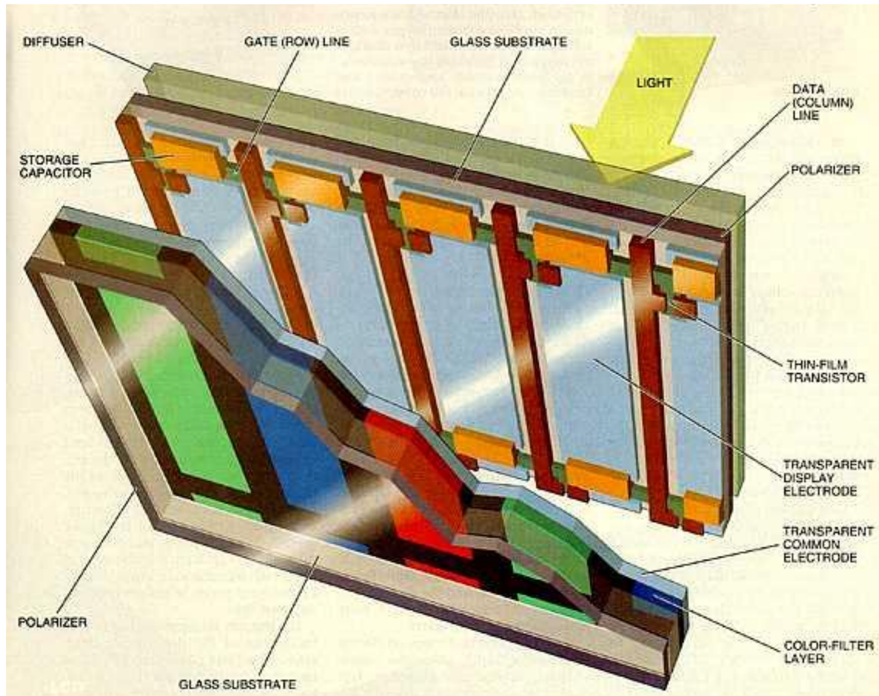
LCD
TRAINING COURSE



This was for engineer training on LCD's put together by Thierry Borel.

PRINCIPLE TRAINING

- Introduction
- General training
  - LCD Pixel Structure
    - Optical Effects
    - Electrical Effects
  - LCD Panel Structure
  - Active Matrix Displays
    - Structure
    - Addressing Techniques
  - General Electronics Block Diagram
    - LCD Drivers
    - LCD Controller
    - Upstream Video Processing
  - Back Lighting
  - Characterization Principles
    - Main Optical Parameters to Examine
    - Measurement Methods and Tools

ADDITIONAL TRAINING
For interested audiences!

- **Annex training**
  - **Passive Matrix displays**
    - **Structure**
    - **STN**
    - **Addressing**
  - **Viewing angle improvements**
    - **Gray level inversion**
    - **Compensation film**
    - **Multidomain**
    - **IPS**

Some LCD Applications

Application	Typical Definition (Column x Line)	Colors	Typical Size (Diagonal)	Special Characteristics
Laptop PC	800 x600 SVGA 1024x768 XGA	3x6 bits	12” – 15” (Palmtop ~8")	Low power
PC-Monitor	1024x768 XGA 1280x1024 SXGA	3x6 bits 3x8 bits	14”5 – 21” ~17”-25” CRT	Very wide viewing angle
PDA	640x240 1/2 VGA	Monochrome or up to 3x6 bits	6"4	Low power or reflective
Automotive	(320+X)x240 QVGA (640+X)x480 VGA X: 16/9 add. Pixels	3x6 bits or analog	5" - 8"	Wide viewing angle
View Finder (Camcorder, Still camera)	320x240 QVGA	3x6 bits or analog	2" to 6"	Wide viewing angle
Light Valve (Projection)	1024x768 XGA 1280x1024 SXGA	Analog	0.7" - 1"3	High light output
LCOS (Rearprojection)	1024x768 XGA 1280x1024 SXGA 1920x1080 HDTV	3x8 bits or analog	0.5" - 0.7 - 1"	Very small size high light output

GENERAL TRAINING

PRINCIPLE TRAINING

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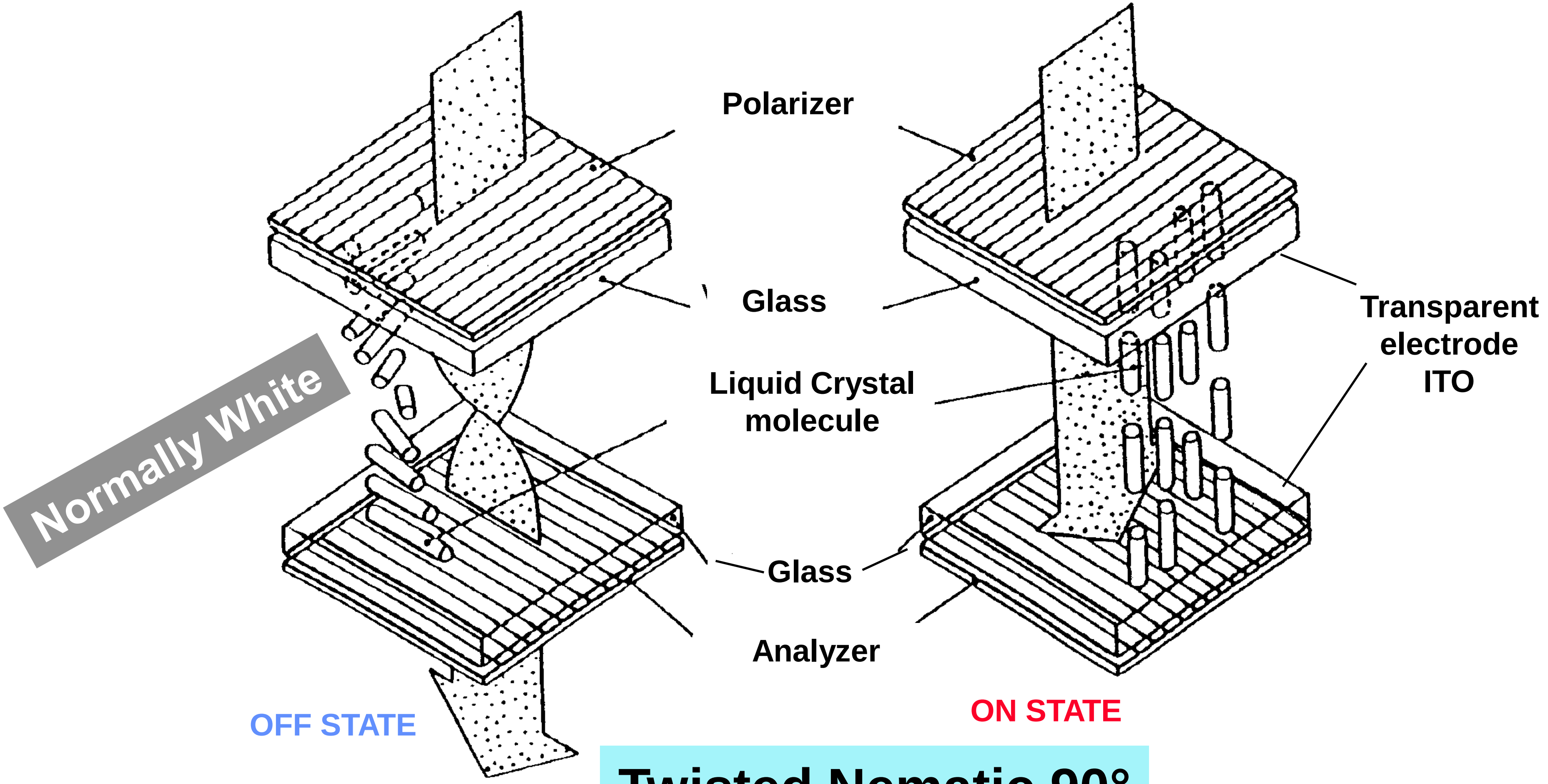
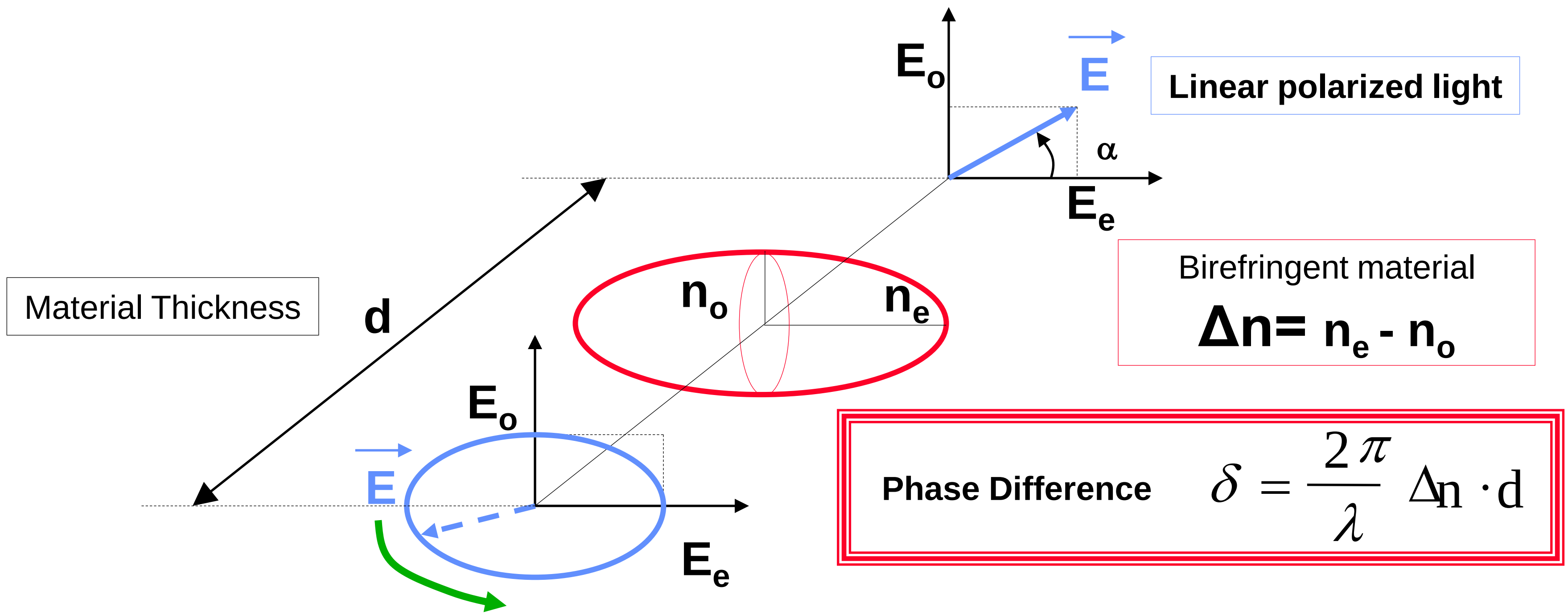
LCD Pixel Structure



Twisted Nematic 90°

LCD Pixel Structure

- Liquid Crystal is a birefringent material
  - Optical anisotropy Δn
  - Dielectric anisotropy $\Delta\varepsilon$
  - The propagation speed of the light depends on the position of the polarization plane versus the birefringence axis

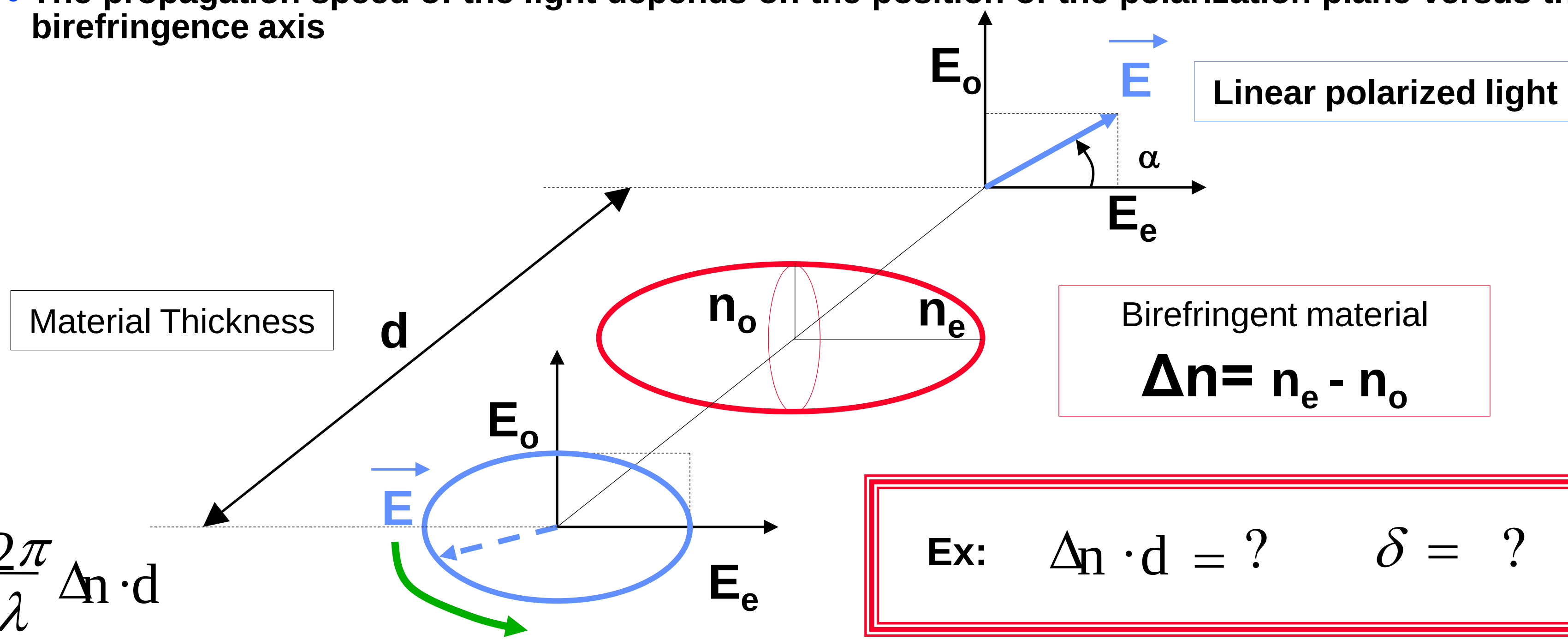


Phase Difference $$\delta = \frac{2\pi}{\lambda} \Delta n \cdot d$$

LCD Pixel Structure

Optically

- **Liquid Crystal is a birefringent material**
  - **Optical anisotropy** Δn
  - **Dielectric anisotropy** $\Delta\varepsilon$
  - **The propagation speed of the light depends on the position of the polarization plane versus the birefringence axis**



$$\delta = \frac{2\pi}{\lambda} \Delta n \cdot d$$

Ex: $\Delta n \cdot d = ?$ $\quad \delta = ?$

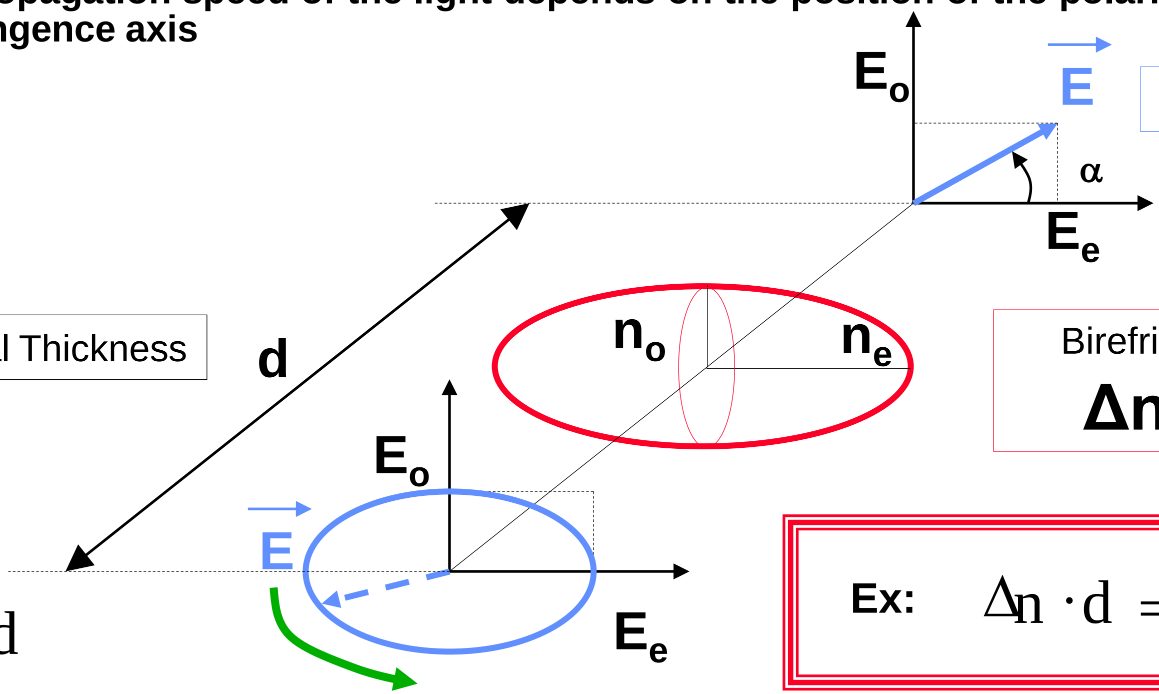
LCD Pixel Structure

- **Liquid Crystal is a birefringent material**
  - **Optical anisotropy** **Δn**
  - **Dielectric anisotropy** **Δε**
  - **The propagation speed of the light depends on the position of the polarization plane versus the birefringence axis**

$$\Delta n \cdot d = \frac{\lambda}{2} + n\lambda$$ ***Optical thickness***

Linear polarized light

Material Thickness



Birefringent material

$$\Delta n = n_e - n_o$$

$$\delta = \frac{2\pi}{\lambda} \Delta n \cdot d$$

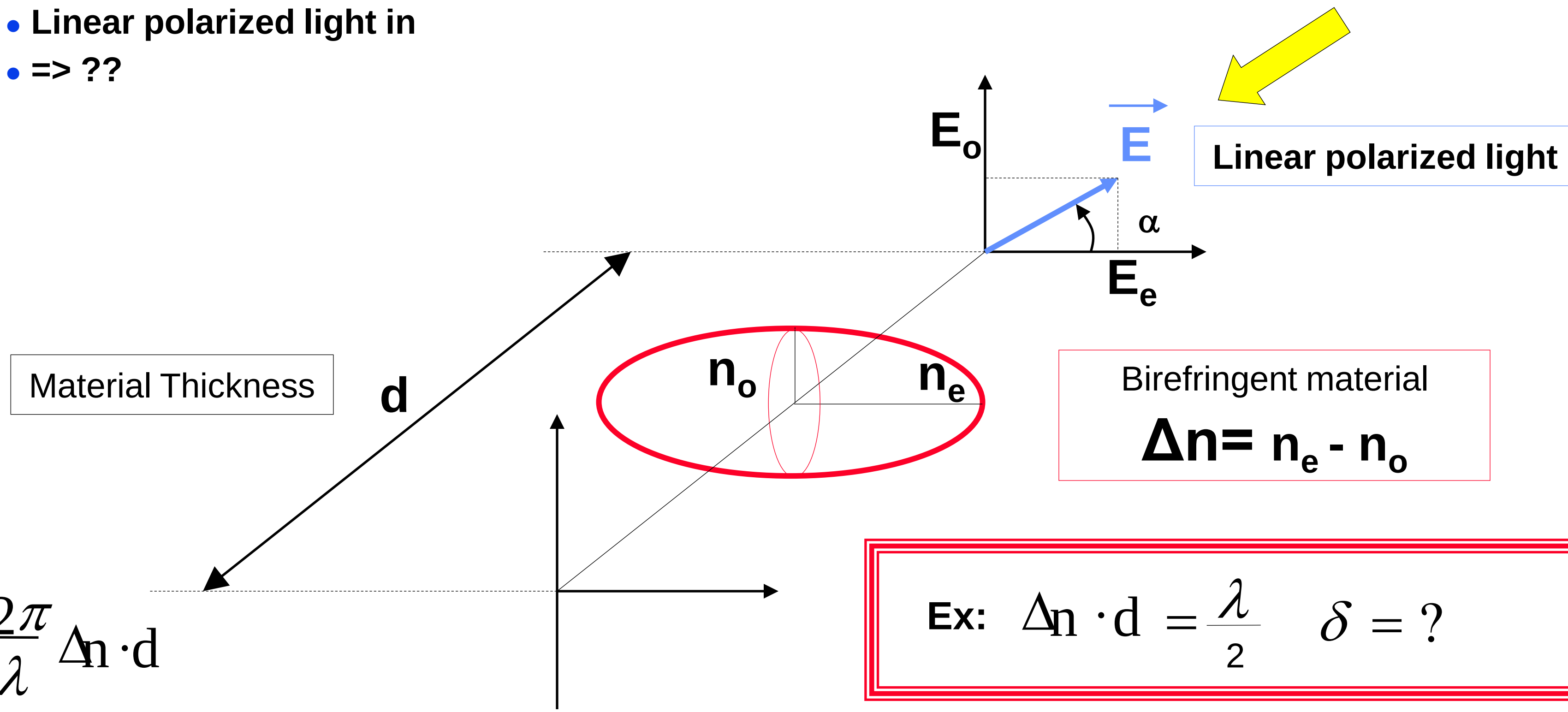
Ex: $\Delta n \cdot d = \frac{\lambda}{4}$ $\delta = \frac{\pi}{2}$

LCD Pixel Structure

- ❑ **Particular case of a λ/2 LC layer**
- ❑ **For a given wave length**
  - **Linear polarized light in**
  - **=> ??**

$$\Delta n \cdot d = \frac{\lambda}{2} + n\lambda$$

Optical thickness



$$\delta = \frac{2\pi}{\lambda} \Delta n \cdot d$$

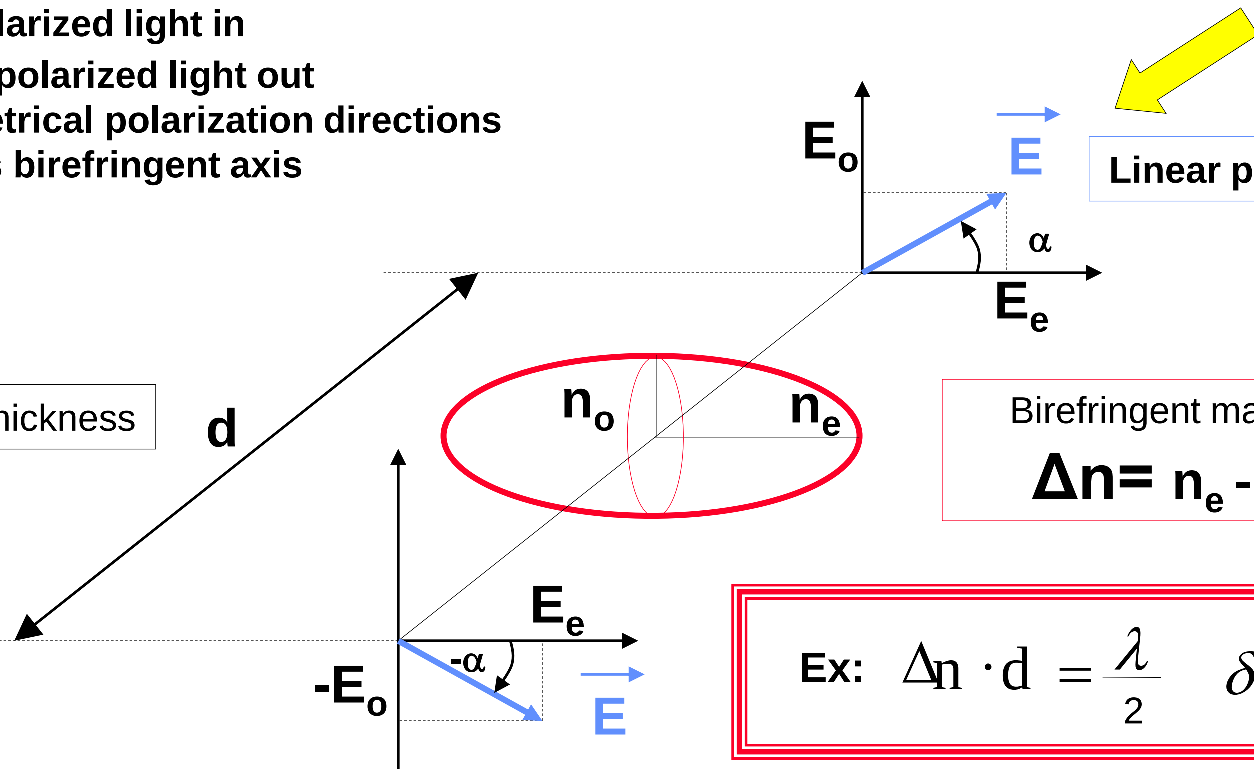
Ex: $\Delta n \cdot d = \frac{\lambda}{2} \qquad \delta = ?$

LCD Pixel Structure

- **Particular case of a $\lambda/2$ LC layer**
- **For a given wave length**
  - **Linear polarized light in**
  - **=>Linear polarized light out**
    Symmetrical polarization directions versus birefringent axis

$$\Delta n \cdot d = \frac{\lambda}{2} + n\lambda$$

Optical thickness



Linear polarized light

Material Thickness

Birefringent material

$$\Delta n = n_e - n_o$$

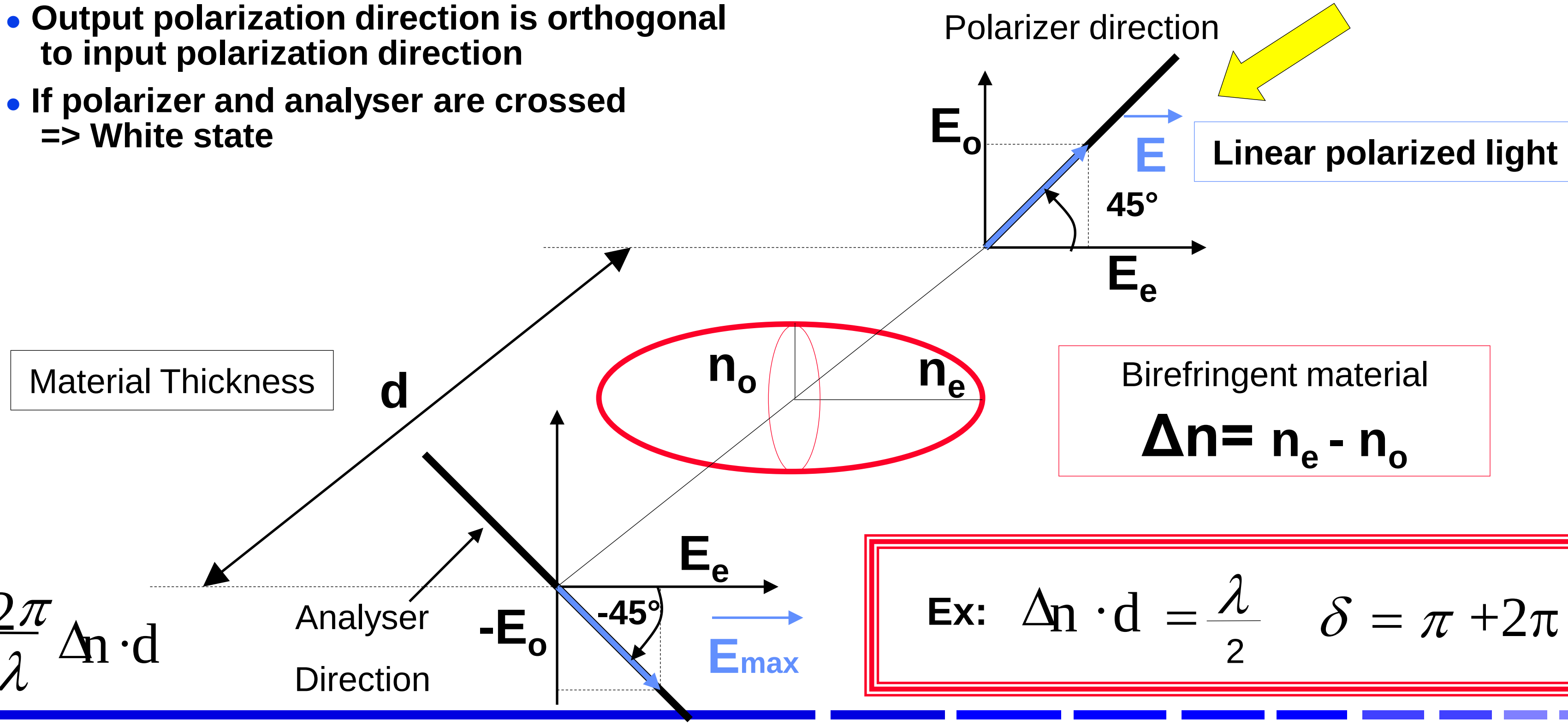
$$\delta = \frac{2\pi}{\lambda} \Delta n \cdot d$$

Ex: $\Delta n \cdot d = \frac{\lambda}{2} \qquad \delta = \pi + 2\pi n$

LCD Pixel Structure

- **Particular case of a λ/2 LC layer and α = 45°**
- **For a given wave length**
  - **Output polarization direction is orthogonal to input polarization direction**
  - **If polarizer and analyser are crossed => White state**

$$\Delta n \cdot d = \frac{\lambda}{2}$$



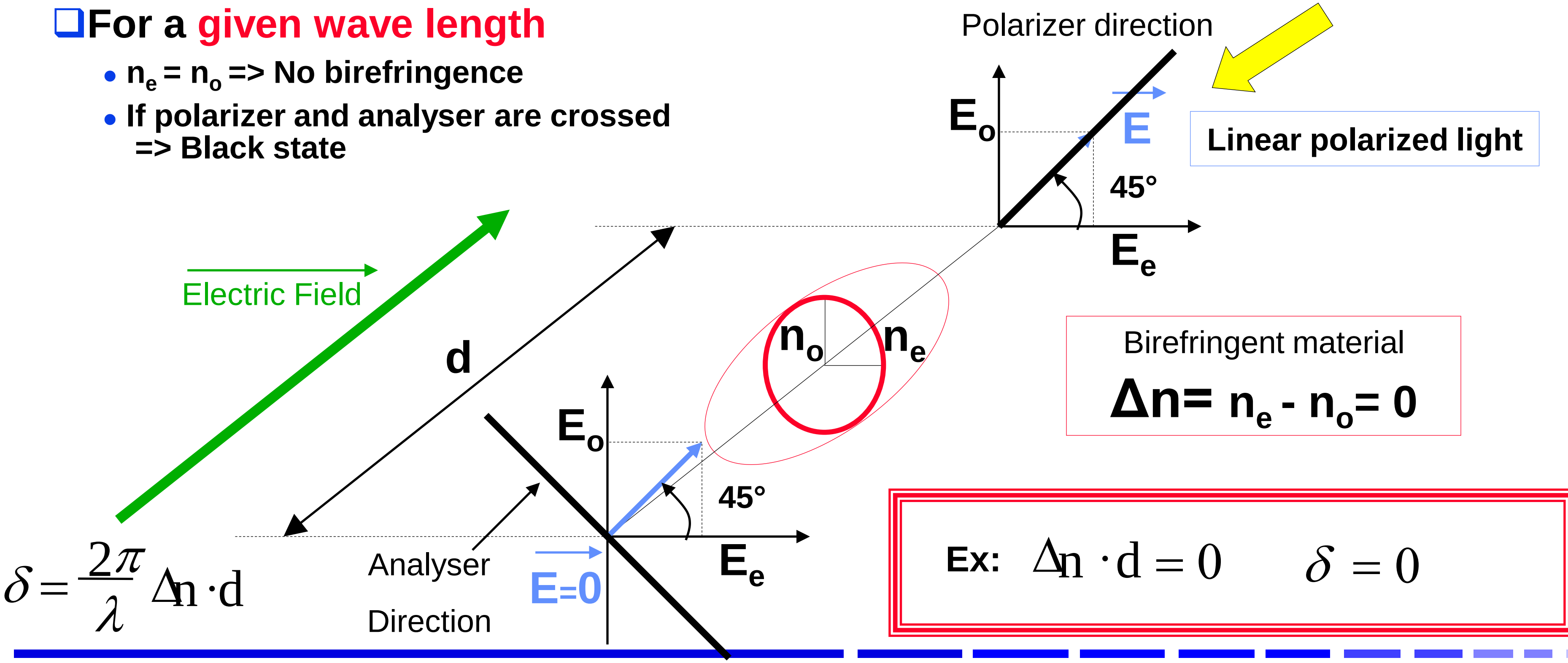
$$\delta = \frac{2\pi}{\lambda} \Delta n \cdot d$$

Ex: $\Delta n \cdot d = \frac{\lambda}{2}$ $\quad \delta = \pi + 2\pi n$

LCD Pixel Structure

- **Particular case of a λ/2 LC layer and α = 45°**
- **+ Electric Field (ON State)**
- **For a given wave length**
  - **$n_e = n_o$ => No birefringence**
  - **If polarizer and analyser are crossed => Black state**

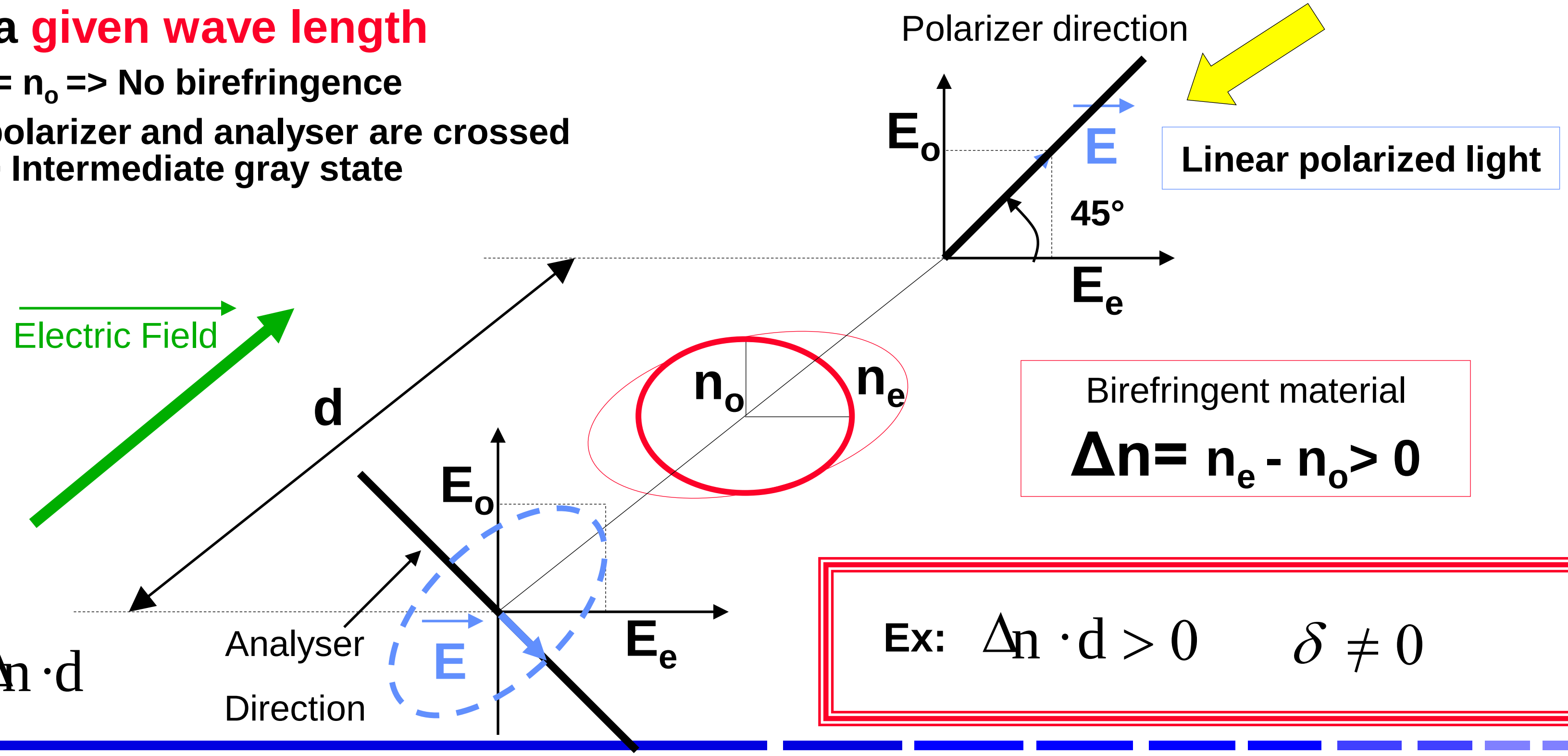
$$\Delta n \cdot d = \frac{\lambda}{2}$$



LCD Pixel Structure

- ❑ **Particular case of a λ/2 LC layer and α = 45°**
- ❑ **+ Electric Field (Intermediate State)**
- ❑ **For a given wave length**
  - **$n_e = n_o$ => No birefringence**
  - **If polarizer and analyser are crossed => Intermediate gray state**

$$\Delta n \cdot d = \frac{\lambda}{2}$$



$$\delta = \frac{2\pi}{\lambda} \Delta n \cdot d$$

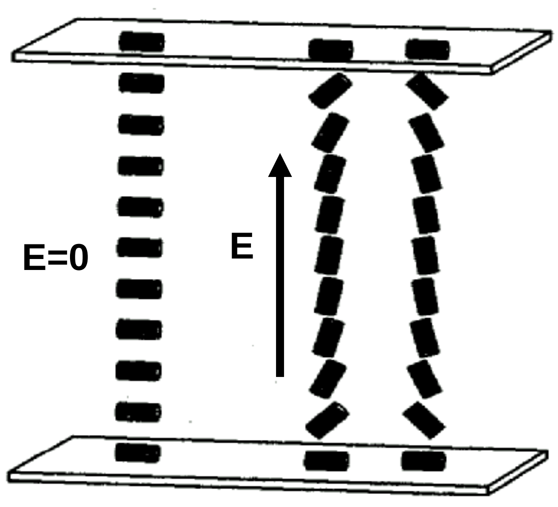
Ex: $\Delta n \cdot d > 0$ $\qquad \delta \neq 0$

LCD Pixel Structure

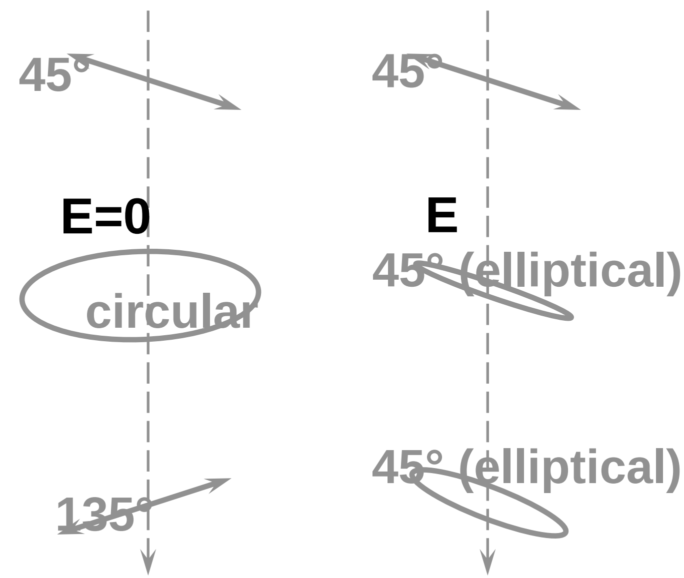
Optically

- **Basic Electro Optic Effect - the Fréedericksz Effect**

LC alignment change



Polarization evolution through the cell



LCD Pixel Structure

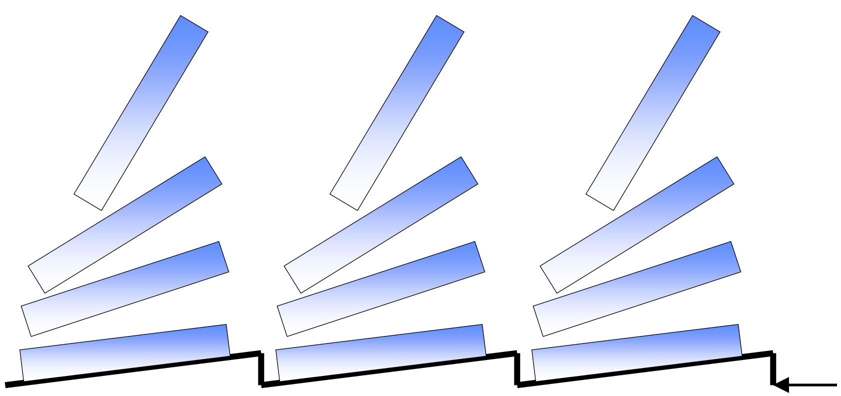
Optically

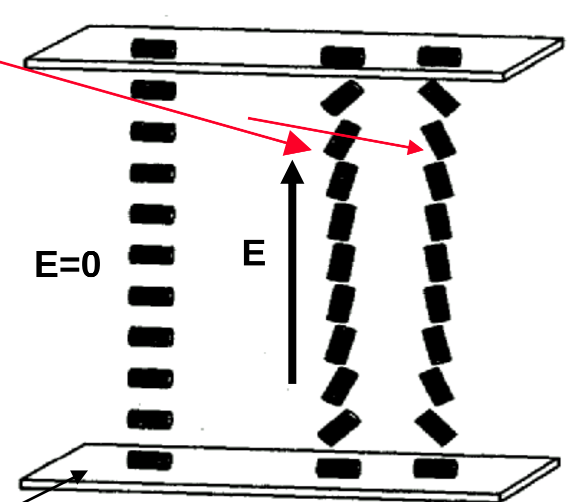
- **Basic Electro Optic Effect - the Fréedericksz Effect**
- **This simple structure cannot be used to build a display:**
  - **As the optical thickness is fixed**
  - **Contrast would be very different for different wave lengths**
  - **High spectral dispersion**

$$\delta = \frac{2\pi}{\lambda} \Delta n \cdot d$$

LC alignment change

- **Note that LC tilt can have 2 different positions**
  - **This defect is corrected by pre-tilting the LC molecules due to use of an alignment layer**

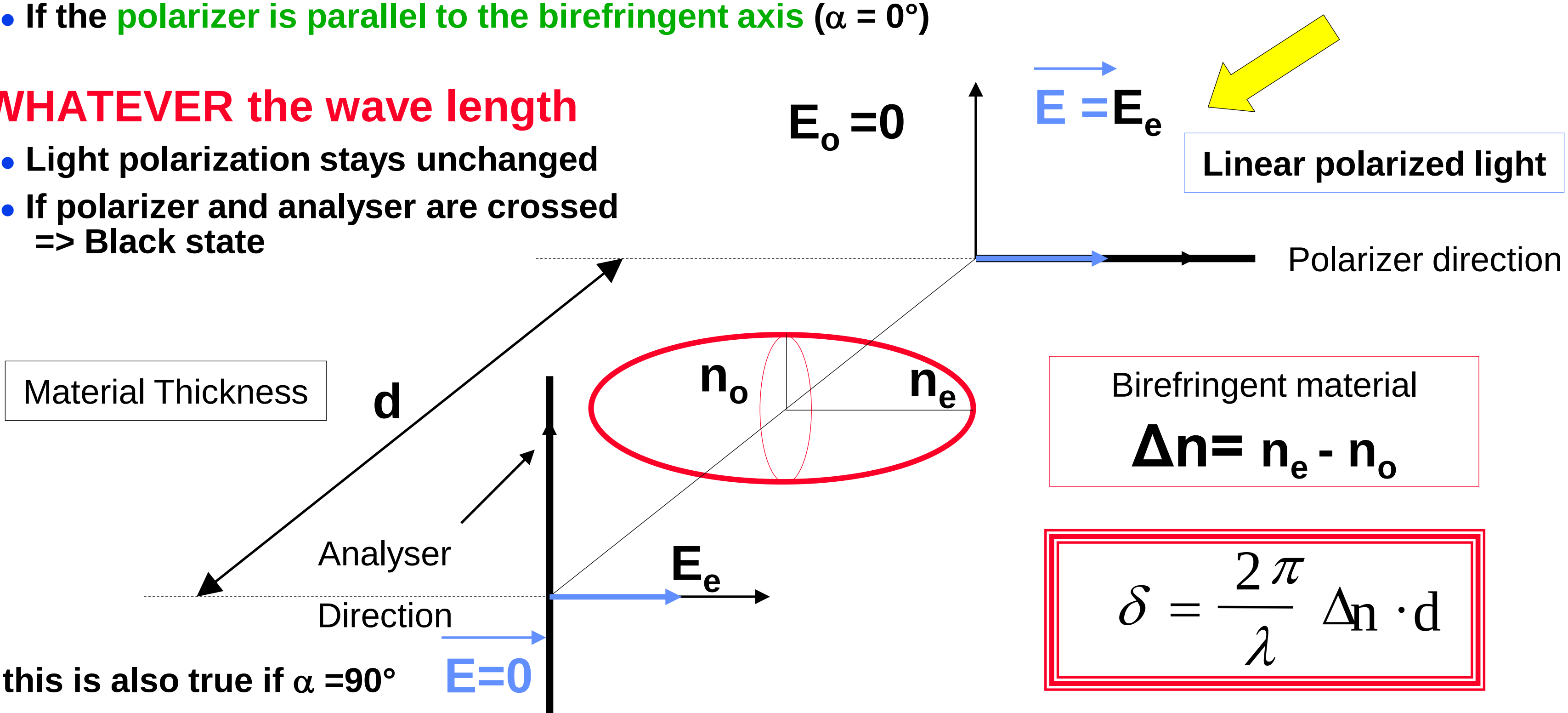




LCD Pixel Structure

Optically

- **Particular case of a any LC layer**
  - **Whatever the phase difference: δ**
  - **If the polarizer is parallel to the birefringent axis (α = 0°)**
- **WHATEVER the wave length**
  - **Light polarization stays unchanged**
  - **If polarizer and analyser are crossed => Black state**



