phase, or polarization

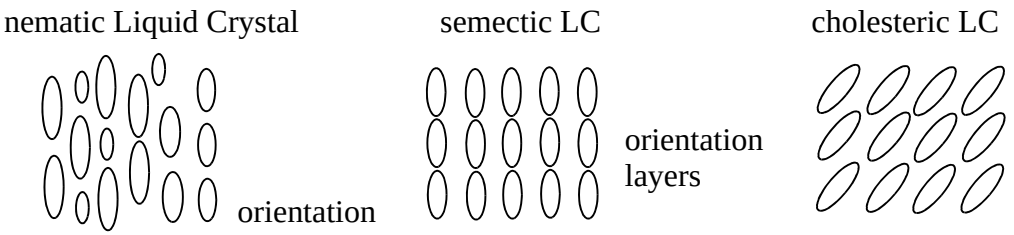
Liquid Crystal Display – Liquid Crystal Light Valve

By using two polarizers, twisted nematic liquid crystal and applied electric field, modulation of light intensity can be achieved

Advantage of LCD	**Disadvantage**
a) size and weight	a) viewing angle
b) low power consumption	b) high cost
c) color performance	c) low temperature operation
d) low cost due to mass production	

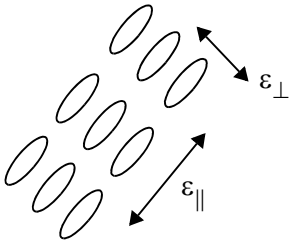
Liquid Crystal





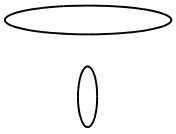
Properties of LC

Dielectric anisotropy



$$\Delta\varepsilon = \varepsilon_{\perp} - \varepsilon_{\parallel} > 0$$

Optical anisotropy (birefringence)

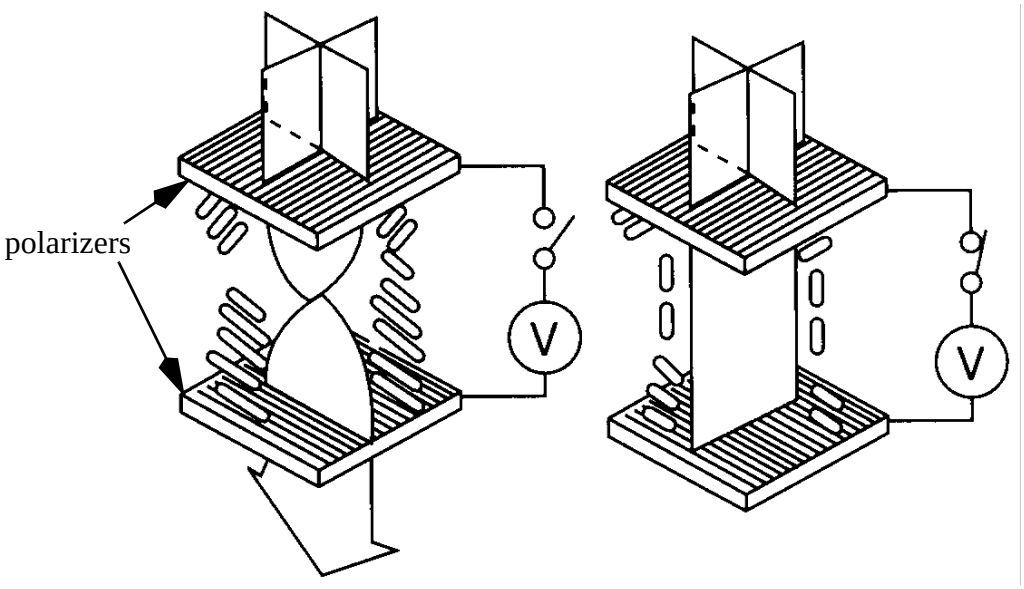


extraordinary (n_e)

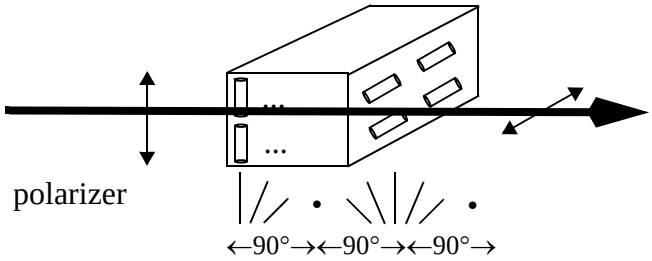
ordinary (n_o)

$$\Delta n = n_e - n_o > 0$$

Twisted nematic Liquid Crystal (90° rotation)

