# LCD Monitors

## Outline:

- How LCD monitors work?
- Basic cell structure.
- Active v. passive matrix.
- Direct v. multiplexed control.
- How LCD monitor fits together with DVI interface?

# **<u>Basic information</u>**

- Liquid crystal was discovered by an Austrian botanist Fredreich Rheinizer in 1888.
- "Liquid crystal" is neither solid nor liquid (an example is soapy water).
- Important: in the mid-1960s, it was shown that **liquid crystals when stimulated by an external electrical charge could change the properties of light passing through the crystals**.
- The early prototypes (late 1960s) were too unstable for mass production. But all of that changed when a British researcher proposed a stable, liquid crystal material (biphenyl).
- Today's color LCD TVs and LCD Monitors have a sandwich-like structure (see figure below).
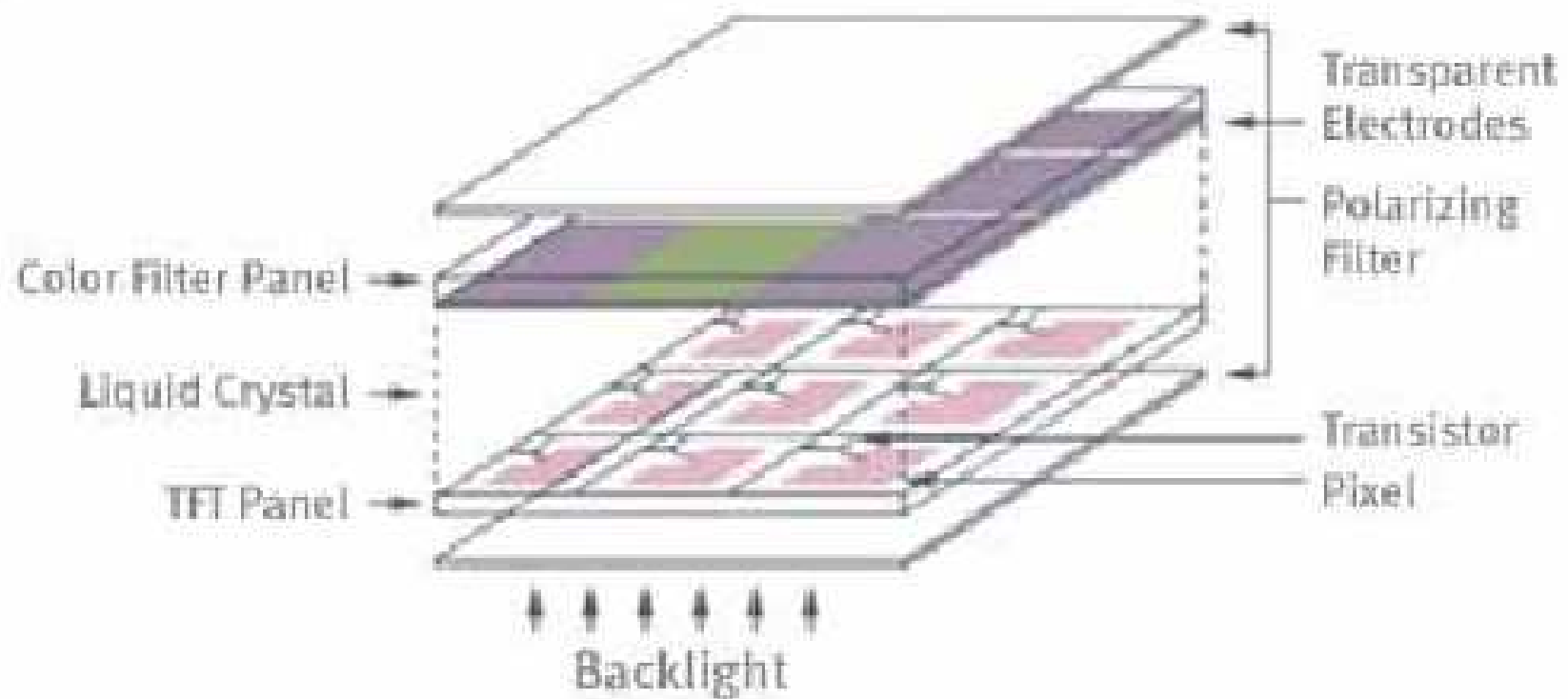
Fig. 1 LCD display structure (active matrix)

What is TFT LCD?