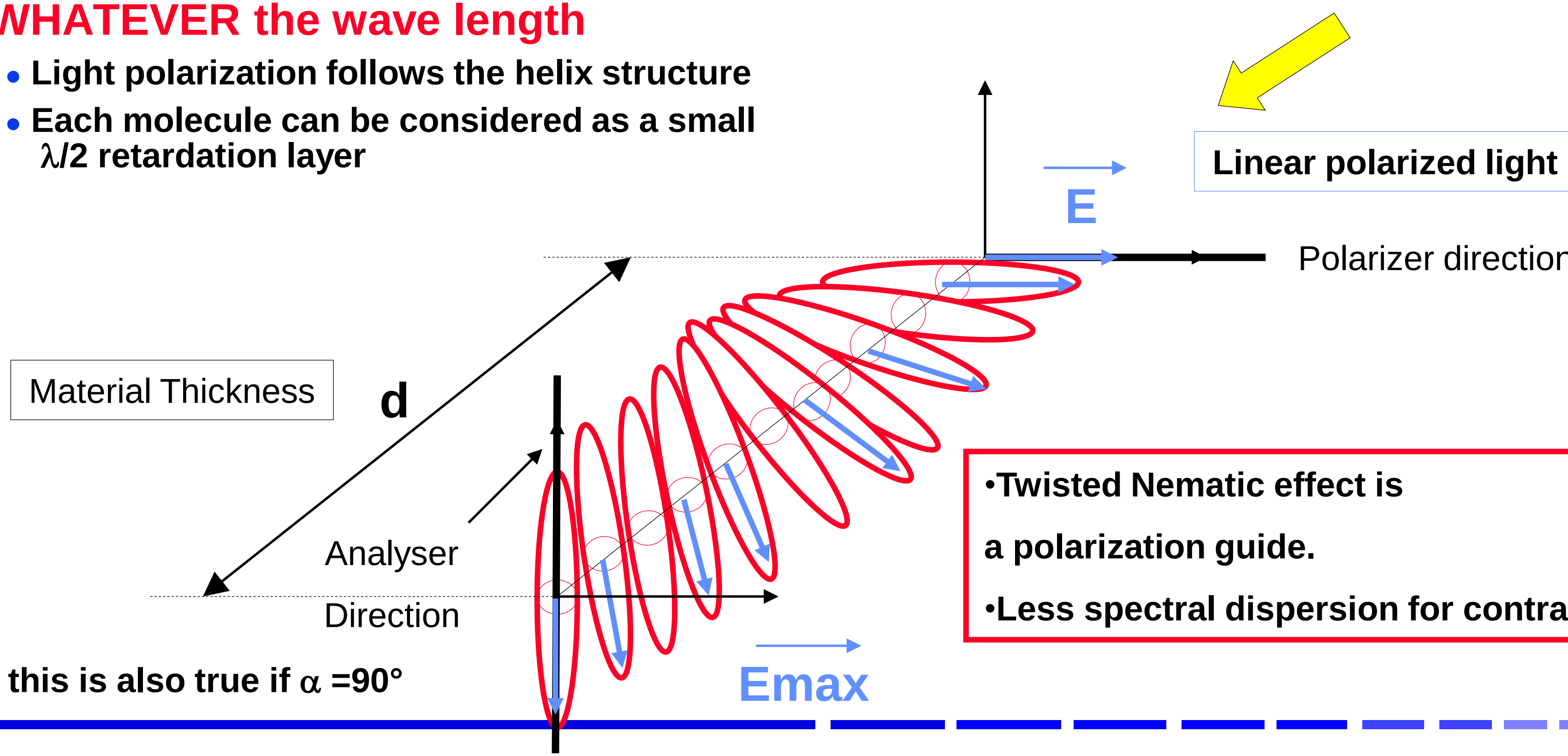
Note: this is also true if α =90°

LCD Pixel Structure

Optically

- ❑ **THE SOLUTION IS THE TN EFFECT**

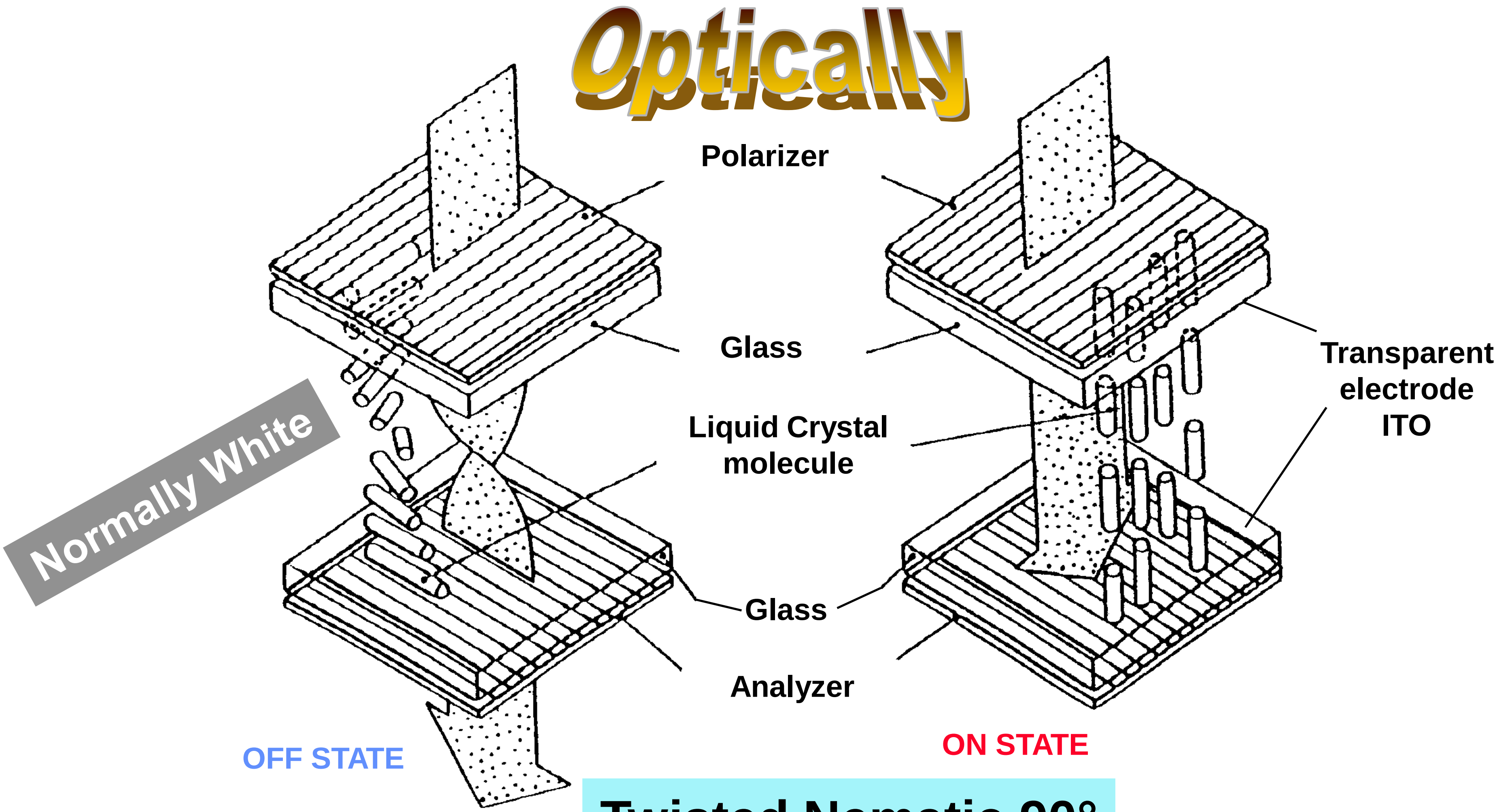
- ❑ **WHATEVER the wave length**
  - **Light polarization follows the helix structure**
  - **Each molecule can be considered as a small λ/2 retardation layer**



- **Twisted Nematic effect is a polarization guide.**
- **Less spectral dispersion for contrast**

Note: this is also true if α =90°

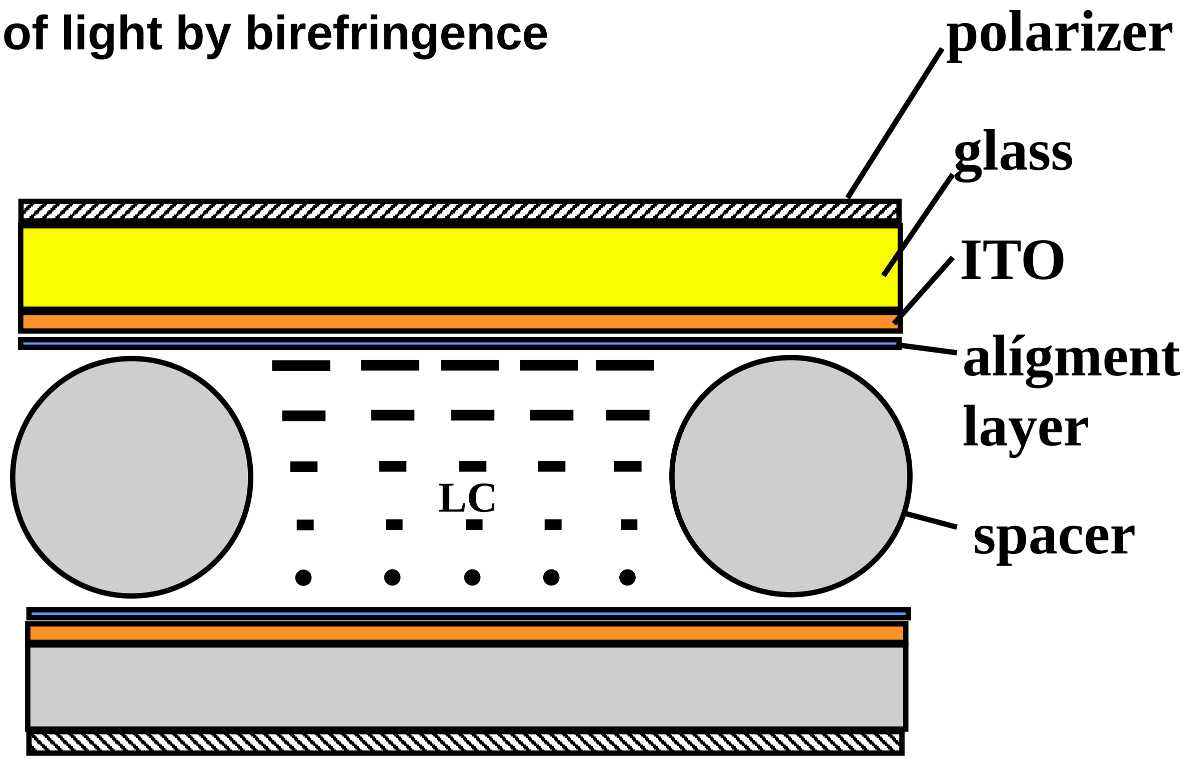
LCD Pixel Structure



Twisted Nematic 90°

LCD Pixel Structure

- ❑Cell gap 3-10μm
- ❑Alignment by rubbed polymer layer
- ❑Transparent ITO electrodes
- ❑Control of polarization of light by birefringence



LCD Pixel Structure

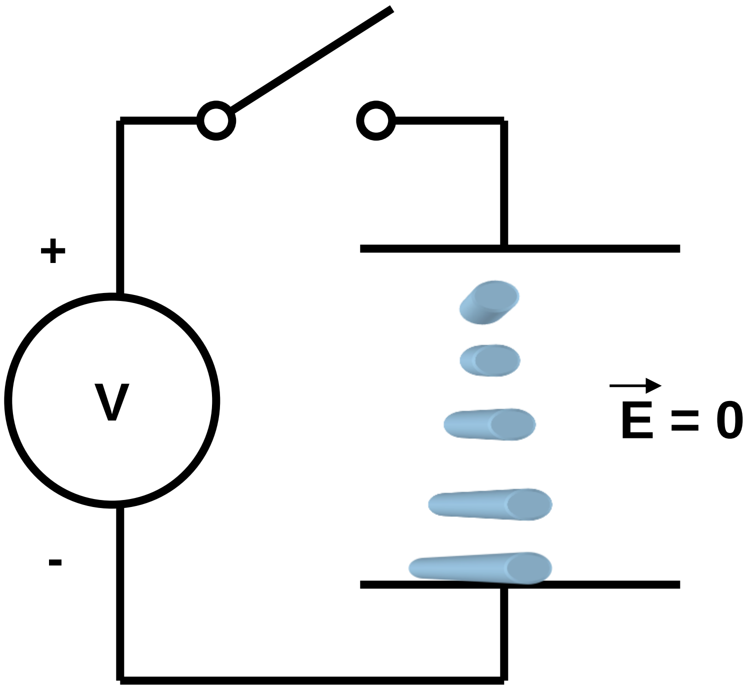
- **Liquid Crystal is a structured liquid which shows a macroscopic structure**
  - **The TN 90° LC structure is the most common one on active matrix LCD**

- **All LCD (Liquid Crystal Display) needs polarized light to display pictures**
  - **exception: Polymer Dispersed Liquid Crystal (PDLC)**
    - **used for electrically controlled tinted windows**
    - **Not addressed in this training**
  - **Crossed polarizer technique is used as it offers an achromatic bright state**

- **A Liquid Crystal Display is made of:**
  - **A layer of Liquid Crystal sandwiched between two transparent substrates**
  - **2 transparent electrodes that can drive an electric field**
  - **By controlling the electric field, polarization plane is more or less rotated and the light is more or less blocked by the analyzer.**
  - **As LC is an insulating material, the pixel is considered as a capacitor**

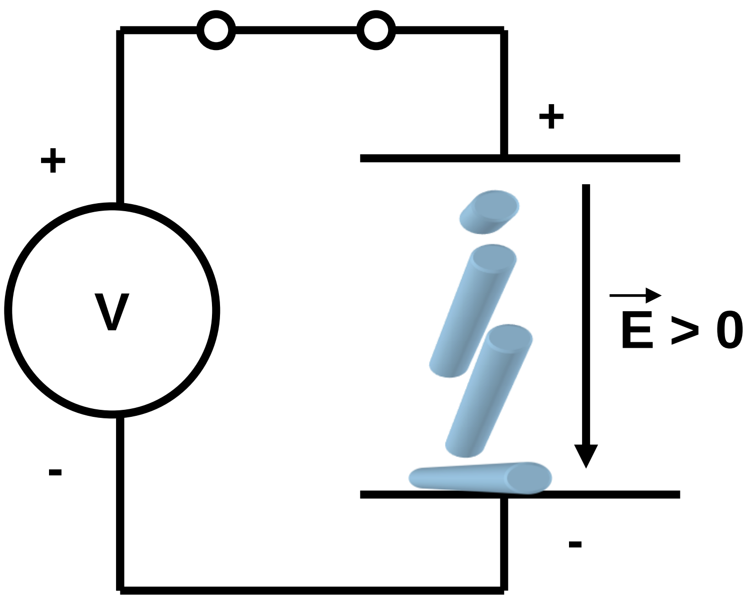
- **Picture quality mainly comes from:**
  - **Transmission efficiency to have the maximum brightness**
  - **Polarizer quality and adjustments to get the better black state possible**
  - **Intrinsic LC material quality: response time, wavelength dependency,...**

LCD Pixel Structure



Pixel OFF => LC molecules stay twisted

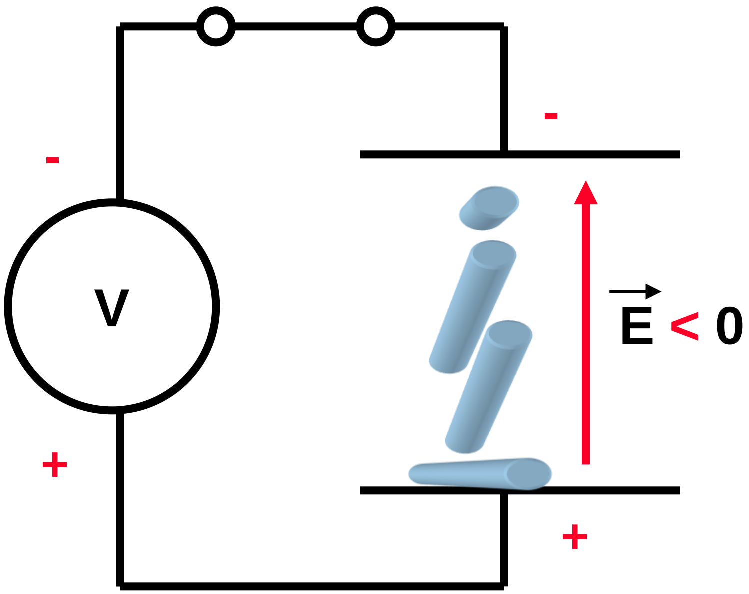
LCD Pixel Structure



Pixel ON => LC molecules turn towards the electric field direction.

Twisted structure is lost

LCD Pixel Structure



Pixel ON => LC molecules turn towards the electric field direction.

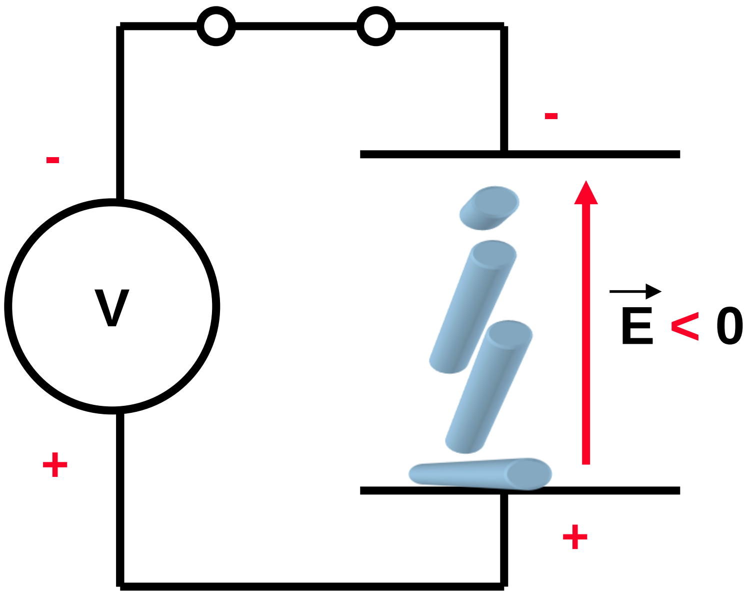
Twisted structure is lost

WHATEVER THE POLARITY

By modulating the value of $\vec{E}$, gray shades can be created

Response time is an important parameter depending on cell gap and LC material

LCD Pixel Structure



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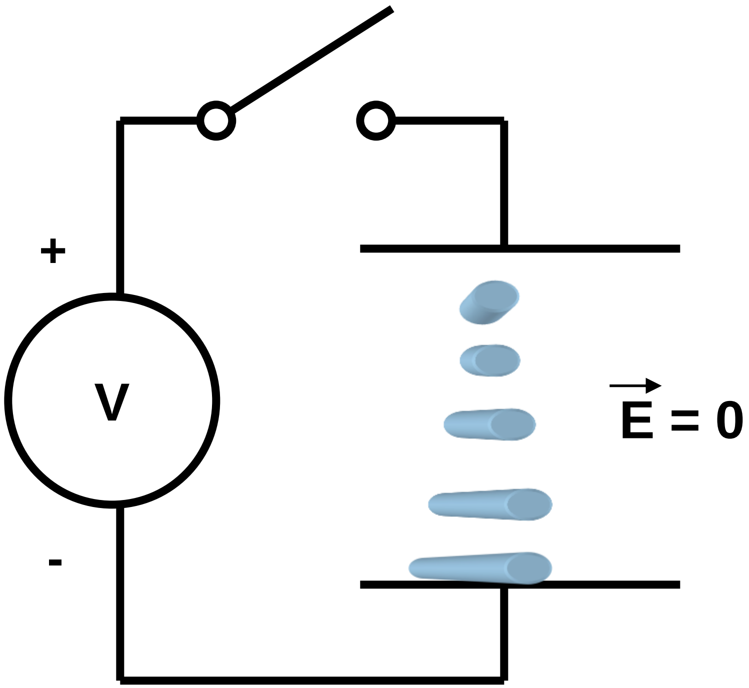
WHATEVER THE POLARITY

LCD Pixel Structure



- We have seen that LC is birefringent
  - Optical anisotropy Δn goes together with
  - Dielectric anisotropy $\Delta\varepsilon = \varepsilon_e - \varepsilon_o > 0$

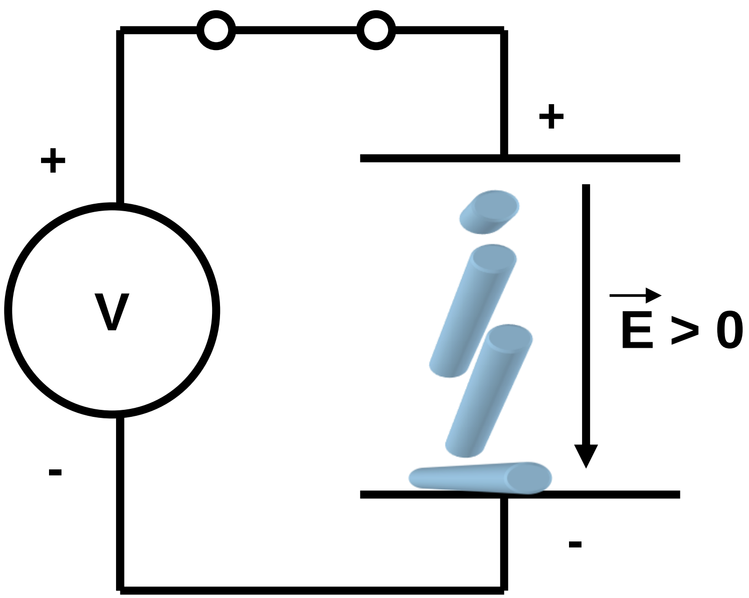
Pixel off => Pixel capacity C_o is proportional to ε_o

Pixel voltage U is 0 Volt

Charge Q is 0 Coulomb

$$Q = C_o \times U = 0$$

LCD Pixel Structure

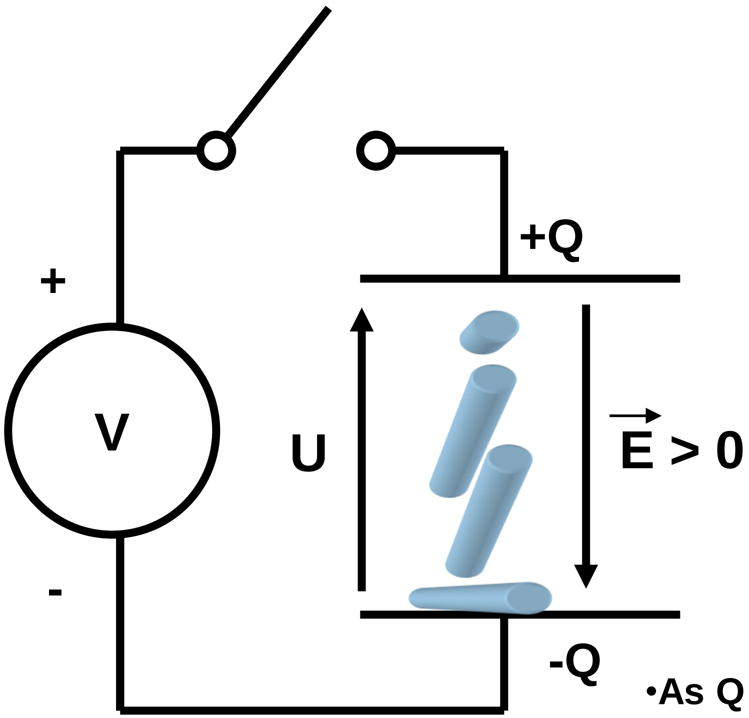


- We have seen that LC is birefringent
  - Optical anisotropy Δn goes together with
  - Dielectric anisotropy $\Delta\varepsilon = \varepsilon_e - \varepsilon_o > 0$

•Pixel ON => LC is stressed by an external electric field

•LC does not like to be disturbed and will try to do its best to decrease the electric field

LCD Pixel Structure



- We have seen that LC is birefringent
  - Optical anisotropy Δn goes together with
  - Dielectric anisotropy $\Delta\varepsilon = \varepsilon_e - \varepsilon_o > 0$

•1Pixel ON => LC is stressed by an external electric field

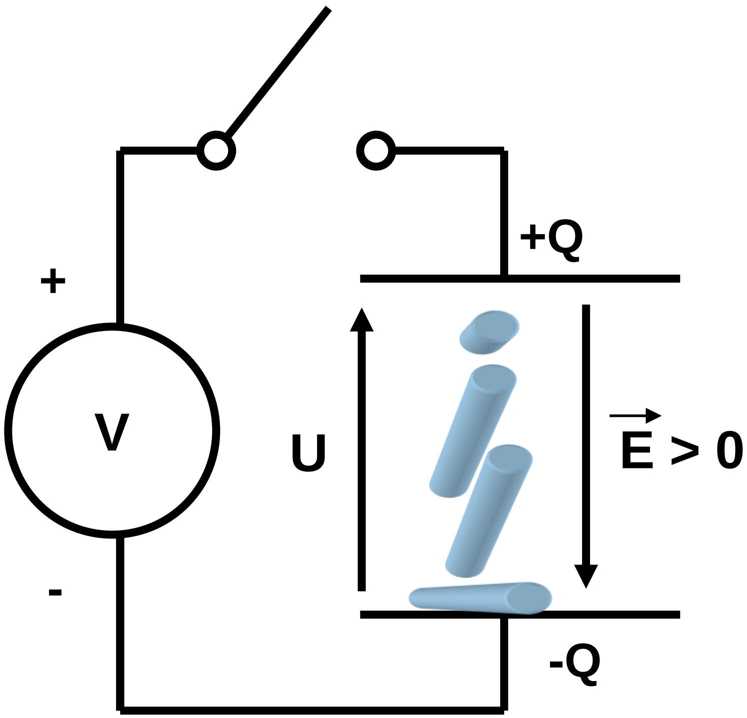
•LC does not like to be disturbed and will try to do its best to decrease the electric field

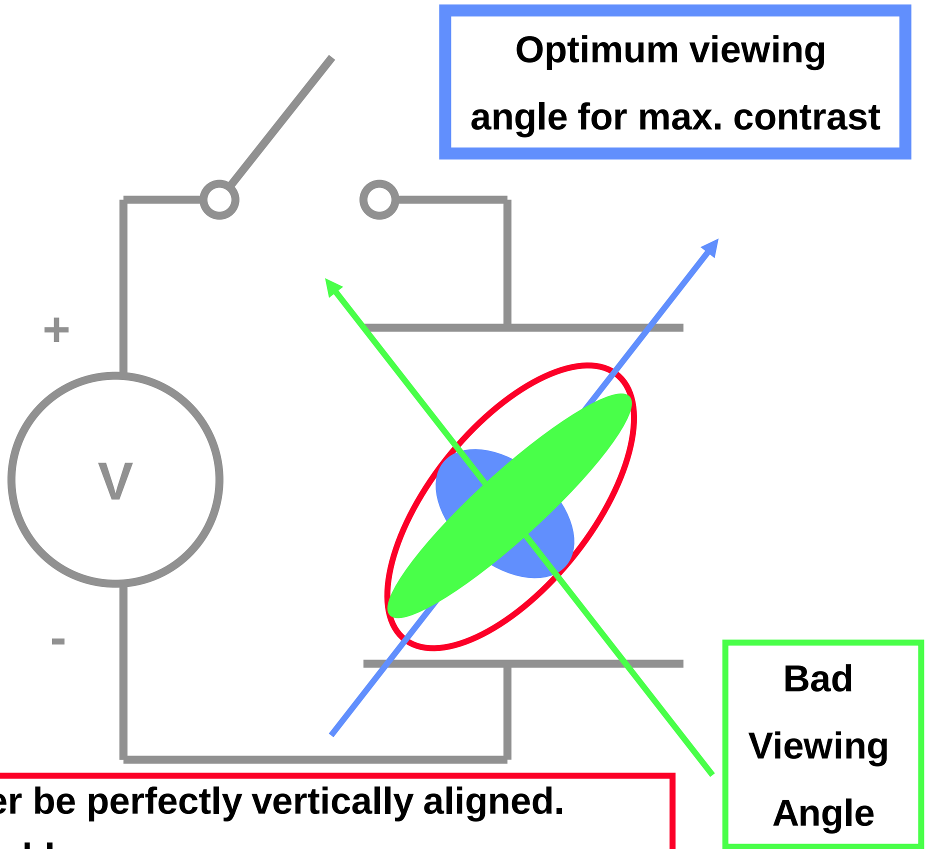
•As Q is constant, the only way is to decrease U by increasing C

•The LC molecules have just to turn towards the field direction to increase C from C_o to C_e

$$Q = C_o \nearrow \times U \searrow \quad \Rightarrow \quad Q = C_e \times U'$$

LCD Pixel Structure



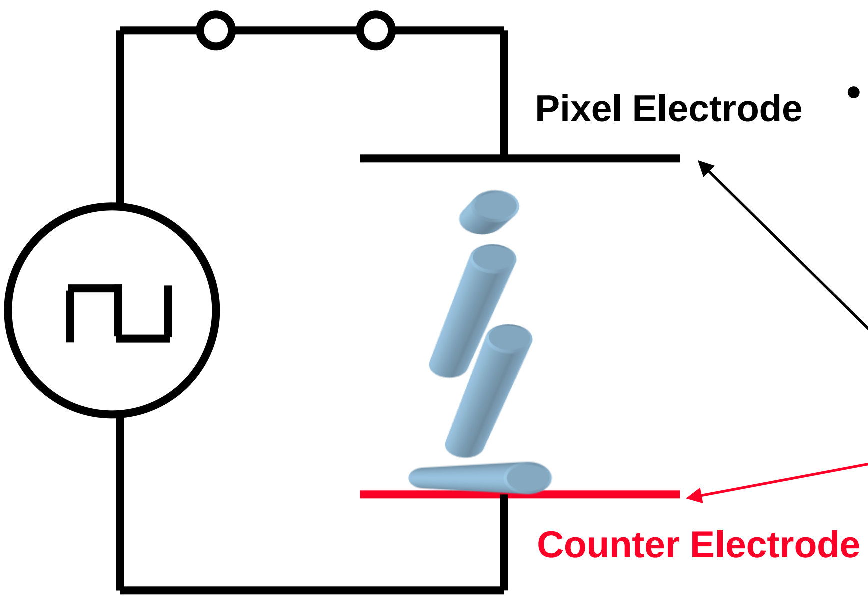


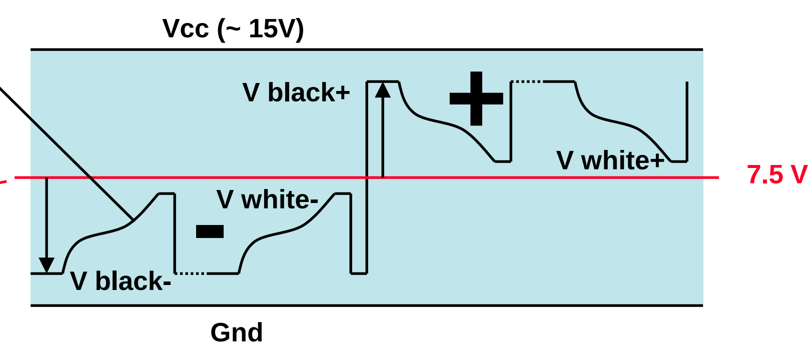
- Due to mechanical constraints, molecules can never be perfectly vertically aligned.
- This is the reason why LCD have viewing angles problems.
- It can be partially solved through compensation films or new LC structures (IPS, VA,…) (See additional training)

LCD Pixel Structure

BASIC RULES:

- **No net DC level allowed on the pixel**
- **Pixel voltage has to be inverted every frame**

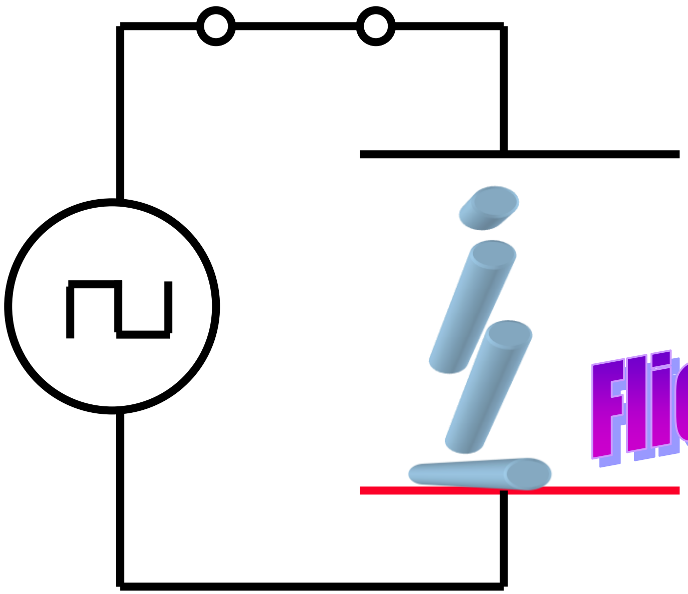




P.E. voltage has to be symmetrical vs. CE voltage

Otherwise: Flicker is visible

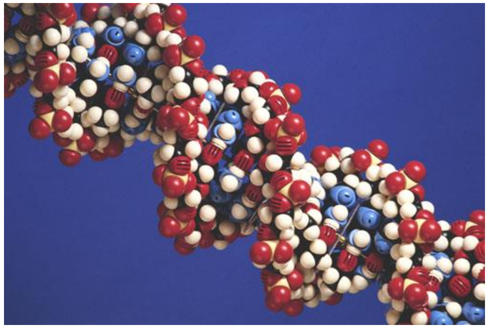
LCD Pixel Structure



BASIC RULES:

- **No DC level allowed on the pixel**
- **Pixel voltage has to be inverted every frame**

Flicker ⟵ **RISK** ⟶ **Sticking Image**



LCD Pixel Structure

- **Pixel voltage is less than 6V**
  - **The goal is to go below 3V to decrease LCD driver cost**
  - **Most of LCD work with crossed polarizers: the higher the voltage, the darker the pixel**
    - **Normally white mode**

- **Normally white mode offer the best black uniformity for direct view displays**
  - **Not true with LCOS projection system where normally black is mostly used**

- **Flicker can be easily eliminated using appropriate addressing schemes**
  - **Line inversion; Column inversion; Dot inversion**

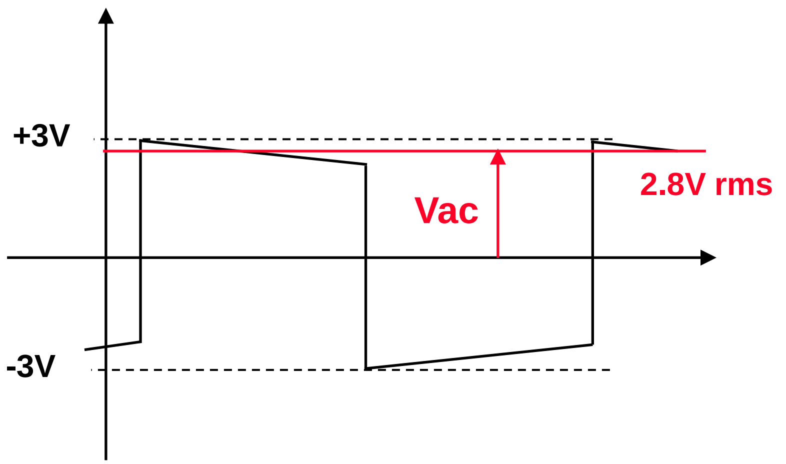
    (See § Active Matrix Addressing techniques)

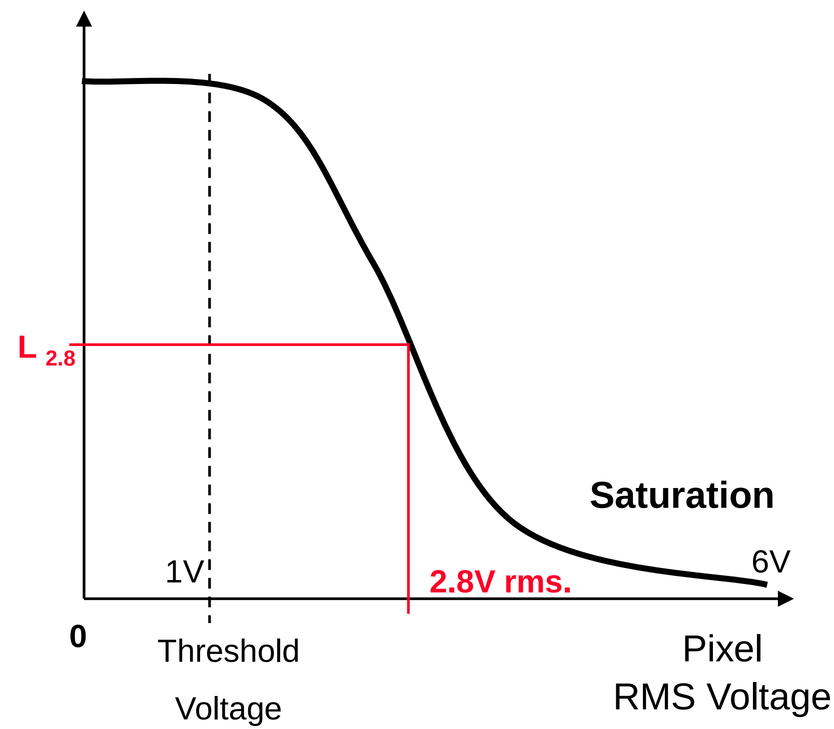
- **If DC voltage is slight, sticking image is reversible**
  - **A DC voltage of less than 50 mV is required**
  - **Sticking images disappear faster when LCD temperature is higher**
  - **Sticking images decrease LCD life time**

LCD Basic Addressing

Electro-Optical Response

•**LC material is sensitive to RMS voltage**





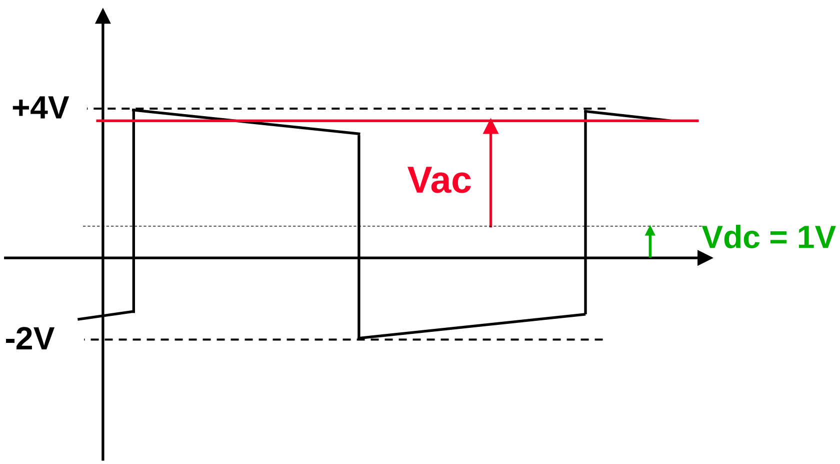
•**LC is not sensitive to polarity**

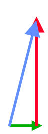
•**Due to slow response time (~20ms) LC is integrating the applied voltage**

LCD Basic Addressing

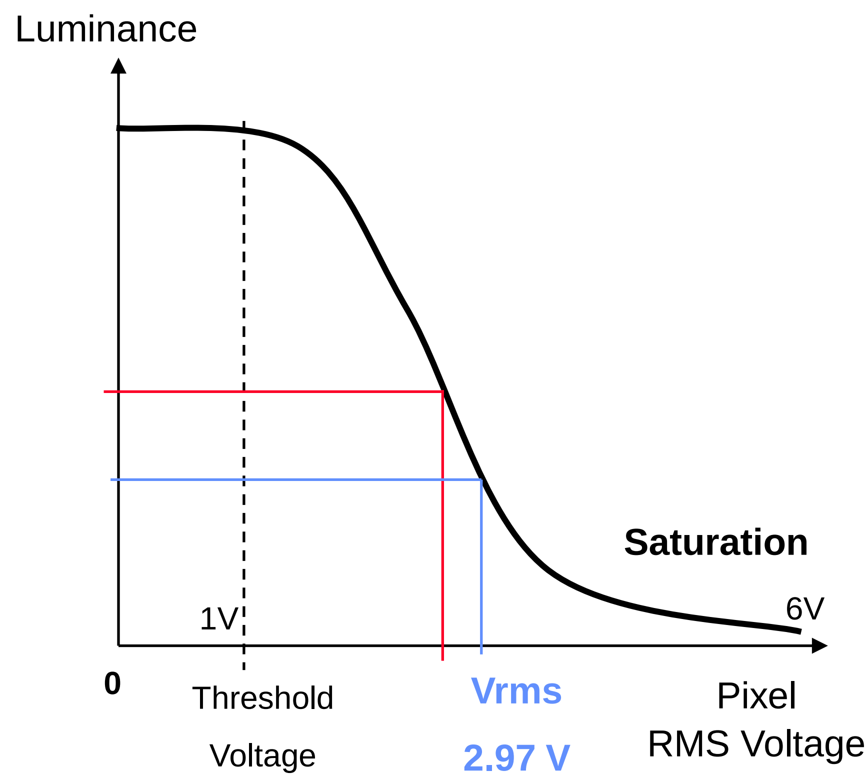
Electro-Optical Response

- **LC material is sensitive to RMS voltage**





$$V^2_{rms} = V^2_{ac} + V^2_{dc}$$



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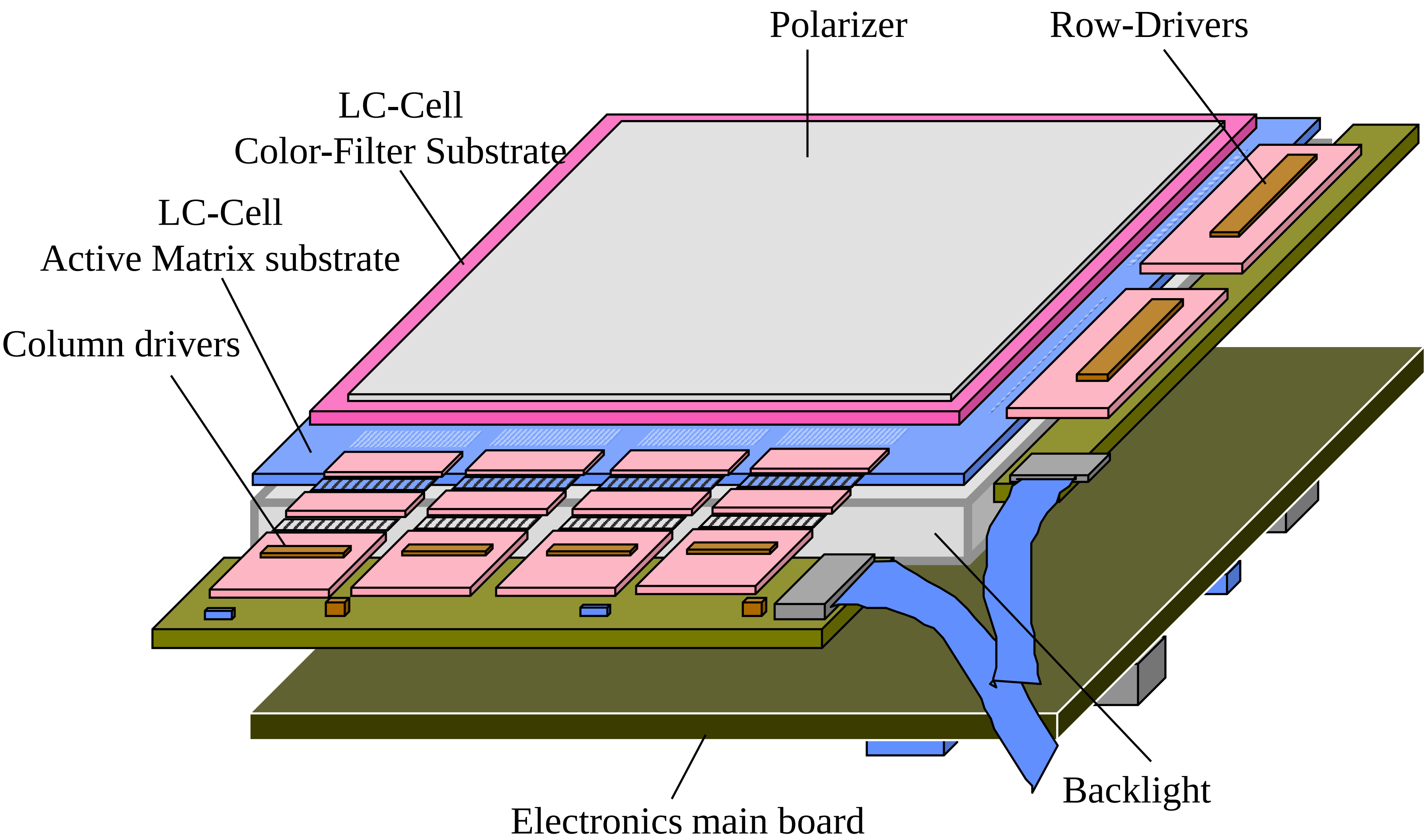
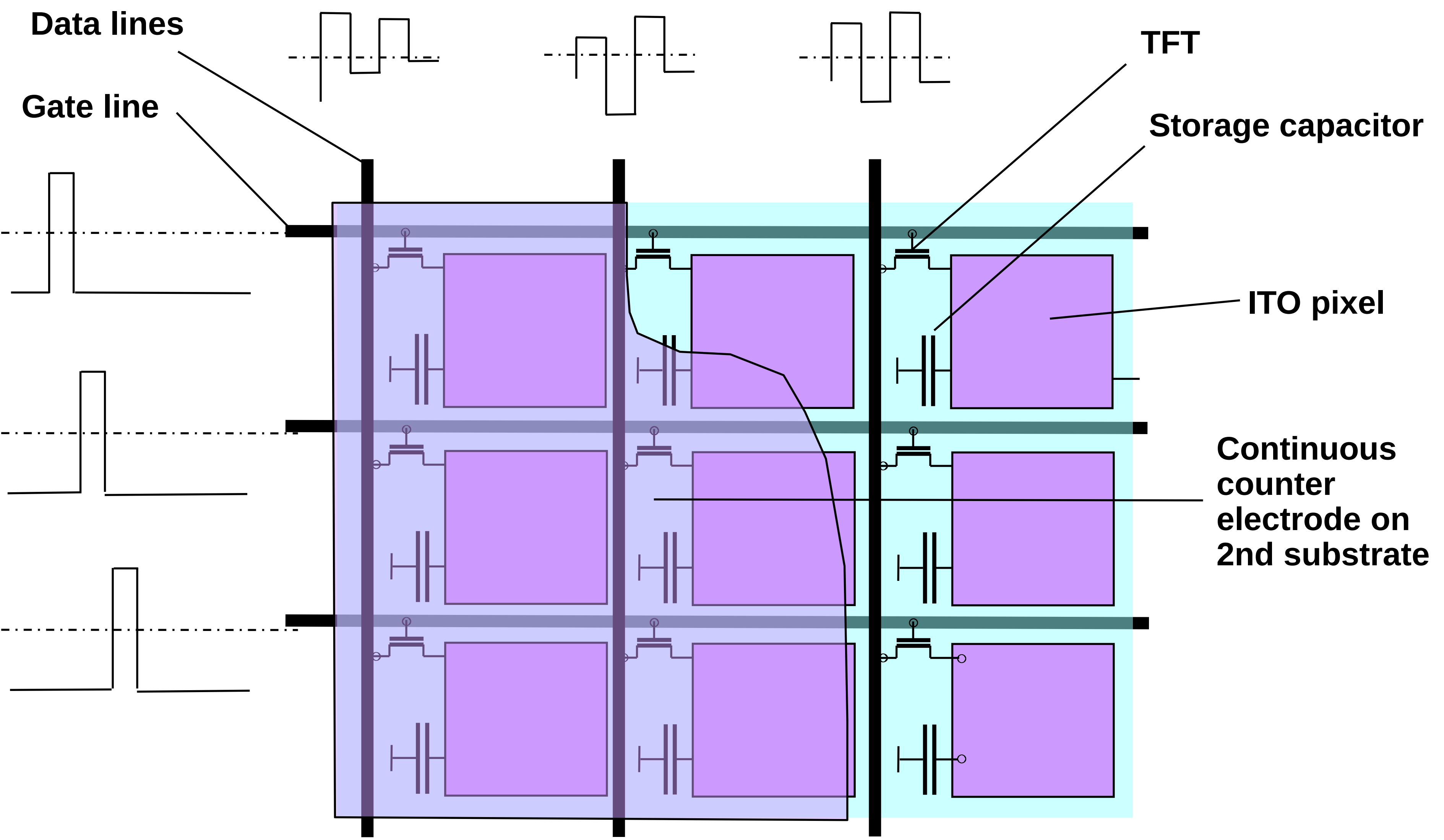
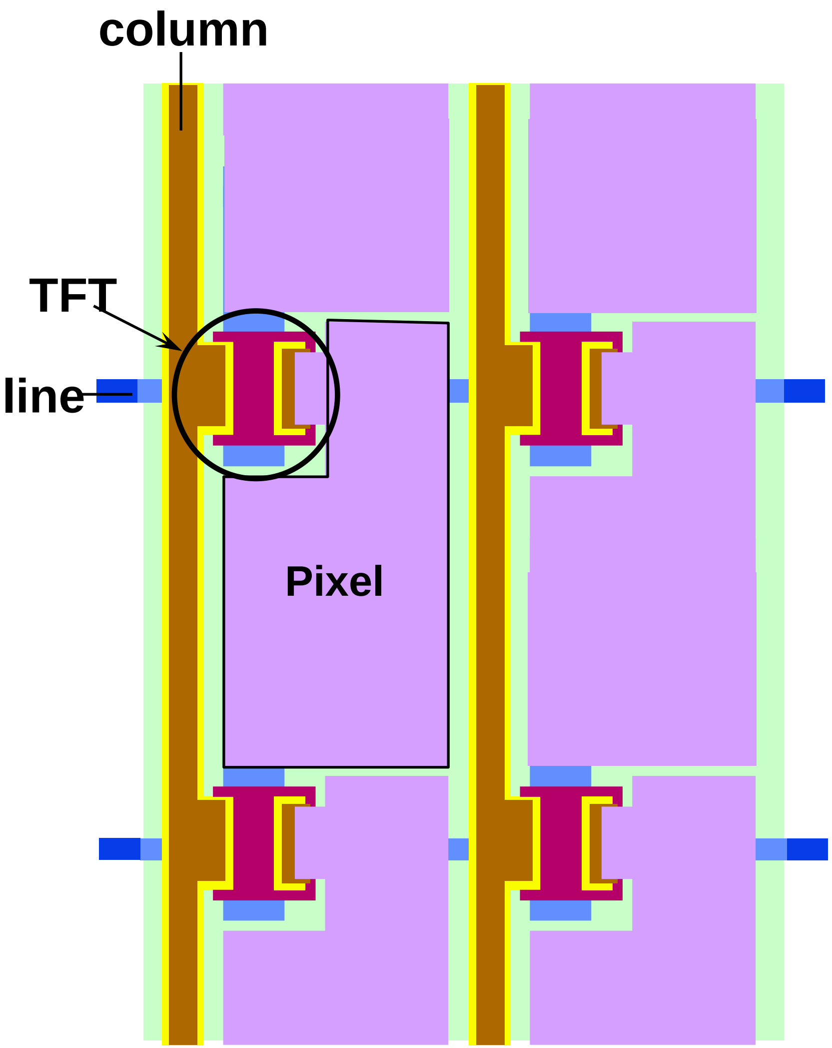
LCD Panel Structure