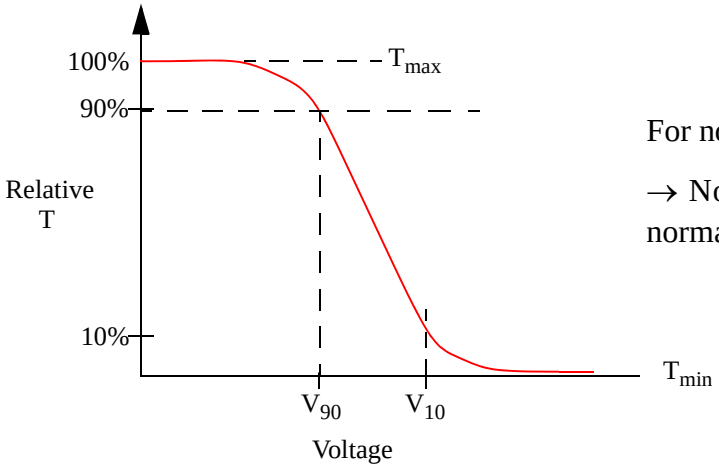


Super twisted nematic Liquid Crystal (180 - 270° rotation)



270° change of polarization

Electro-optic response of a TN LC cell



For normally-white case.

→ Normally-black is a mirror image of normally white.

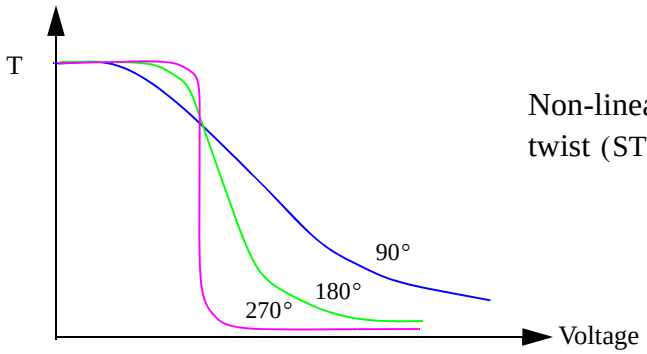
– contrast ratio = T_{max}/T_{min}

– grayscale achieved with intermediate value of V.

Example:

6 bit ⇒ 64 voltage levels
8 bit ⇒ 256 voltage levels

Electro-optic response: Effect of twist



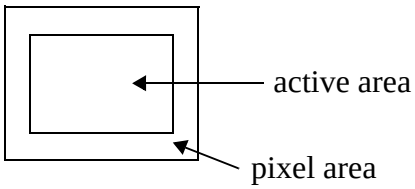
Non-linearity increases as increasing twist (STN > TN).

– steep electro-optic response is needed for high-contrast passive-matrix displays ⇒ NO CROSSTALK– advantage of using STN-LC.

Pixel – Smallest resolvable spatial information element

– May be subdivided to achieve color or gray scales

– Active area can be less than pixel area (~30%).

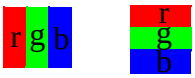


You can calculate the pixel size for a given display type and size.

CGA	640 × 200(V)
VGA	640 × 480(V)
SVGA	800 × 600(V)
XGA	1024 × 768(V)
SXGA	1280 × 1024(V)
VXGA	1600 × 1280(V)