- TFT LCD (Thin Film Transistor Liquid Crystal Display) has a sandwich-like structure, liquid crystal fills the space between two glass plates.
- TFT Glass has as many TFTs as the number of pixels displayed, while a Color Filter Glass has color filter which generates color.
- Liquid crystals rotate according to the difference in voltage between the Color Filter Glass and the TFT Glass.
- The amount of light supplied by Back Light is determined by the "amount" of rotation of the liquid crystals.
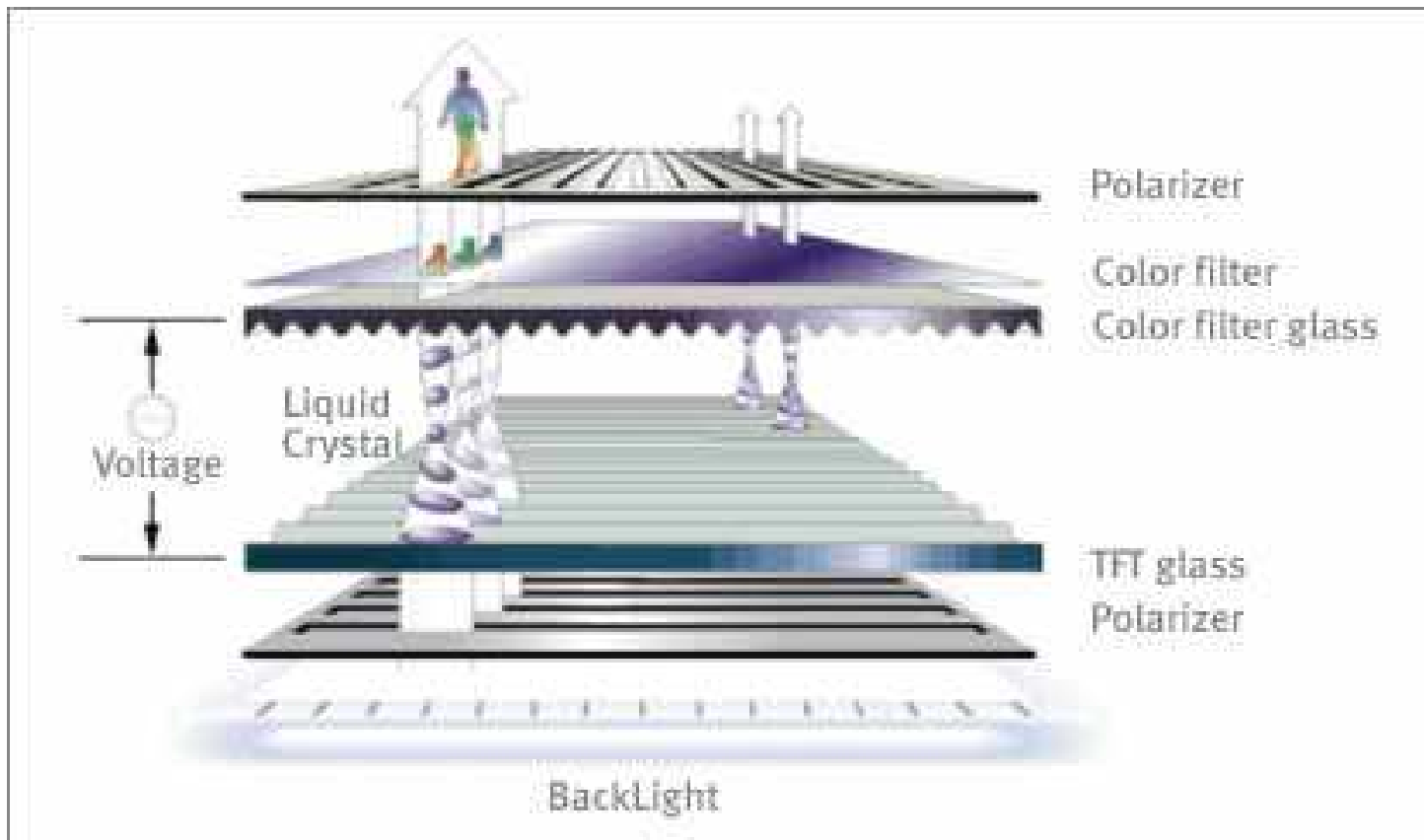
Fig. 2 Basic principles of LCD display

- How it works?
  The source of light produces a light. The light passes through liquid crystal, its intensity is influenced by other layers, especially by liquid crystal.
  Basic structure: two layers made of glass, liquid crystal between them.
- The flow of light is controlled by the voltage applied to the liquid crystal (between color filter glass and TFT glass).
- According to the voltage applied, the structure of the liquid crystal rotates (different angle for different pixel/subpixels) – thus for each pixel/subpixel different amount of light passes through the liquid crystal.
- TFT glass – transistors are on the surface, each of them controls the voltage brought to ITO electrode.