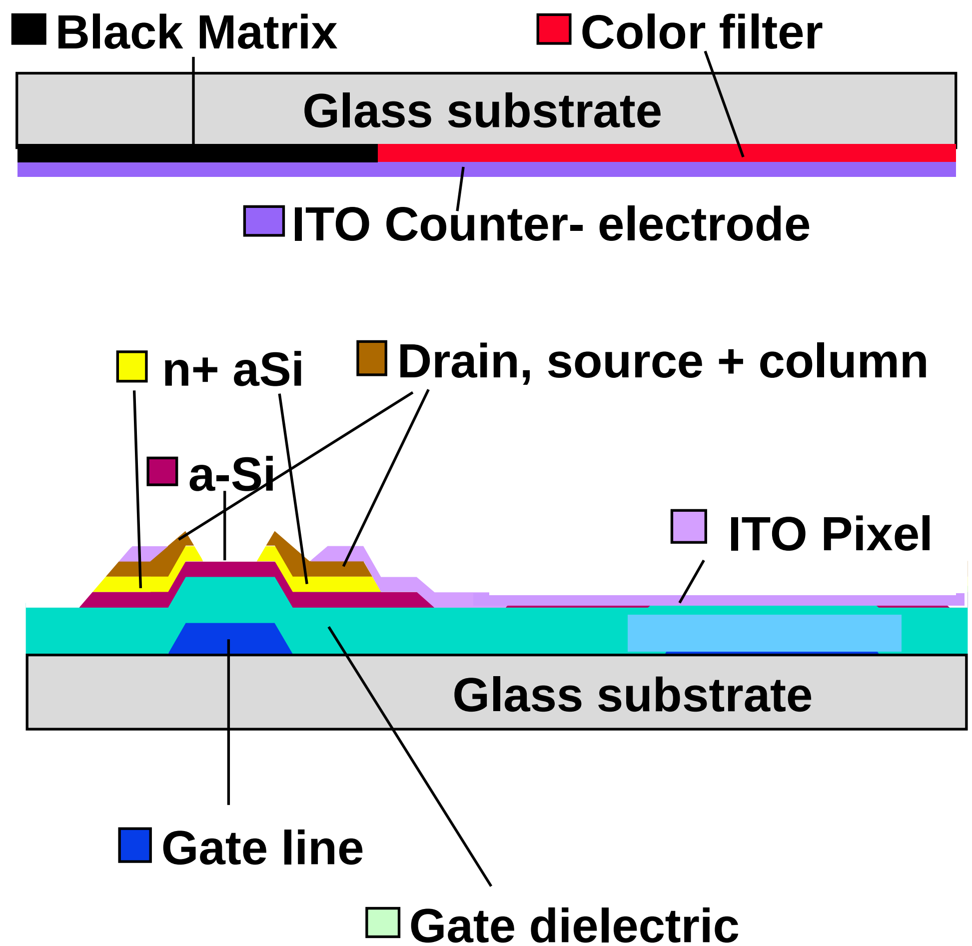
Active Matrix Structure



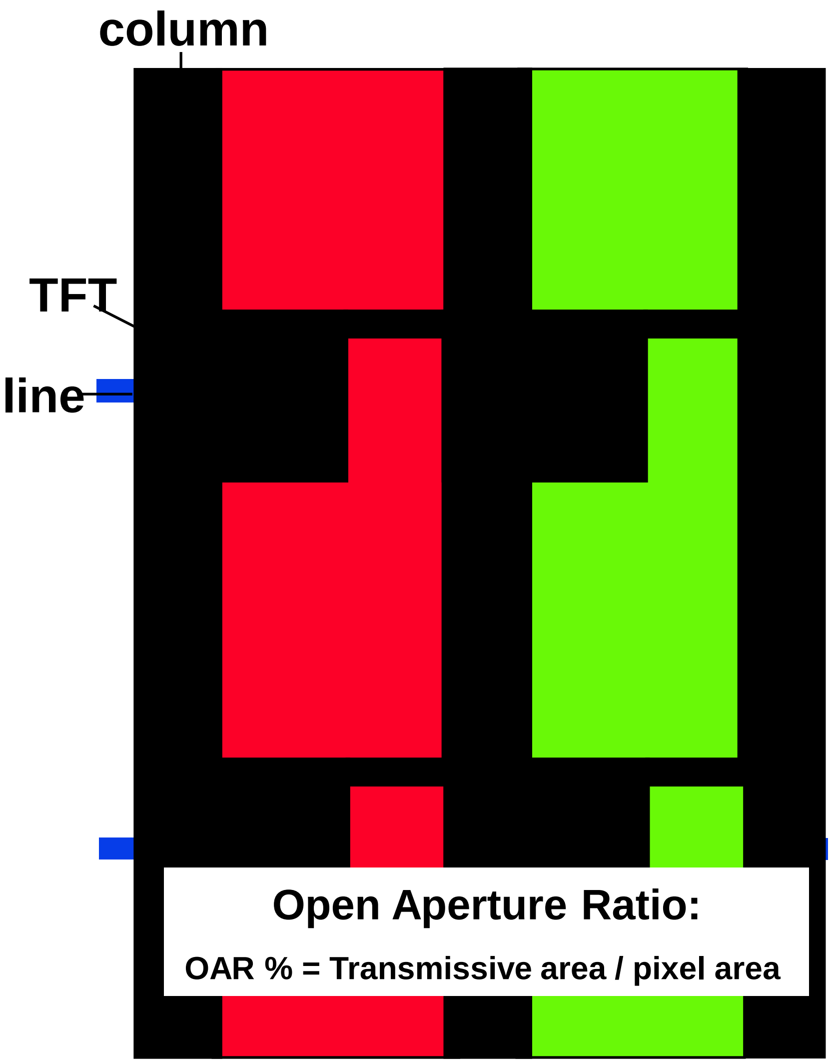
LCD Panel Structure

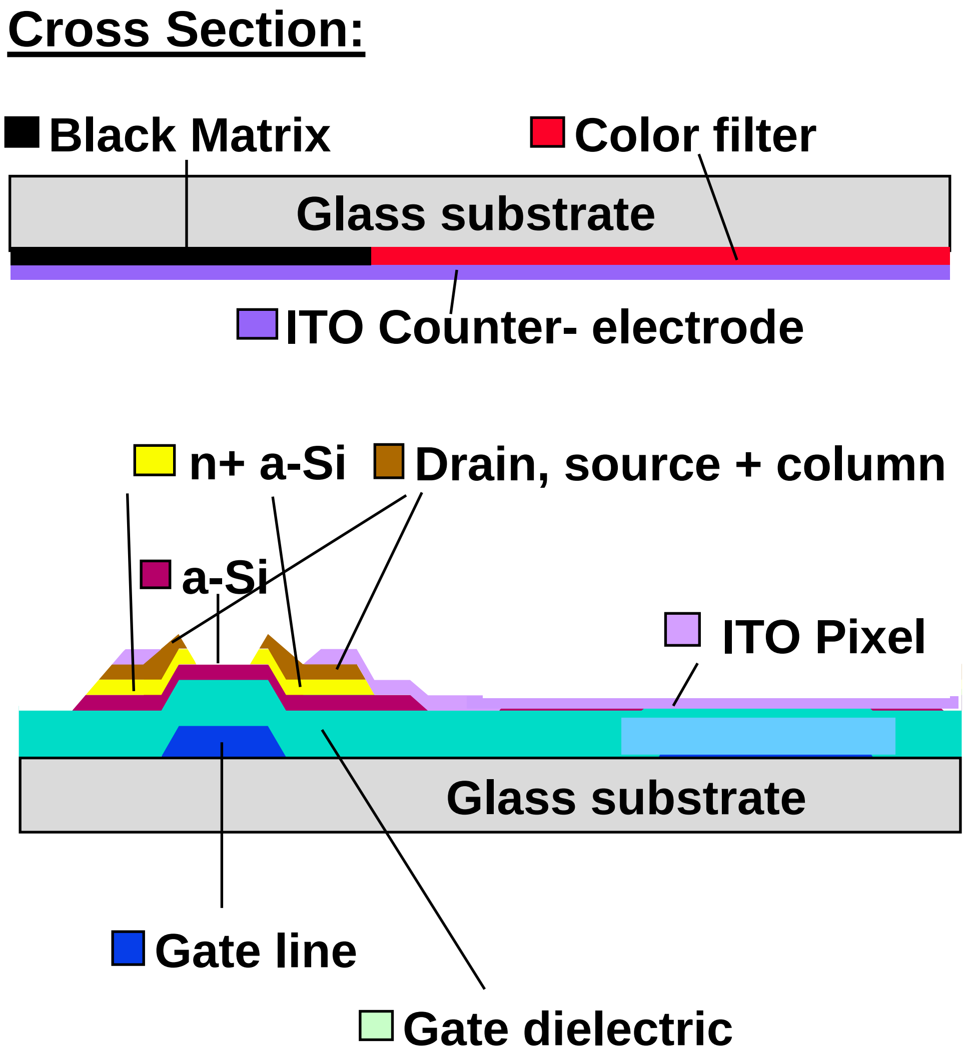


Cross Section:

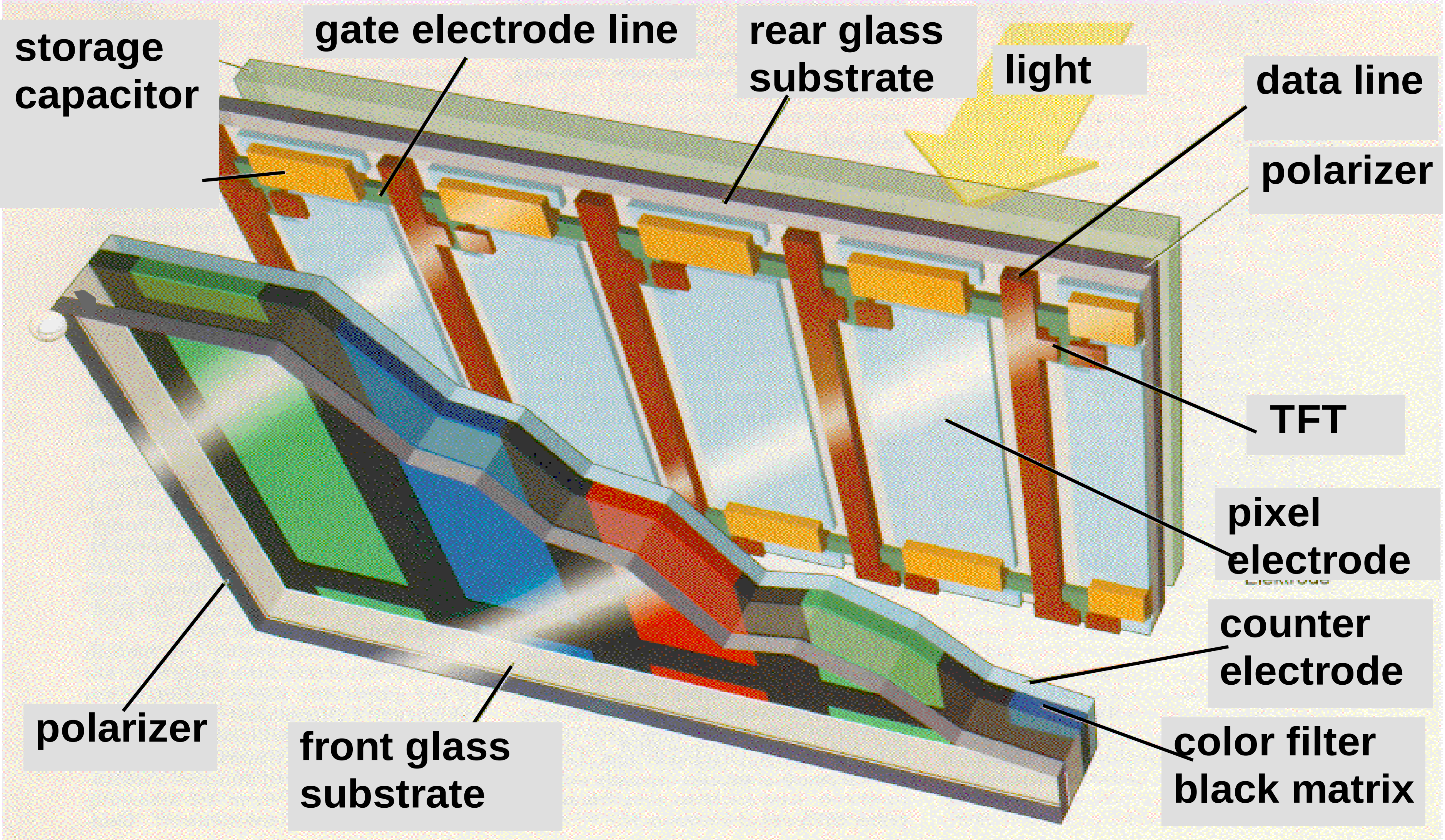


LCD Panel Structure





LCD Panel Structure



LCD Panel Structure

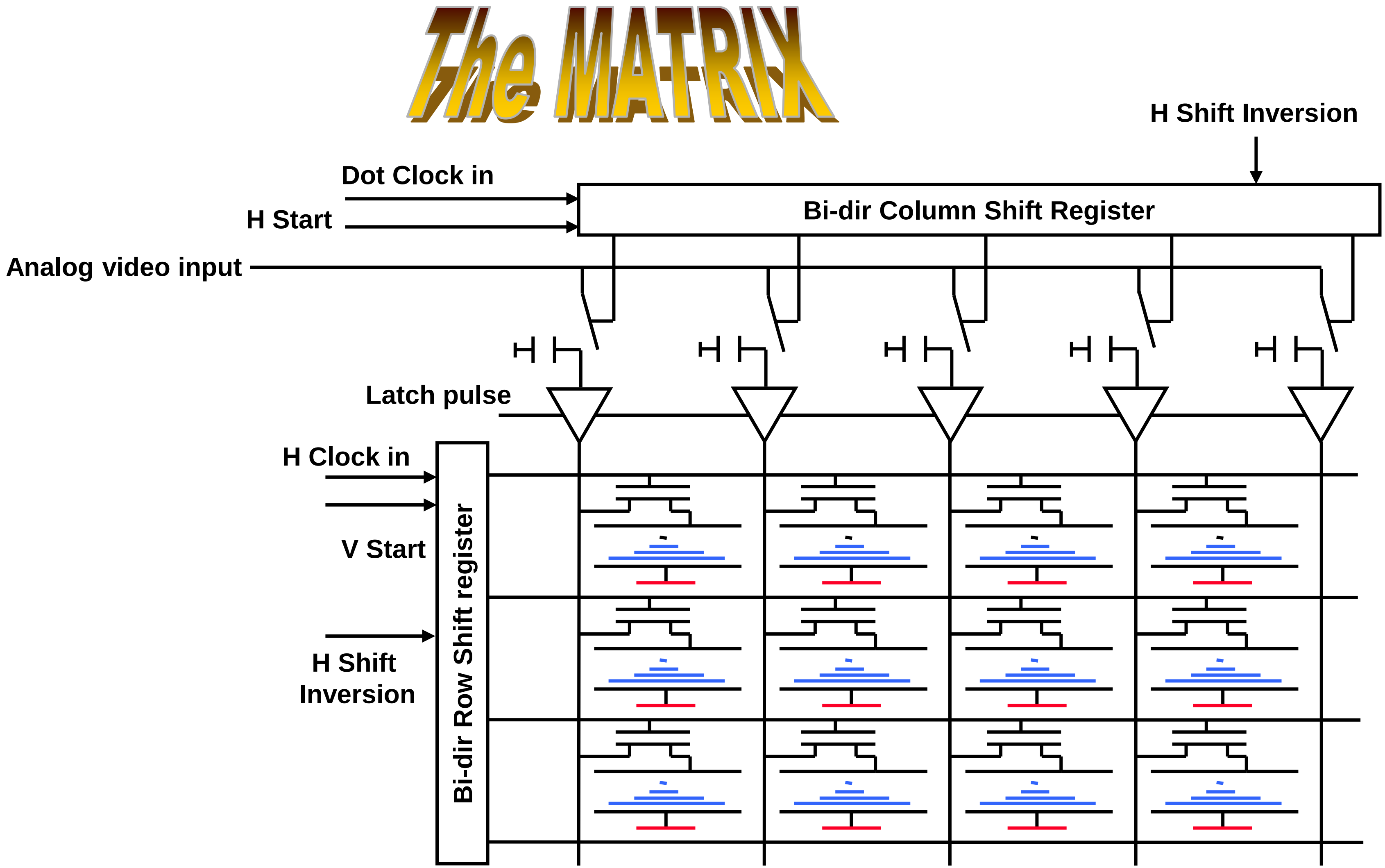
- **An LCD panel is a "huge IC" on glass,**
  - Thin film process => expensive (investment, material, yield)
  - Gap homogeneity typically controlled by spacers
  - The higher the resolution, the darker the picture for a given size and design rules
  - Storage capacity is necessary to increase voltage retention and decrease flicker / sticking image
- **Active matrix TN effect is widely used**
  - Wave guide effect. LCD transmission theoritically independent of wavelength
  - Large number of gray shades compatible with TV requirements
  - POOR viewing angles for TV application
- **In-Plane Switching Structure (Hitachi)**
  - Good viewing angle
  - Lower response time
- **Vertically aligned LCD (JVC)**
  - Good viewing angle and response time
  - Difficult to manufacture today
- **Possibility to integrate drivers:**
  - a-Si integrated drivers on glass
  - Low temperature P-Si on glass

Poly-Si integrated drivers on Quartz

PRINCIPLE TRAINING

- ❑ Introduction
- ❑ General training
  - LCD pixel structure
    - Optical effect
    - Electrical effect
  - LCD panel structure
  - Active matrix displays
    - Structure
    - Addressing techniques
  - General electronics block diagram
    - LCD drivers
    - LCD controller
    - Upstream video processing
  - Back lighting
  - Characterization principles
    - Main optical parameters to look at
    - Measurement methods and tools

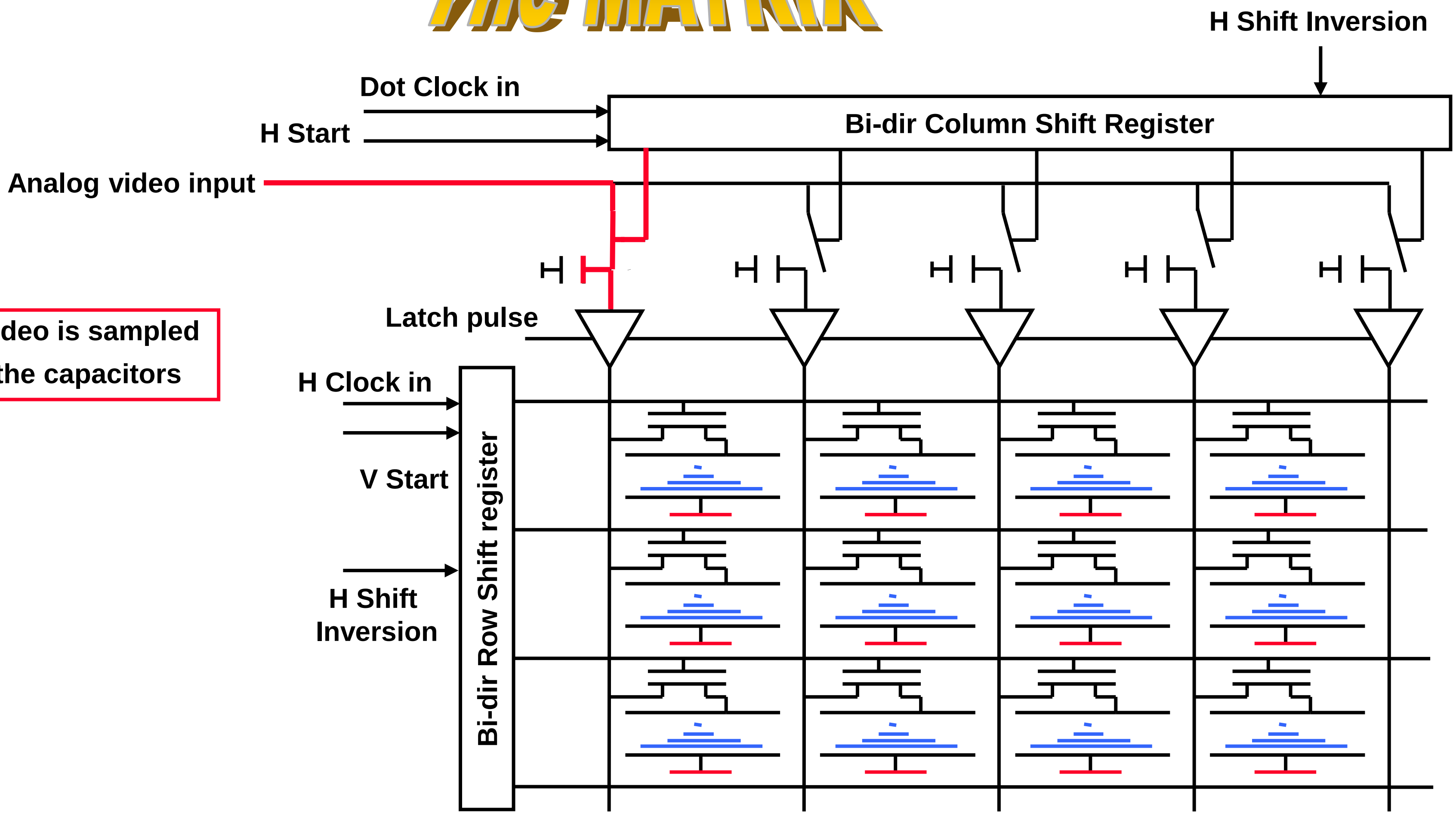
LCD ADDRESSING



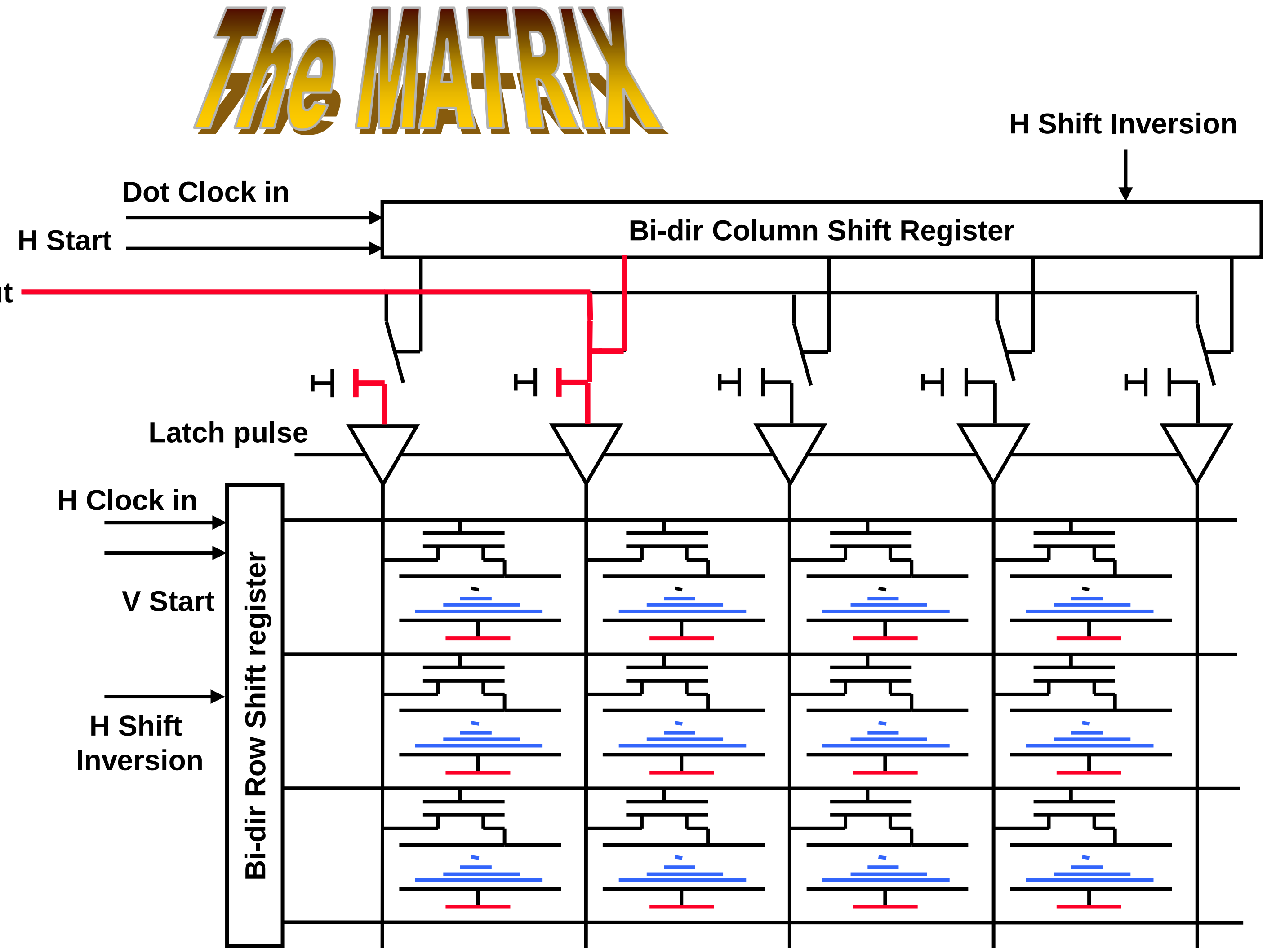
LCD ADDRESSING

The MATRIX

The Video is sampled into the capacitors



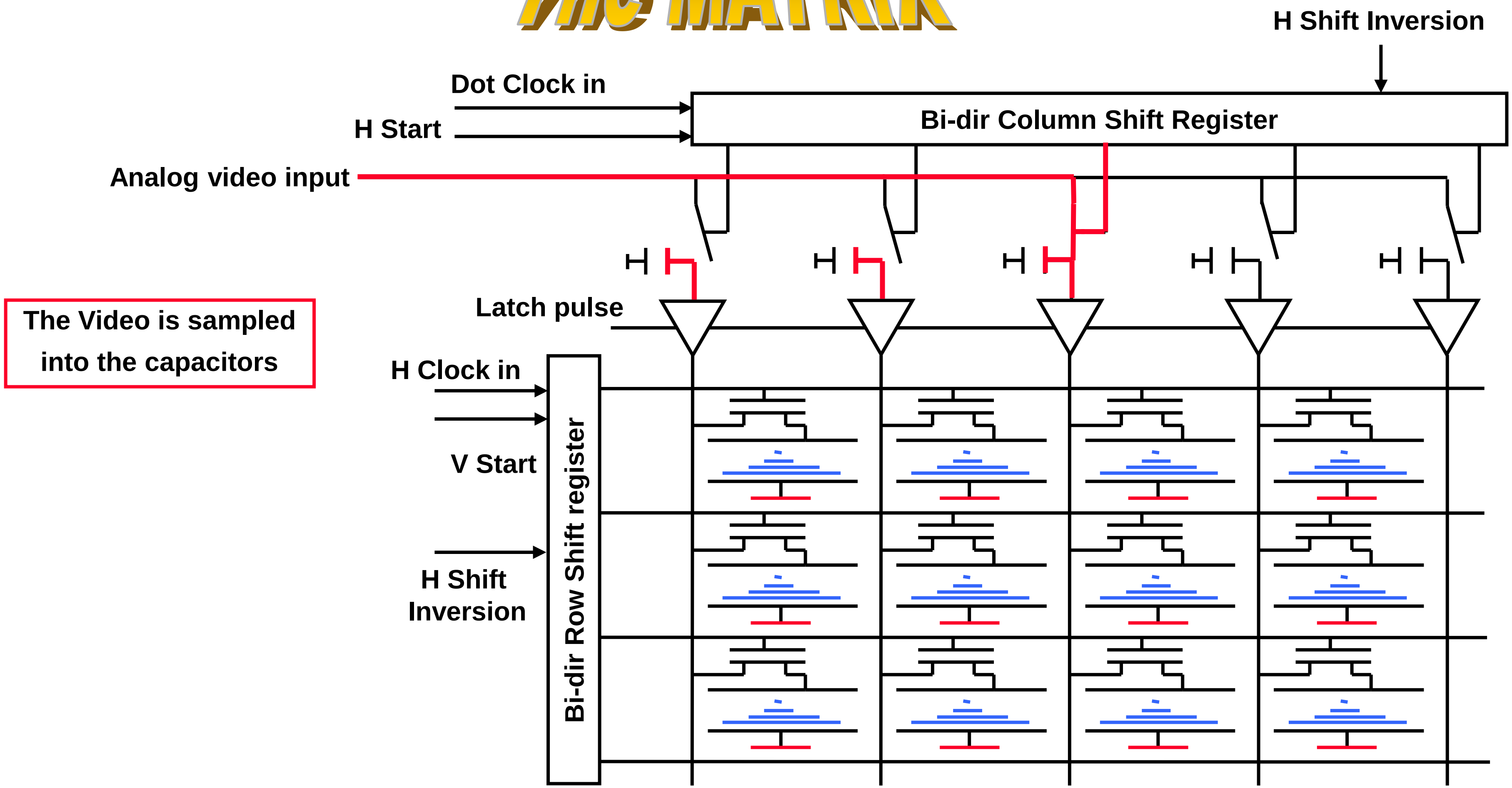
LCD ADDRESSING



The Video is sampled into the capacitors

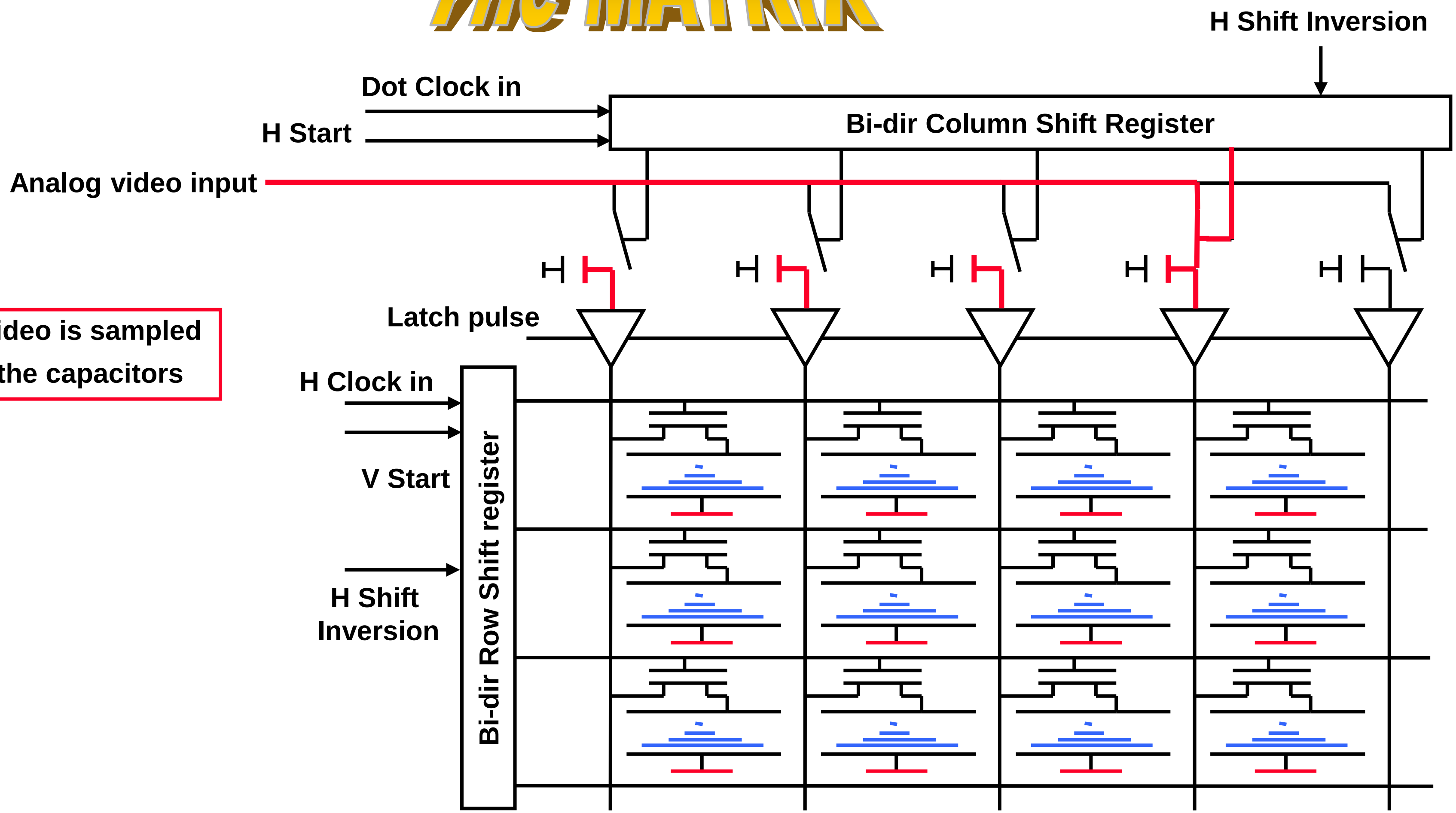
LCD ADDRESSING

The MATRIX



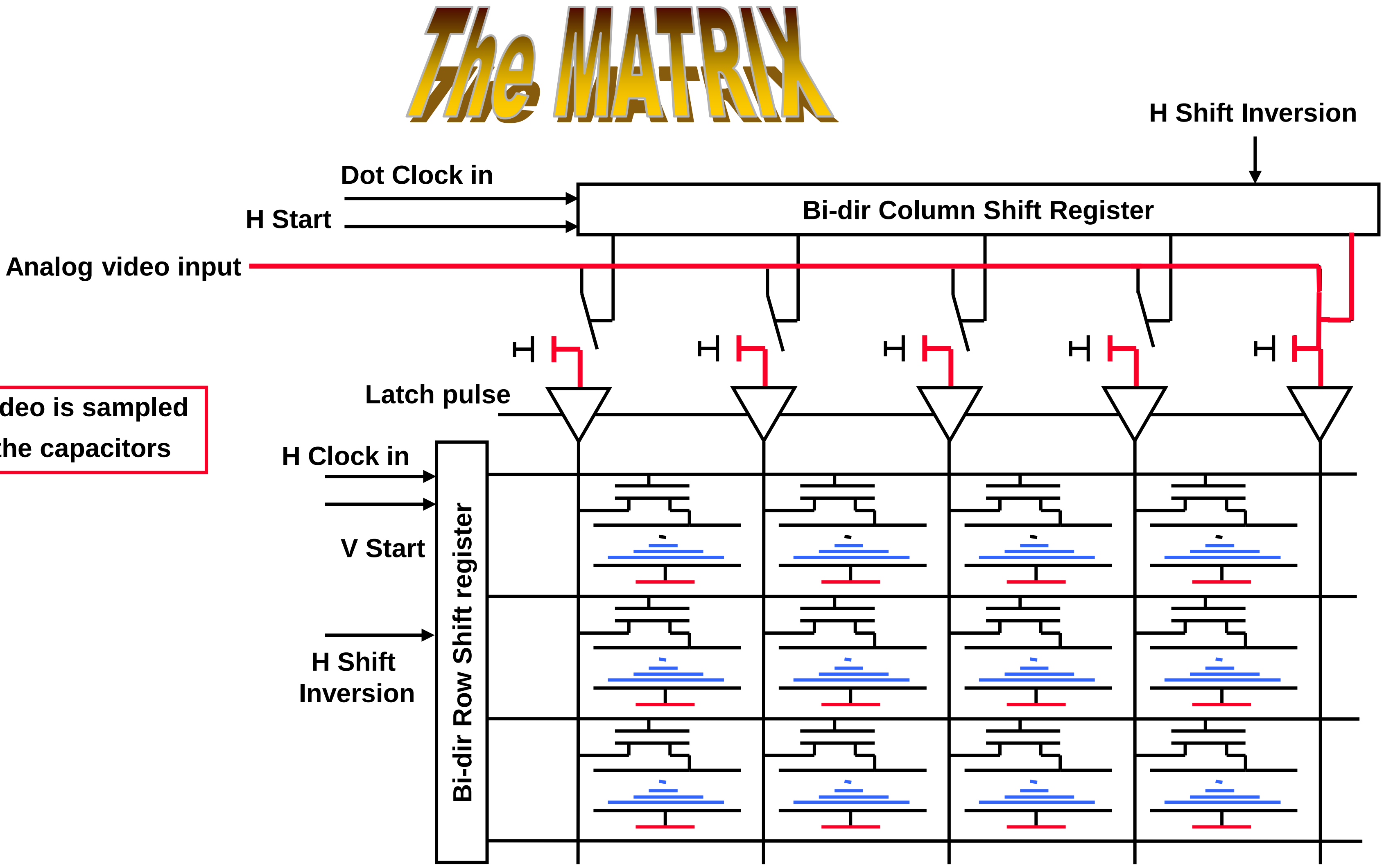
LCD ADDRESSING

The MATRIX



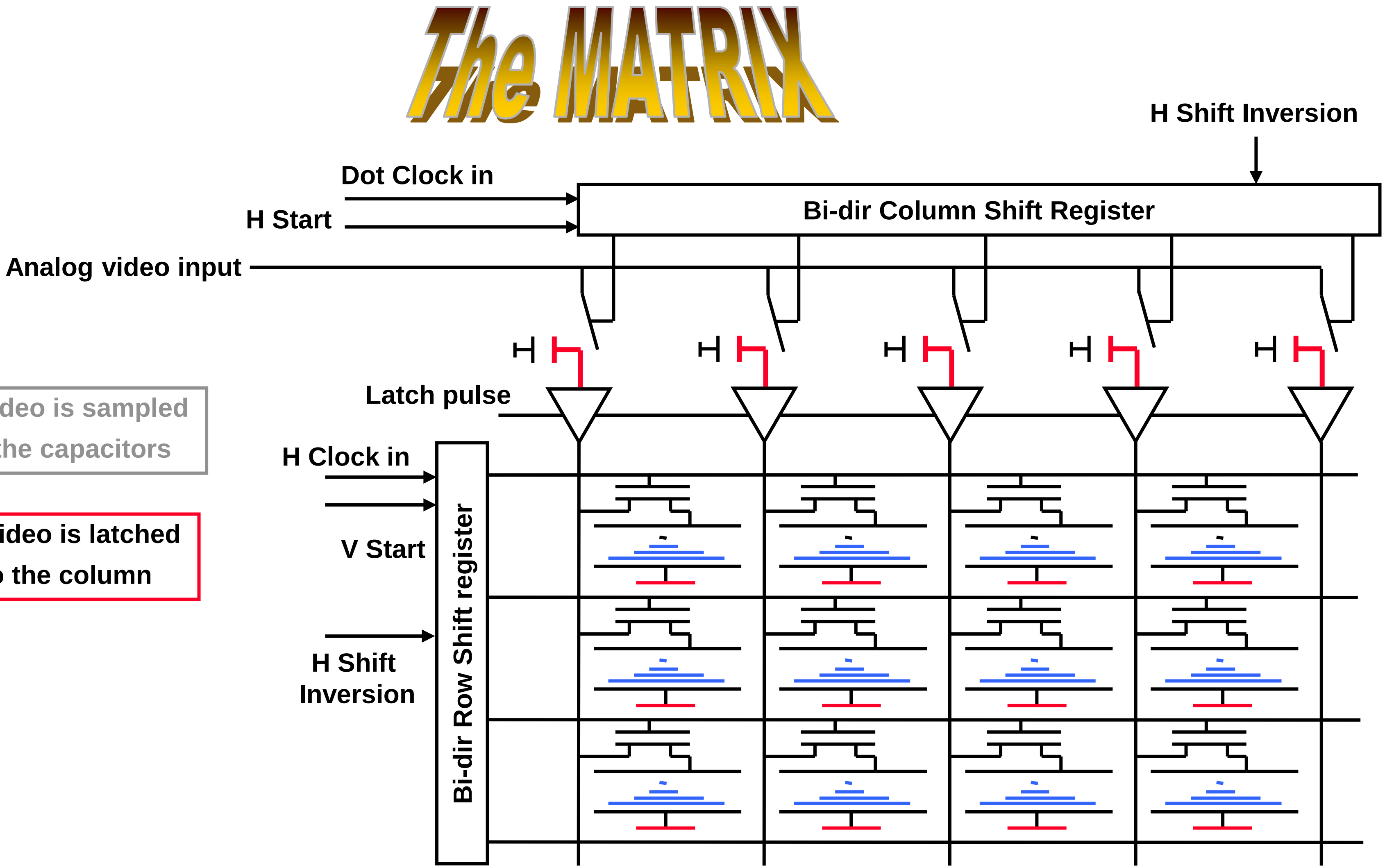
The Video is sampled into the capacitors

LCD ADDRESSING



The Video is sampled into the capacitors

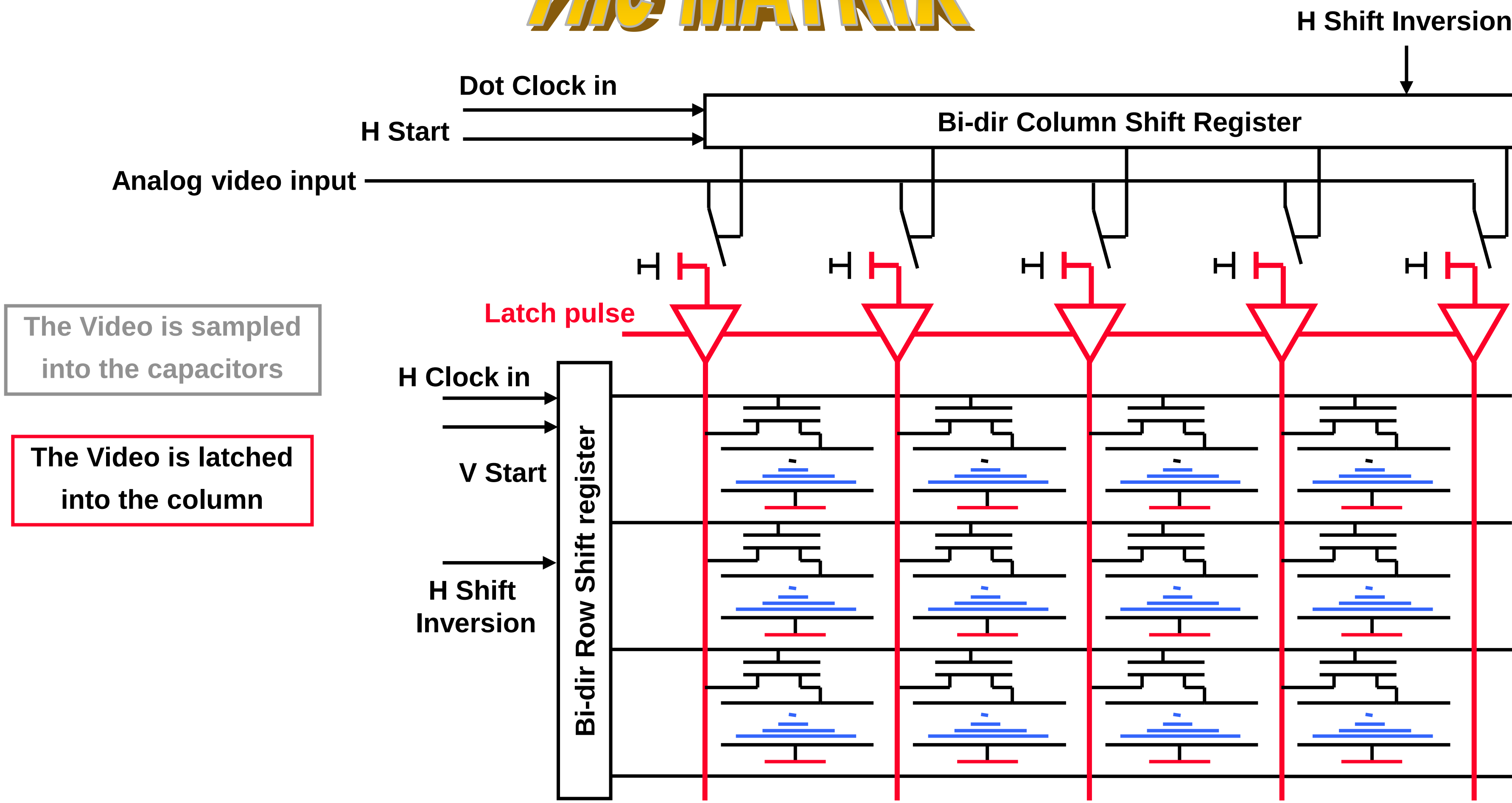
LCD ADDRESSING



The Video is sampled into the capacitors

The Video is latched into the column

LCD ADDRESSING



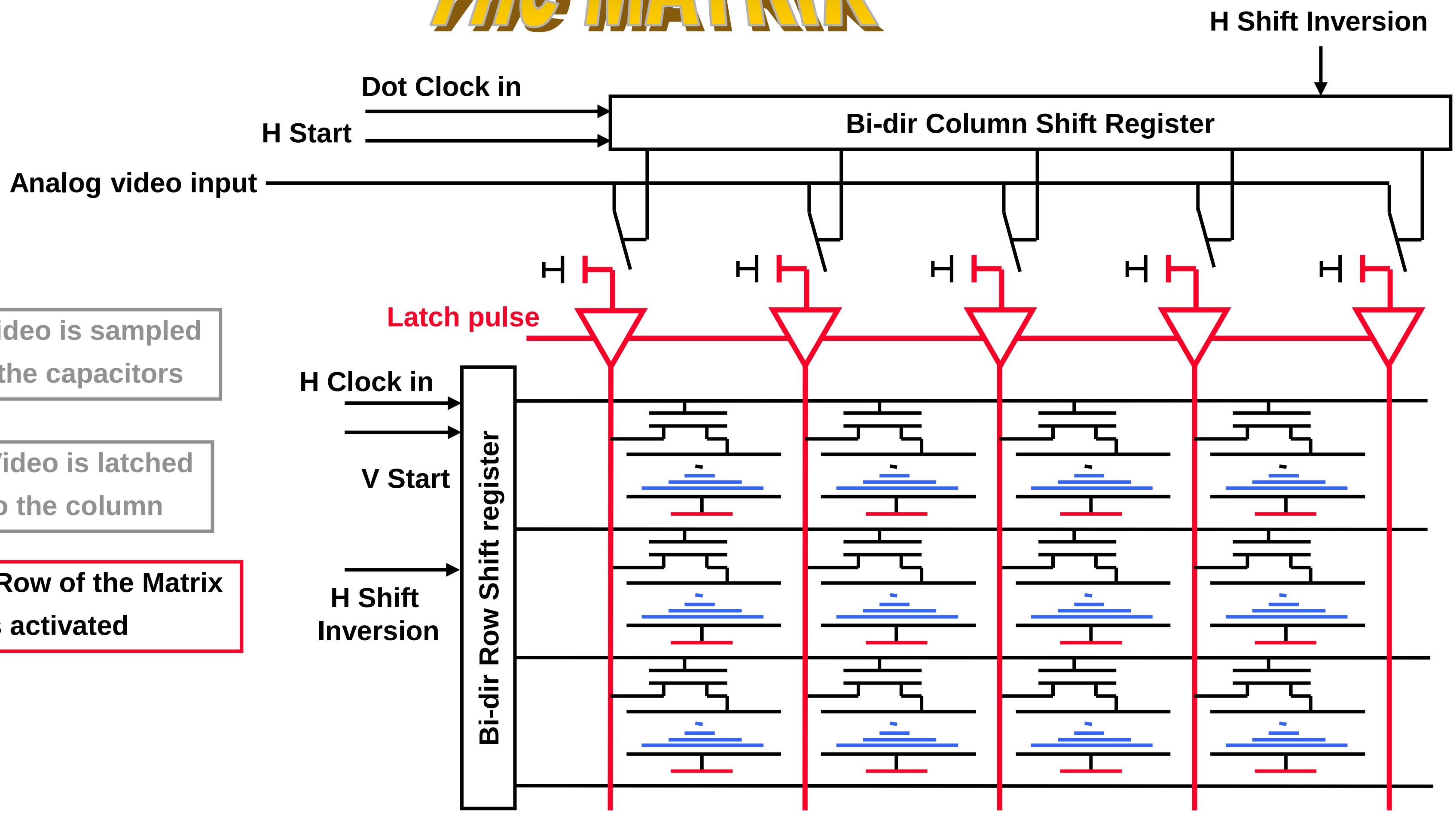
LCD ADDRESSING

The MATRIX

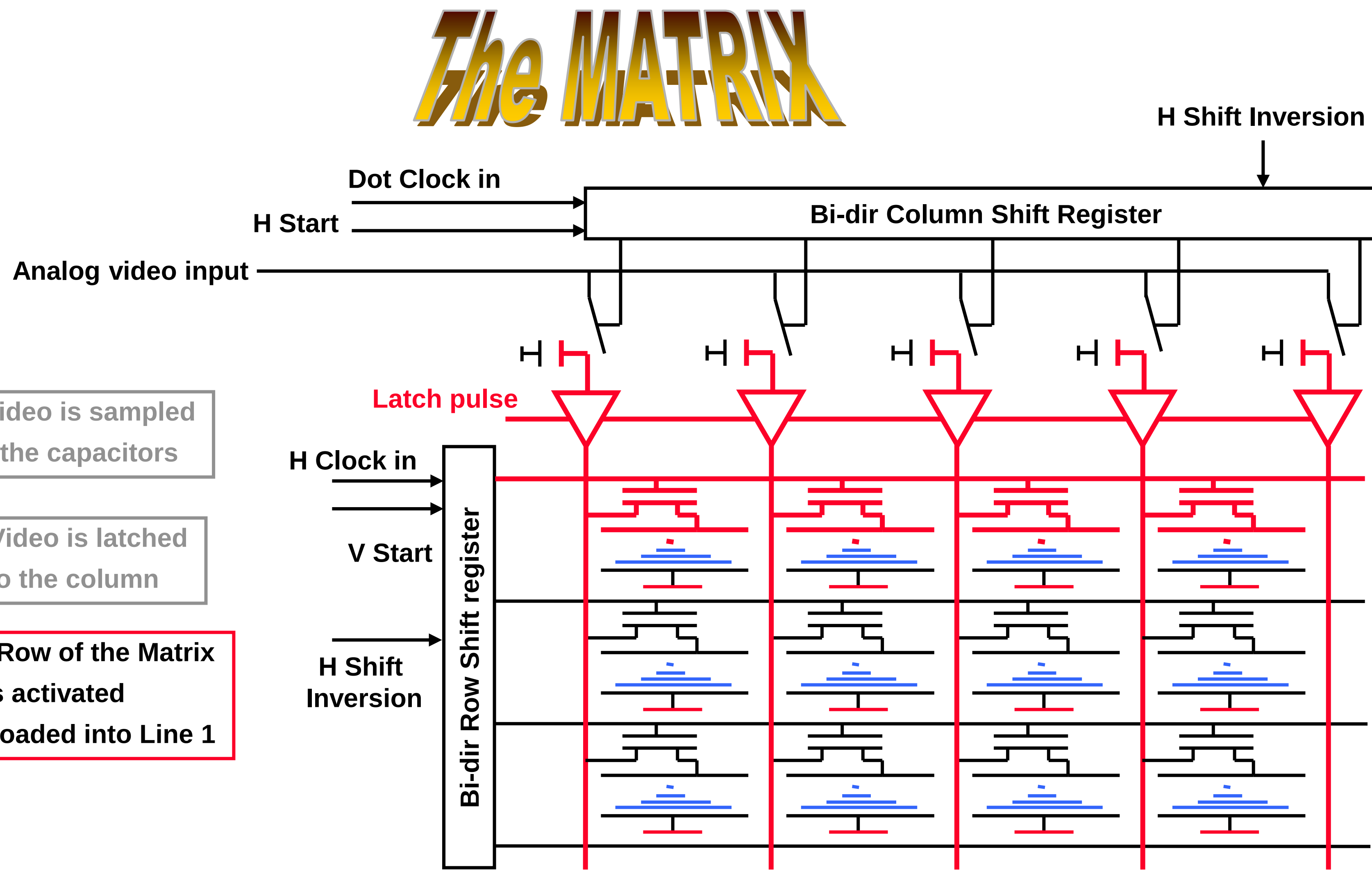
The Video is sampled into the capacitors