Pixel arrangement for color displays

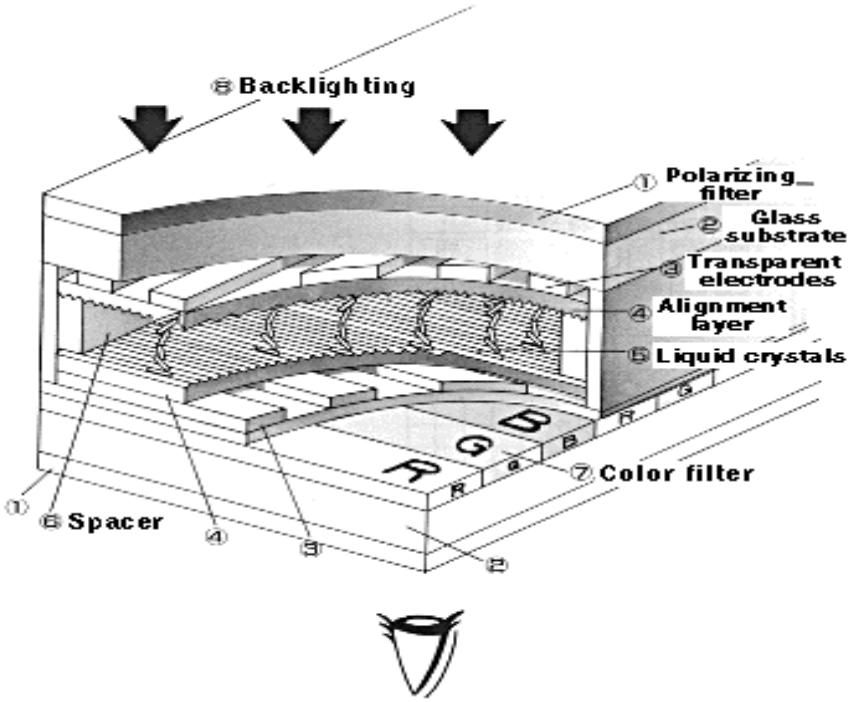
Triad 

Stripe 

Quad 

⇒ human eyes pick up green more

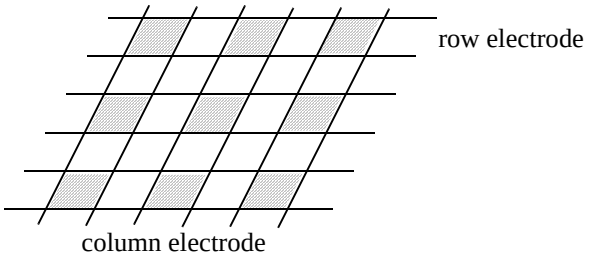
Cross-section of LCD (typical)



Matrix Addressing Mode

Passive Matrix

Example: Earlier laptop display, PDAs



– stripes of conductor on opposing glass plates

– pixels defined by intersection of electrodes

- Non-linearity requirement for PM LCD
  – want to have high non-linearity to reduce cross-talk
- Discrimination ratio (D): $D = L_{on}/L_{off}$, where L = luminance (transmitted)
- Pixel Contrast Ratio (PCR): $= \frac{L_{on} + (M-1)L_{off}}{M \cdot L_{off}}$, where M = number of display rows

–TN LCD:Low PCR and D

STN LCD:High PCR and D

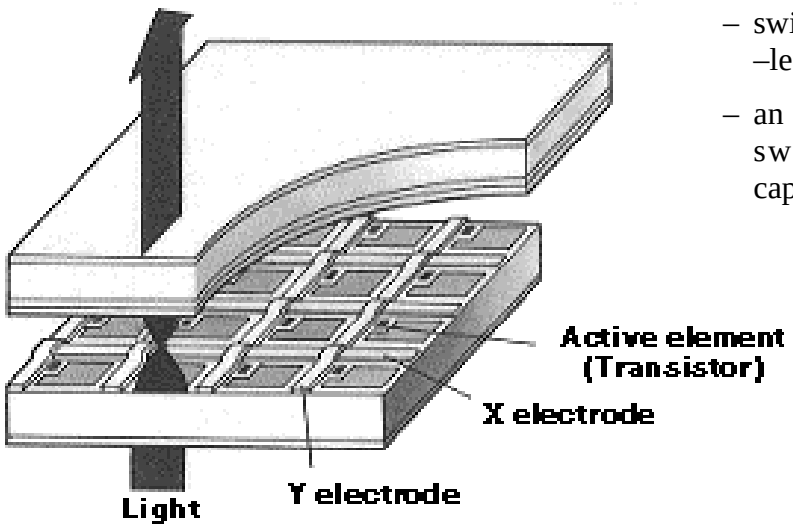
Active Matrix

Example: Laptop display, desktop monitor

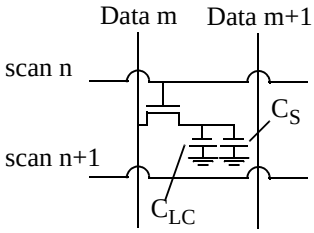
– array of pixel electrodes on one glass plate

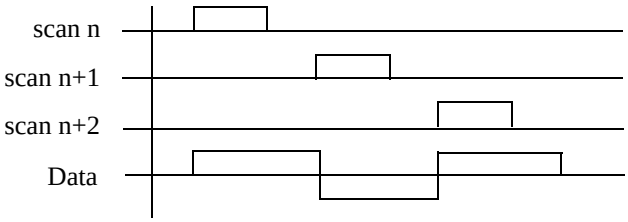
– switch at each pixel for isolation –less crosstalk

– an active element is used as a switch to store charge on LC capacitor



– switching element = thin-film transistor (TFT)





C_{LC}: liquid crystal capacitance
C_S: storage capacitance