- Front glass – Colored RGB filters on the surface. They develop each color in the intensity corresponding to the amount of light passing through the liquid crystal.
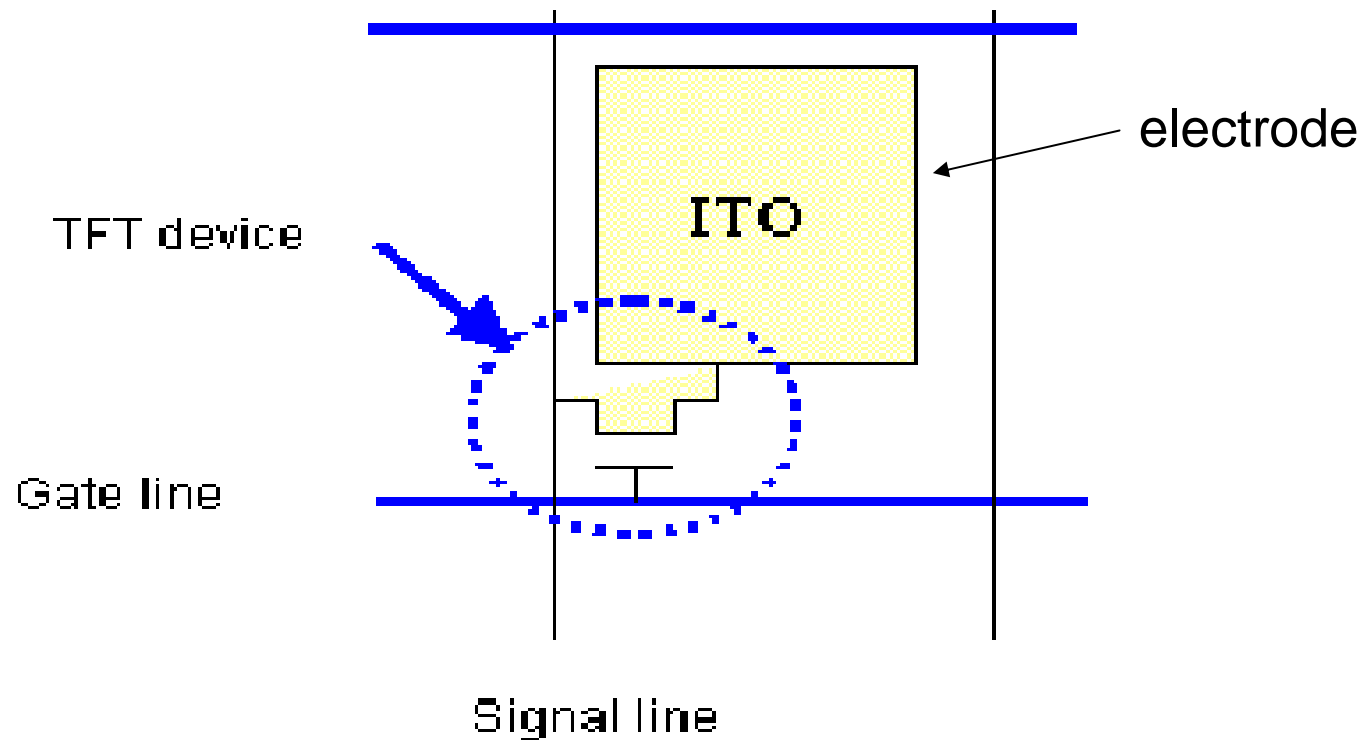- The electrode on the side of screen is common for all pixels.

Fig. 3 Basic LCD display cell (active element)

- Terminology:
  Gate line – selection, signal line – information about color

ITO - Indium-Tin Oxide (ITO) electrode (the electrode is transparent).



Fig. 4 The control of display segments (active matrix)

- How it works?

  – 20 V brought to a line  (to the TFT control electrode) – the line is selected.

  -5 V brought to the line, the line is not selected.

  **If a line is selected (- 20 V on the line) then it is possible to bring voltages through signal lines on to electrodes. This causes that the liquid crystal cell rotates and the amount (intensity) of light passing through the liquid crystal is changing.**

- The voltages brought to signal lines are derived from values transferred through DVI (from graphics adapter to monitor).

- On the glass layer, the number of transistors is the same as the number of pixels multiplied by 3 (each pixel consists of 3 subpixels) – the number of TFTs might be a problem from the

technological point of view (the association with the resolution required).