The Video is latched into the column

The first Row of the Matrix is activated



LCD ADDRESSING



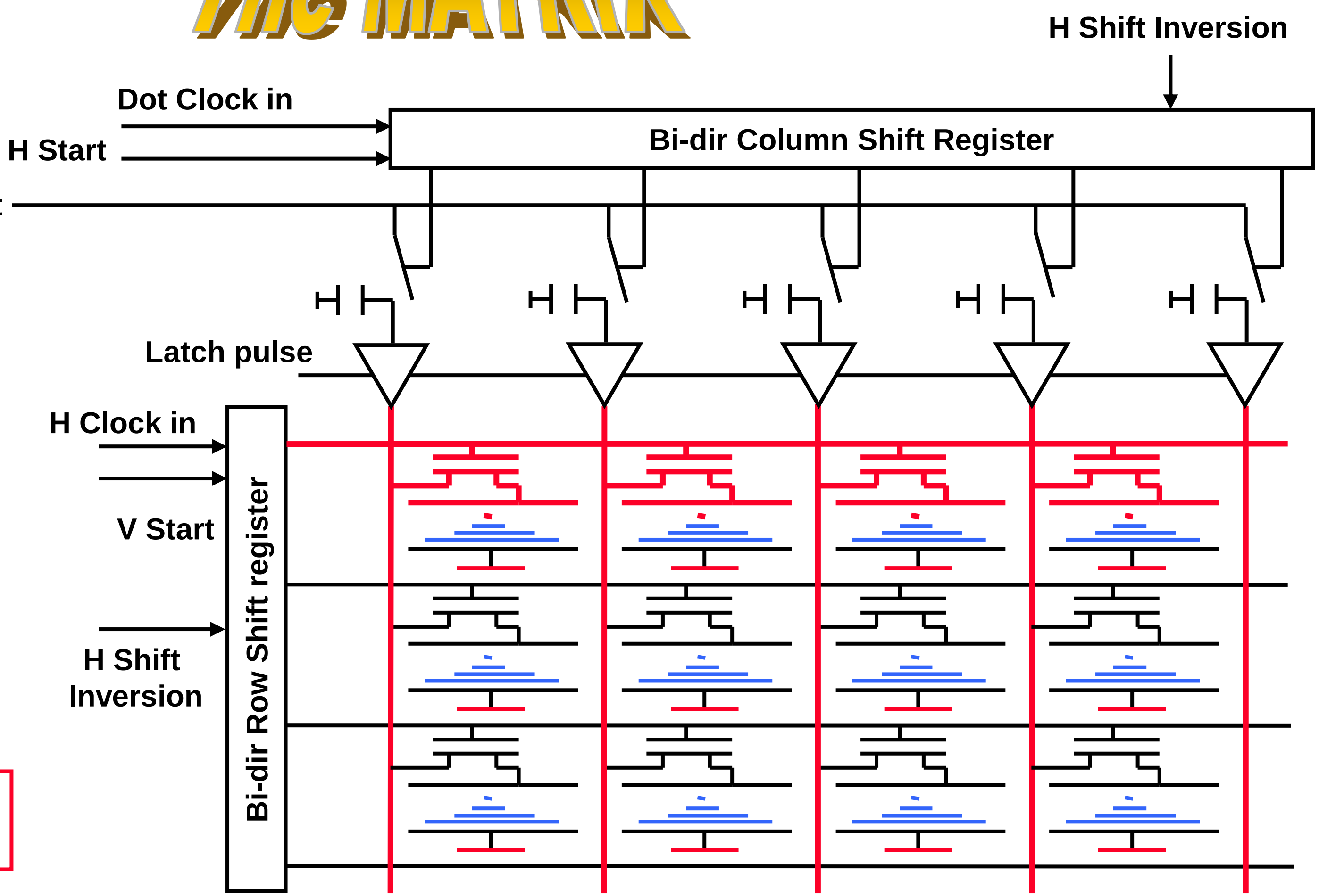
The Video is sampled into the capacitors