- Each subpixel has its own transistor, ITO electrode and capacitor.
- Note: in mono monitor there should be no subpixels but just one TFT (transistor) for each pixel.
- By scanning the gate bus-lines sequentially, and by applying signal voltages to all signal lines in a specified sequence, we can address all pixels. One result of all this is that the addressing of an LCD is done line by line.
- Mono LCDs are designed to produce gray levels - intermediate brightness levels between the brightest white and the darkest black a unit pixel can generate. There can be either a discrete numbers of levels - such as 8, 16, 64, or 256 - or a continuous gradation of levels, depending on the LCD monitor.
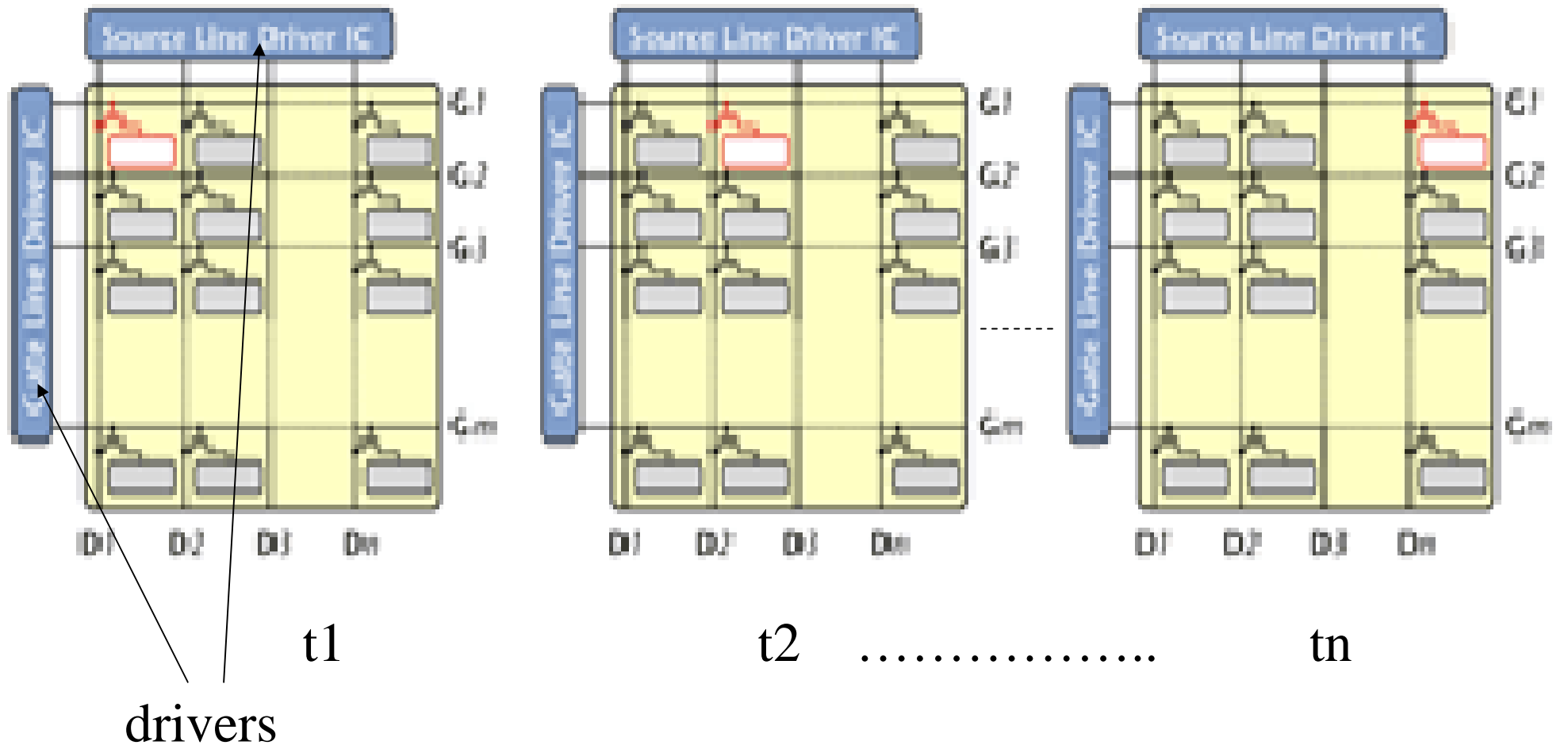
t1                    t2    ……………..            tn

drivers

Fig. 5  How it works within one scan-line
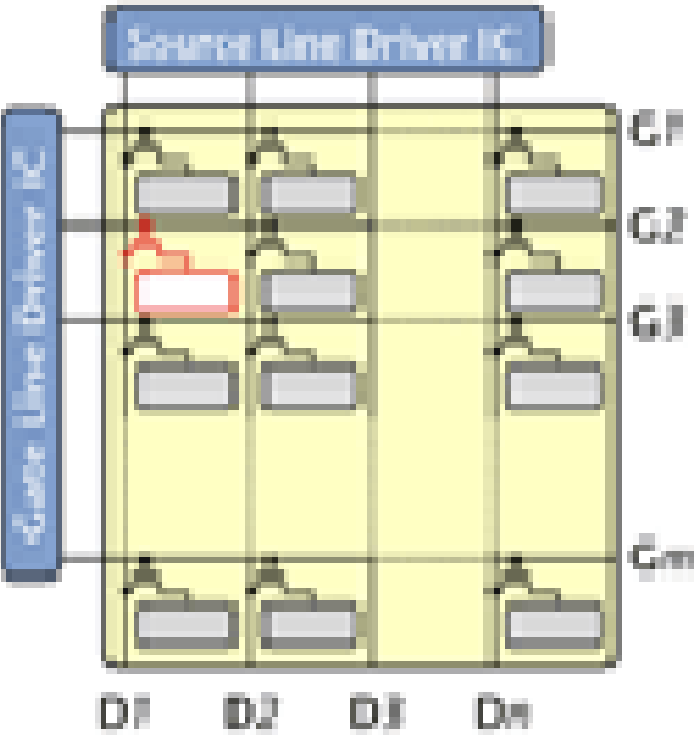
- The following scan-line.