The Video is latched into the column

The first Row of the Matrix is activated
Video is loaded into Line 1

LCD ADDRESSING

The MATRIX



The Video is sampled into the capacitors

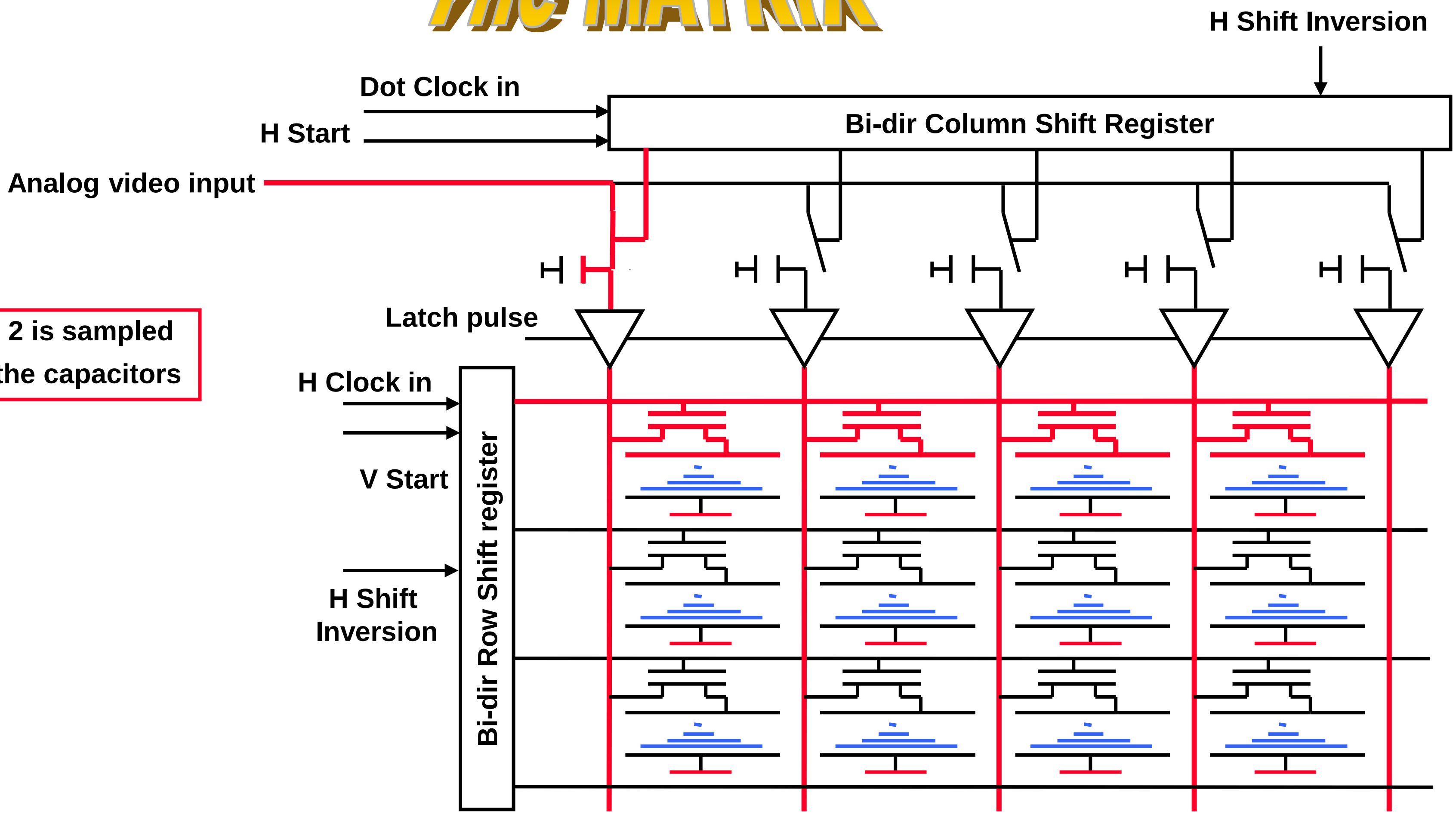
The Video is latched into the column

The first Row of the Matrix is activated

Output buffers are turned off and Line 2 sampling can start

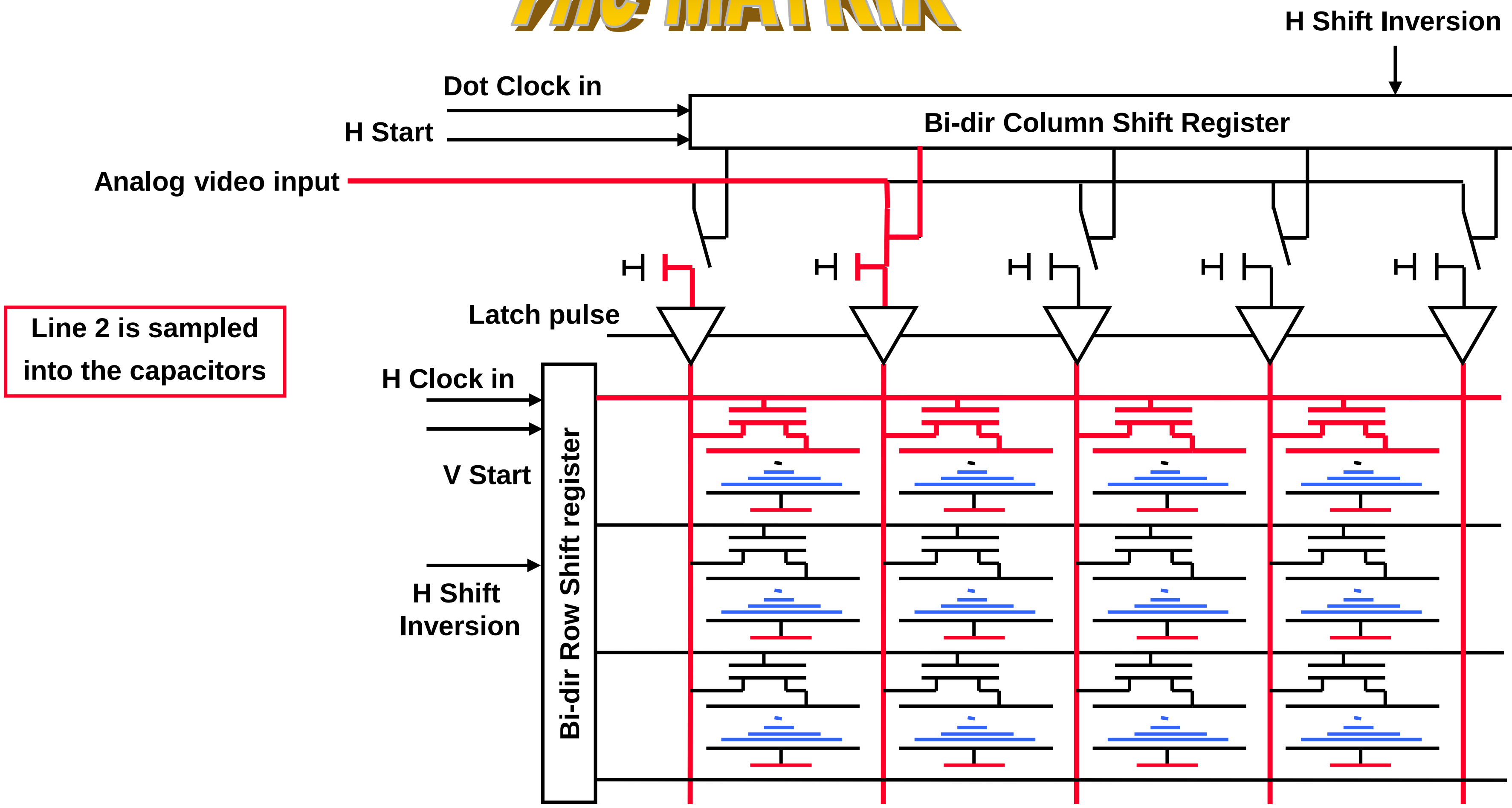
LCD ADDRESSING

The MATRIX

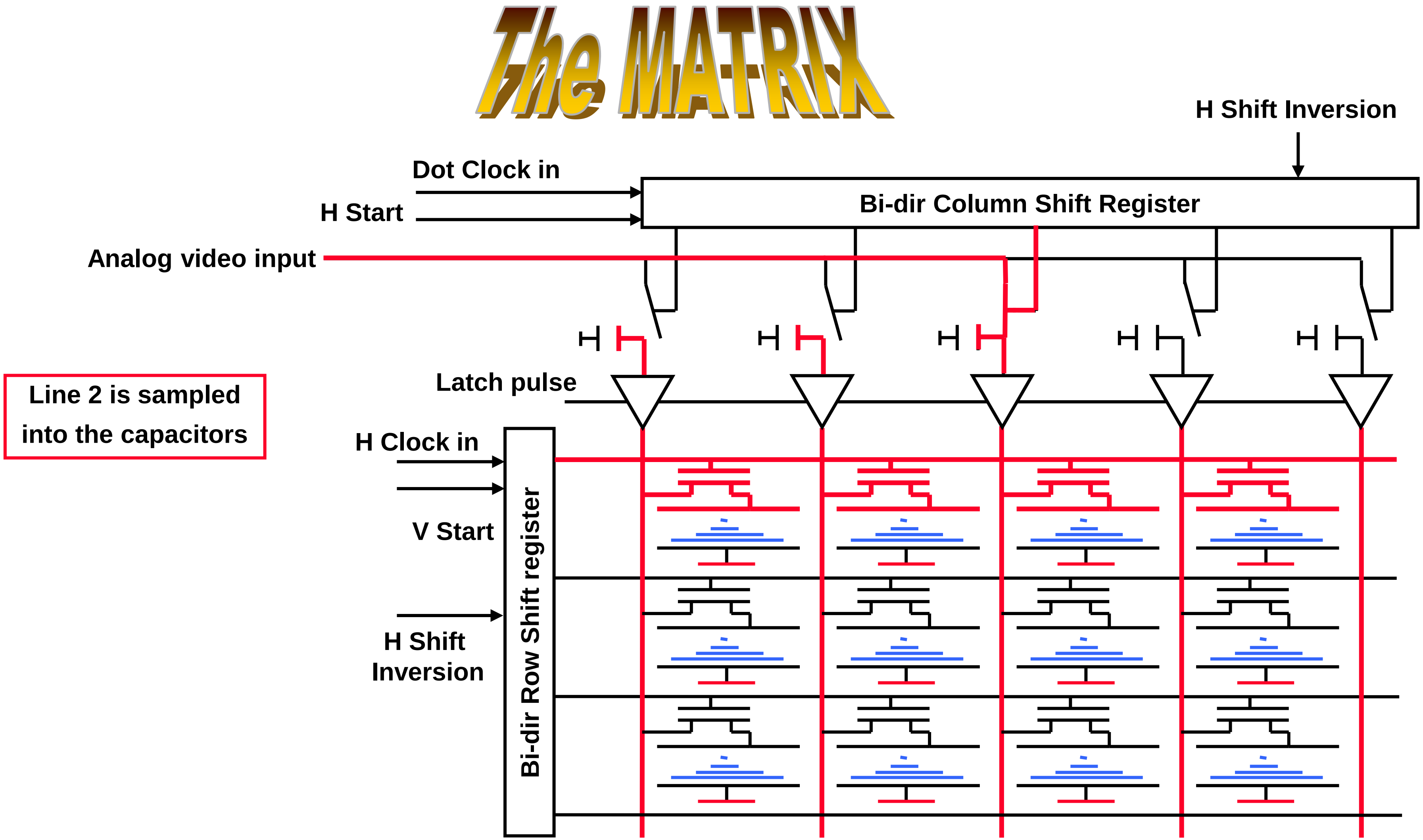


Line 2 is sampled into the capacitors

LCD ADDRESSING

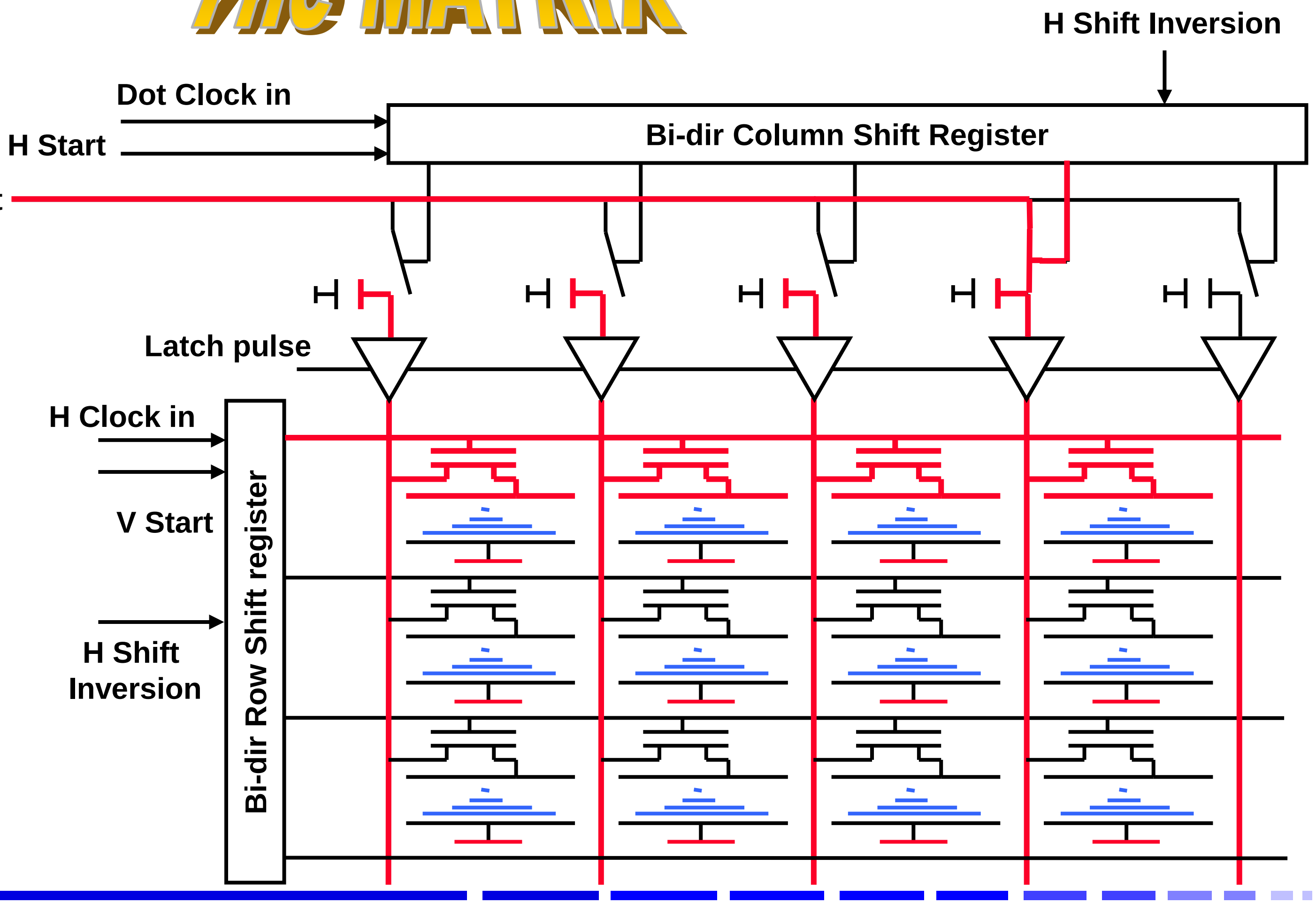


LCD ADDRESSING



LCD ADDRESSING

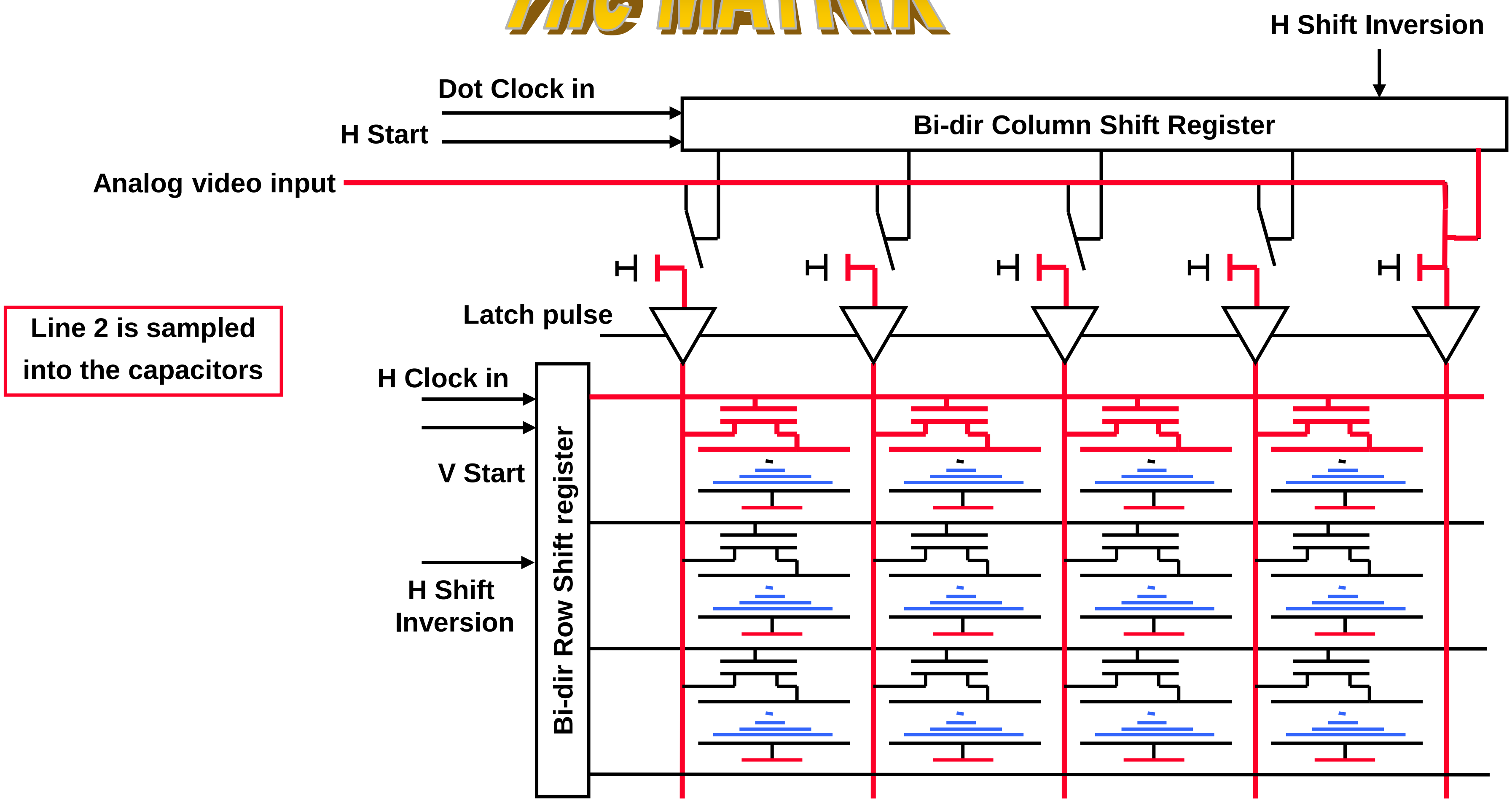
The MATRIX



Line 2 is sampled into the capacitors

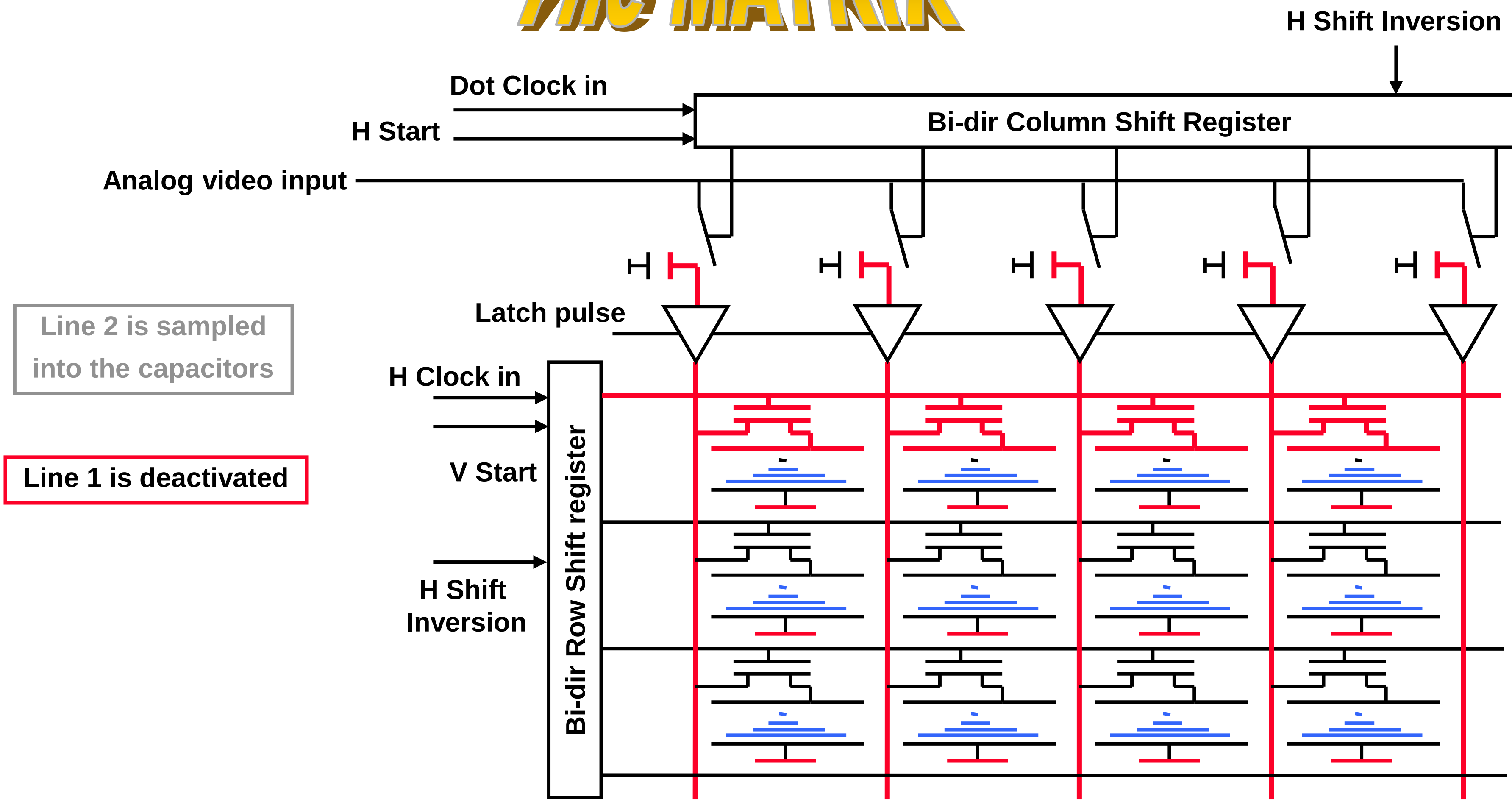
LCD ADDRESSING

The MATRIX



LCD ADDRESSING

The MATRIX

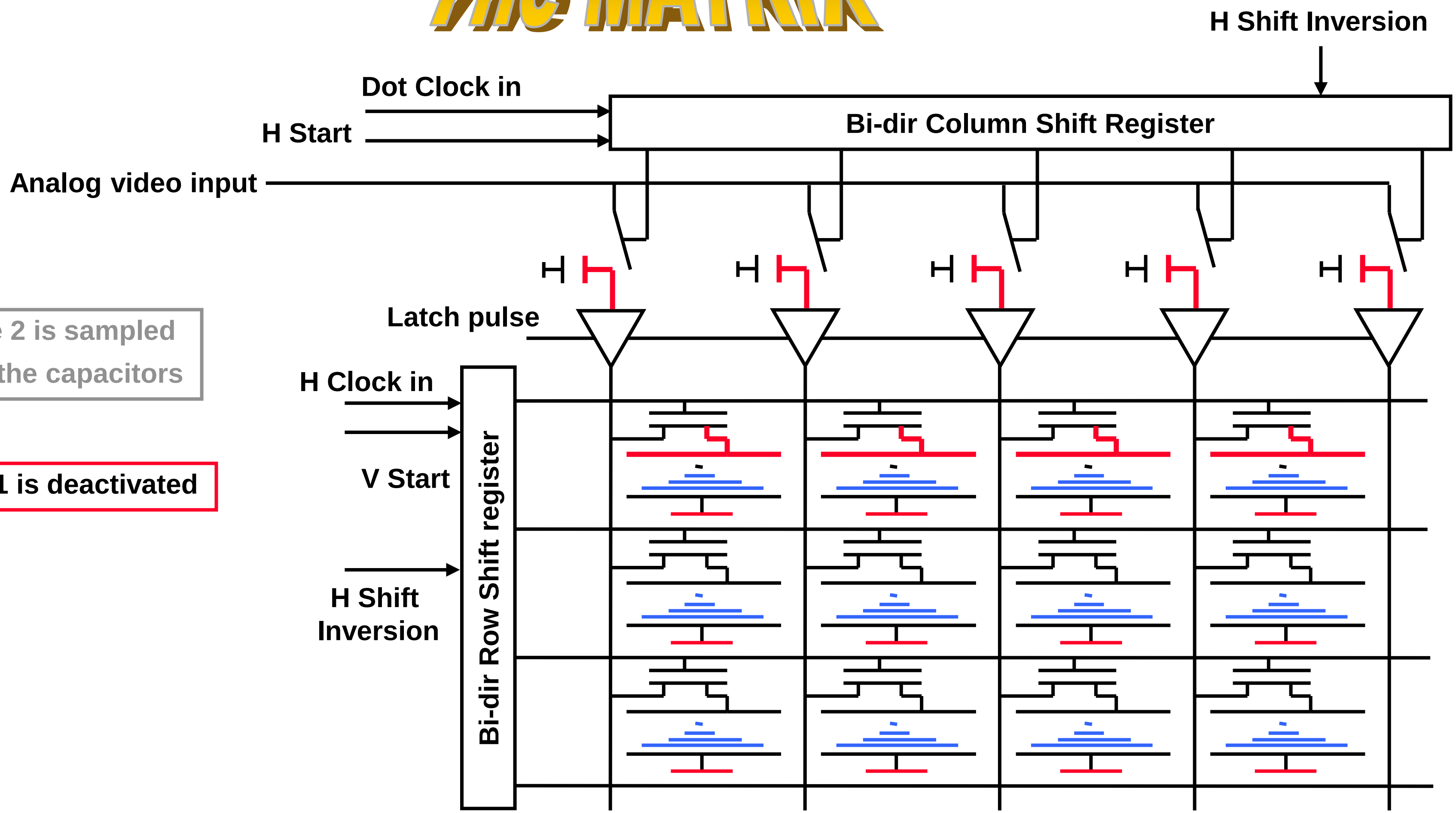


LCD ADDRESSING

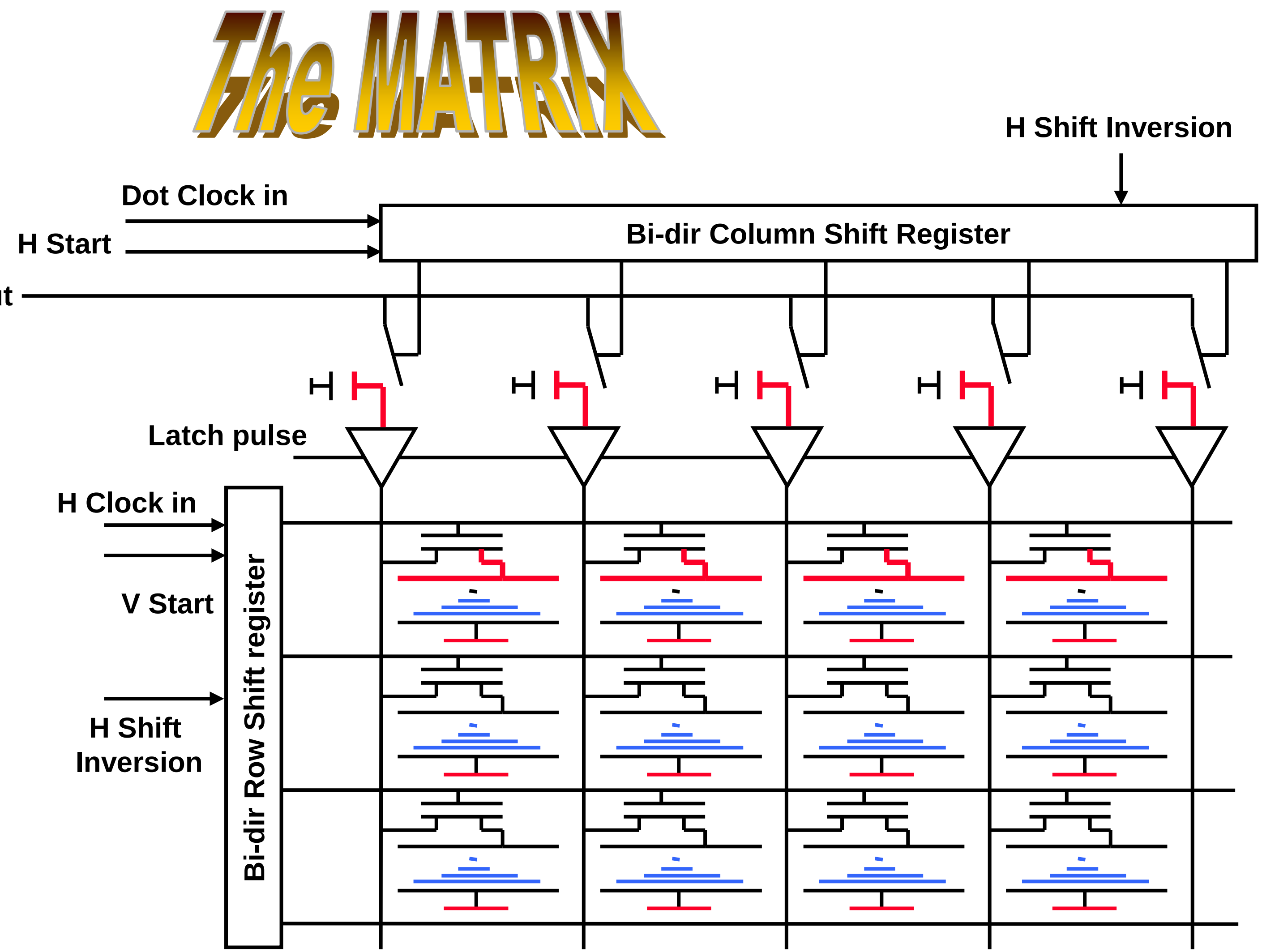
The MATRIX

Line 2 is sampled into the capacitors

Line 1 is deactivated



LCD ADDRESSING

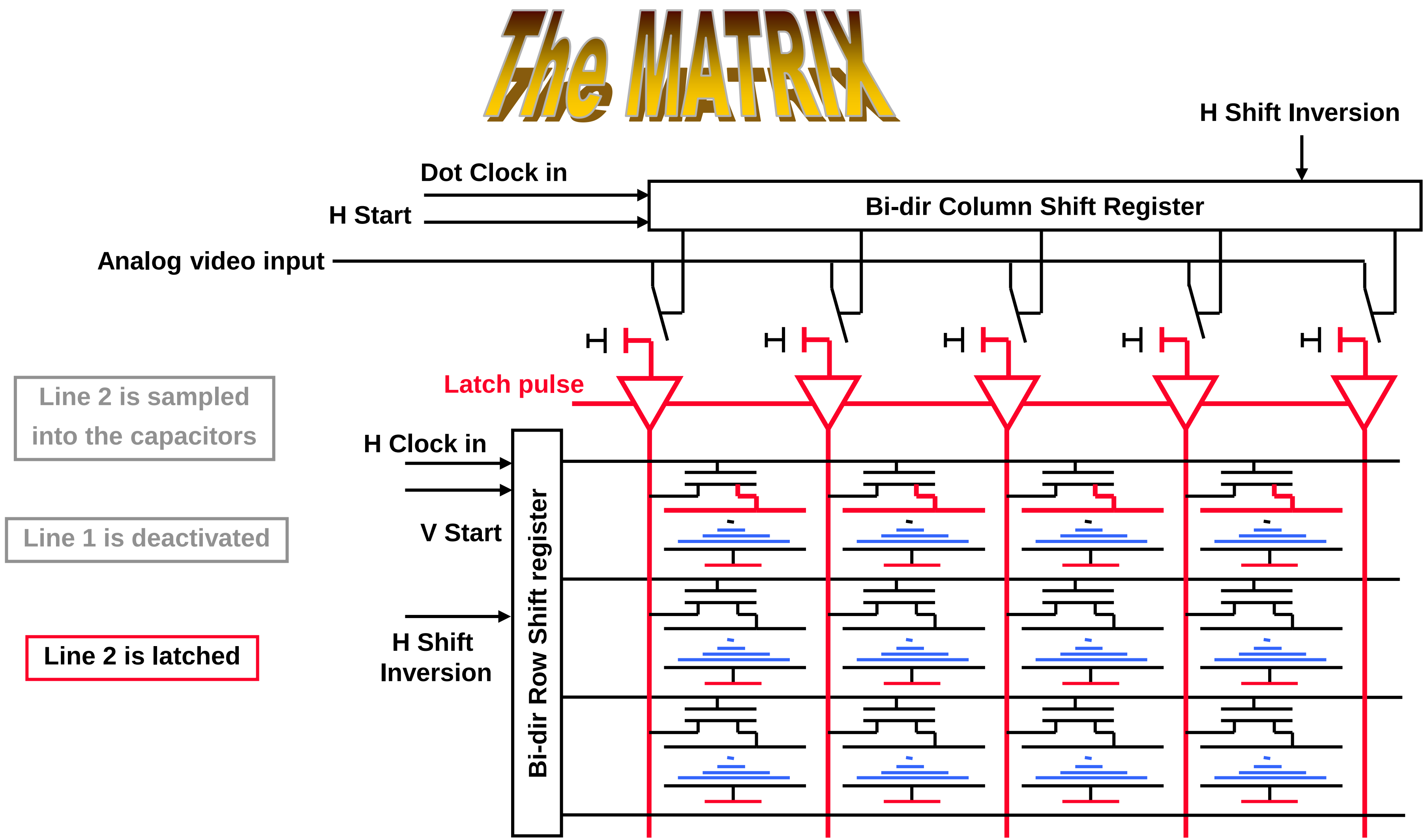


Line 2 is sampled into the capacitors

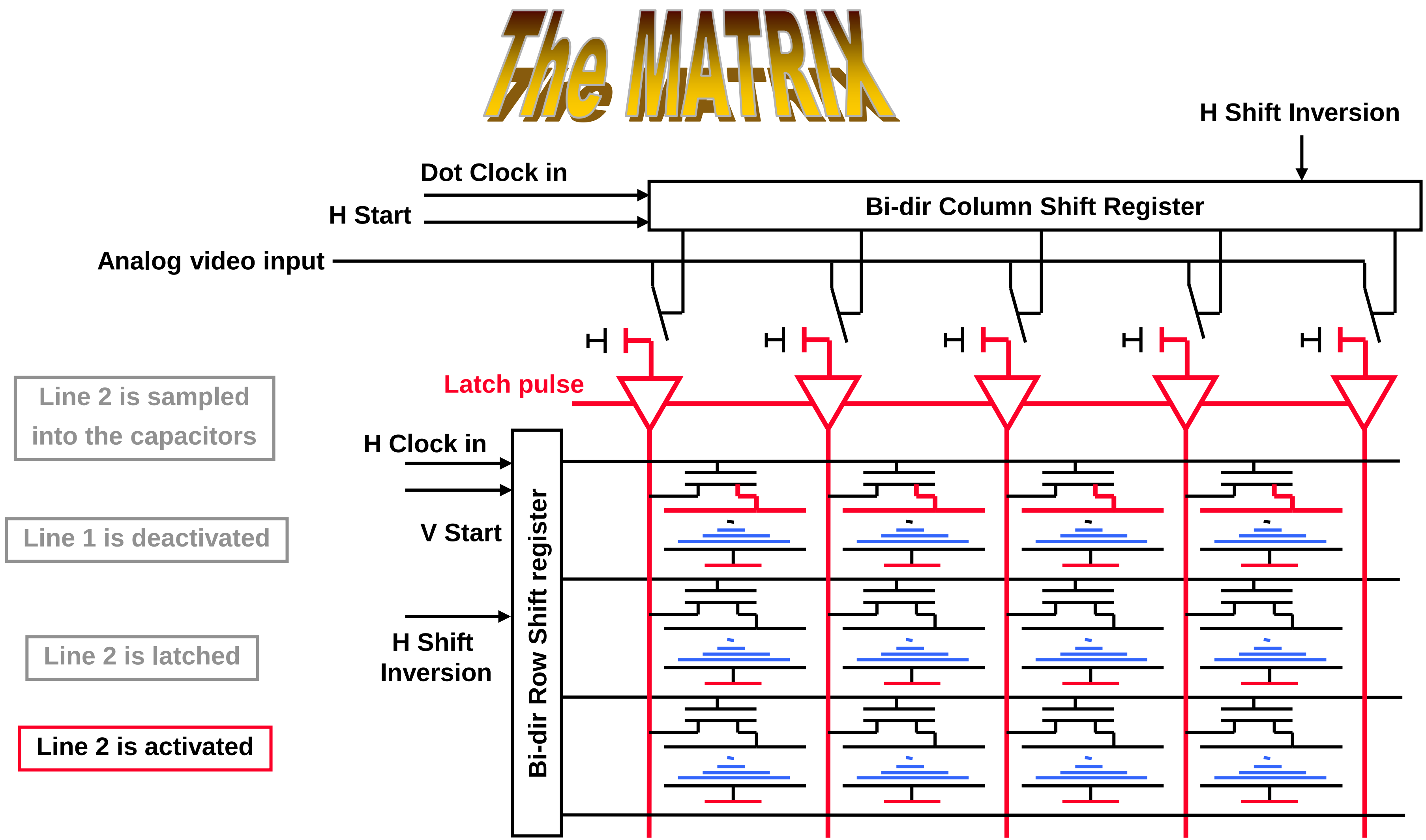
Line 1 is deactivated

Line 2 is latched

LCD ADDRESSING

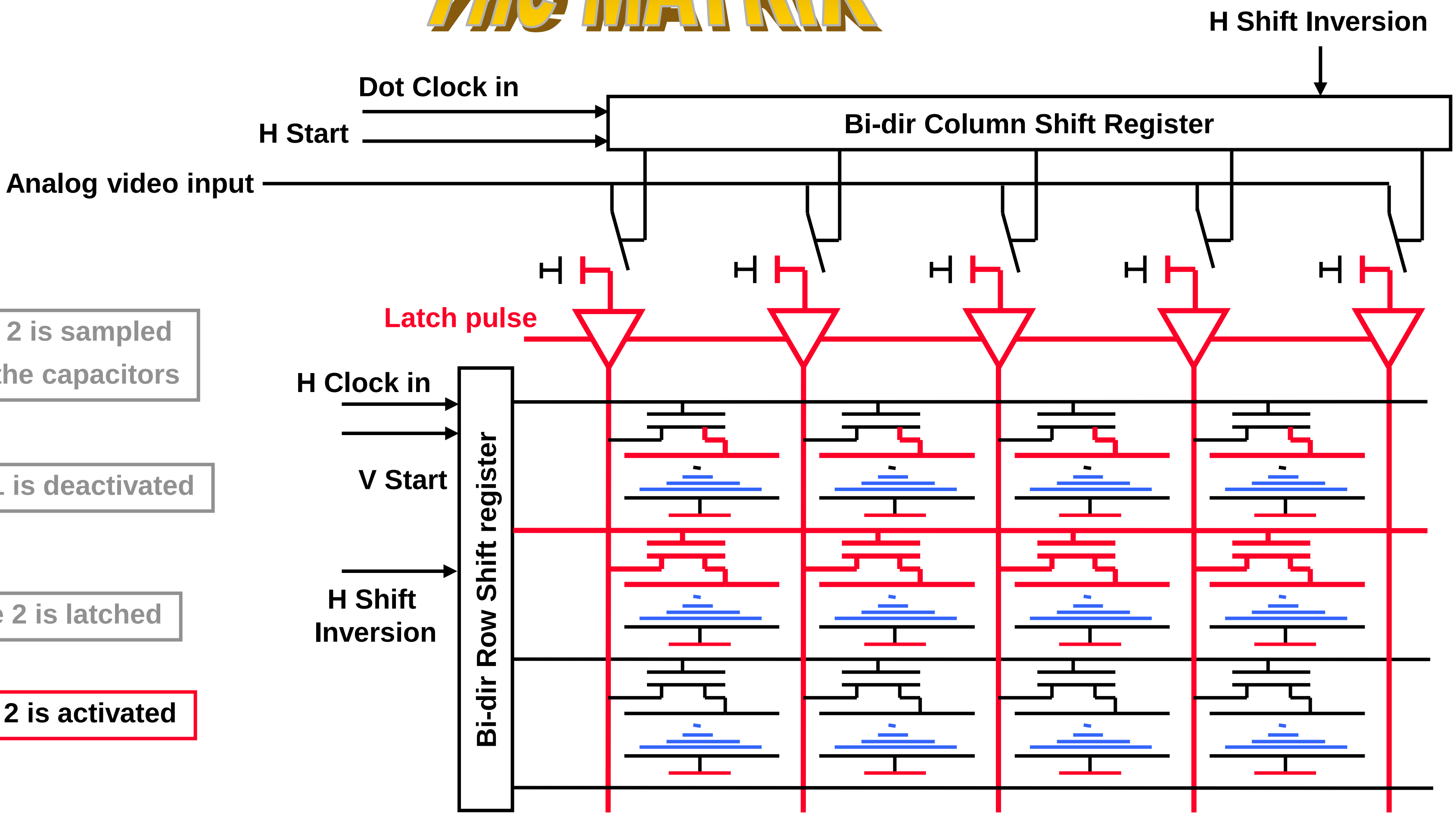


LCD ADDRESSING



LCD ADDRESSING

The MATRIX



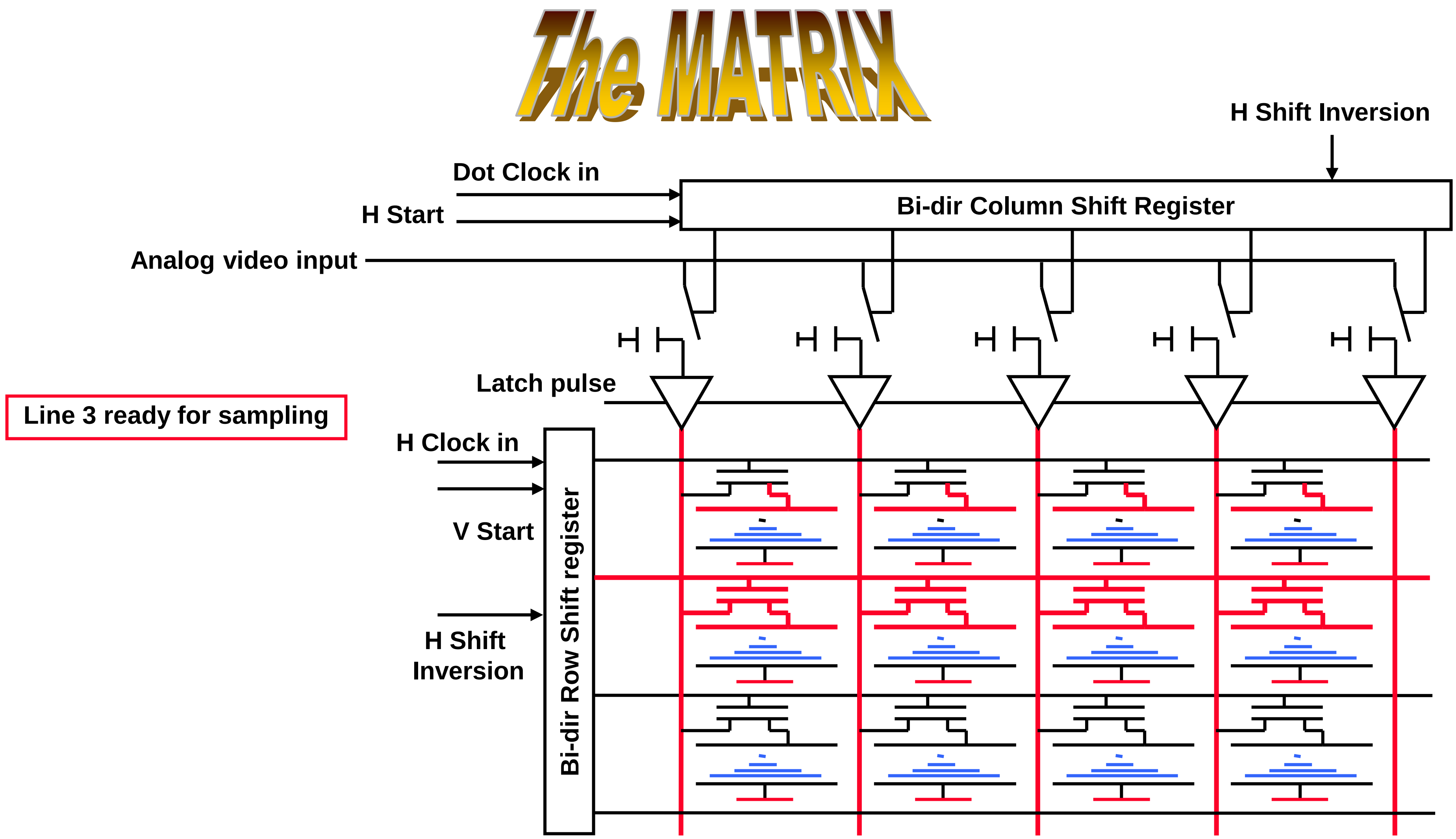
Line 2 is sampled into the capacitors

Line 1 is deactivated

Line 2 is latched

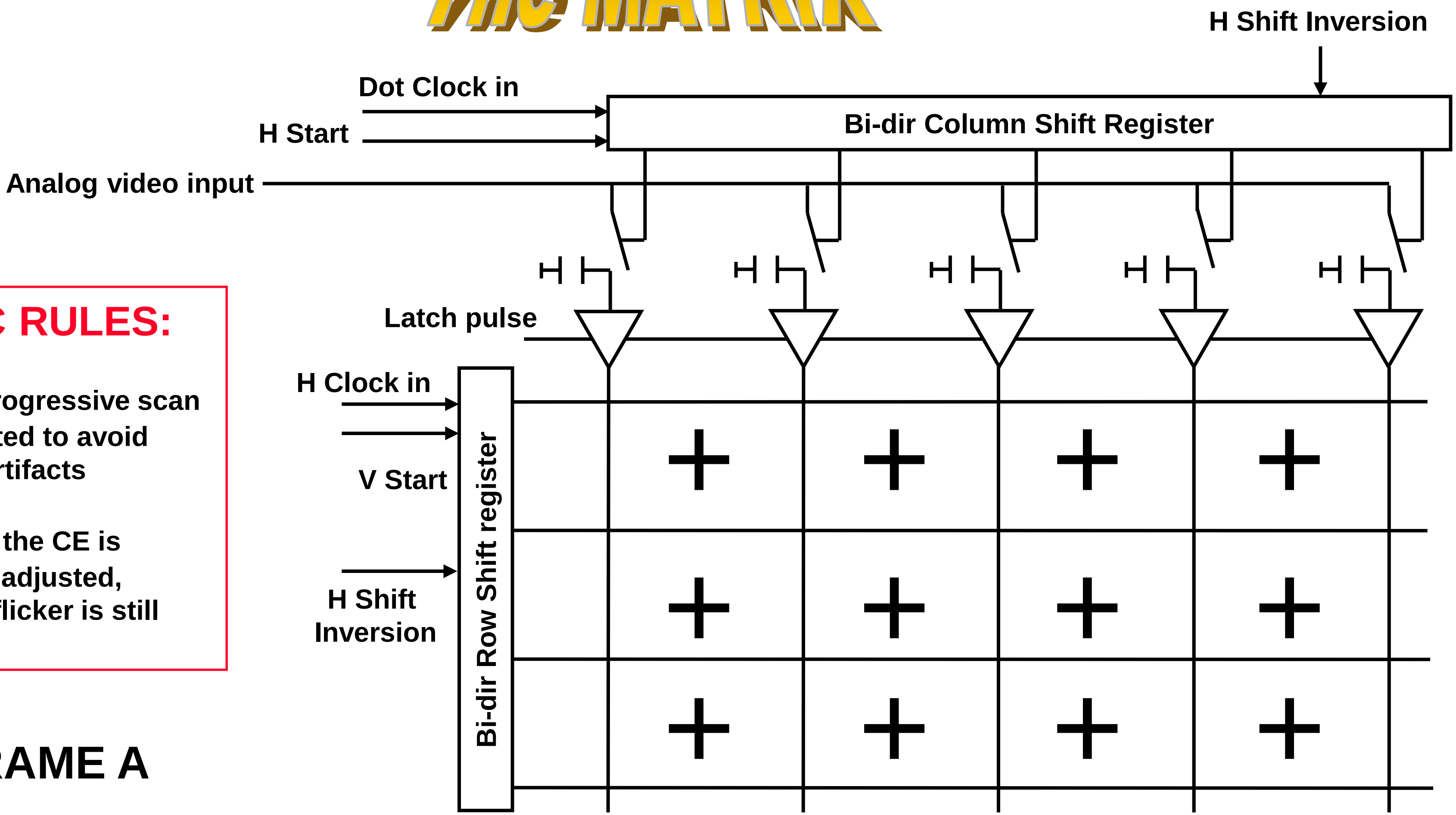
Line 2 is activated

LCD ADDRESSING



LCD ADDRESSING

The MATRIX

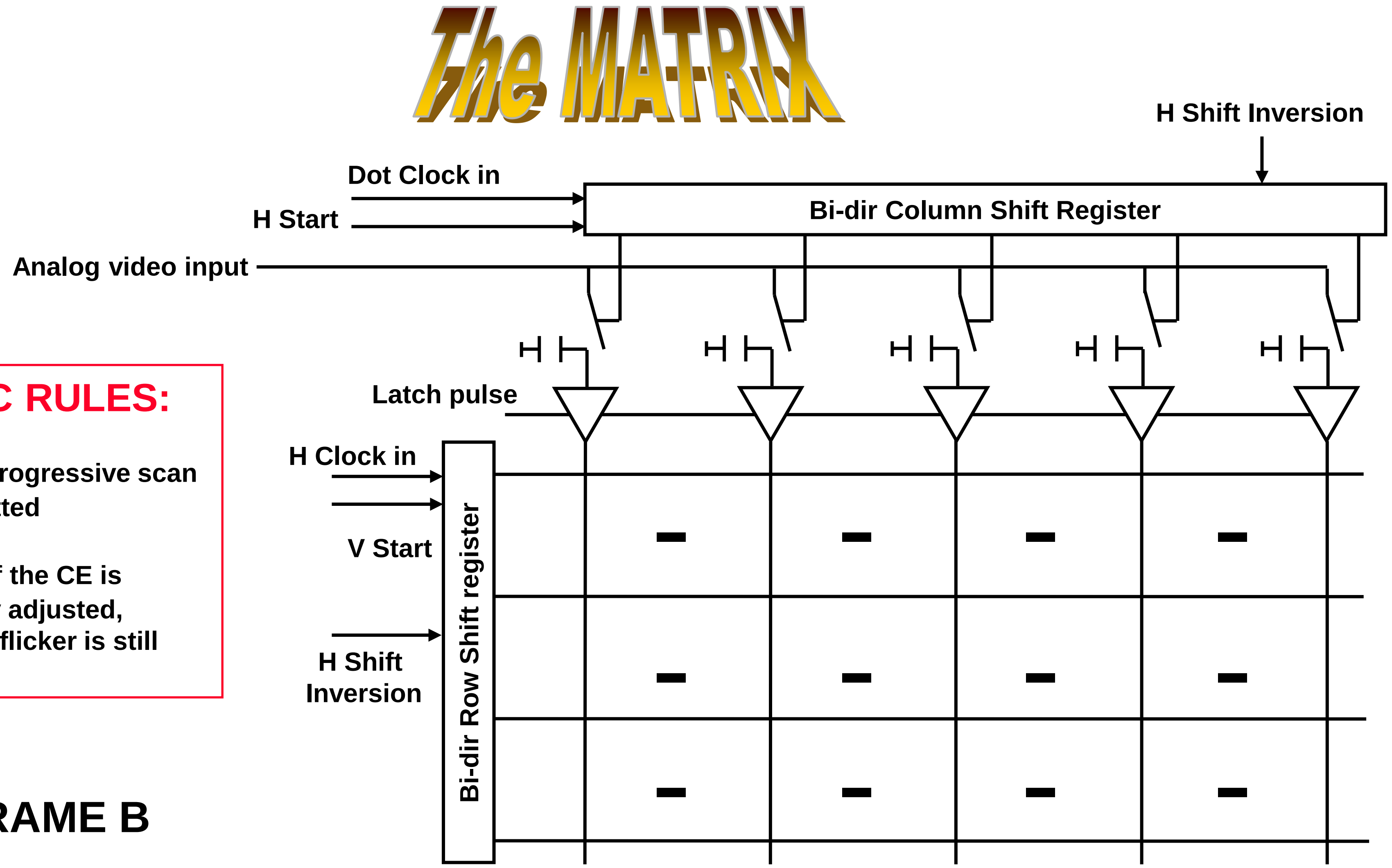


BASIC RULES:

- Only progressive scan is permitted to avoid motion artifacts
- Even if the CE is perfectly adjusted, residual flicker is still visible.

FRAME A

LCD ADDRESSING



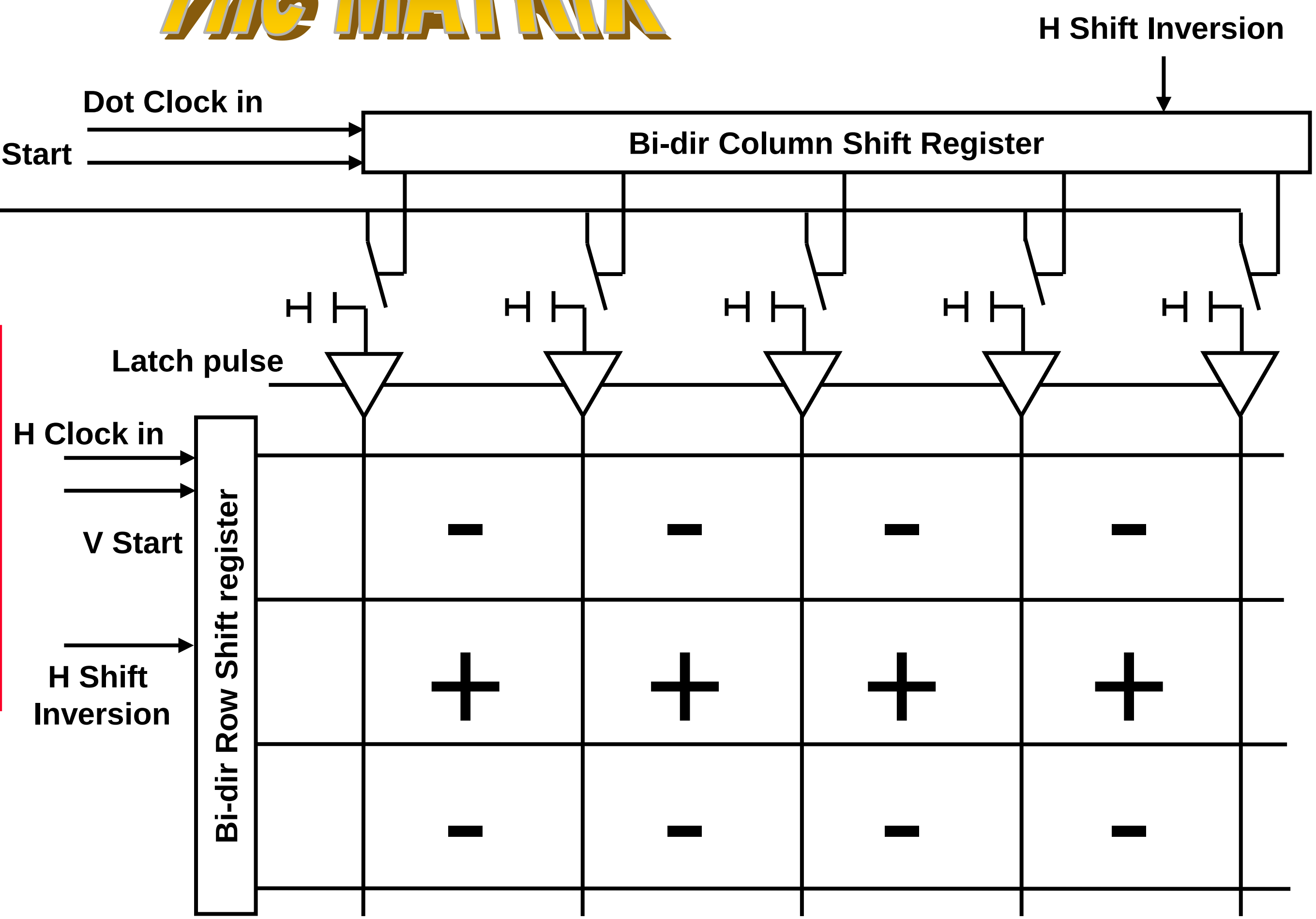
BASIC RULES:

- Only progressive scan is permitted
- Even if the CE is perfectly adjusted, residual flicker is still visible.

FRAME B

LCD ADDRESSING

The MATRIX



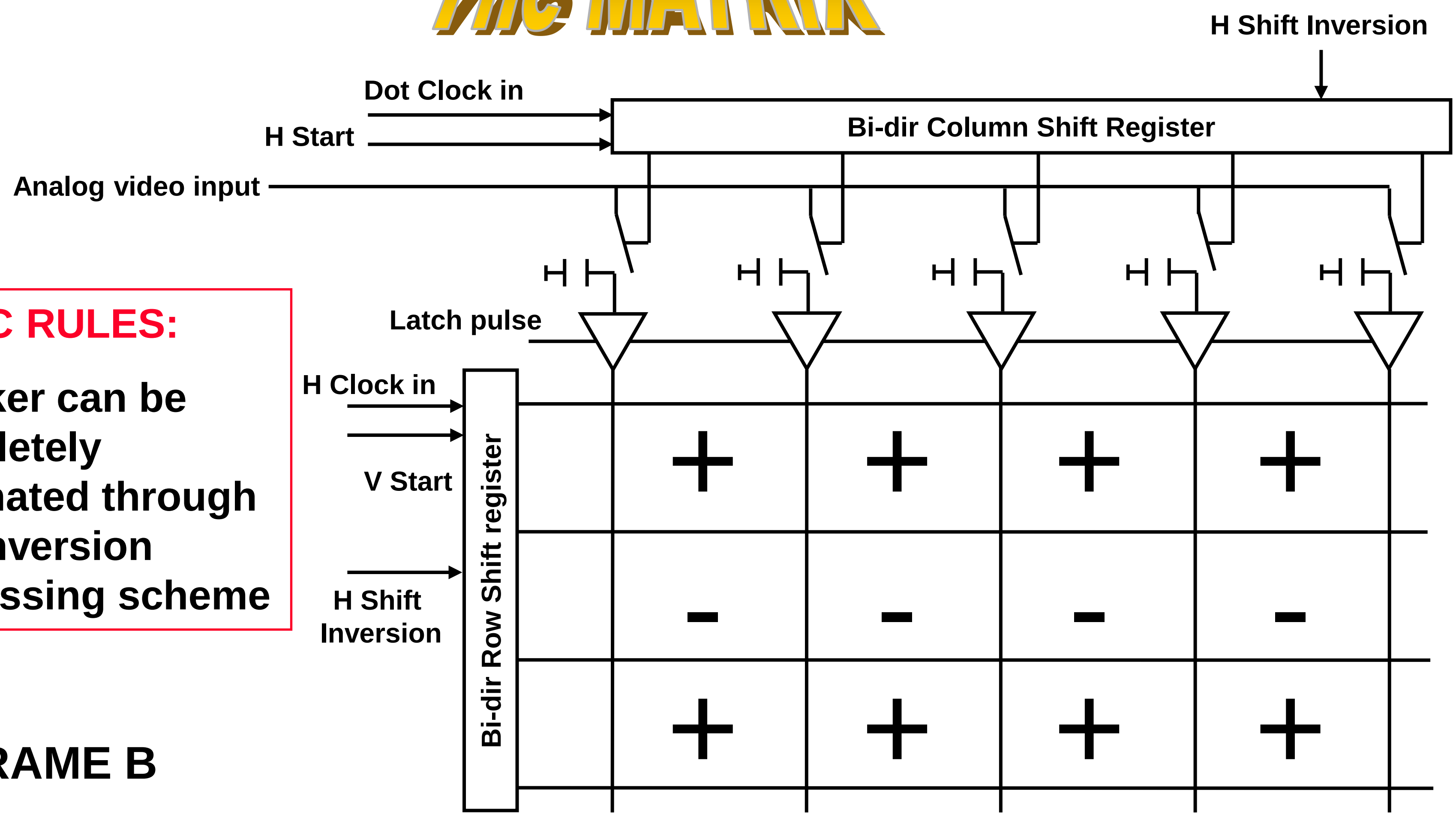
BASIC RULES:

- **Flicker can be completely eliminated through row inversion addressing scheme**

FRAME A

LCD ADDRESSING

The MATRIX



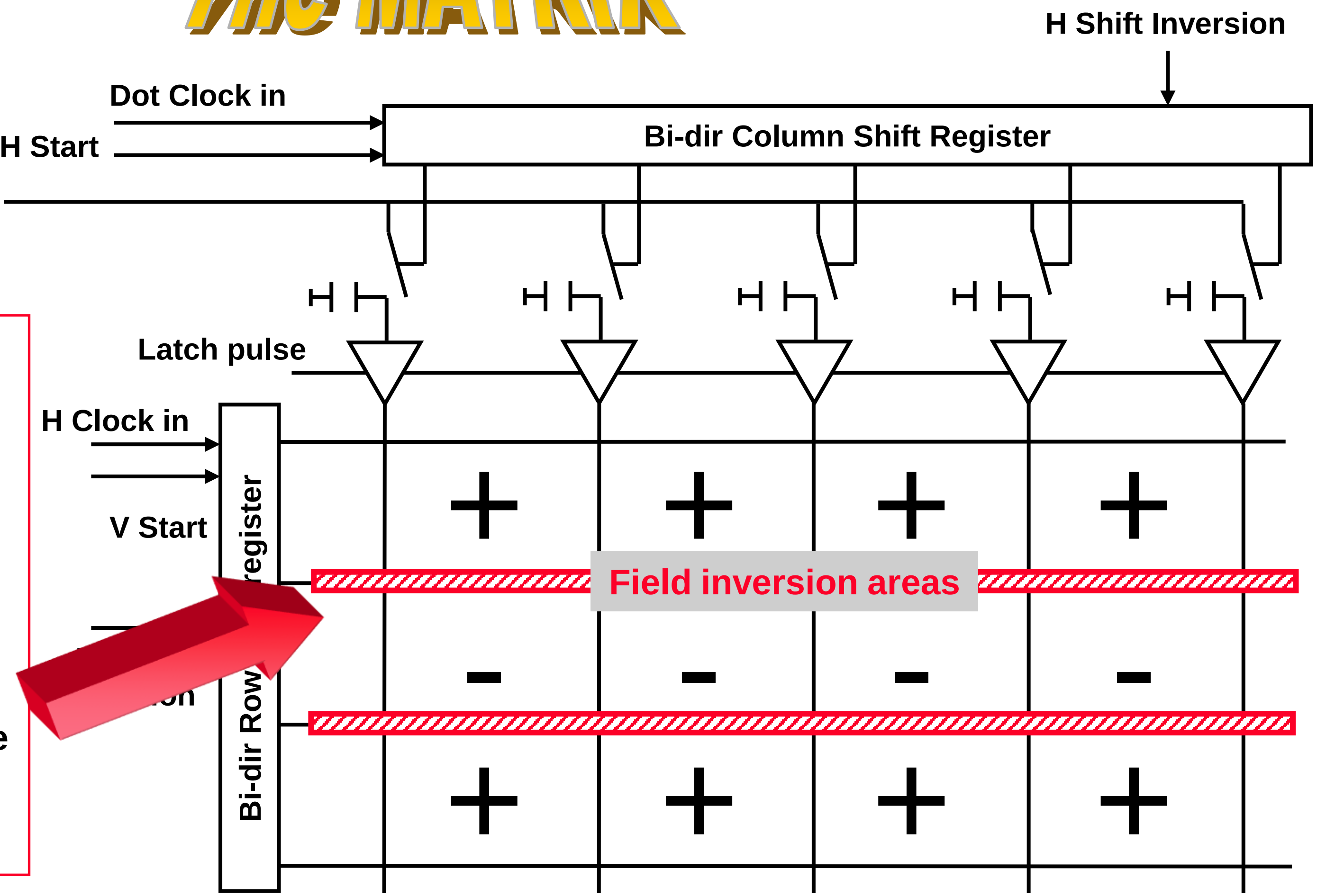
BASIC RULES:

- Flicker can be completely eliminated through row inversion addressing scheme

FRAME B

LCD ADDRESSING

The MATRIX

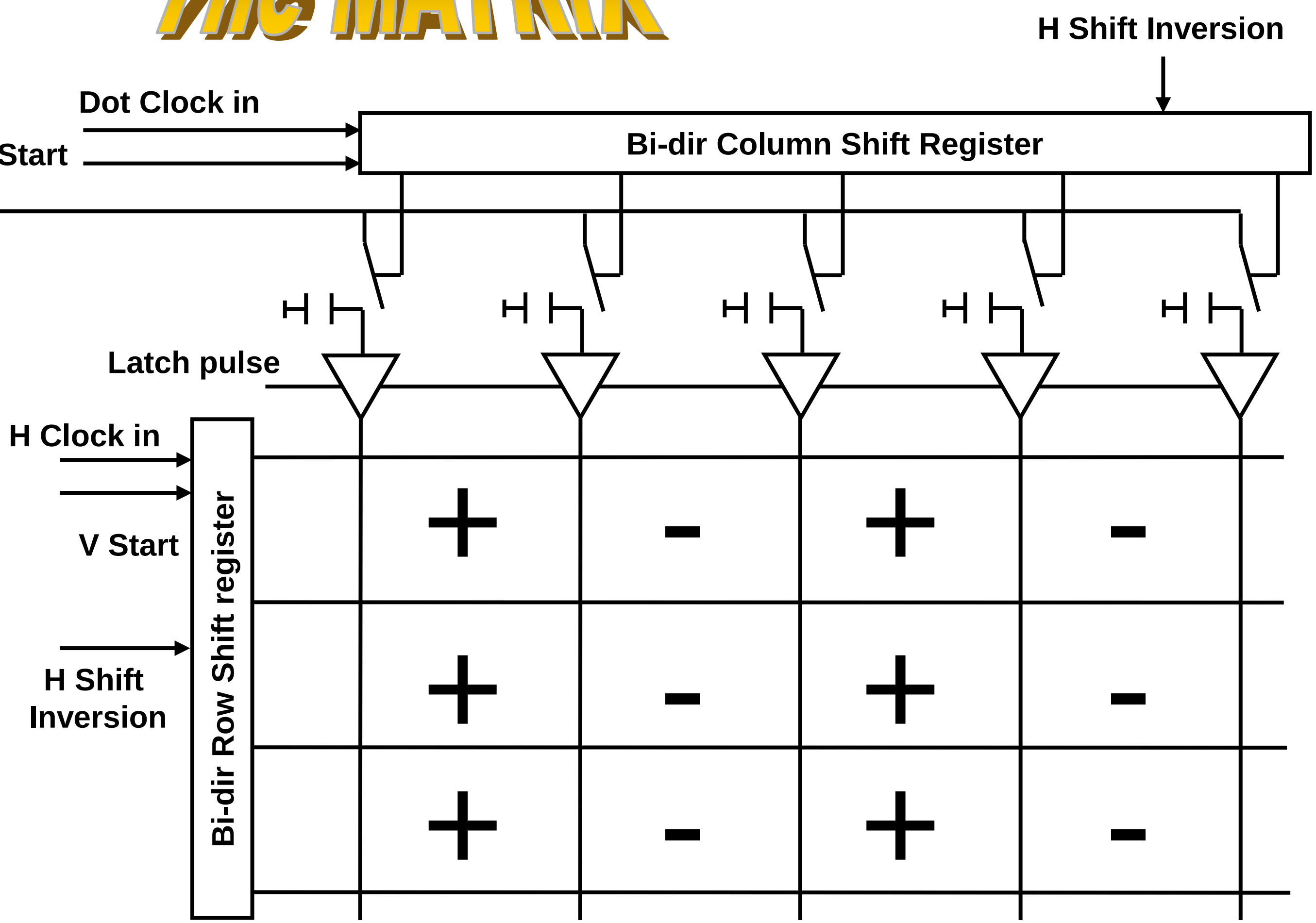


BASIC RULES:

- Row inversion system is widely applied in LCD monitors and projectors
- LCD is not properly addressed inside field inversion area.
- No electric field => white
- Necessity for Black Matrix

LCD ADDRESSING

The MATRIX



BASIC RULES:

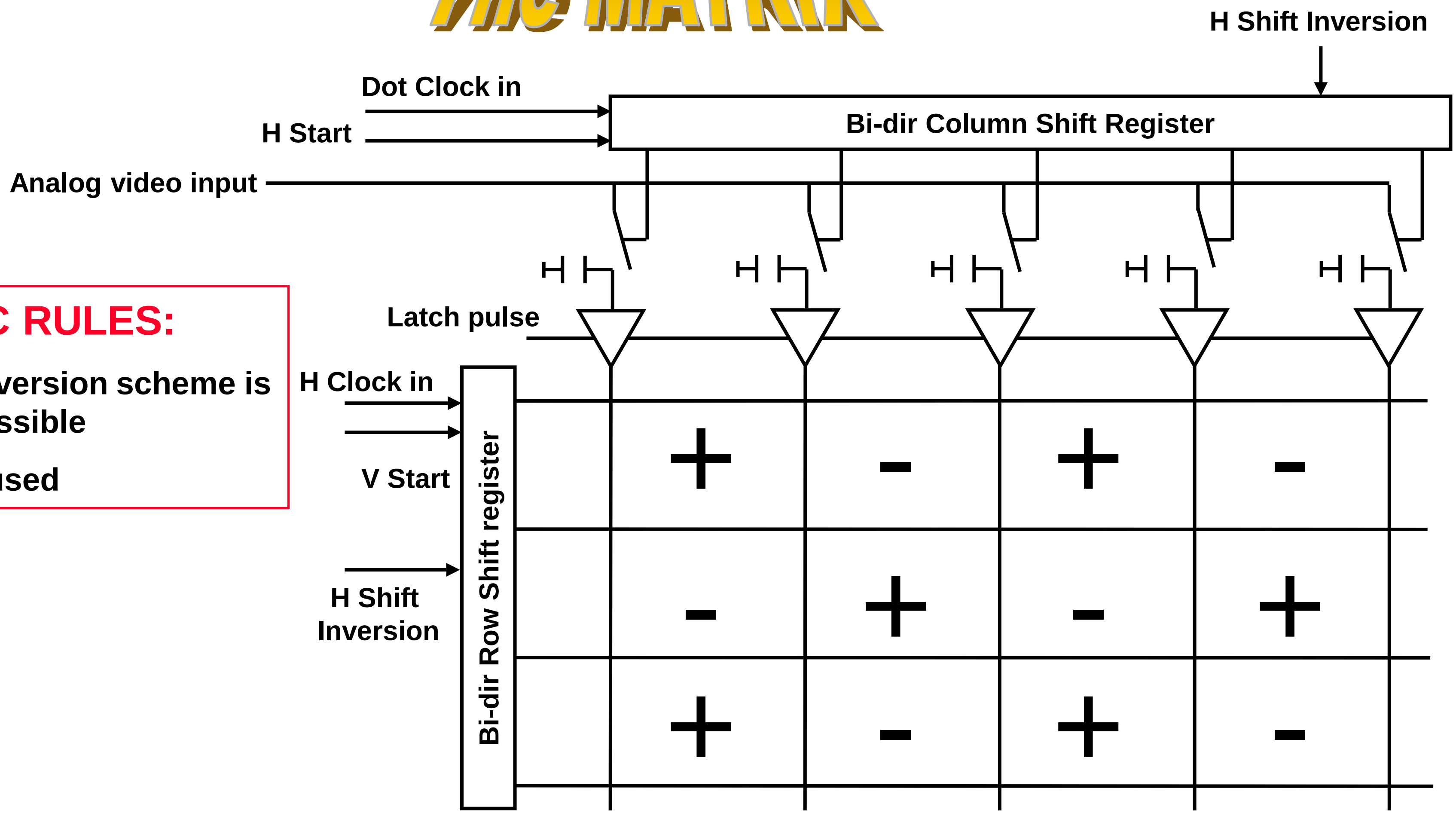
- **Column inversion scheme is also possible**
- **Less used**

LCD ADDRESSING

The MATRIX

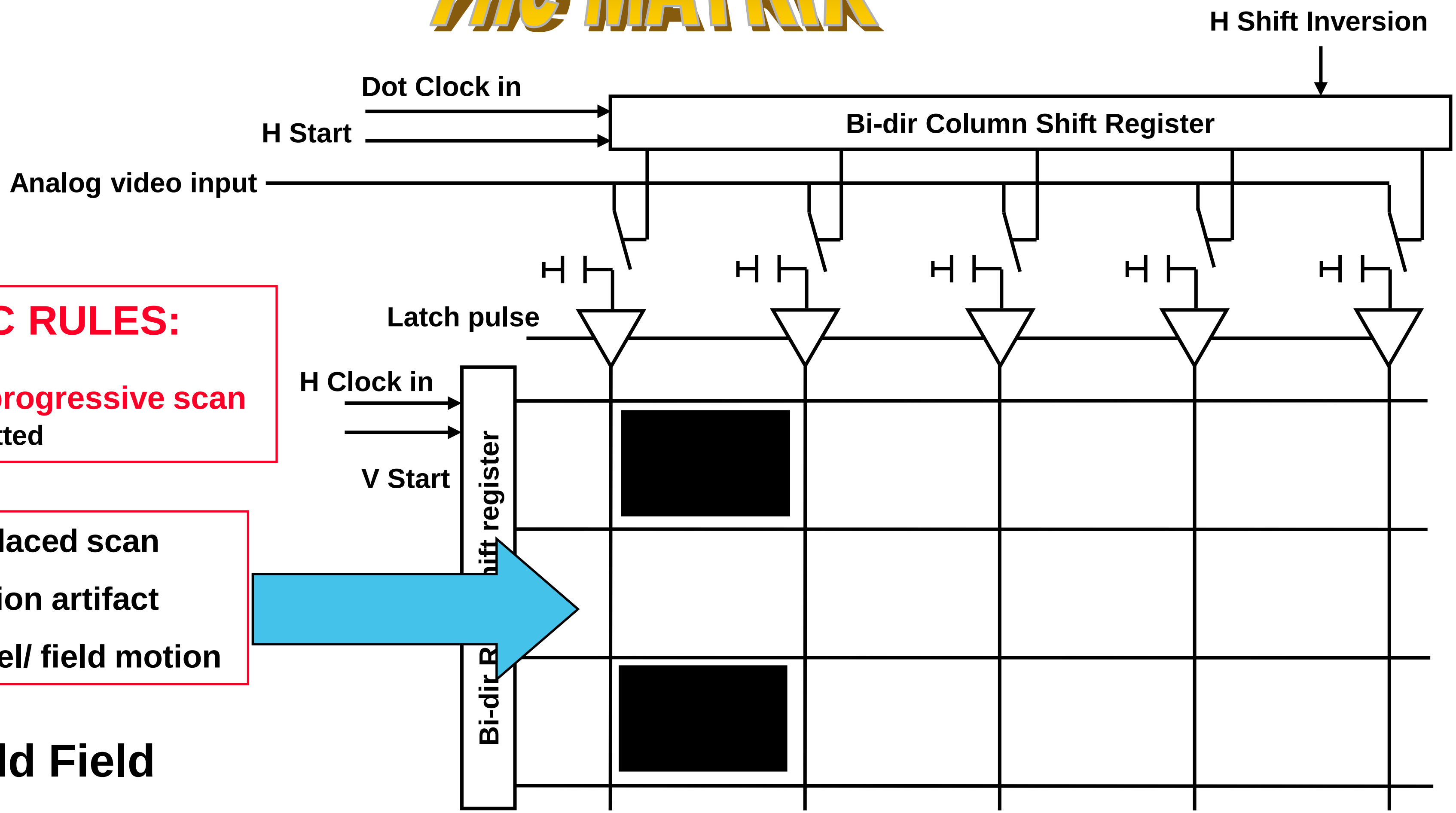
BASIC RULES:

- Dot inversion scheme is also possible
- Less used



LCD ADDRESSING

The MATRIX



BASIC RULES:

- Only **progressive scan** is permitted

Interlaced scan

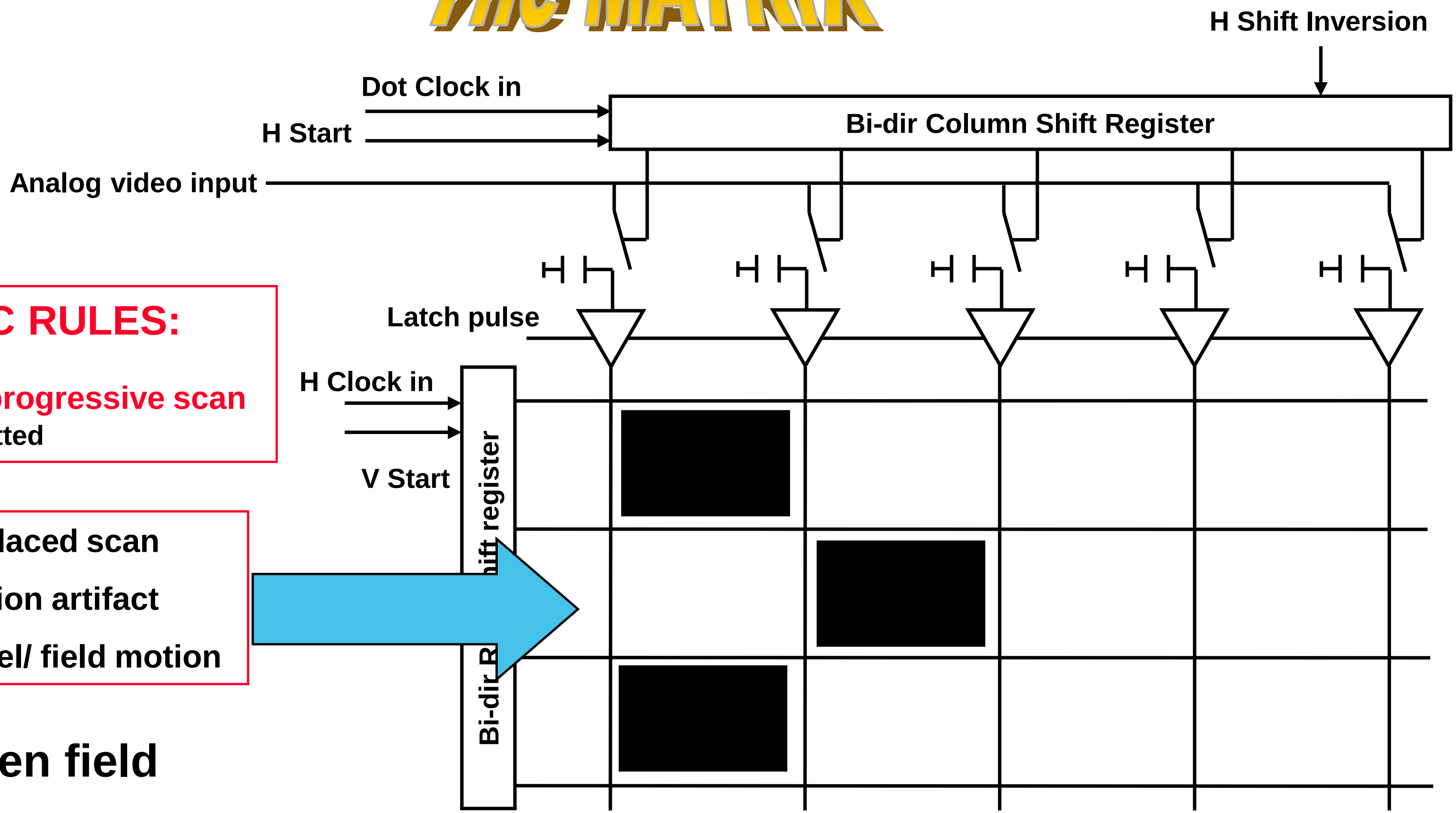
motion artifact

Ex: 1 pixel/ field motion

Odd Field

LCD ADDRESSING

The MATRIX



BASIC RULES:

- Only **progressive scan** is permitted

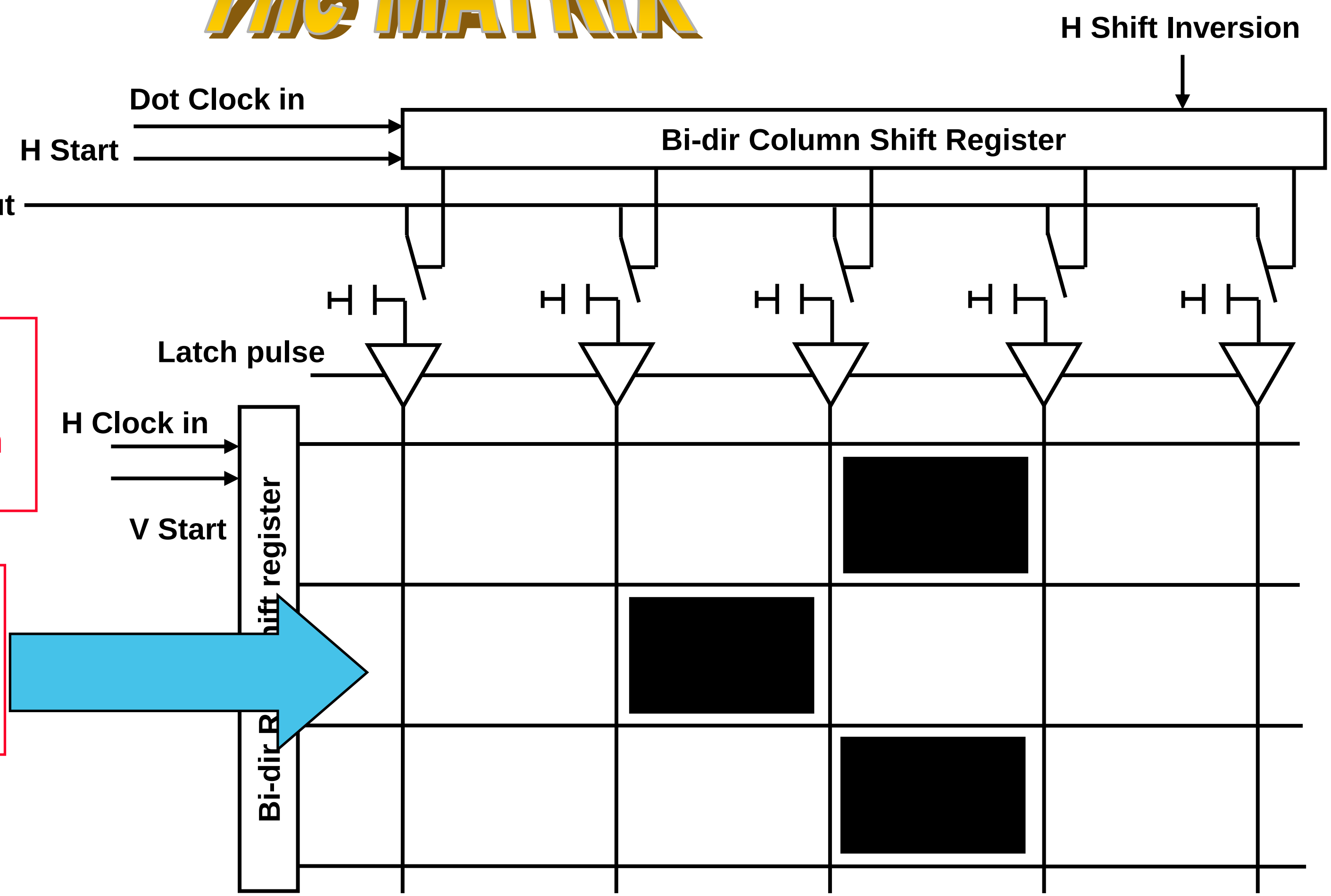
Interlaced scan motion artifact

Ex: 1 pixel/ field motion

Even field

LCD ADDRESSING

The MATRIX



BASIC RULES:

- Only **progressive scan** is permitted

Interlaced scan

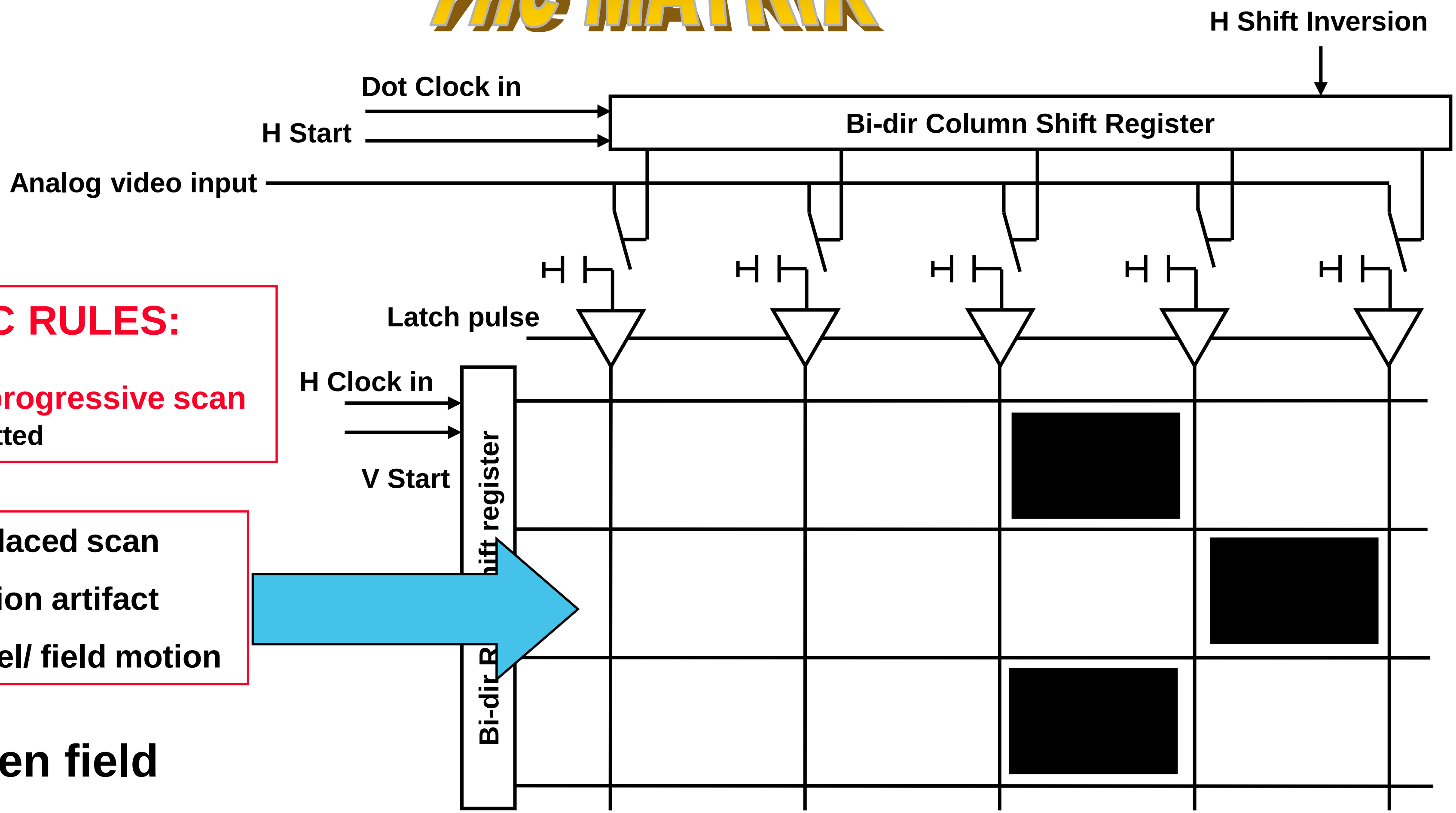
motion artifact

Ex: 1 pixel/ field motion

Odd Field

LCD ADDRESSING

The MATRIX



BASIC RULES:

- Only **progressive scan** is permitted

Interlaced scan

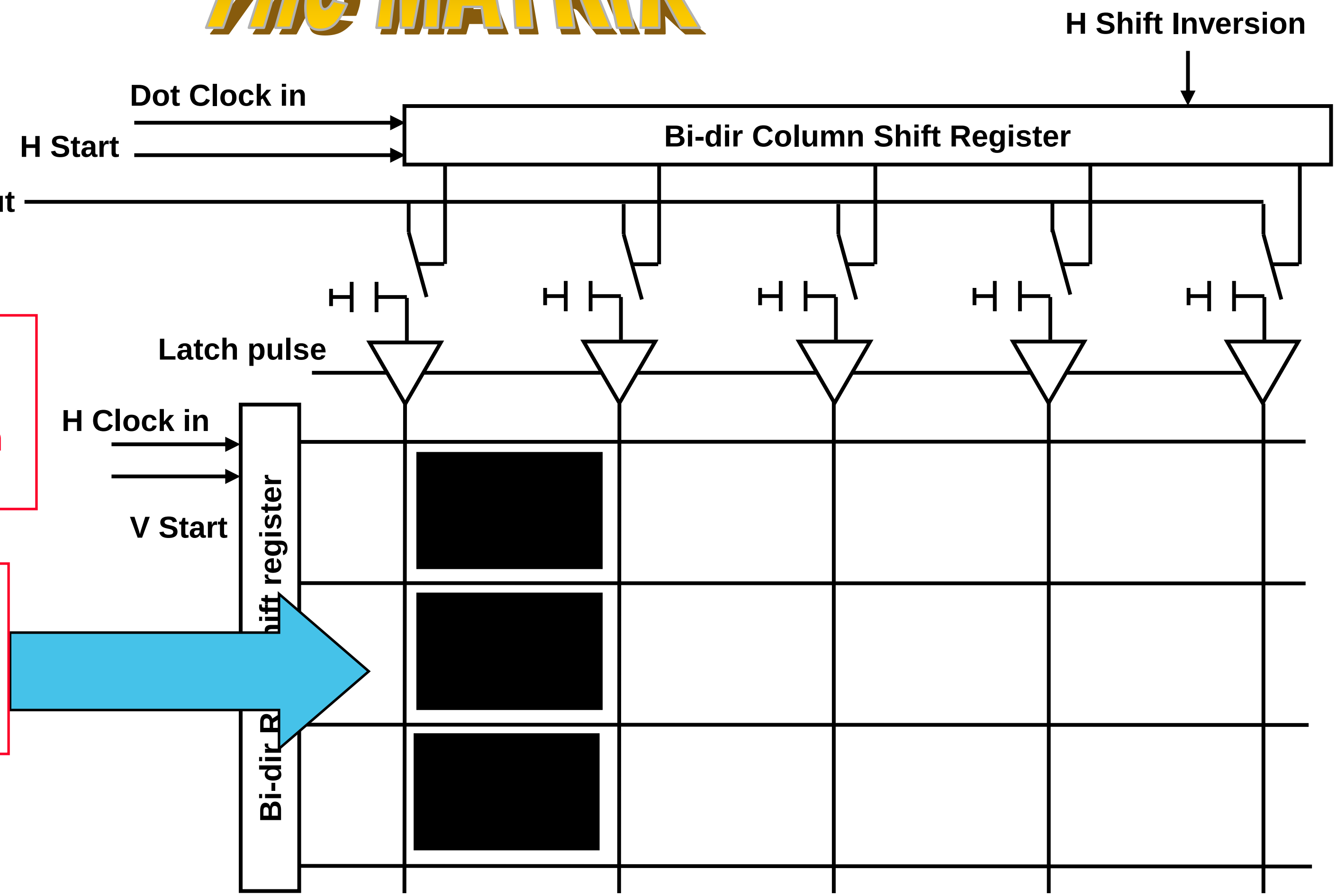
motion artifact

Ex: 1 pixel/ field motion

Even field

LCD ADDRESSING

The MATRIX



BASIC RULES:

- Only **progressive scan** is permitted

Progressive scan

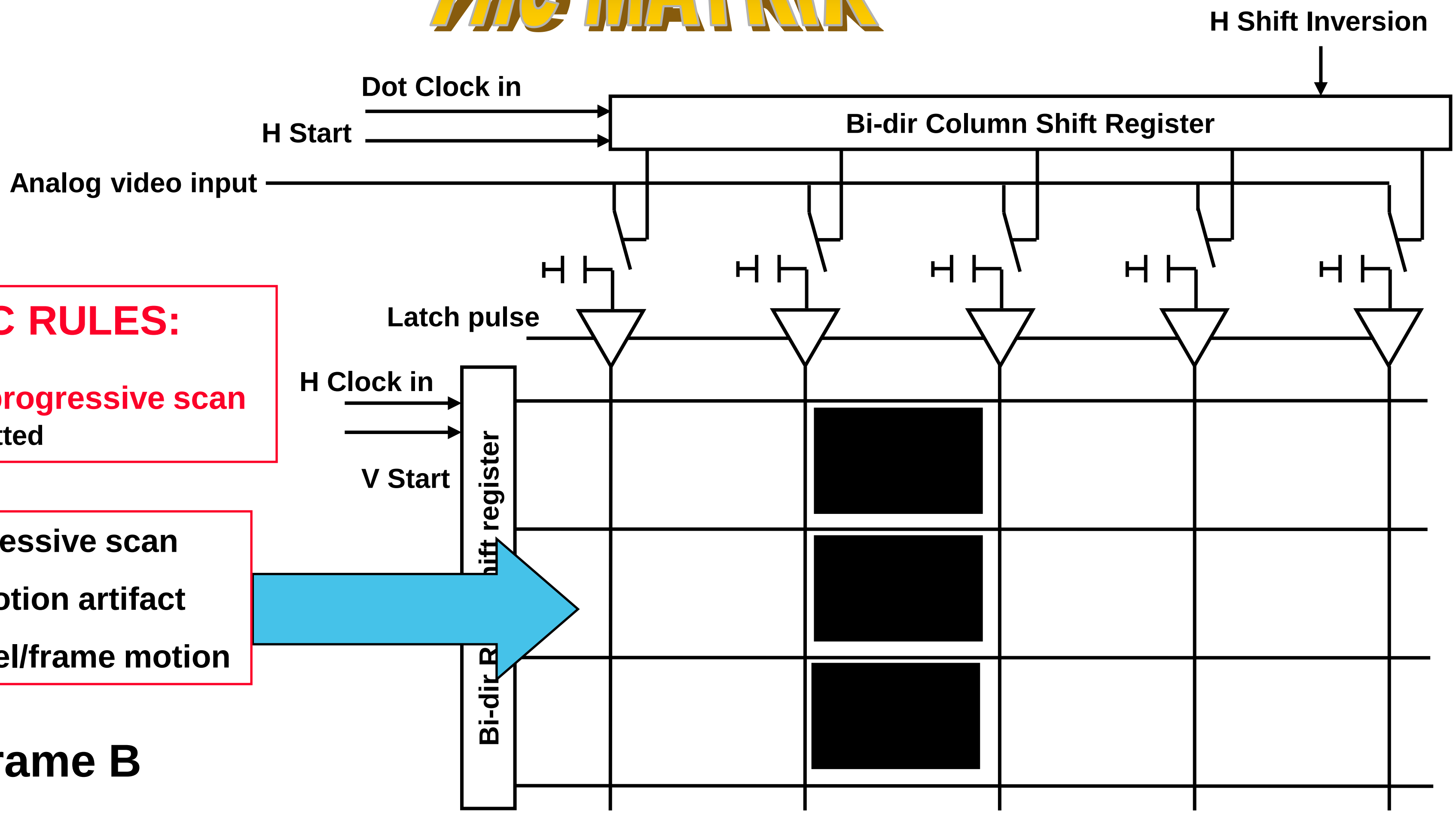
NO motion artifact

Ex: 1 pixel/frame motion

Frame A

LCD ADDRESSING

The MATRIX



BASIC RULES:

- Only **progressive scan** is permitted

Progressive scan

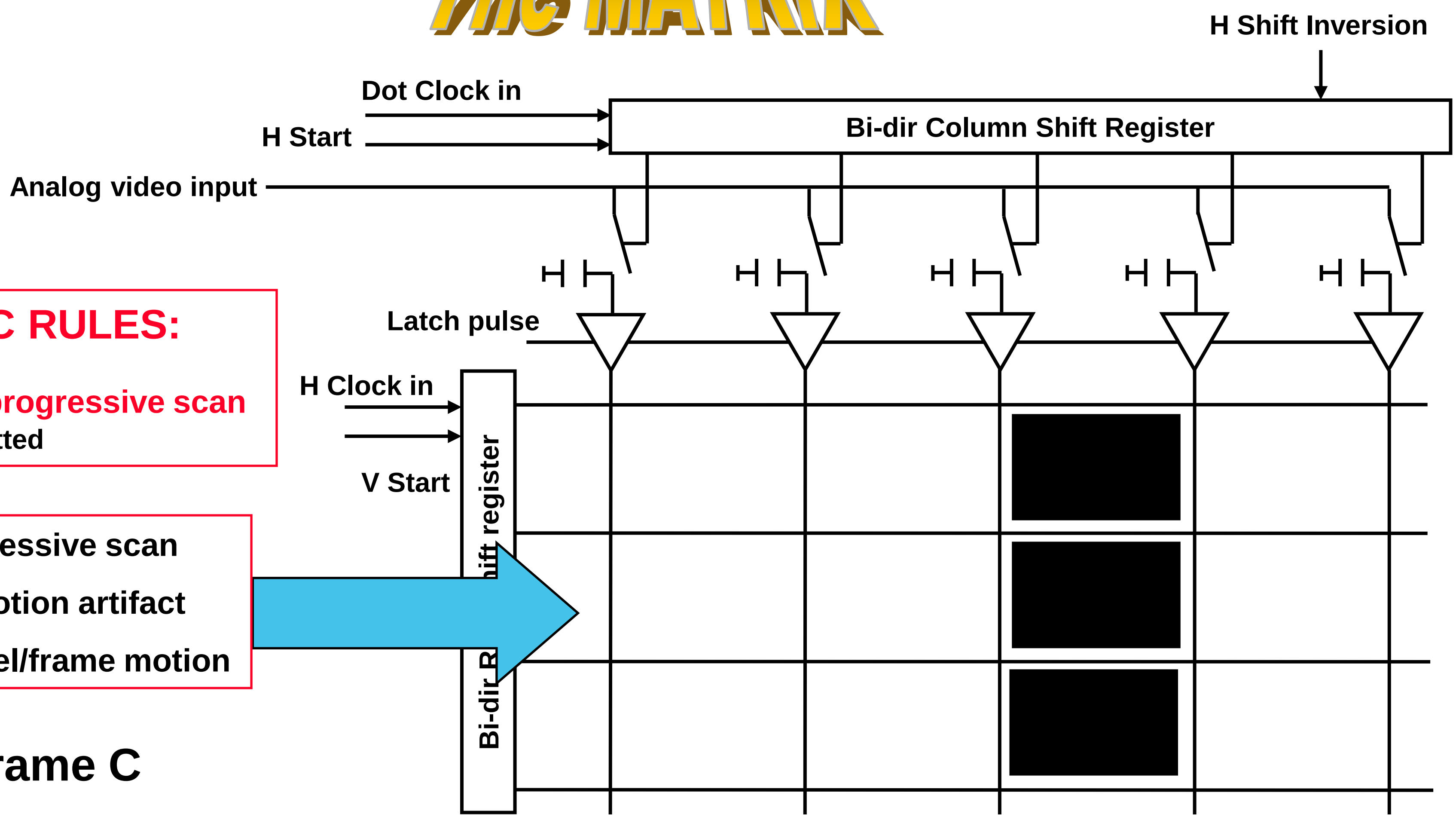
NO motion artifact

Ex: 1 pixel/frame motion

Frame B

LCD ADDRESSING

The MATRIX



BASIC RULES:

- Only **progressive scan** is permitted

Progressive scan

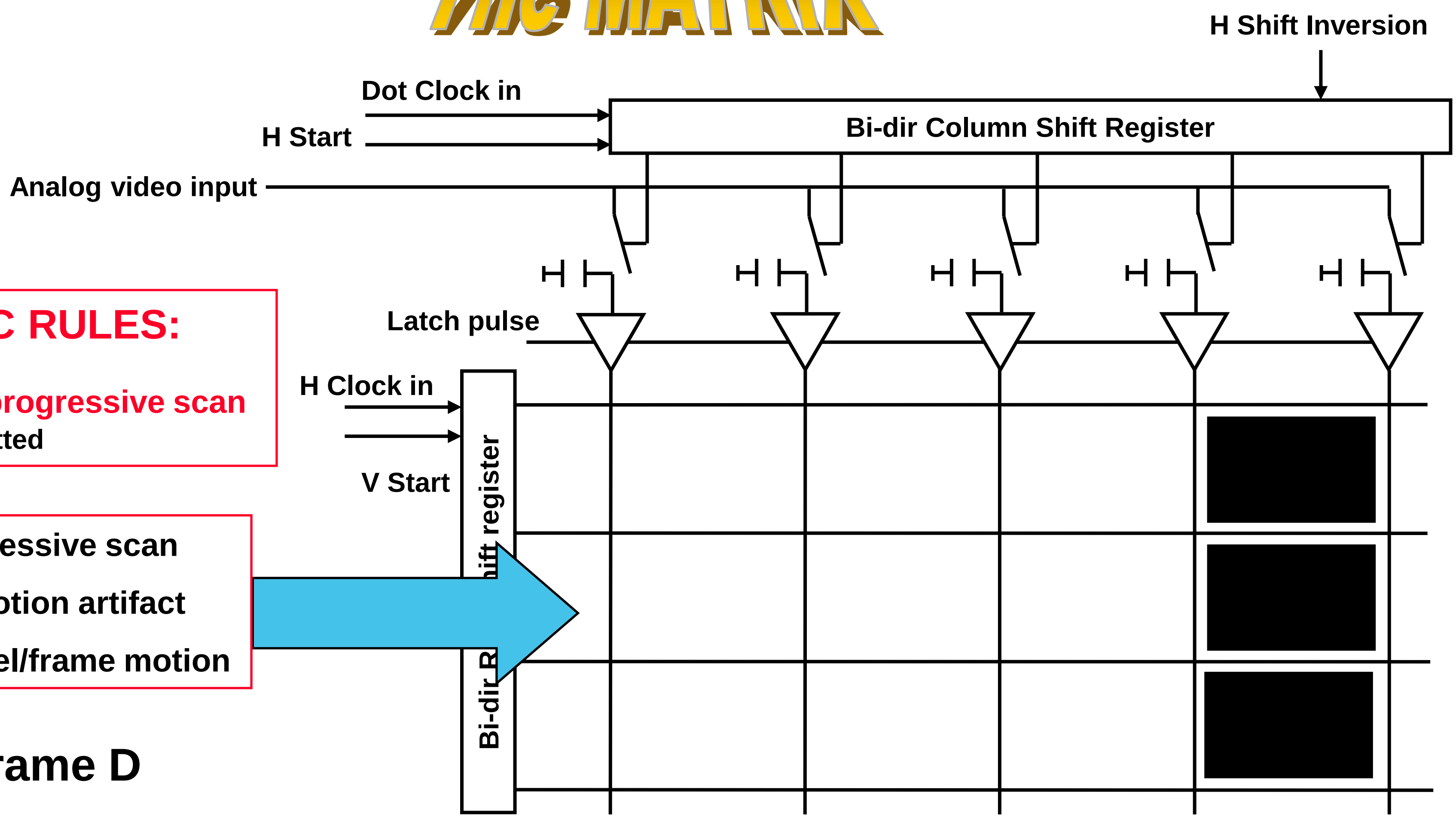
NO motion artifact

Ex: 1 pixel/frame motion

Frame C

LCD ADDRESSING

The MATRIX



BASIC RULES:

- **Only progressive scan is permitted**

Progressive scan

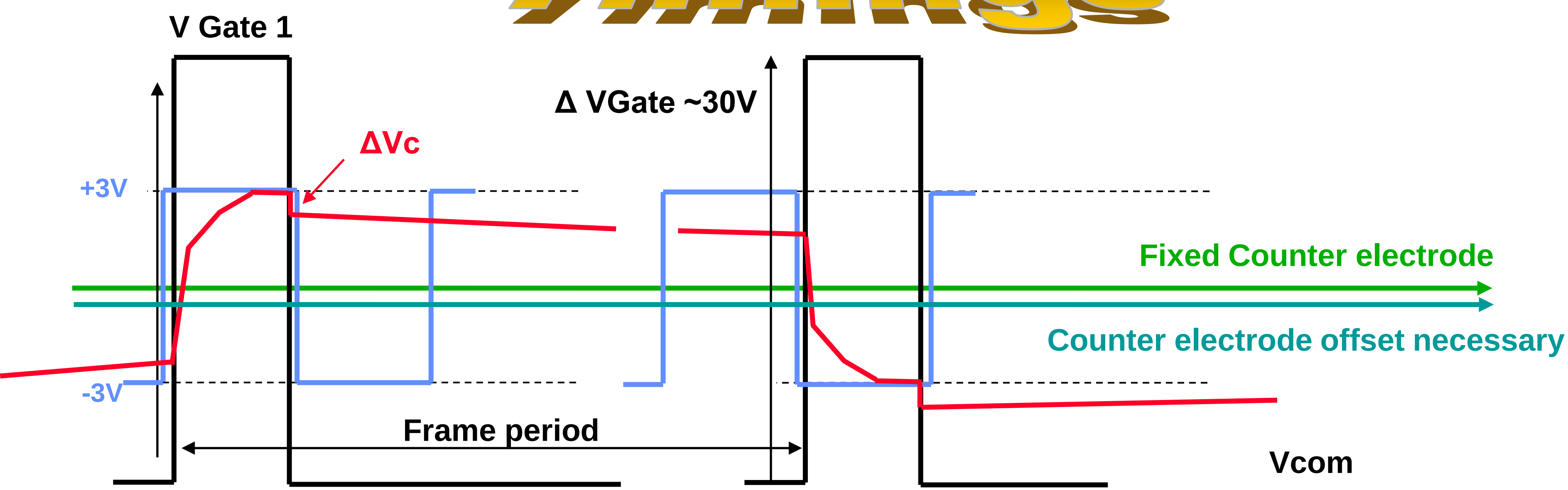
NO motion artifact

Ex: 1 pixel/frame motion

Frame D

LCD ADDRESSING

Timings

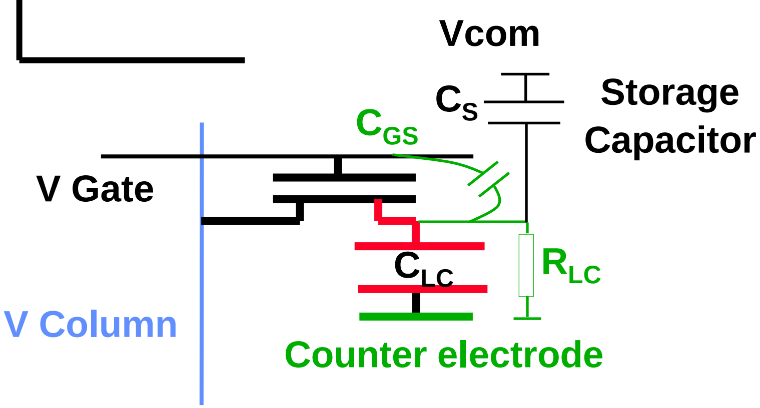


Addressing mode: row inversion

$$\Delta V_c = \Delta V_{Gate} \times \frac{C_{GS}}{C_{LC} + C_S + C_{GS}} \sim 1V$$

Voltage retention capability depends on:

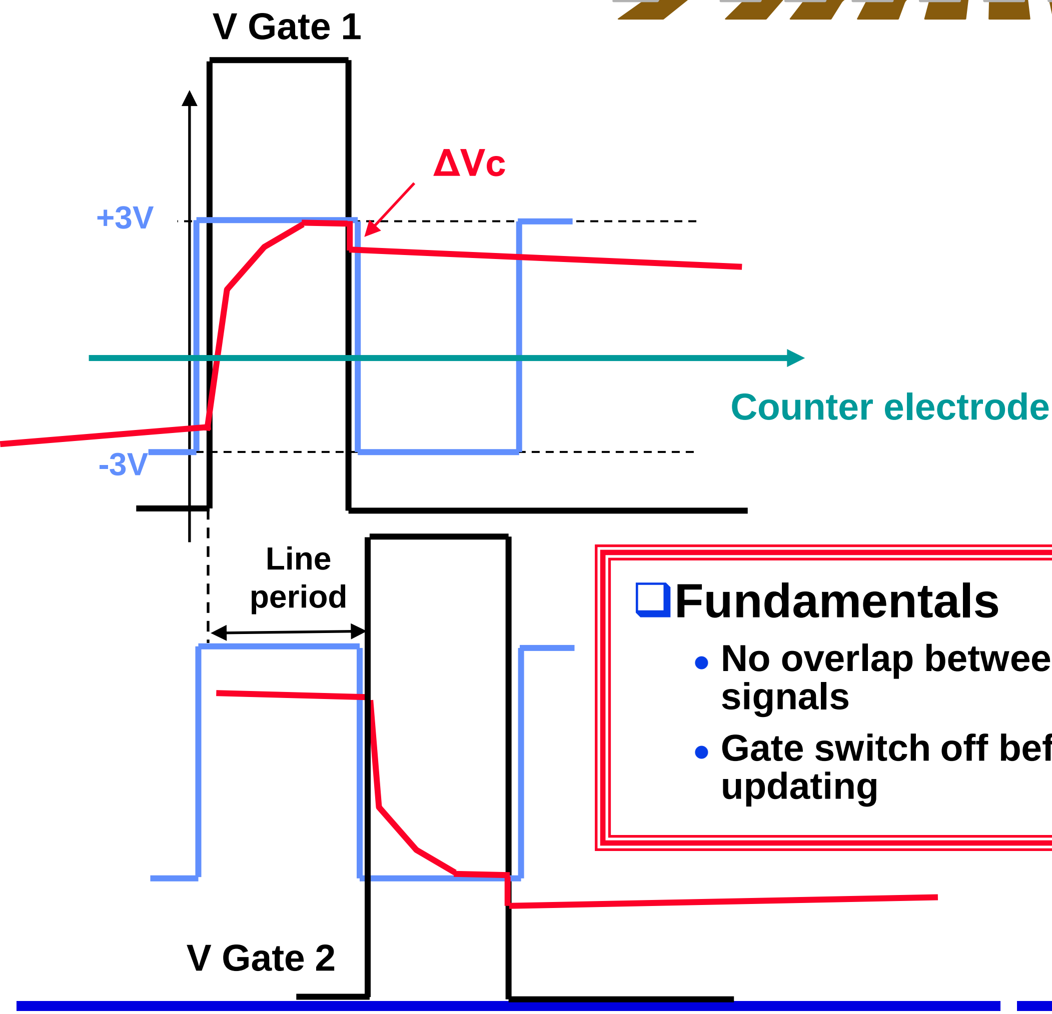
$R_{LC} \times (C_{LC} + C_S + C_{GS})$

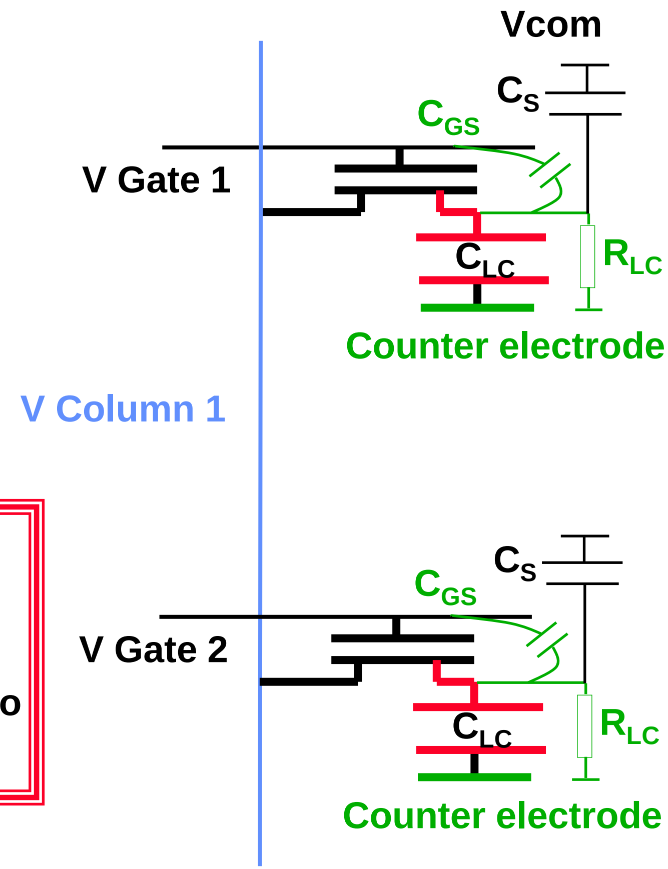


C_{LC} : is a function of the applied voltage

LCD ADDRESSING

Timings



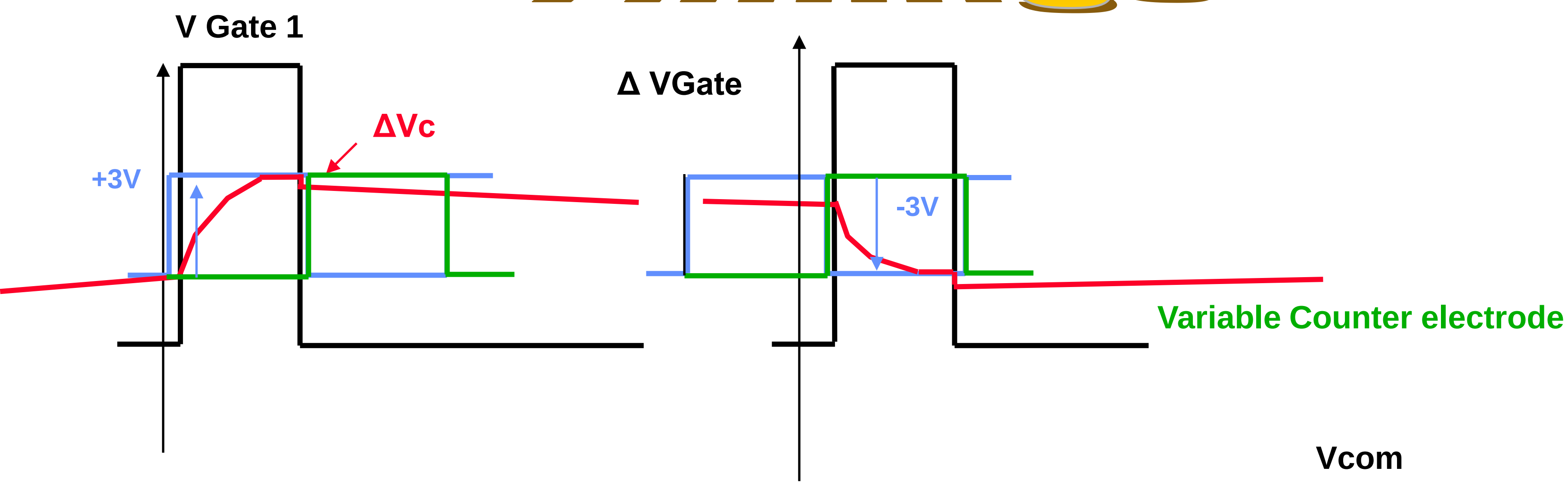


❑ Fundamentals

- No overlap between gate signals
- Gate switch off before video updating

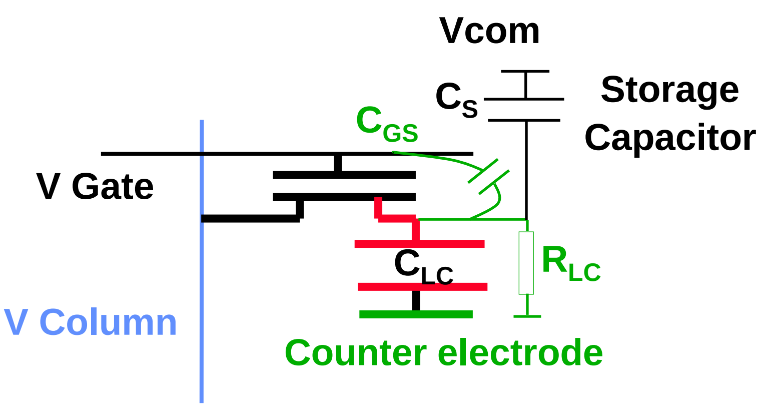
LCD ADDRESSING

Timings



Addressing mode: row inversion + var. CE

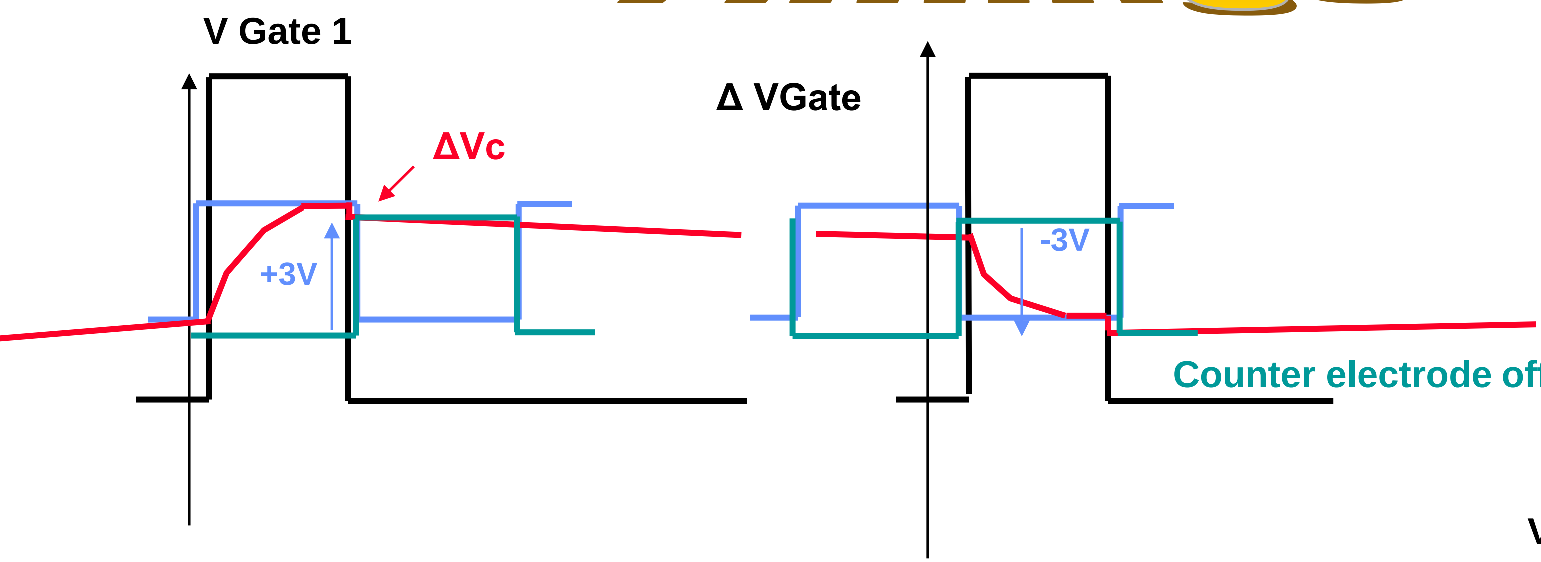
Advantages:	**Driver dynamics is divided by 2**
	Lower cost drivers
Drawbacks:	**Large CE capacity to drive**
	Difficult to get a noise free CE



C_{LC} : is a function of the applied voltage

LCD ADDRESSING

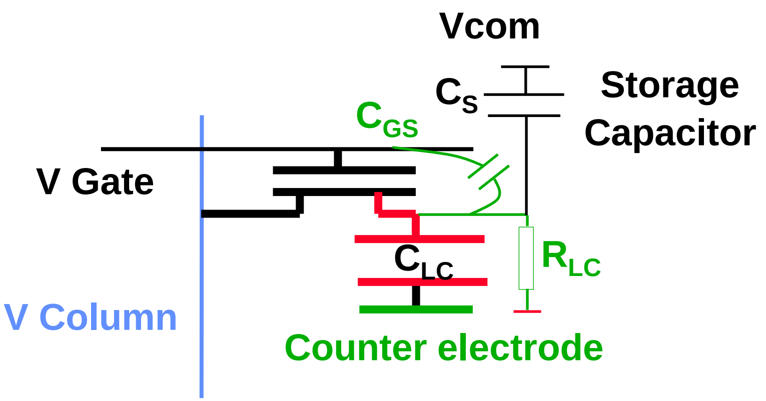
Timings



Counter electrode offset necessary

Addressing mode: row inversion + var. CE

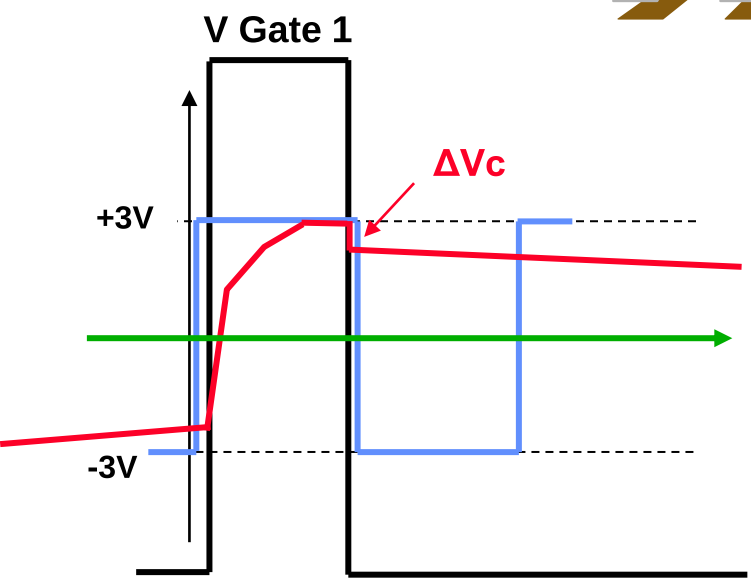
Advantages:	**Driver dynamics is divided by 2**
	Faster and Lower cost drivers
Drawbacks:	**Large CE capacity to drive**
	Difficult to get a noise free CE

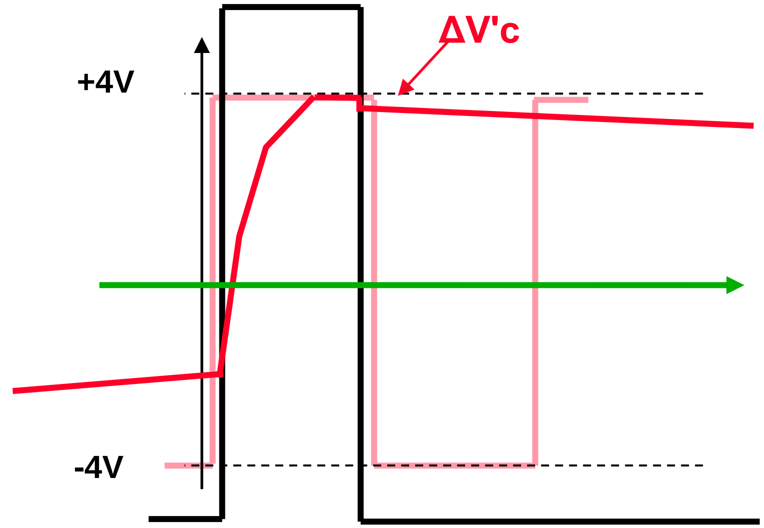


C_{LC} : is a function of the applied voltage

LCD ADDRESSING

Timings





$$\Delta V_c = \Delta V_{Gate} \times \frac{C_{GS}}{C_{LC} + C_S + C_{GS}} \sim 1V$$

C_{LC} ↗ when applied voltage ↗

ΔV_c ↘ when applied voltage ↗

❑ **Consequences:**

- **The counter-electrode cannot be perfectly adjusted for all gray levels. DC level risk.**
- **To decrease the risk, the storage capacitor has to be as high as possible**

PRINCIPLE TRAINING

- Introduction
- General training
  - LCD pixel structure
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    - Electrical effect
  - LCD panel structure
  - Active matrix displays
    - Structure
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  - General electronics block diagram
    - LCD drivers
    - LCD controller
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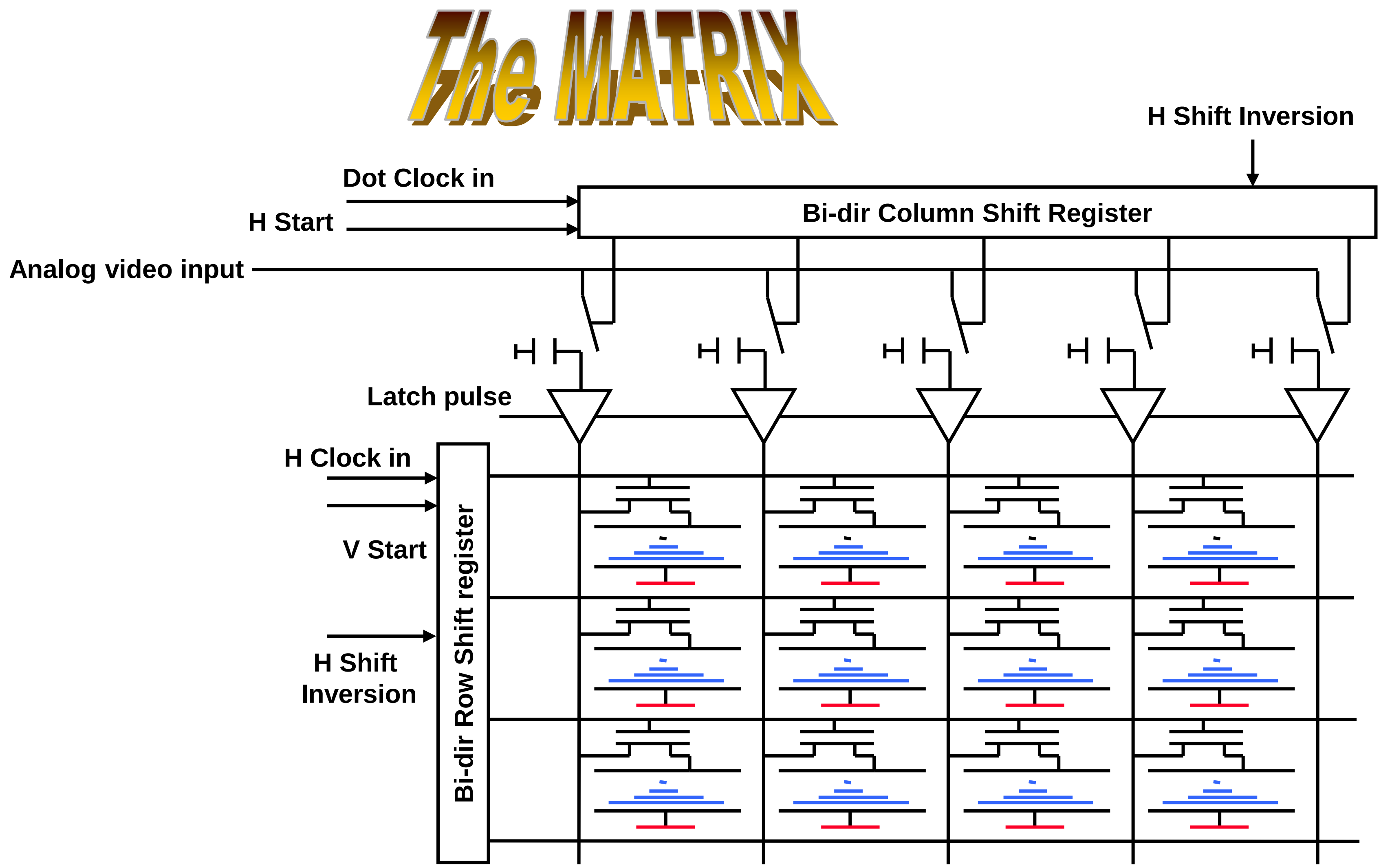
  - Back lighting
  - Characterization principles
    - Main optical parameters to look at
    - Measurement methods and tools

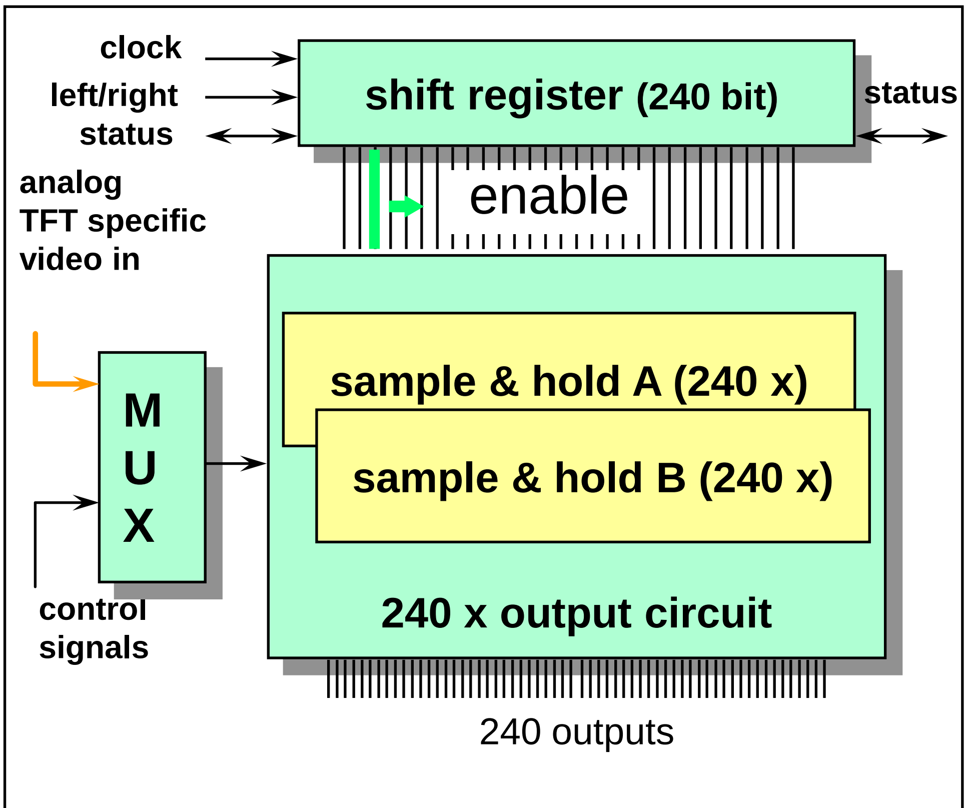
General Electronics



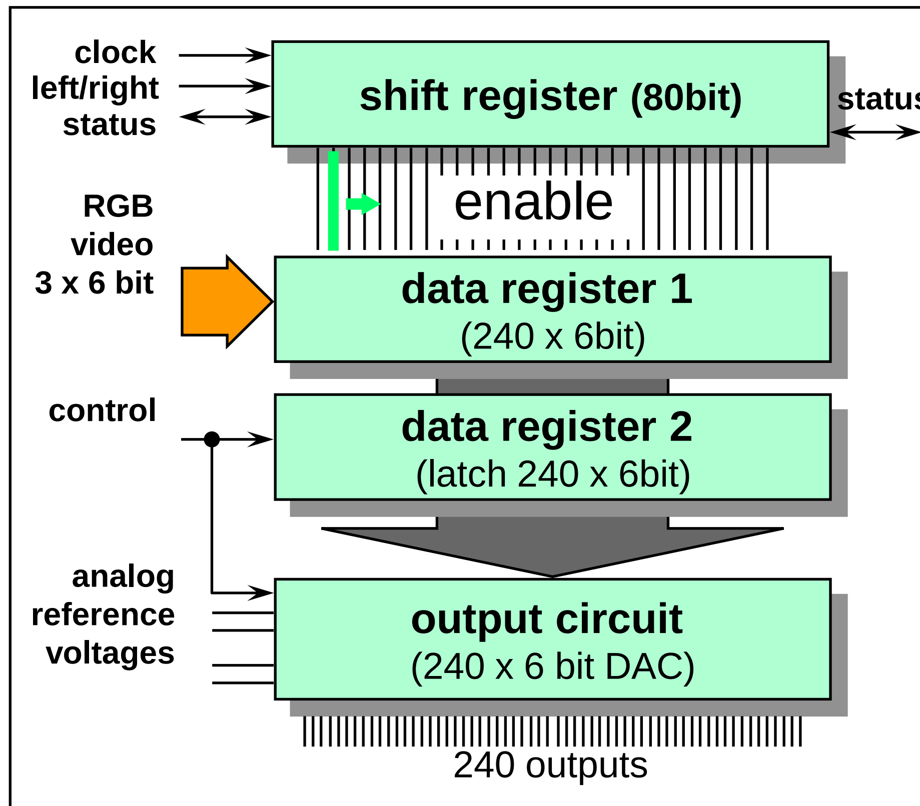
General Electronics

The Drivers

Analog Column Driver IC



Digital Column Driver IC

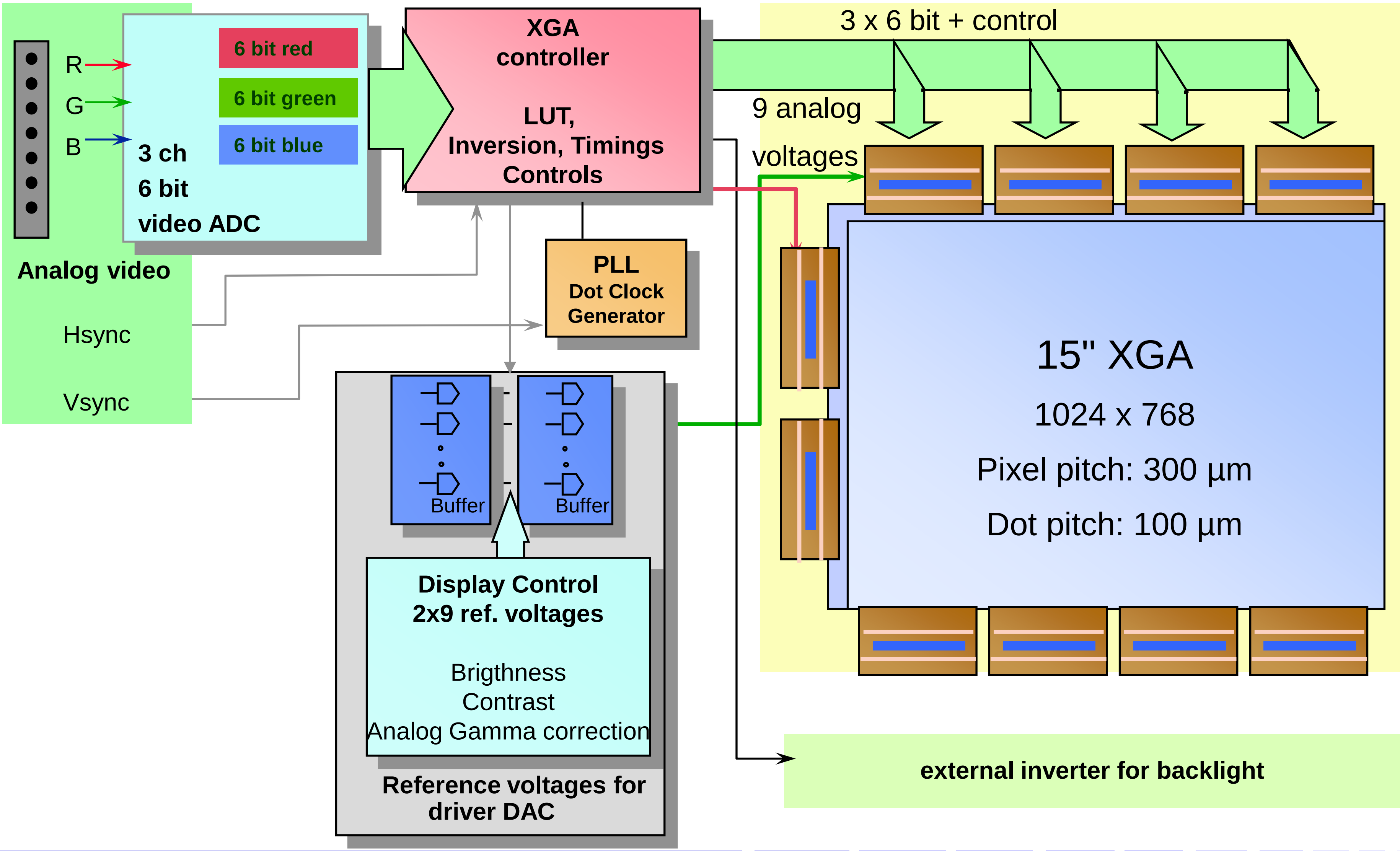


General Electronics

The Drivers

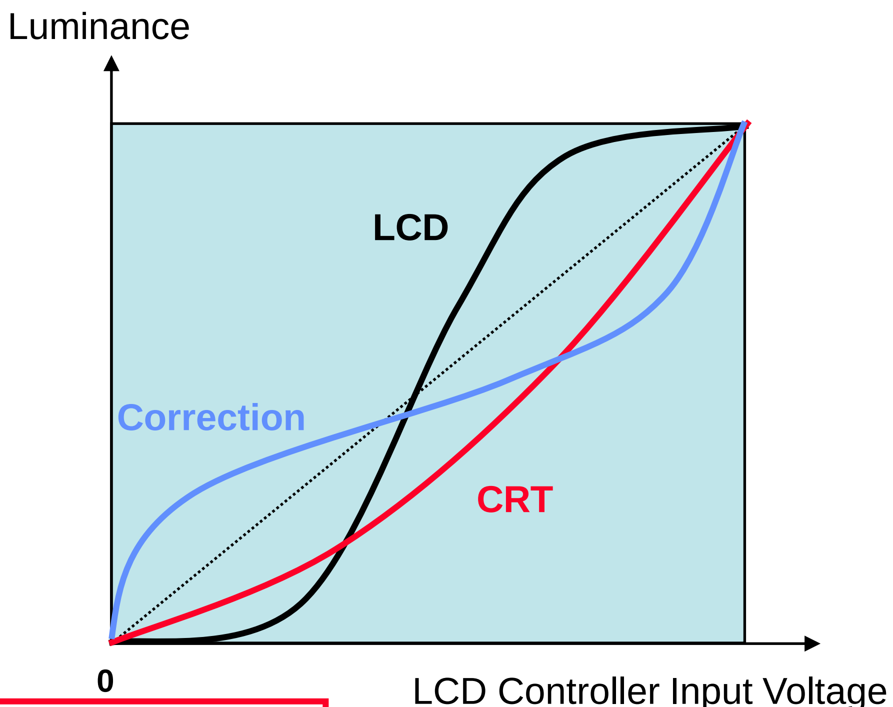
- Gamma correction can be set up by polarizing external ref. Voltages
  - Non linear DAC conversion
  - 8 bit driver => 256 real optical gray levels
  - Sufficient for most PC applications
  - Adequate for large screen TV video
  - Frequently use more than 8 bit and use some data for adjustment with a effective useable dynamic range of 256 gray scale levels

LCD Controller (6 bit gray scale) for PC



LCD ADDRESSING

Gamma



- **The LCD electro-optical response is different from a CRT curve.**
- **It is then necessary to introduce an electronic correction to accurately display gray shades**
- **This can be done in an analog, digital or mixed way**

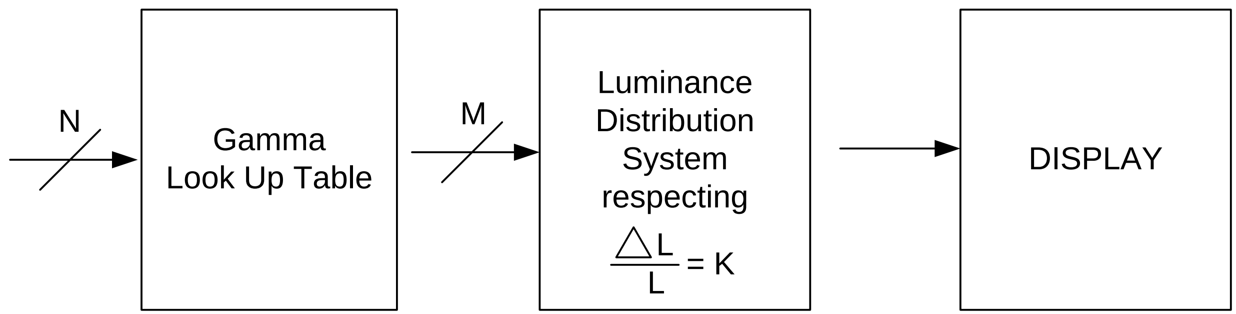
❑Question: What is the best way to do Gamma correction?