Fig. 6

## Segment v. matrix driving

- The most common liquid-crystal displays (LCDs) in use today rely on picture elements, or pixels, formed by liquid-crystal (LC) cells that change the polarization direction of light passing through them in response to an electrical voltage.
- As the polarization direction changes, more or less of the light is able to pass through a polarizing layer on the face of the display. When the voltage changes, the amount of light is changed.
- There are two ways to produce a liquid-crystal image with such cells: the segment driving method and the matrix driving method.

- The segment driving method displays characters and pictures with cells defined by patterned electrodes (7 segment display).
- The matrix driving method displays characters and pictures in sets of pixels.
- The segment driving method is used for simple displays, such as those in calculators, while the pixel-matrix drive method is used for high-resolution displays, such as those in portable computers and TFT monitors.

**Direct vs. multiplex driving of LCD TVs.**
- Two types of drive methods are used for matrix displays:
    - static, or direct, driving,
    - multiplexed driving method

**Static (direct) driving**

- Each pixel is individually wired to a driver. This is a simple driving method, but, as the number of pixels is increased, the wiring becomes very complex. An alternative method is the multiplex drive method, in which the pixels are arranged and wired in a matrix format.
- Disadvantage: a great number of wires, it can be used in applications with a small number of pixels. It cannot be used for monitors.
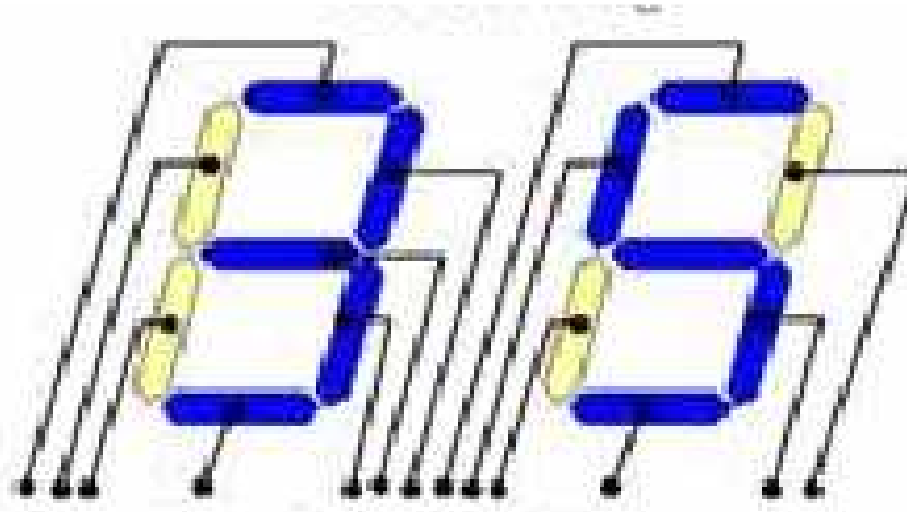
Fig. 7 Direct driving

**Multiplexed driving**

- To drive the pixels of a pixel-matrix LCD, a voltage is applied at the intersections of specific vertical signal electrodes and specific horizontal scanning electrodes.
- This method involves driving (selection) several pixels at the same time by time-division in a pulse drive. Therefore, it is also called a multiplex, or dynamic, drive method.
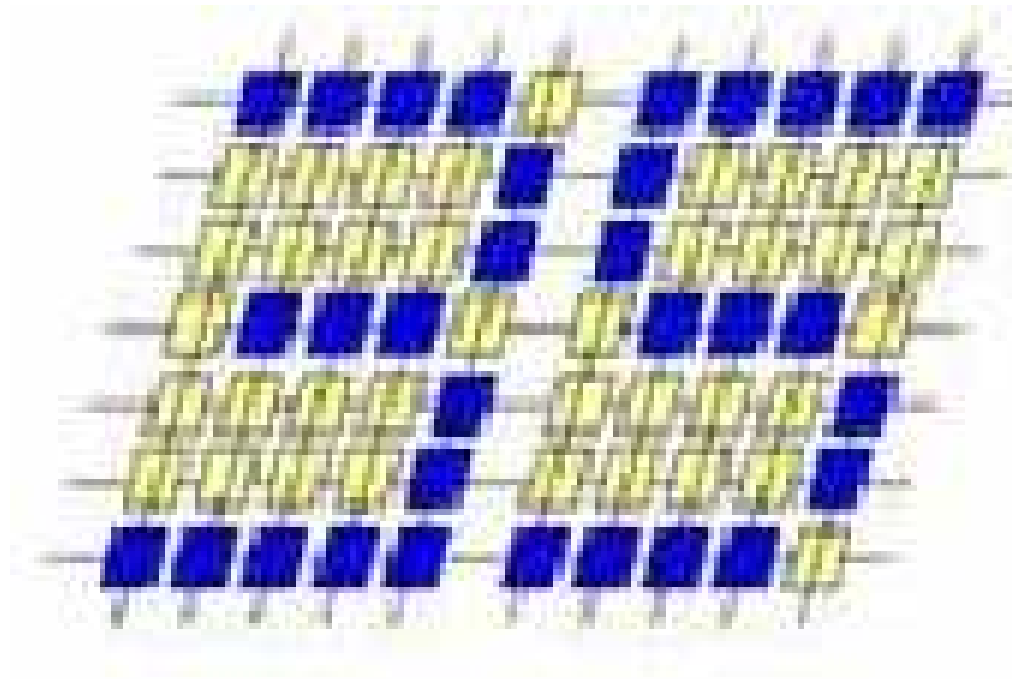
Fig. 8 Multiplexed driving

- Horizontal wire is driven first, then the columns are driven sequentially.
- Advantage: lower number of wires.
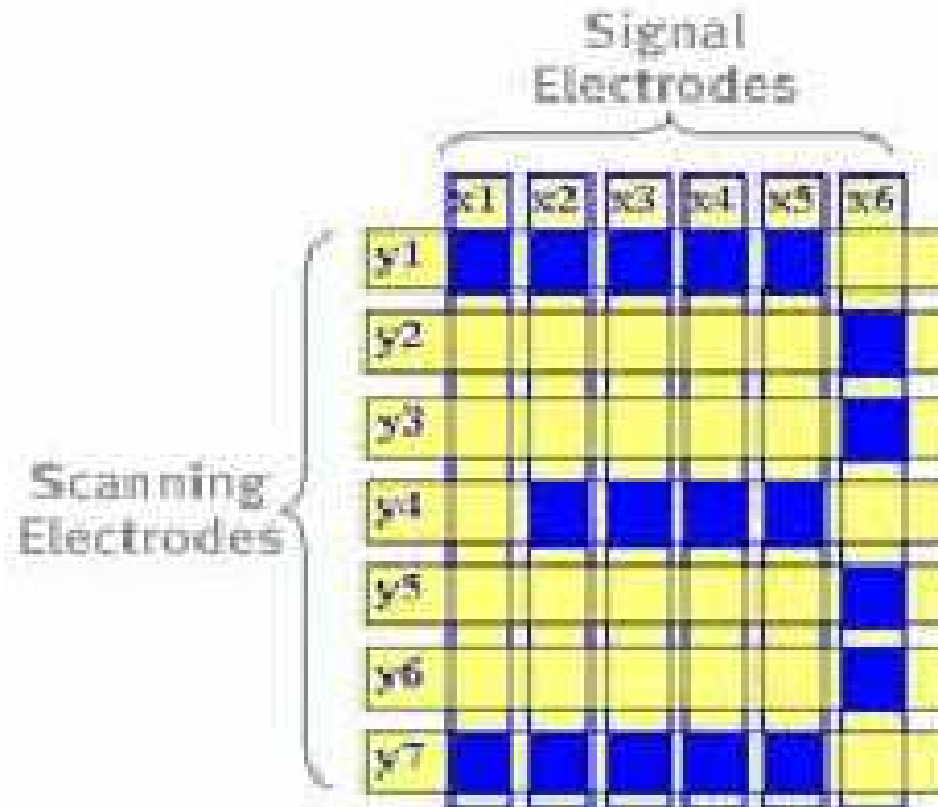
# Passive matrix (PMLCDs)