- **Analog**
- **Digital**
- **Mixed**

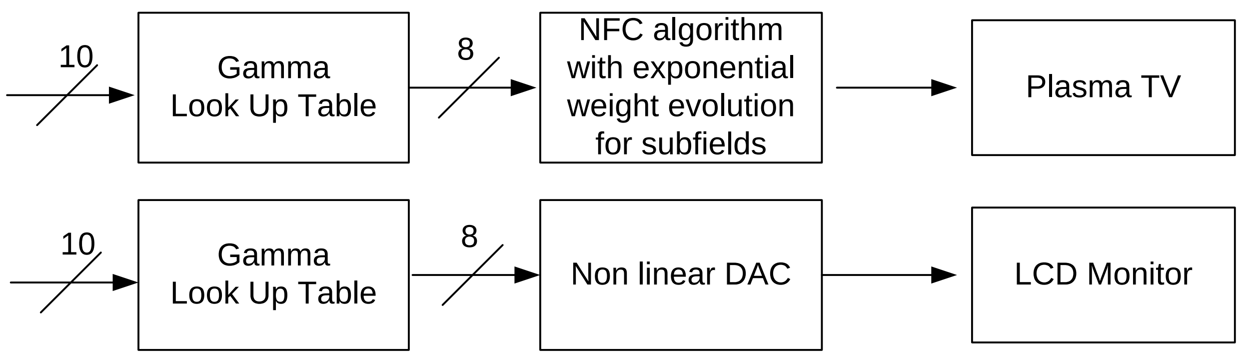
LCD ADDRESSING

Gamma

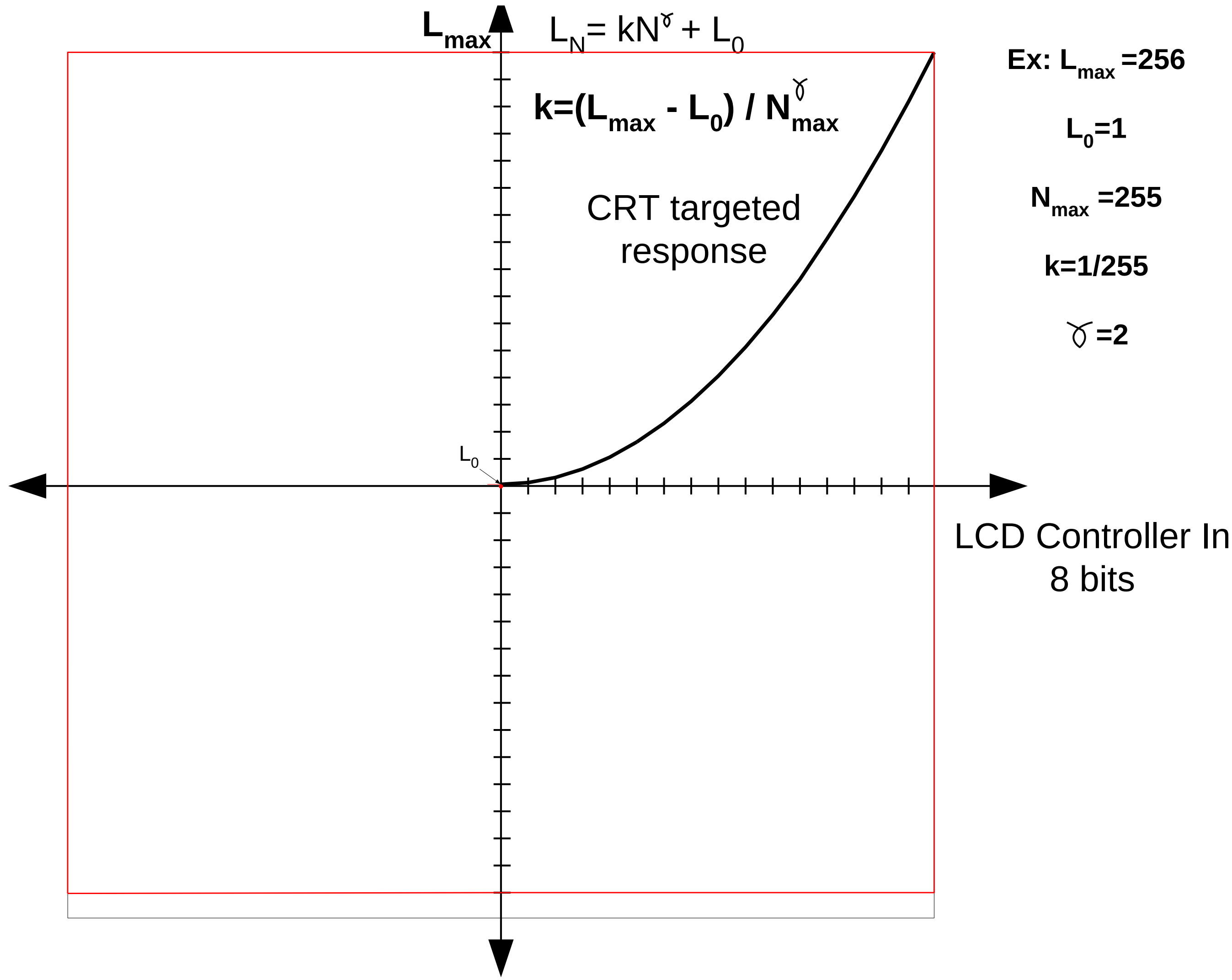
SMART POSITIONING OF LIMITED GREY LEVELS ON A NON CRT DISPLAY



EXAMPLES



GAMMA Processing Diagram



Ex: $L_{max}=256$

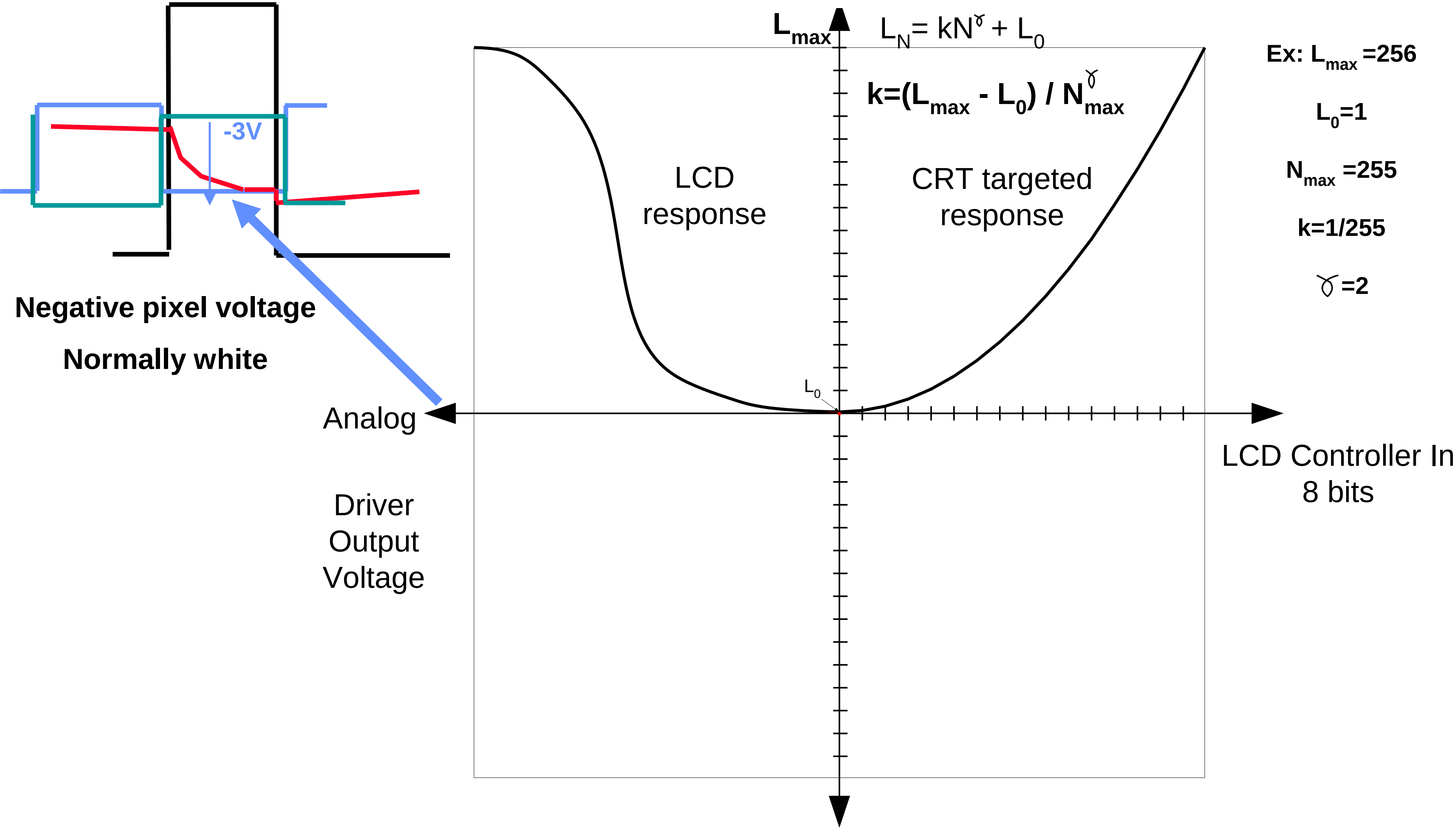
$L_0=1$

$N_{max}=255$

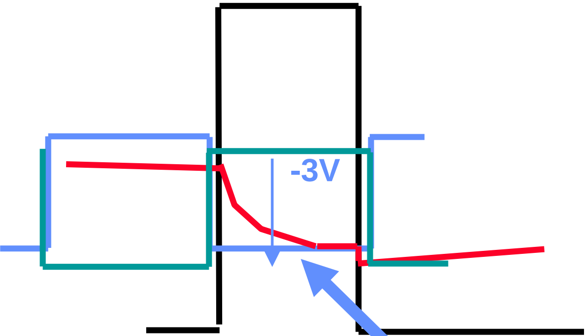
$k=1/255$

$\gamma=2$

GAMMA Processing Diagram

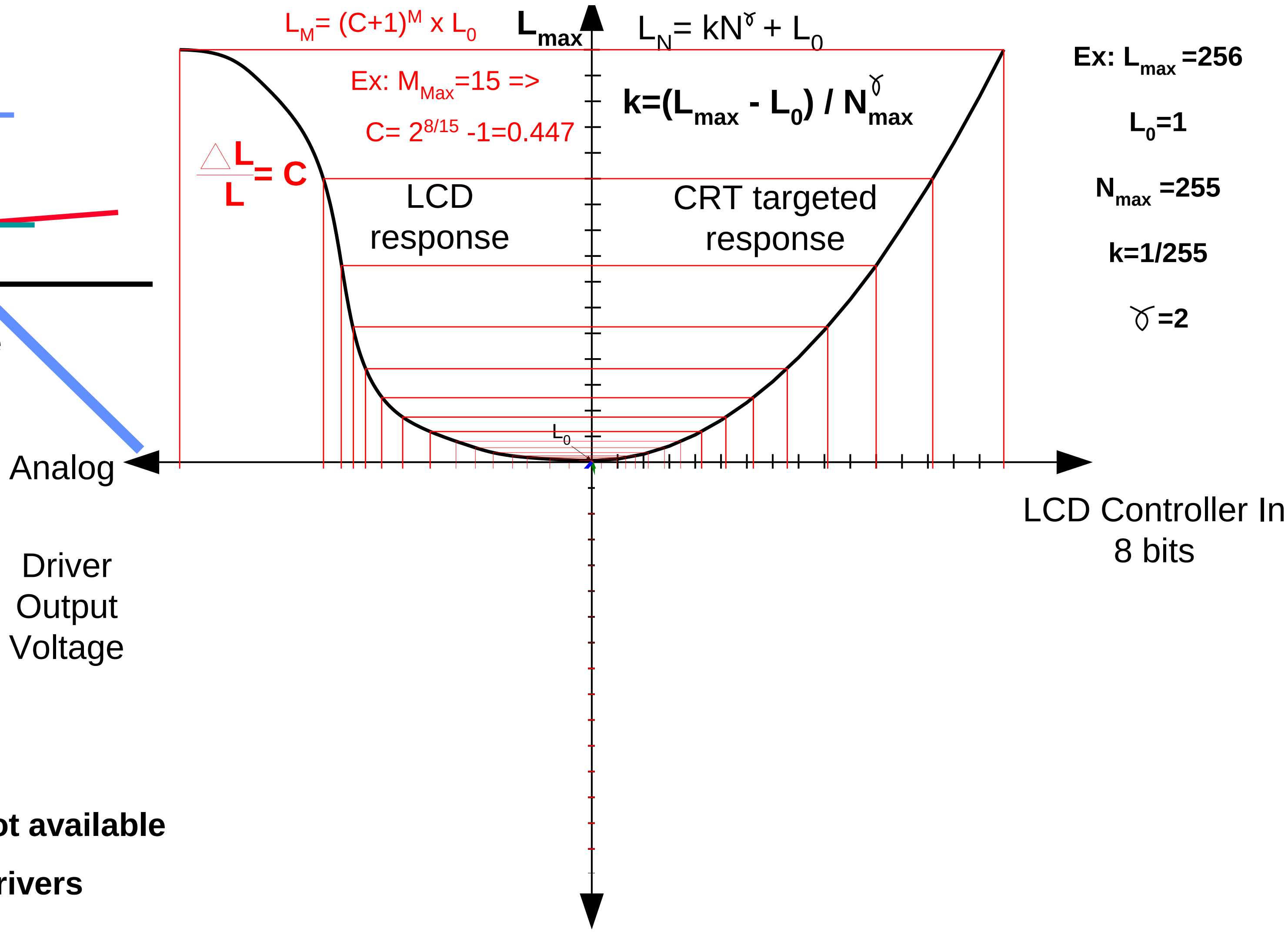


GAMMA Processing Diagram



Negative pixel voltage

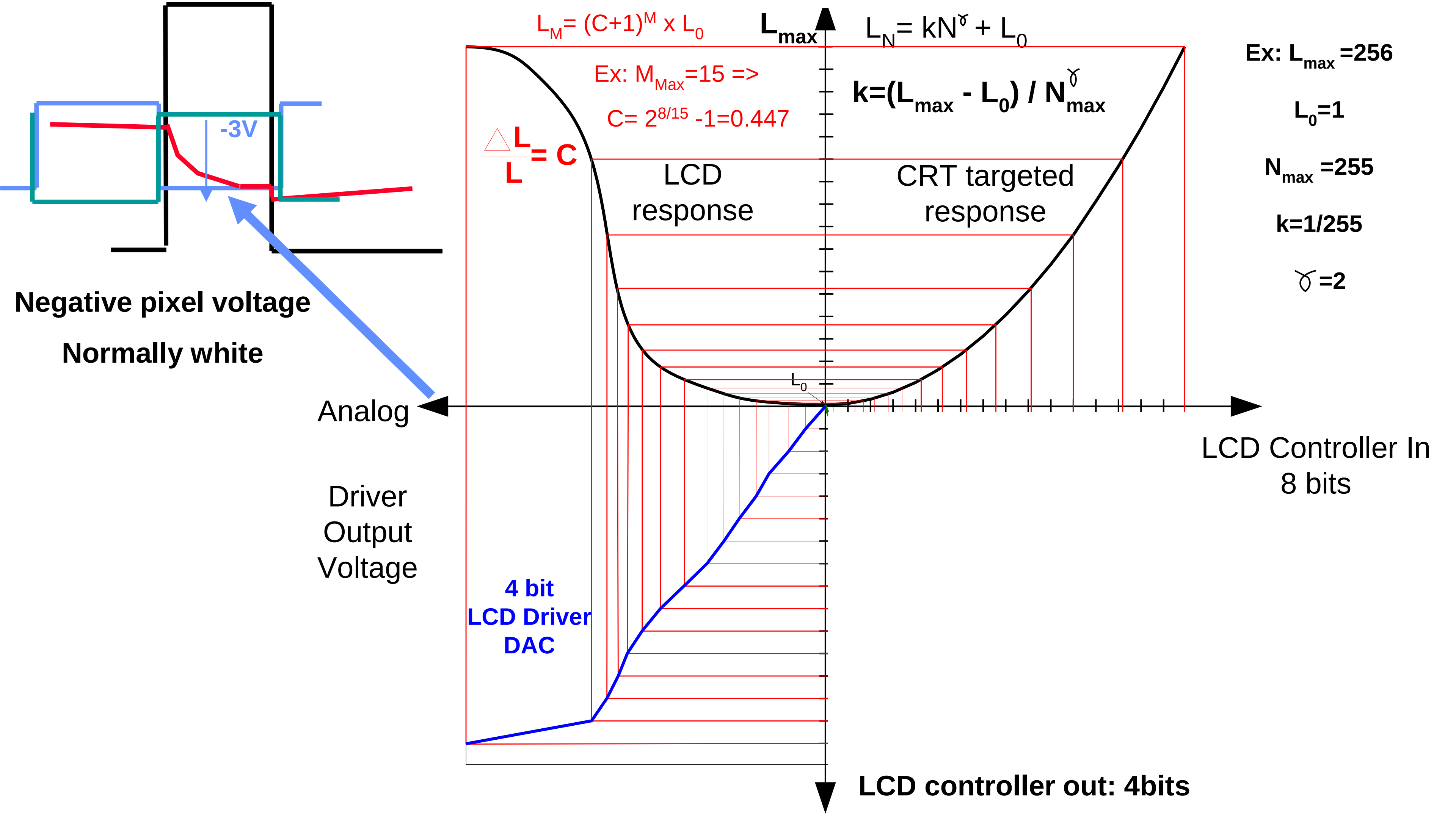
Normally white



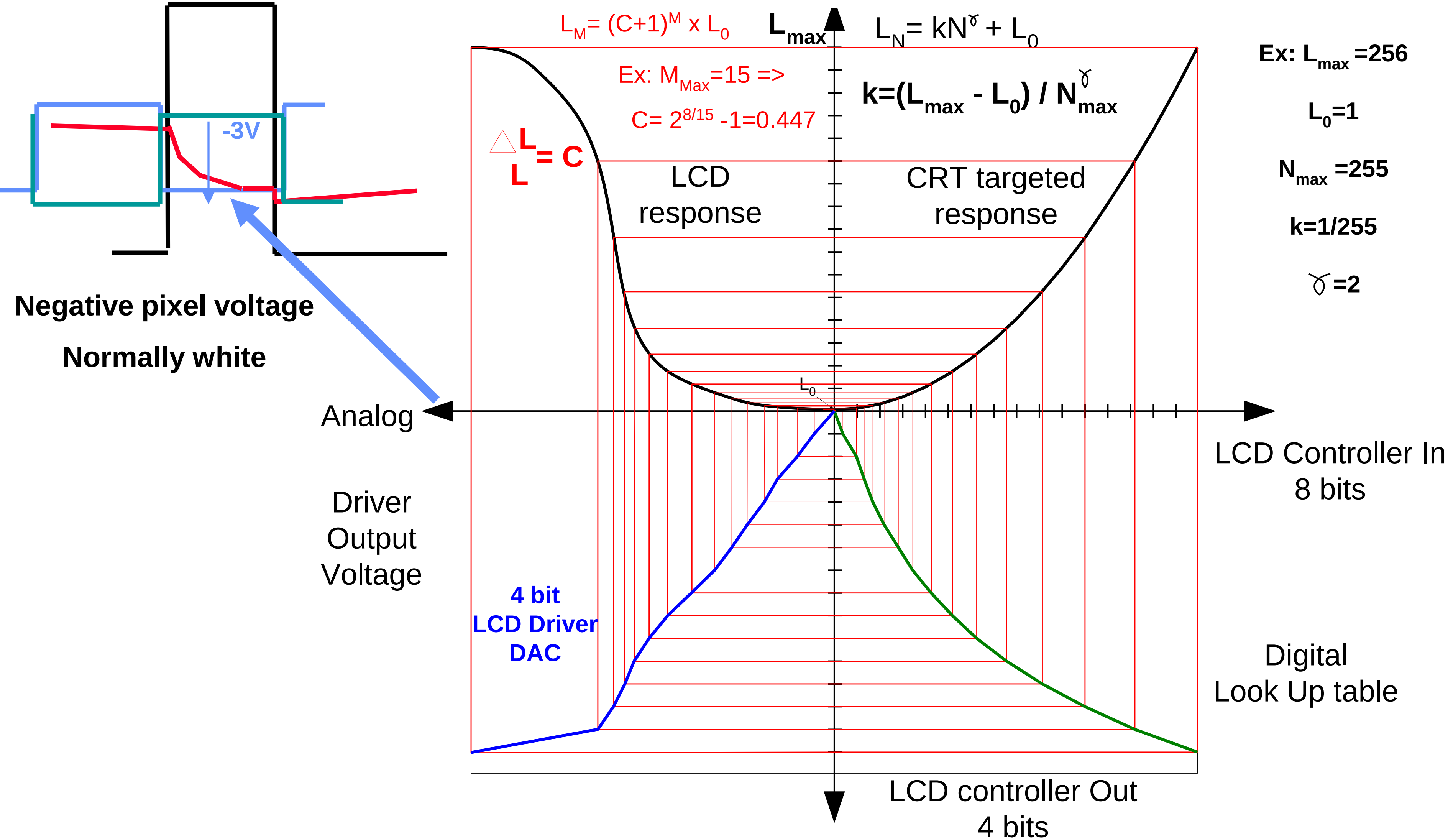
Hyp: 8 bit drivers not available

We use 4 bit drivers

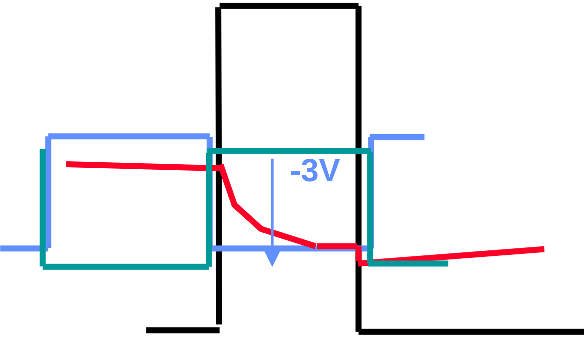
GAMMA Processing Diagram



GAMMA Processing Diagram

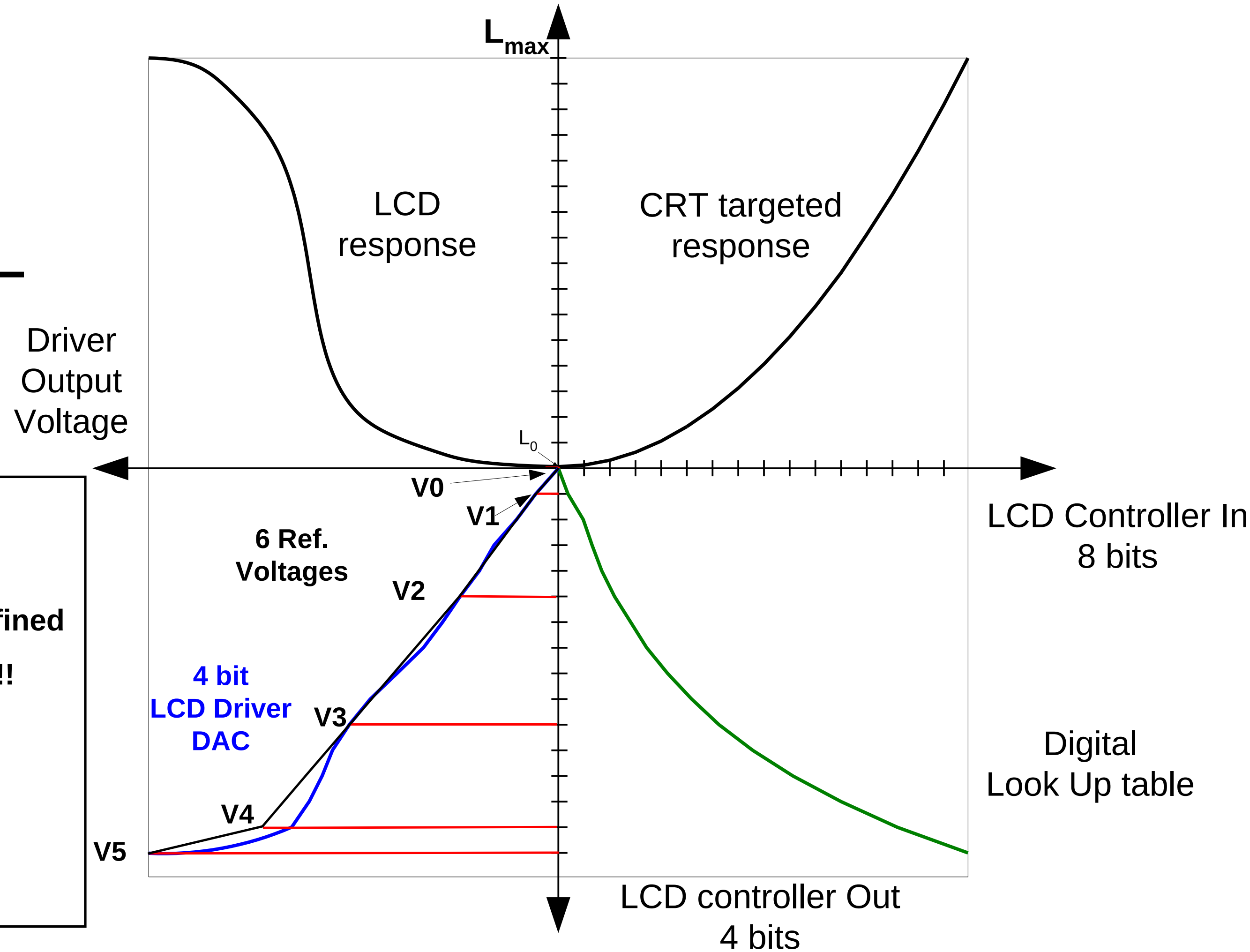


GAMMA Processing Diagram



Negative pixel voltage

Normally white



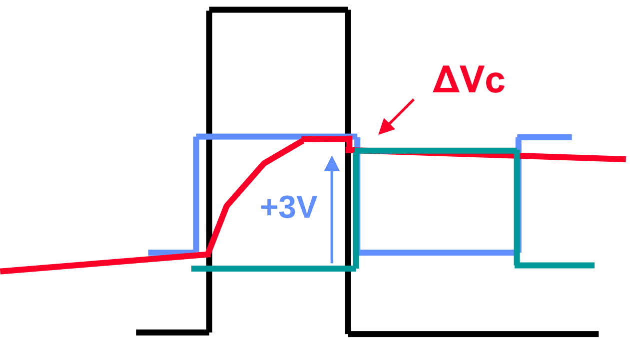
Ref. Voltages are limited

- **9 for 6 bit drivers**
- **Switching points are predefined**
- **Vi to be changed every line!!**

Difficult to make gamma

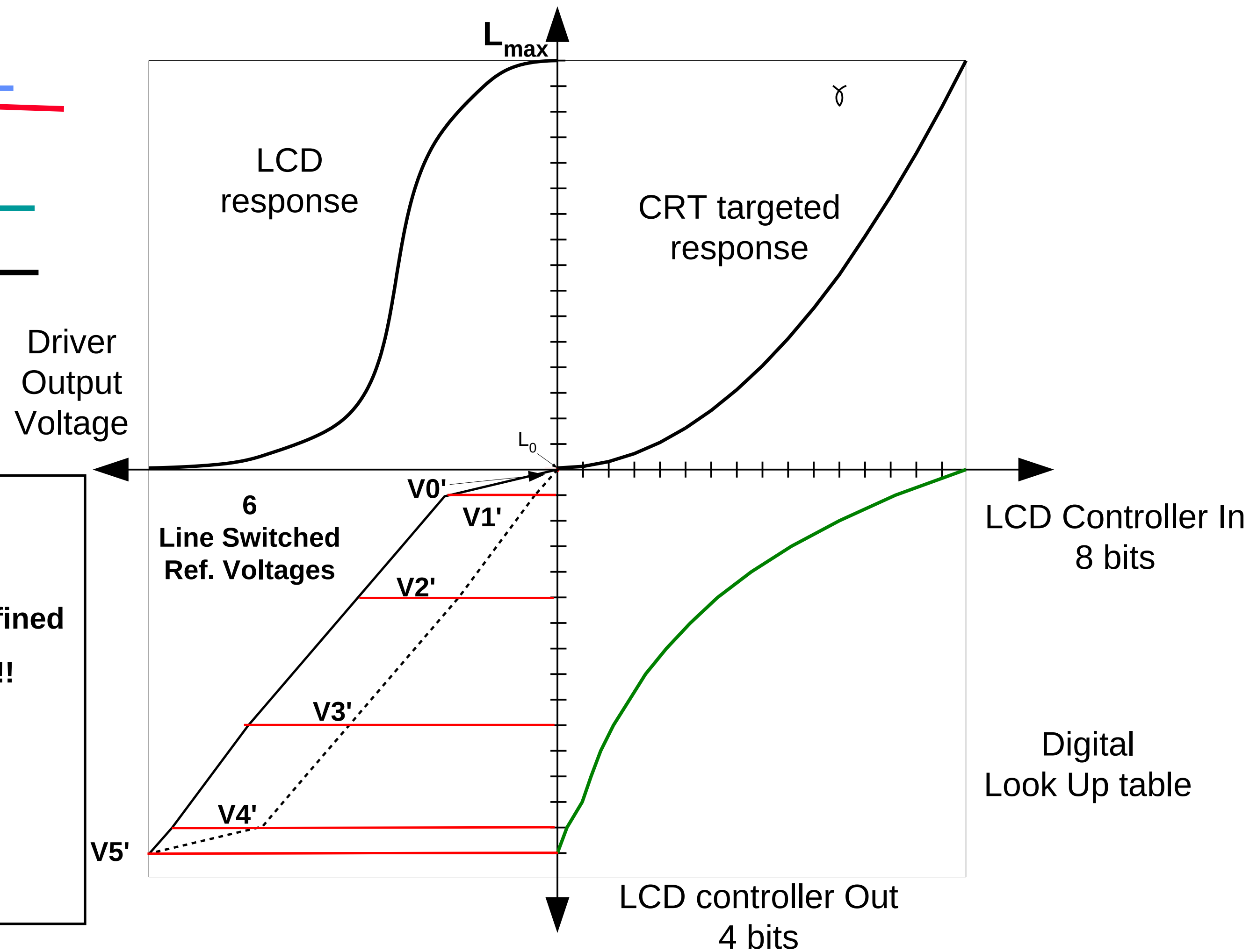
- **Additional LUT necessary**
- **Easier with 8 bit drivers**

GAMMA Processing Diagram



Positive pixel voltage

Normally white



Ref. Voltages are limited

- **9 for 6 bit drivers**
- **Switching points are predefined**
- **Vi to be changed every line!!**
- **18 ref. Voltage gen. needed**

Difficult to make gamma

- **Additional LUT necessary**
- **Easier with 8 bit drivers**

LCD Electronics

Sum Up

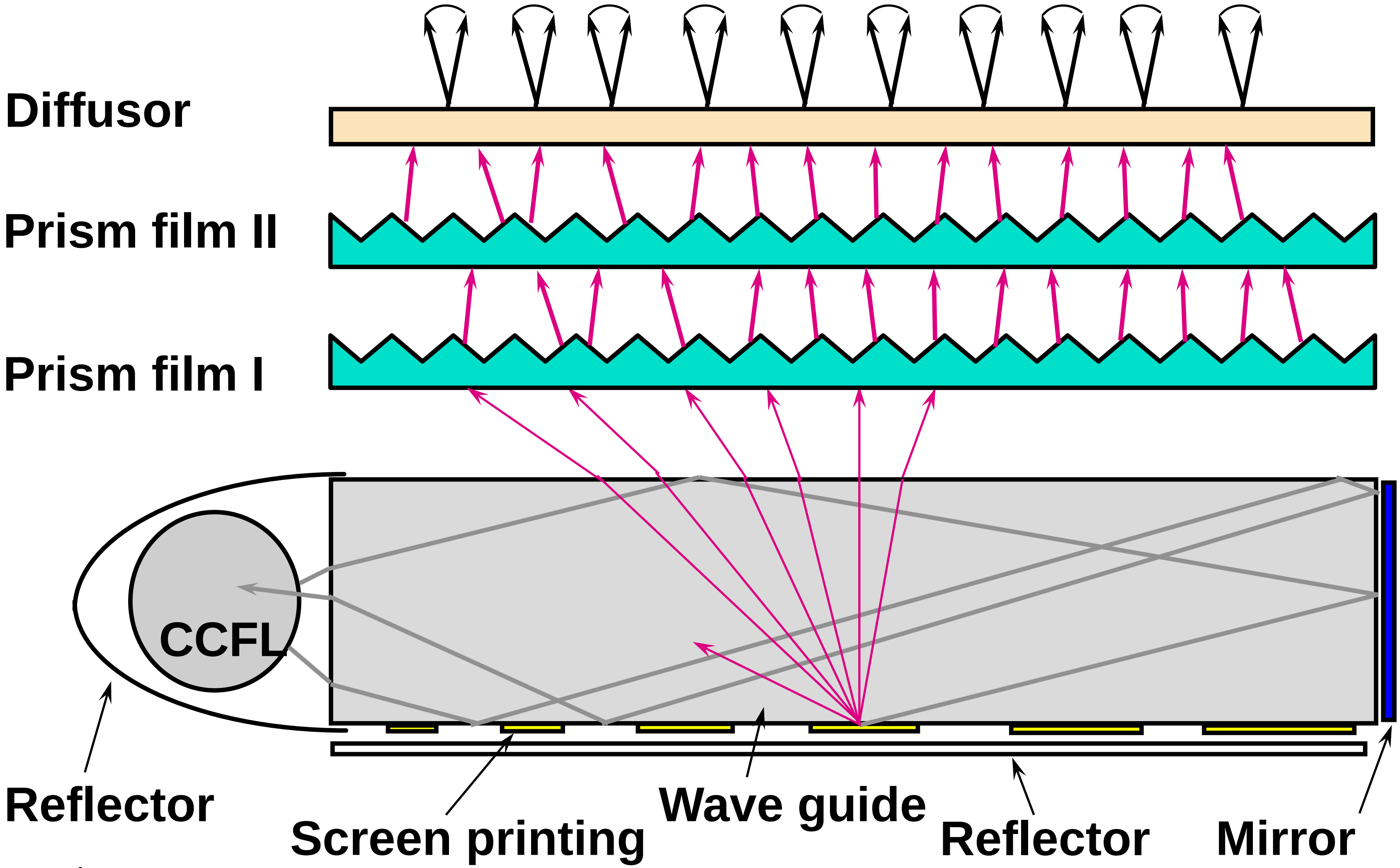
- **The counter-electrode is the most important signal for LCD life time**
  - **It has to be Noise Free**
  - **It must be adjusted in such a way that no flicker is visible**
    - **Adjustment to be made in row inversion mode**
    - **Using a black-gray specific pattern**

- **The vertical scanning has to be progressive**
  - **Good de-interlacing algorithm needed in the TV chassis**
  - **Better with motion compensation**
- **Complete digital path for Video Processing available**
- **The gamma correction is the most important function for picture quality**
  - **Make the LCD electro-optical response appear like a CRT one from the outside**
  - **Avoid quantization noise specially in dark regions: more bits in dark**
  - **Unlike on projection systems, gamma correction curves can be the same on R,G and B channels.**
  - **For TV applications, 8 bit or even 10 bit drivers are preferable**

PRINCIPLE TRAINING

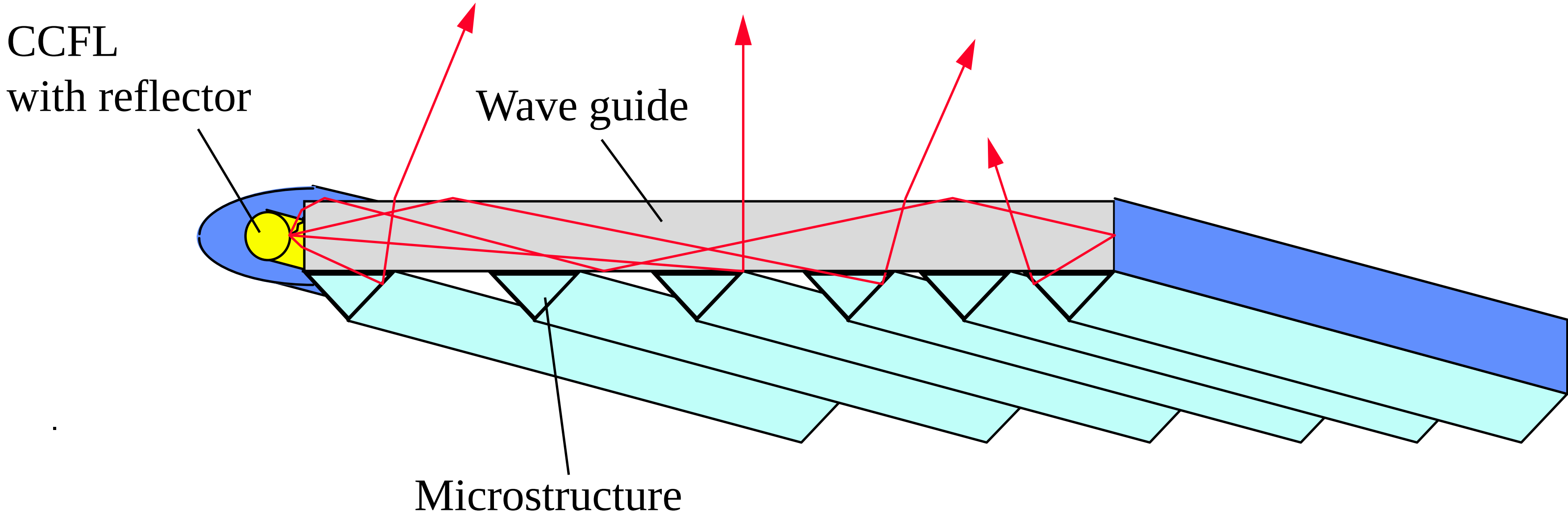
- Introduction
- General training
  - LCD pixel structure
    - Optical effect
    - Electrical effect
  - LCD panel structure
  - Active matrix displays
    - Structure
    - Addressing techniques
  - General electronics block diagram
    - LCD drivers
    - LCD controller
    - Upstream video processing
  - Back lighting
  - Characterization principles
    - Main optical parameters to look at
    - Measurement methods and tools

Back-light Principle



Back-light Improvements

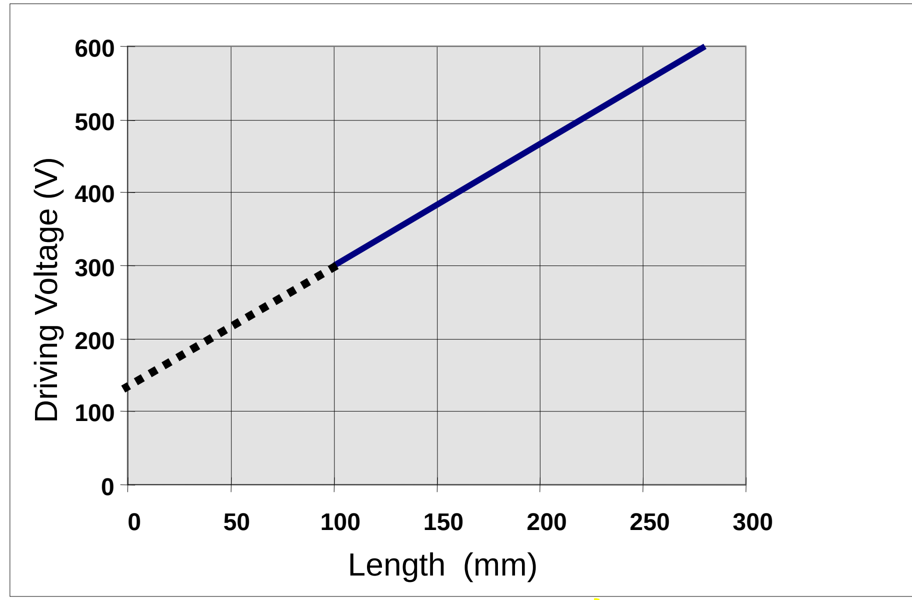
- **Benefits:**
  - **Light extraction by direct reflection rather than scattering**
  - **Higher efficiency / better collimation**
  - **Only one manufacturing process (injection mold)**
  - **Only one additional prism film**
  - **Gain in luminance about 30% to screen printed type**

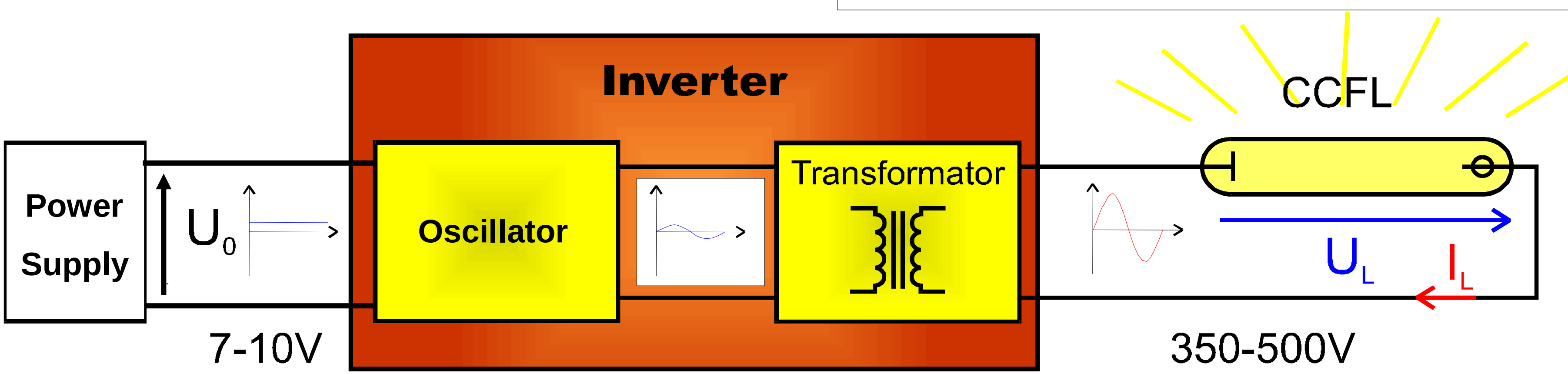


Back-light Inverter

CCFL: Cold Cathode Fluorescent Lamp

- **Diameter:** **1.8 - 3.0mm**
- **Luminance** **20000 - 40000Cd/m²**
- **Efficiency:** **30-60lm/W, depending on length**
- **Life Time:** **typ. 20000h**





PRINCIPLE TRAINING

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- ❑ **General training**
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    - Main optical parameters to look at
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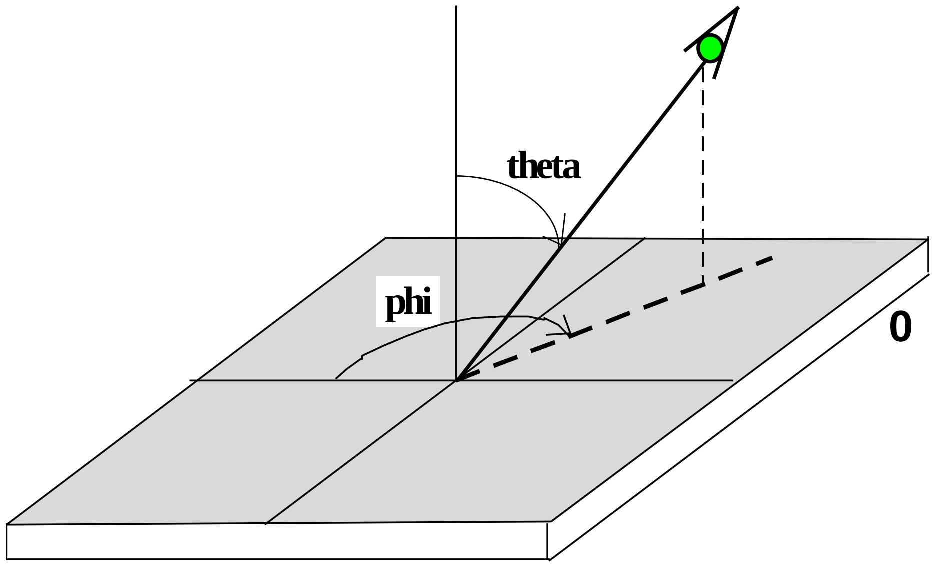
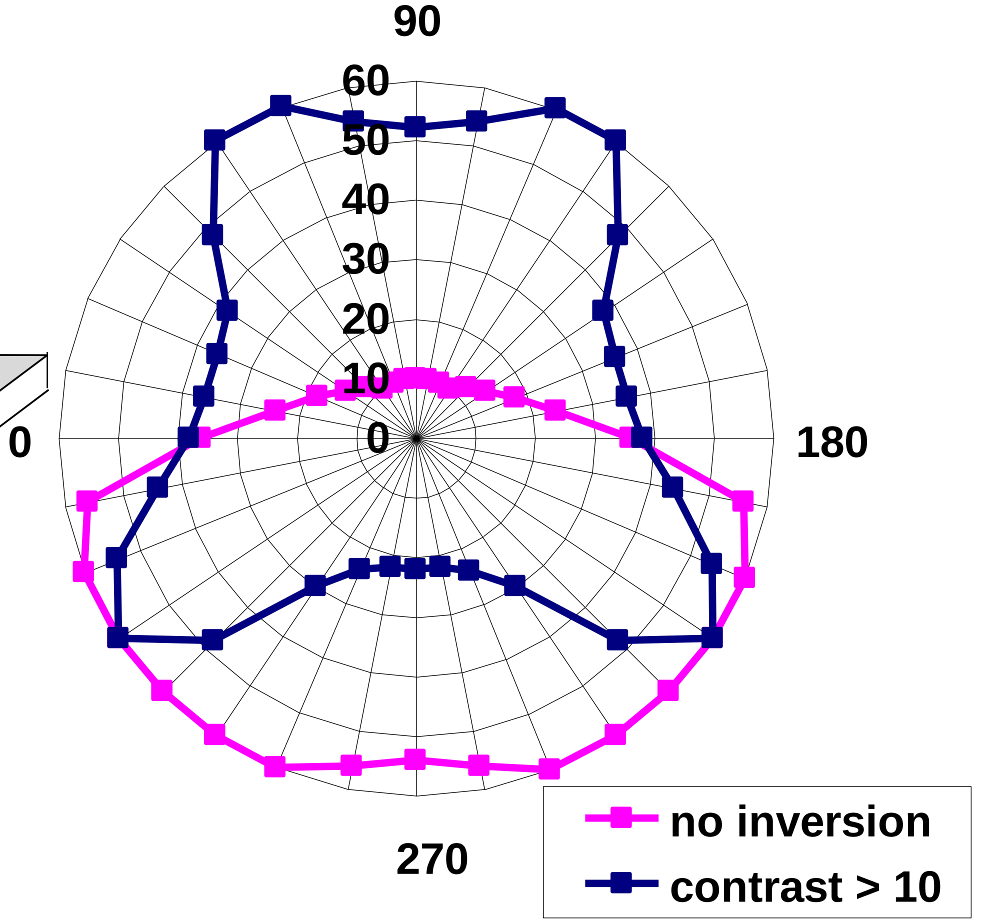
LCD Characterization

- Conoscopic measurement principle





How to characterize a LCD

❑ Critical parameters:

Display parameters

- **Brightness :** Cd/m² (nit) value, ANSI standard uniformity & Brightness vs viewing angle.
- **Contrast :** White/Black (in dark room) & Contrast uniformity vs viewing angle.
- **Color Rendering:** R,G&B color coordinates (x/y or u'/v'), Color uniformity over the panel. White coordinates locus vs gray level. Equivalent color temperature.
- **Viewing angle:** Vertical & Horizontal viewing angle, color shift (du',dv') vs viewing angle.
  LOOK OUT: Viewing angle values w/o associated contrast does not mean anything
- **Pixel defect:** R,G &B pixel defect (pixel on or partially on) inside two areas in the panel.