Fig. 9 Passive matrix
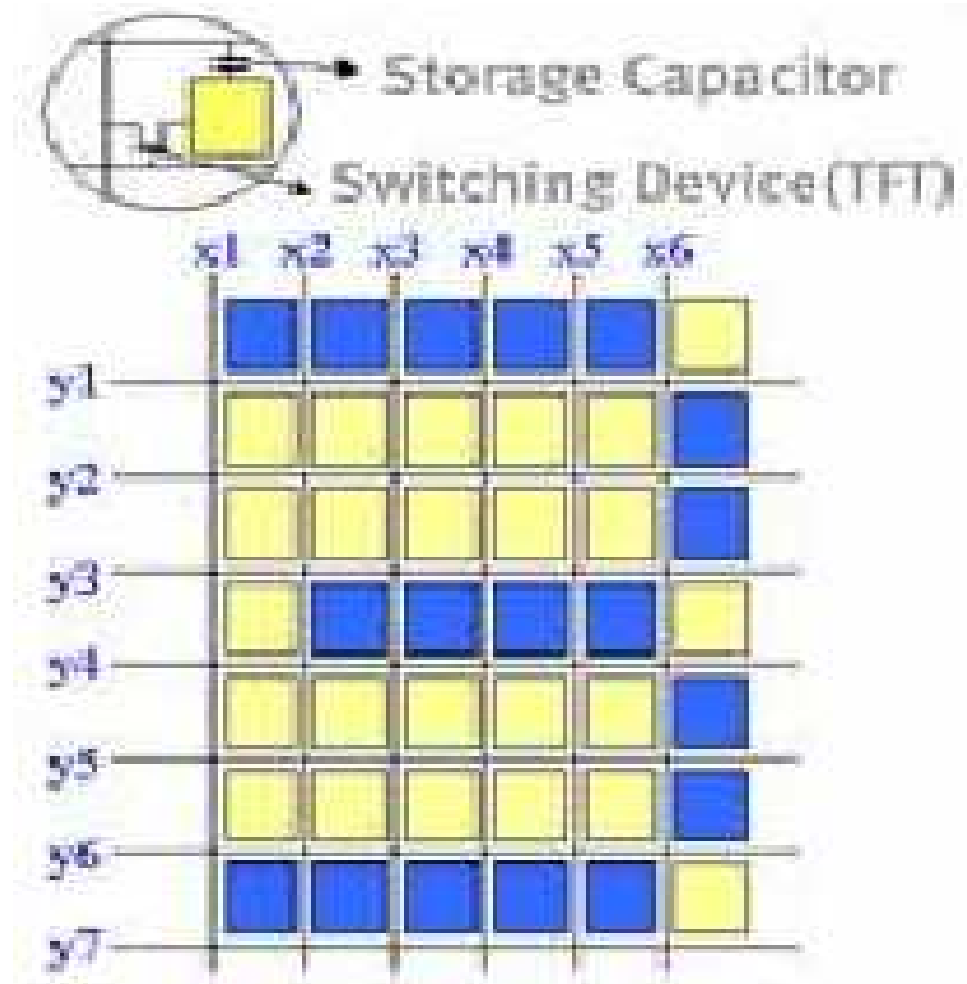
## Active matrix



**Fig. 10 Active matrix**

- Passive matrix: no active elements.
  It is slower.
  Lower resolution.

- Active matrix: active elements (transistors) are used to address pixels.
  Higher resolution.
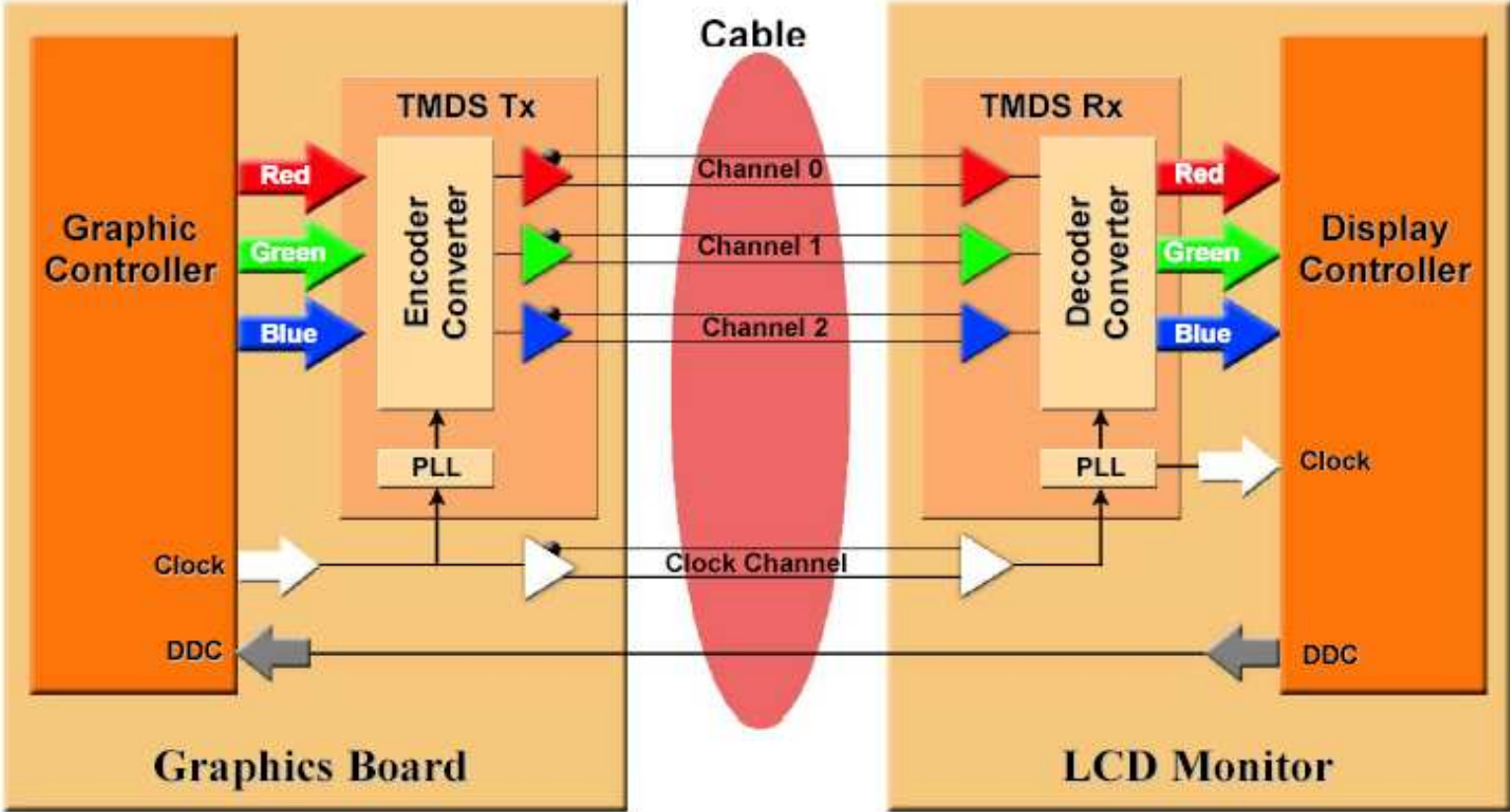
# How LCD monitor fits together with DVI interface?



Fig. 11 LCD monitor with DVI interface

- The information about color is transported serially from the graphics adapter to monitor through 3 wires (R, G, B) - possibly 8 bits per color.
- This information is processed by the monitor and converted into 3 voltages for each color.
- For higher resolutions – 2 channels must be used (the higher resolution is required, the higher bandwidth is needed – one channel cannot cope with it).
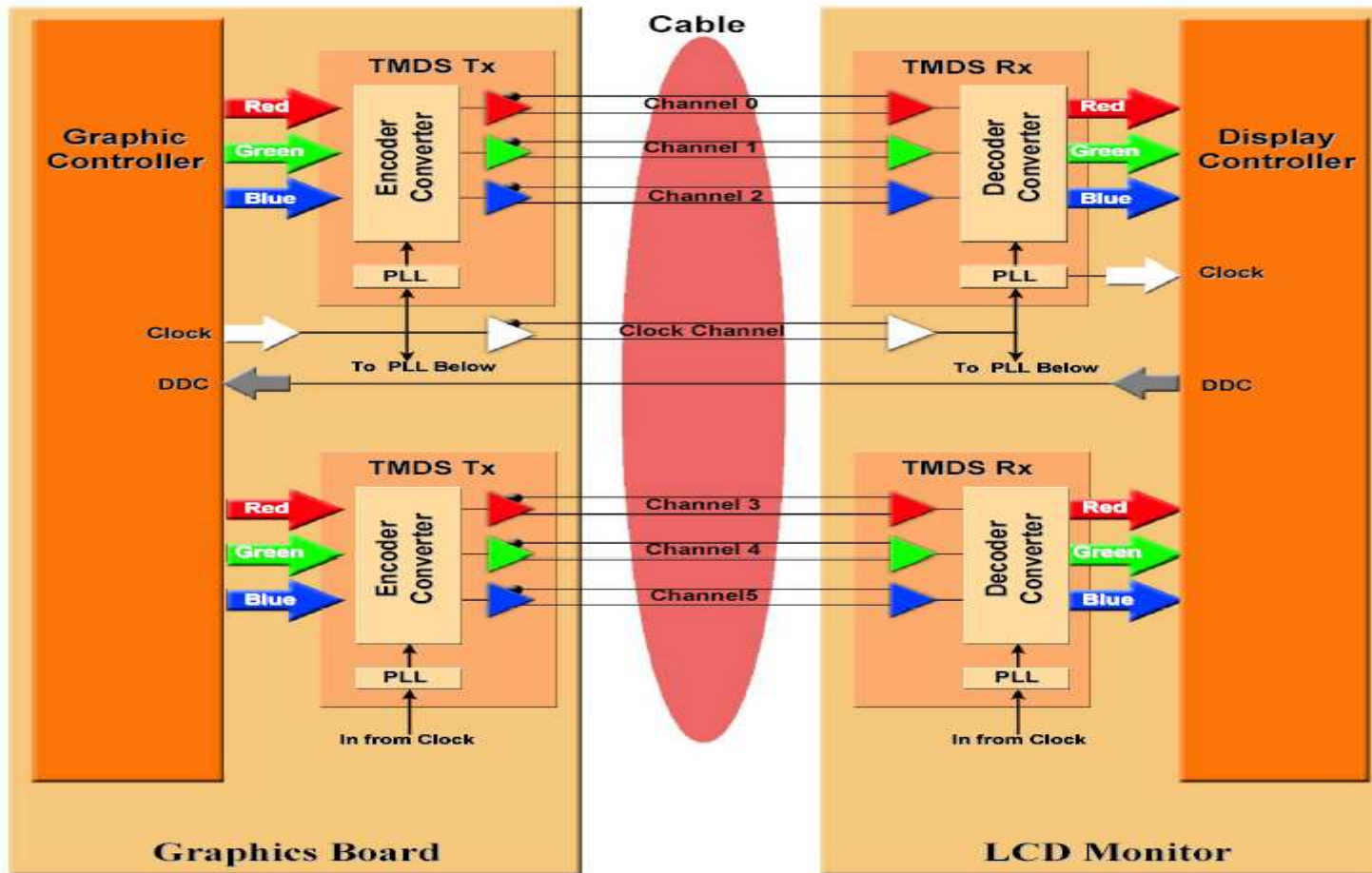
Fig. 12 LCD monitor with DVI interface – 2 channels

These voltages are derived from information about color delivered
serially through DVI interface.