Electronic parameters

- **Response Time**:
  - **Especially for video, ton & toff should be less than fixed value**
- **Gray Level performances:**
  - **6 bits or more?**
  - **Gray level inversion**
- **Flicker:**
  - **if present, adjustment problem**
- **Power consumption:**
  - **Backlight & Drivers, stand-by power**
- **Others effects (if present):**
  - **cross-talk, still images**

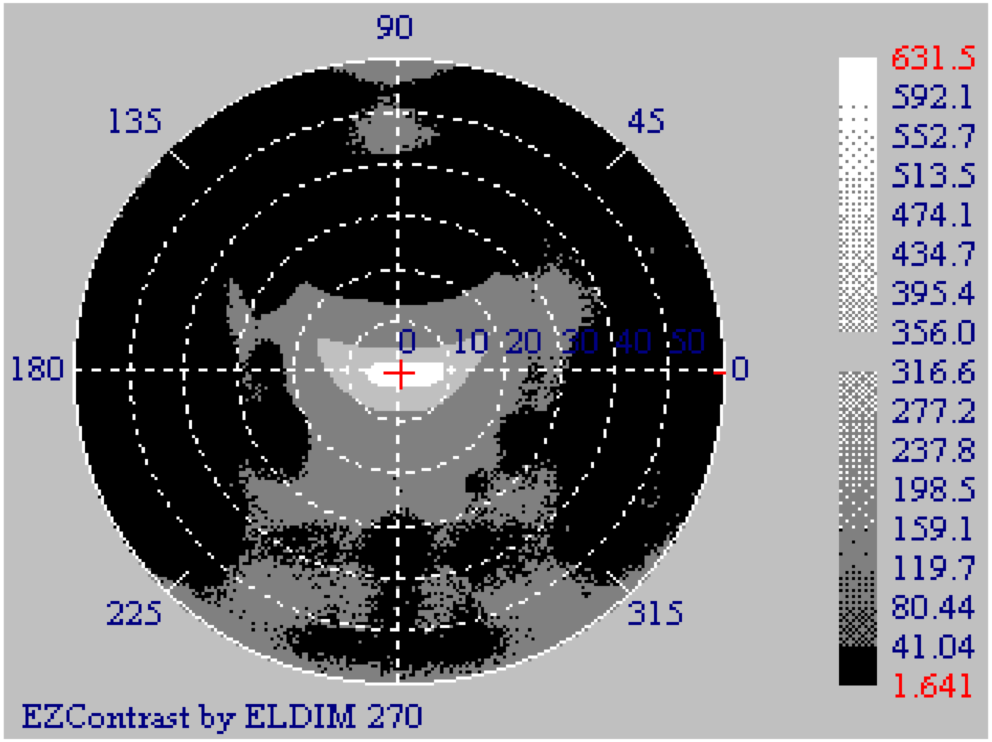
How to characterize a LCD

❑Conoscopic representation:

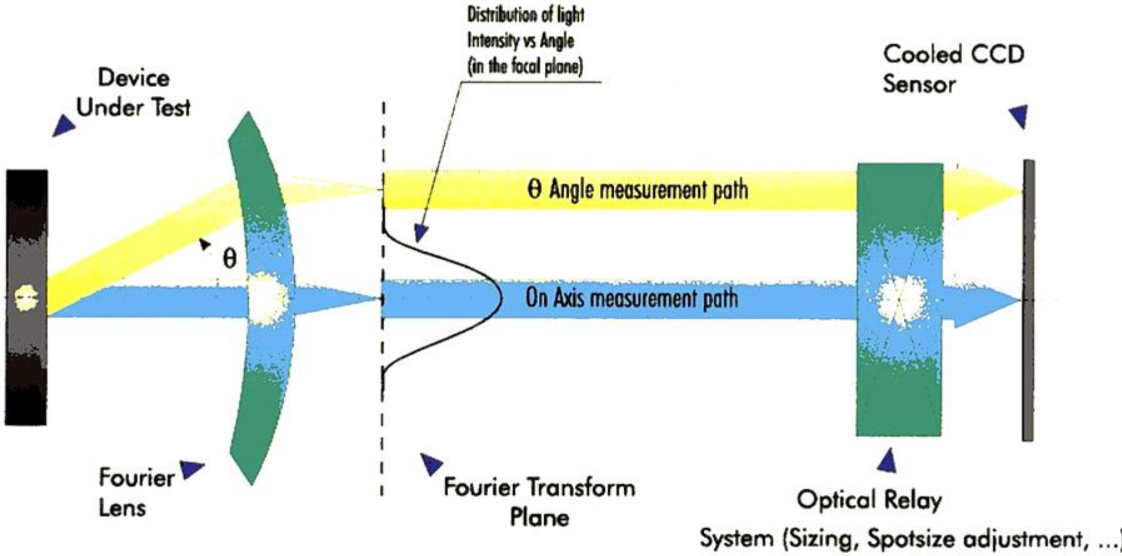
- **Contrast evaluation: function of viewing angle (half space:θ, ϕ).**

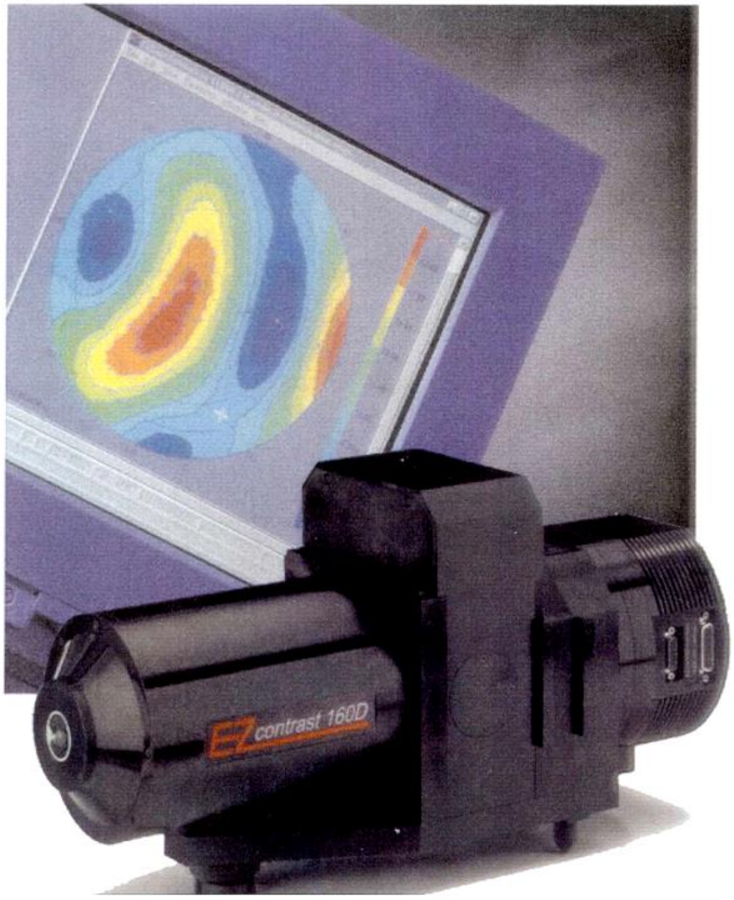
Curves delimit the viewing angle with same contrast for each color

example:



How to characterize a LCD
Measurements Tools:EZContrast 160D





How to characterize a LCD

❑ Measurements Tools (suggestion):

- Ezcontrast 160D for the Contrast by Eldim (see previous slide)
- Or a precise Luxmeter for White/Black contrast like Luxmeter110 by PRC GmbH.
- Optiscope for Flicker and Response Time by Eldim
- Spectro-photometer for (ex PR 740 from Photo Research):
  - color characterization (over the panel and over the viewing angle)
  - Brightness vs viewing angle
- Or a simple HandPhotometer like Chroma-meter CS-100 by Minolta
  - Brightness and x/y values

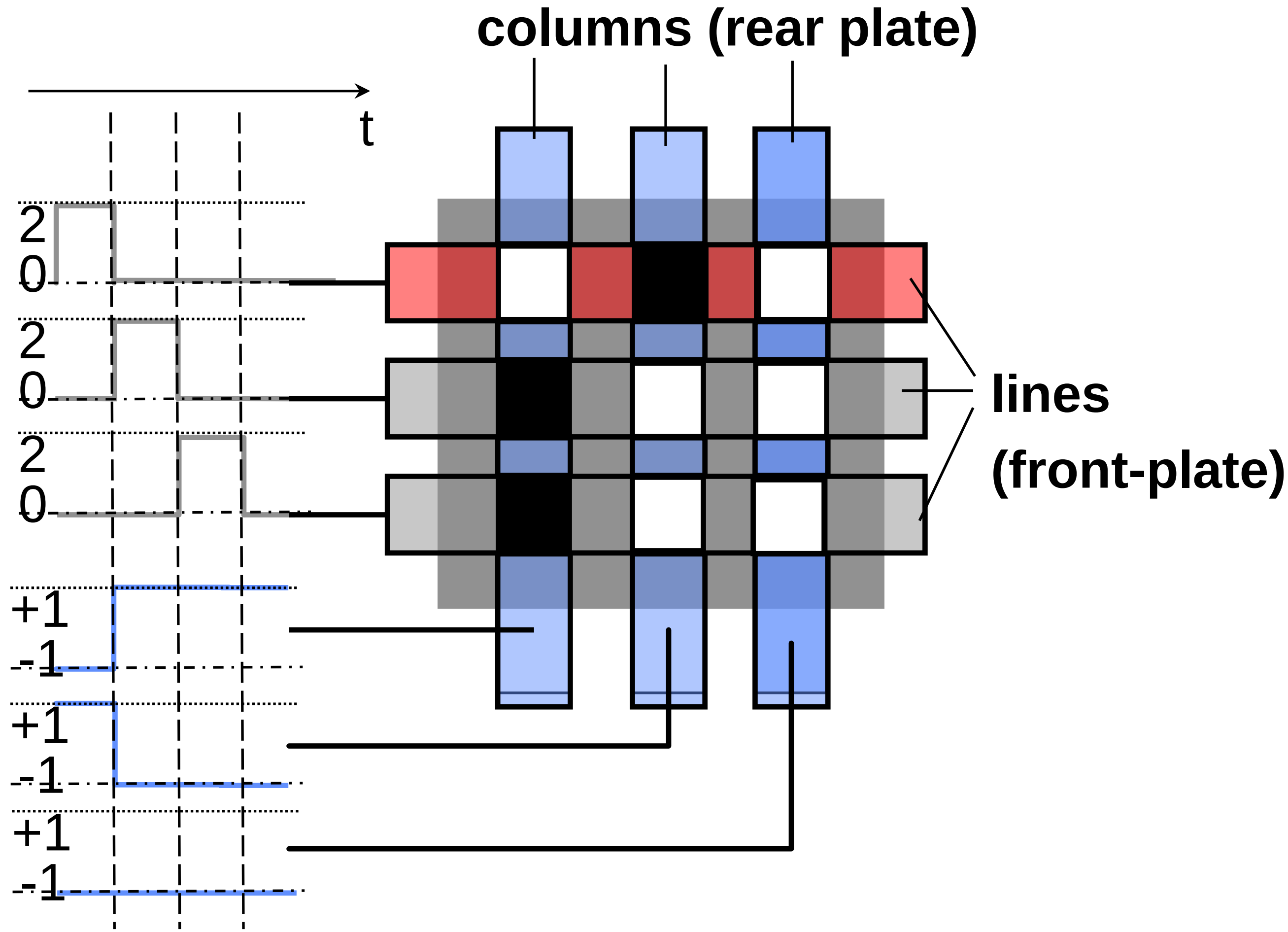
ADDITIONAL TRAINING
For interested audiences!

- **Additional training**
  - **Passive Matrix displays**
    - **Structure**
    - **STN**
    - **Addressing**
  - **Viewing angle improvements**
    - **Gray level inversion**
    - **Compensation film**
    - **Multidomain**
    - **IPS**

Passive Matrix Addressing Principles

Row-Signals
(line-select)

Column Signals
(Data)



- **RMS-response requires: response time >> frame time (OK for STN)**
- **DC-free by frame inversion**

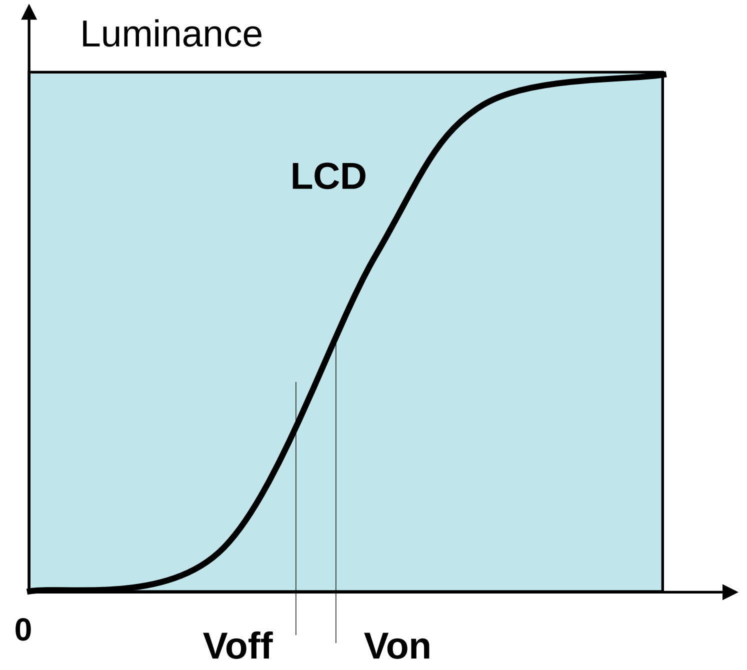
Passive Matrix Addressing Principles

❑No storing element (TFT)

- Difference between Von rms and V off rms is tiny
- TN LCD cannot be used for Passive Matrix applications

❑Need for a very steep LCD response

- STN is the solution
- Limited number of gray levels

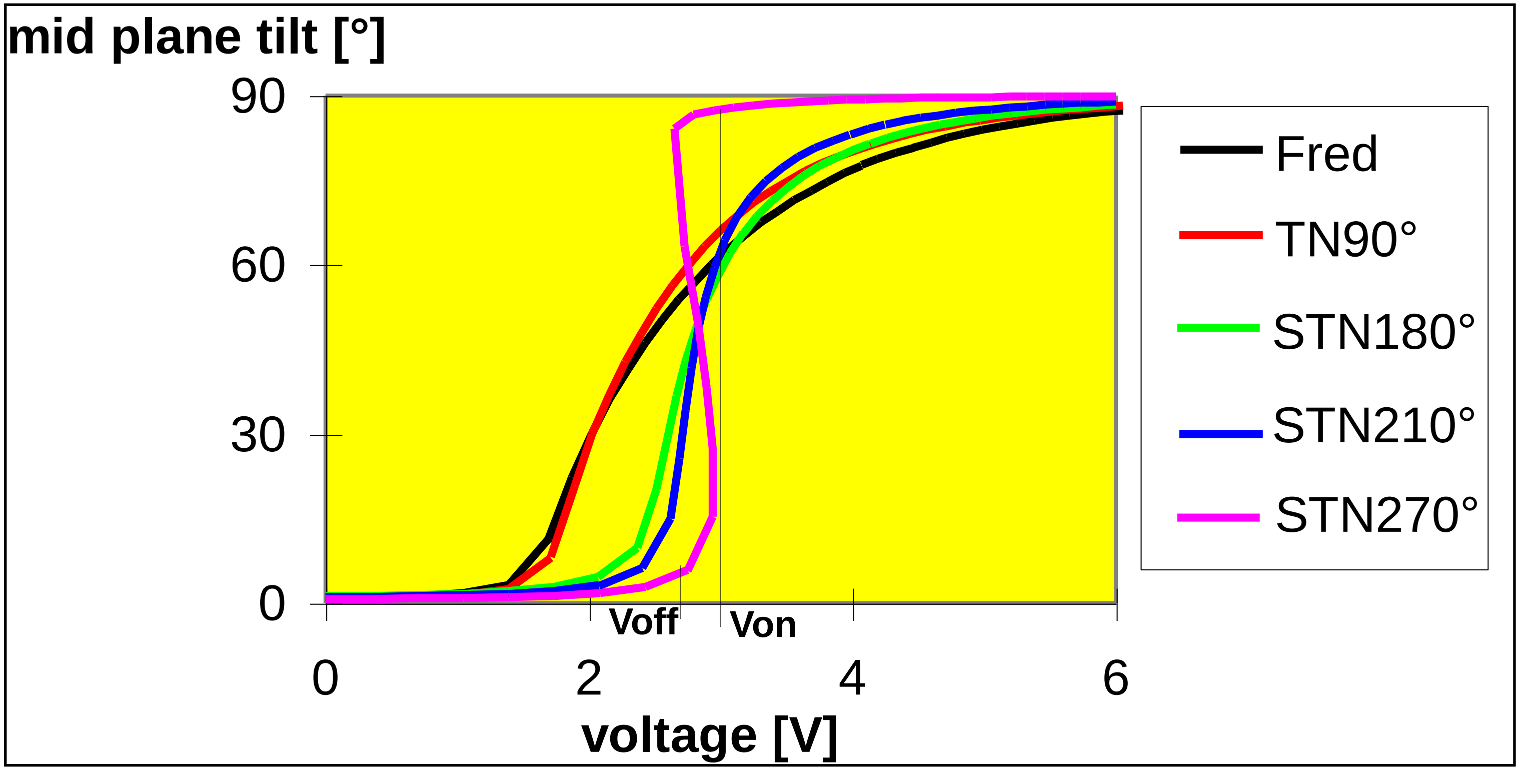


PASSIVE MATRIX DISPLAYS

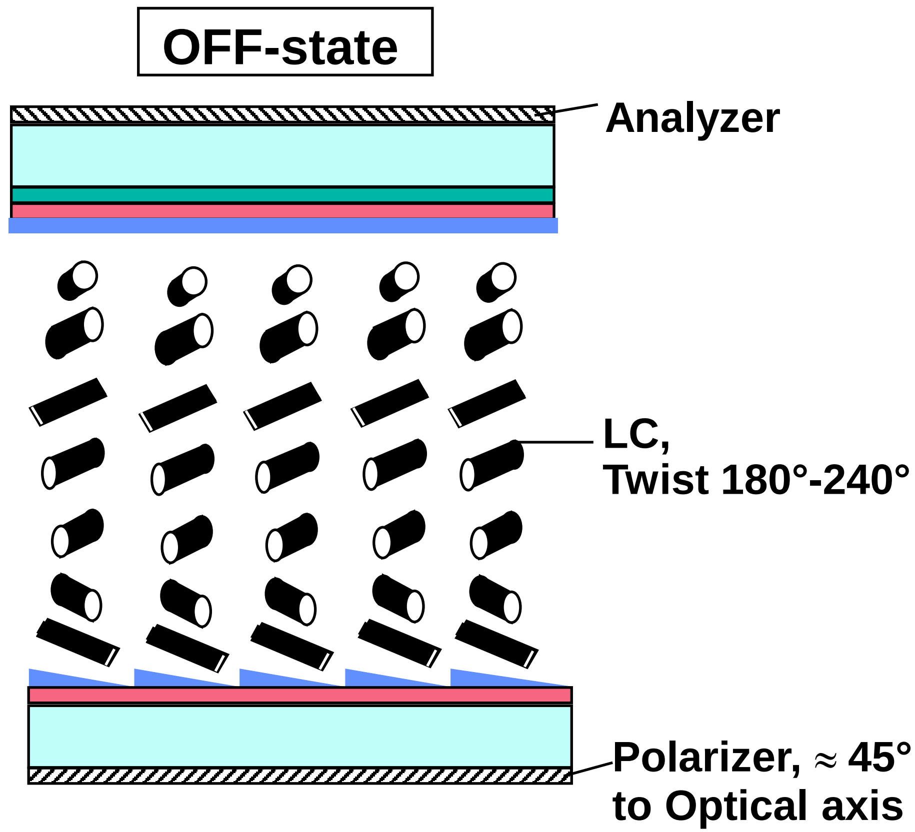
❑ **Increase of the steepness of the EOR for passive addressing:**

=>Increase the twist angle (cholesteric LC)

Electro-mechanical response:



Structure of a STN-LCD:



STN Characteristics

- **Steep Electro Optical response (EOR)**
  - **Ideal for passive addressing**
- **Slow response time: 50-300 ms**
- **OFF state chromatism**
  - **Blue mode, yellow mode**
  - **Transmission sensitive on $\Delta nd/\lambda$**
- **Very limited viewing angle**
- **Limited gray level rendition**
- **Vertical crosstalk**
- **Not usable for TV applications**

ADDITIONAL TRAINING
For interested audiences!

❑ **Annex training**

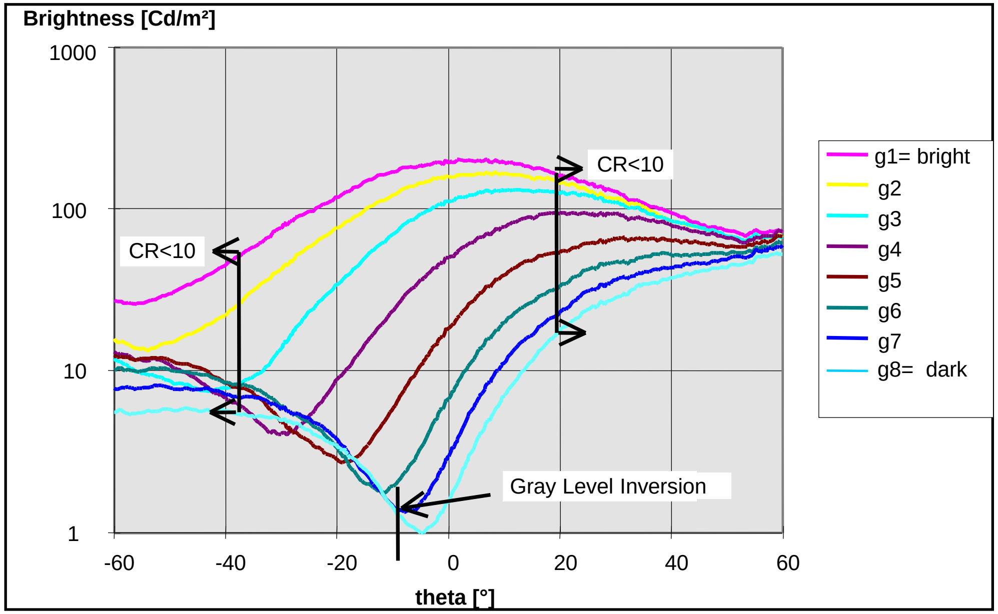
- **Passive Matrix displays**
  - **Structure**
  - **STN**
  - **Addressing**

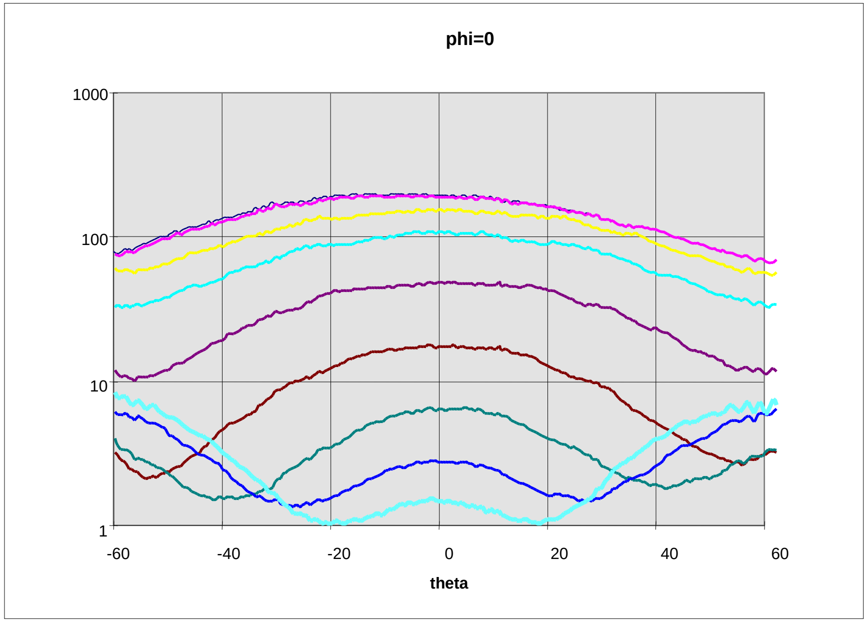
- **Viewing angle improvements**
  - **Gray level inversion**
  - **Compensation film**
  - **Multidomain**
  - **IPS**

Viewing Angle Improvements

Angular luminance distribution of a AMLCD for 8 gray-levels:

vertical viewing plane | **horizontal viewing plane**





1. Contrast loss, especially in upper vertical direction

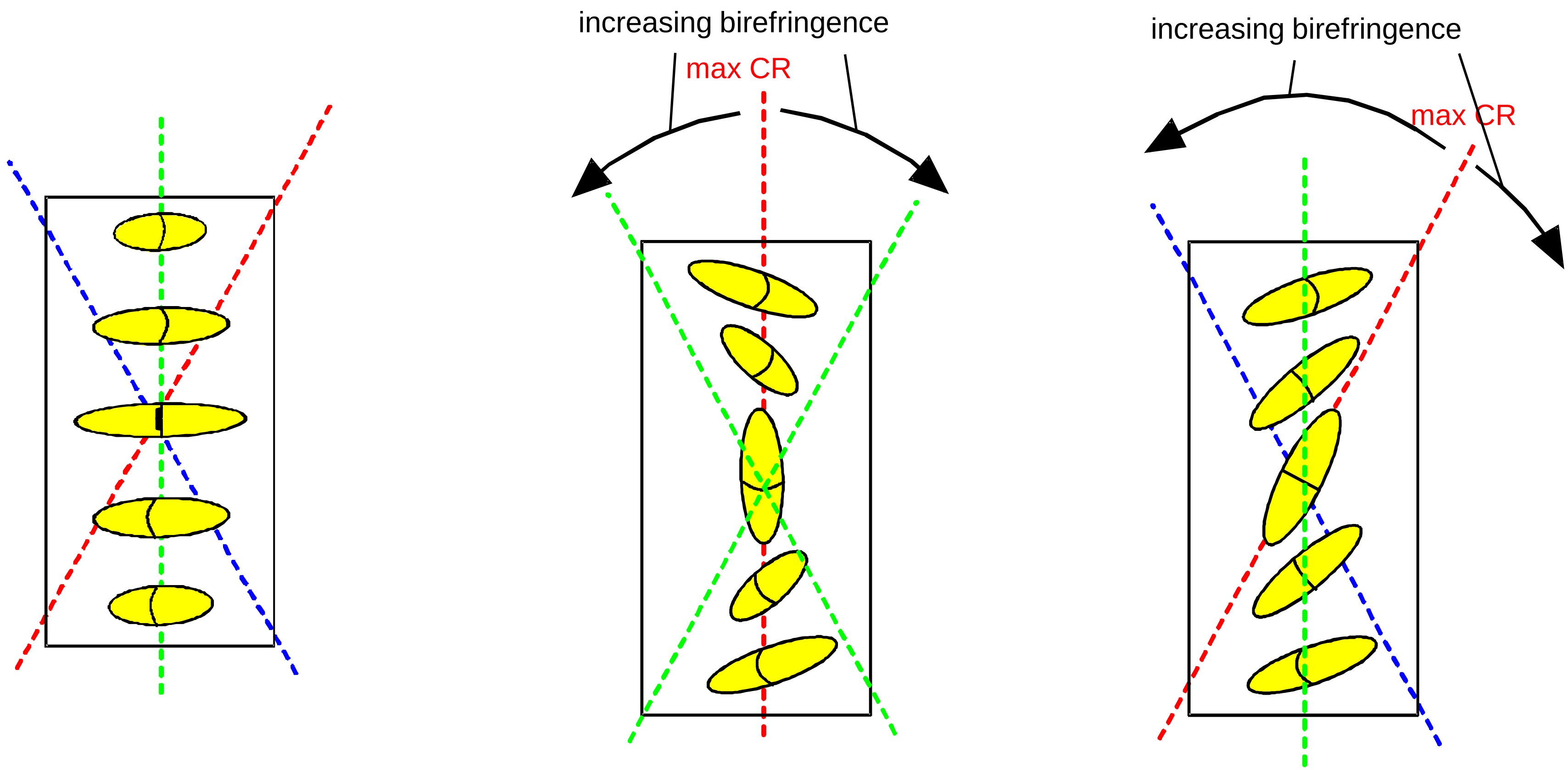
2. Gray level inversion, especially in lower vertical direction

Viewing Angle Improvements

Bright (ON)-state
Little angular change

Dark (OFF)-state
Principal reason for limited viewing angle

Horizontal plane **Vertical plane**



Viewing Angle Compensation Principle

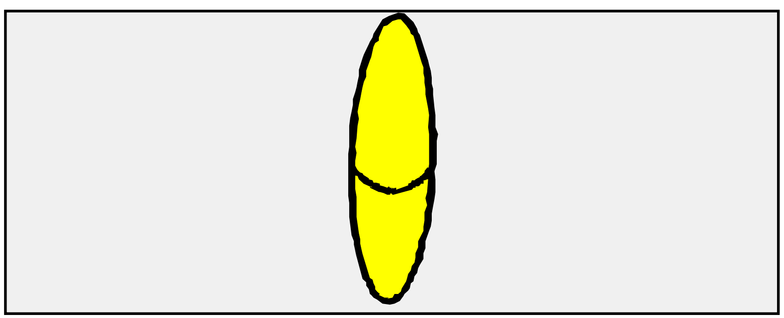
❑ **Basic Idea**:

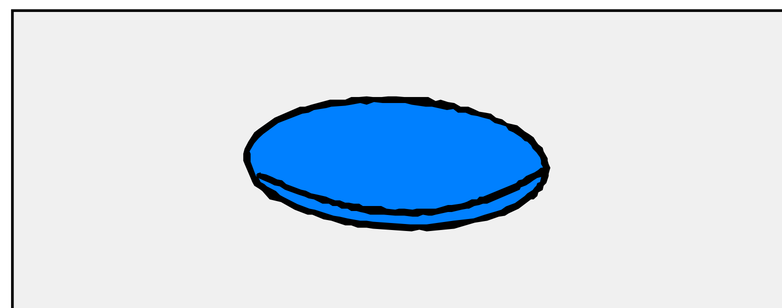
- **Add birefringent element exhibiting the inverse angular characteristics of LC dark state**
- **=> Small birefringence, bright state not affected**

Index Ellipsoids:

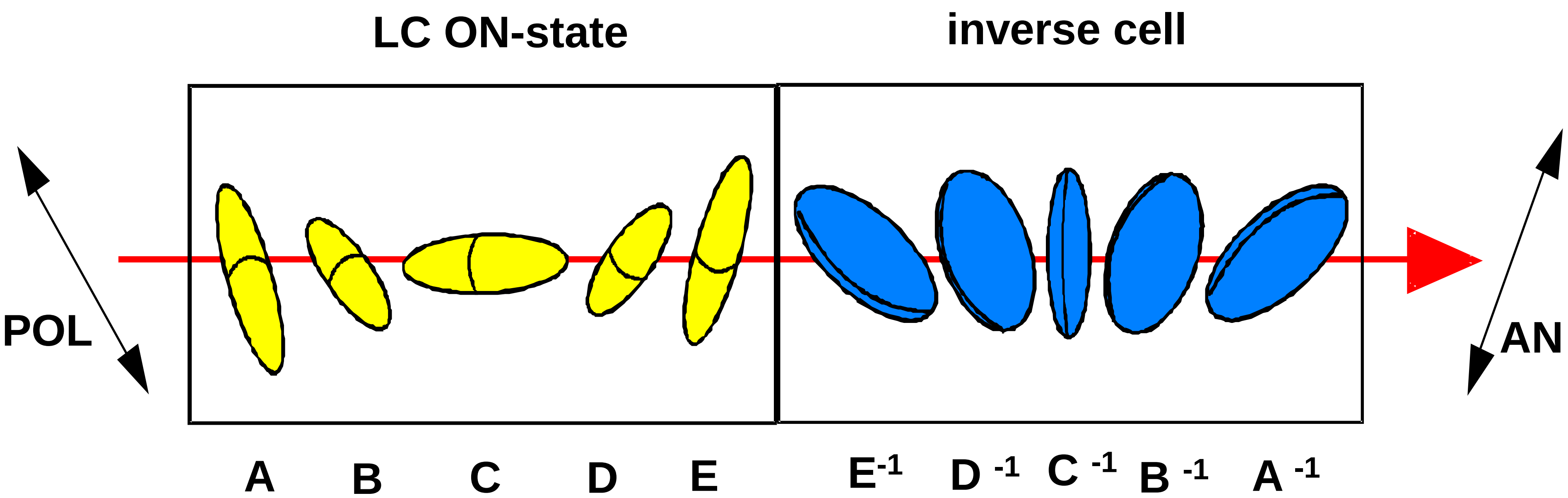
LC-Layer: cigar shape

Compensation layer: pancake-shape



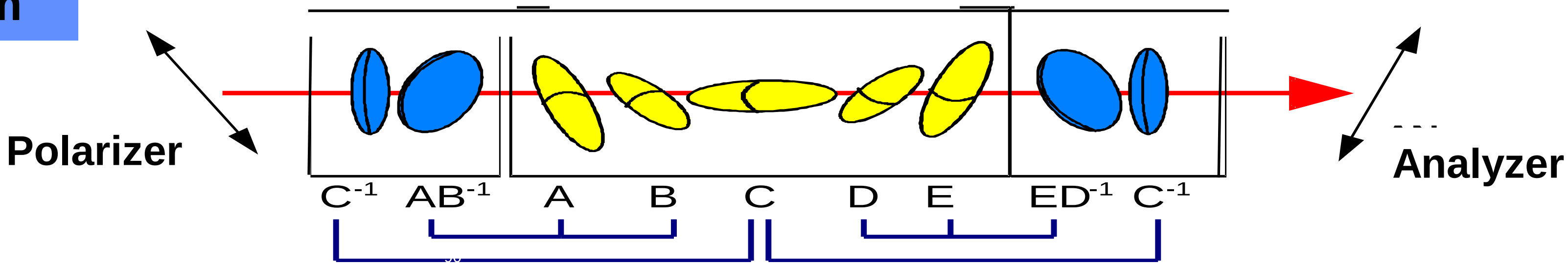


Viewing Angle Compensation Principle



Viewing Angle Compensation Principle

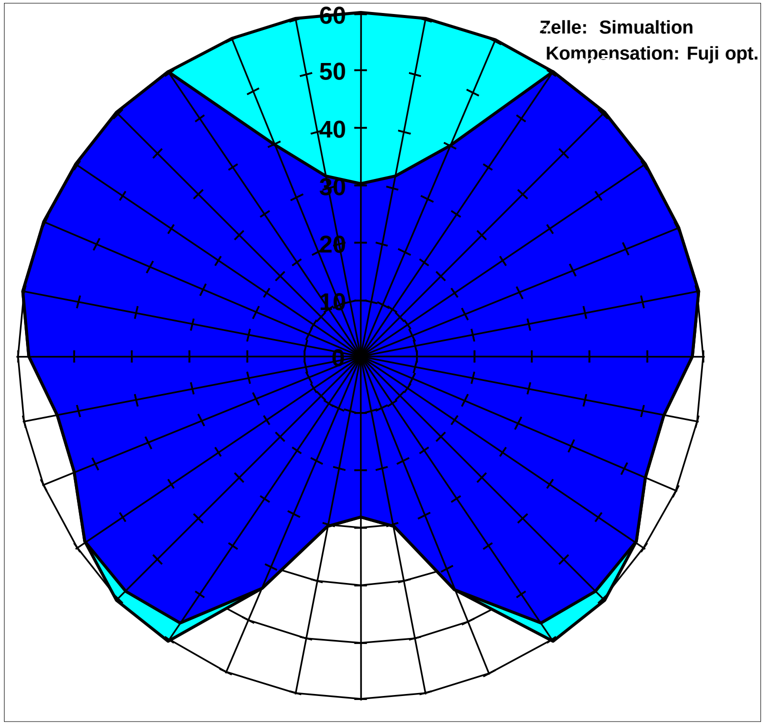
Fuji film

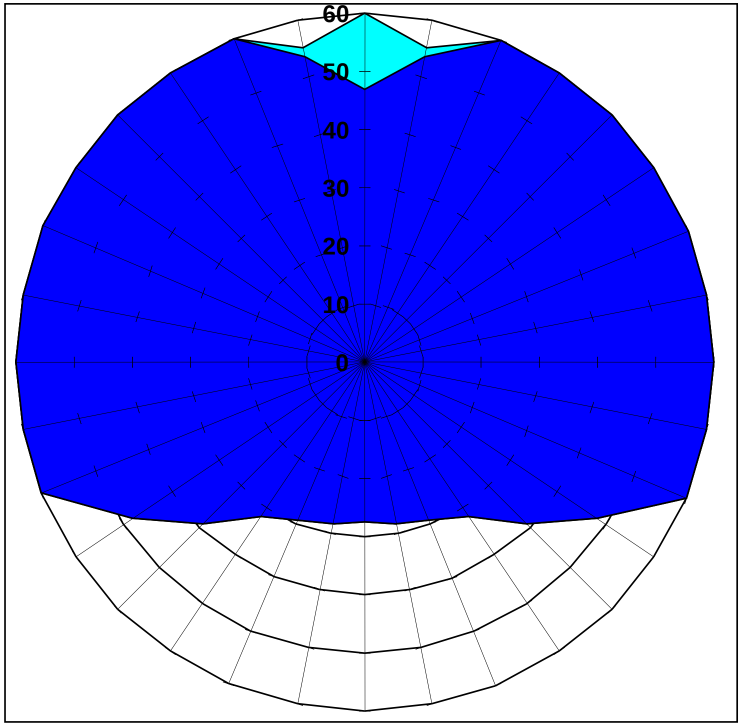


Results of Optimization:

: Contrast > 5, 6 no inversion (6 levels)

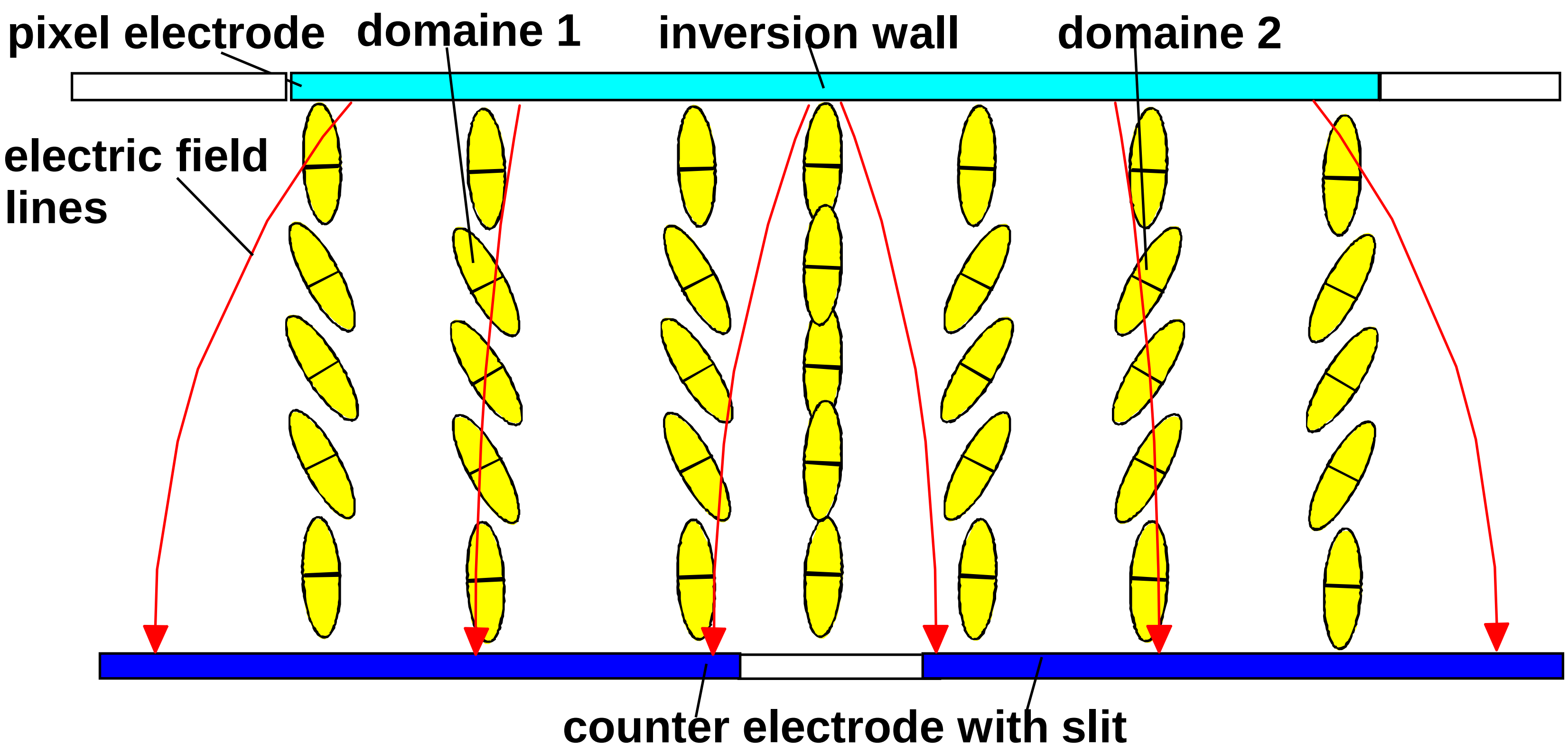
: Contrast > 10, no inversion (8 levels)





Viewing Angle - Multidomain Technique

- Symmetrization of adressed LC-Profile: Multidomain Structure
- Each pixel divided into 2 or more domains
- Domains created either by patterned alignment layer or by fringe field

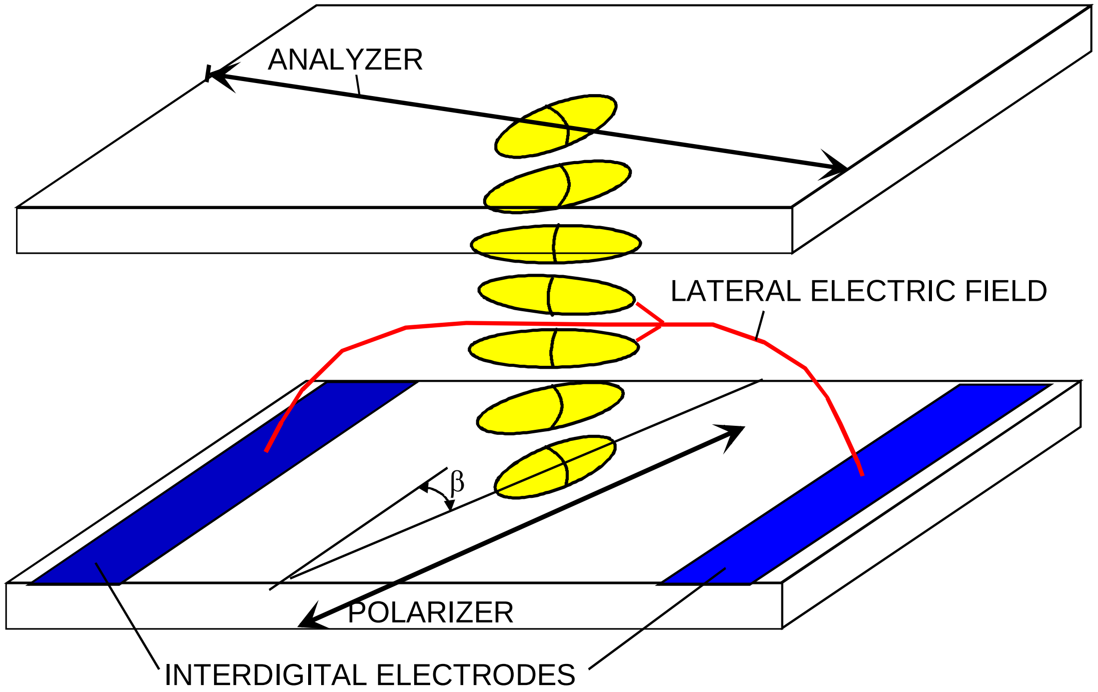


Viewing Angle - In Plane Switching

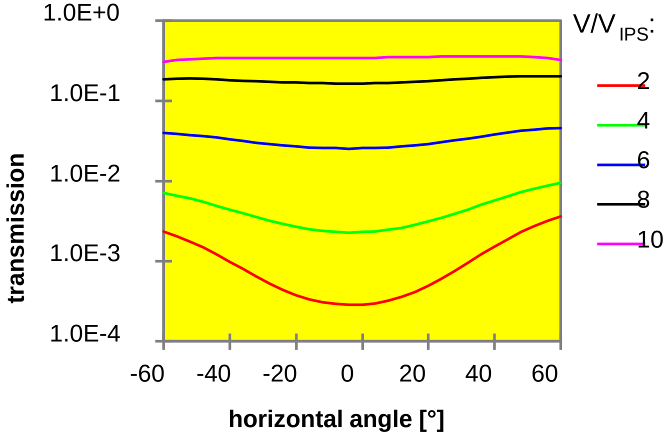
❑ **<u>Principle:</u> lateral electrical field effect**

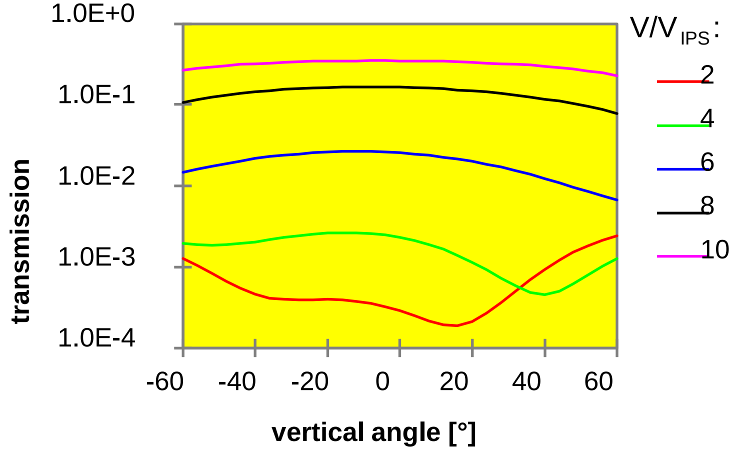
OFF-state: homogenous texture, 'perfect' dark state

ON-state: LC molecules Ð polarizer axis, l/2-plate (like ECB)



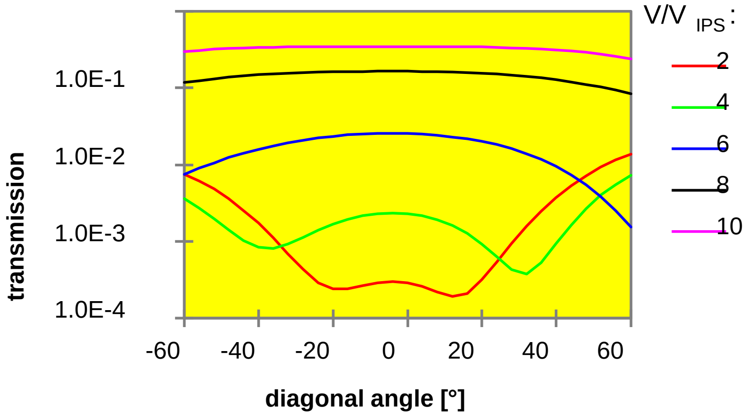
Viewing Angle - IPS Characteristics





- **Contrast range mainly limited by Polarizers**
- **High Contrast over whole viewing angle**
- **Only few gray-level inversions**
- **Best viewing angle of all LCD-Modes**

Diagonal:



Large Viewing Angle - Sum Up

- **Comparison of Different LC-Modes:**

- **1. Enhanced TN Mode using LC-Polymer Film Compensation**
  - easy add-on component
  - viewing angle sufficient for small displays or graphics applications

- **2. TN-Multidomain Modes**
  - basically standard TN process, but:
  - patterning of alignment layer technologically difficult
  - good gray level fidelity, but vertical contrast range limited

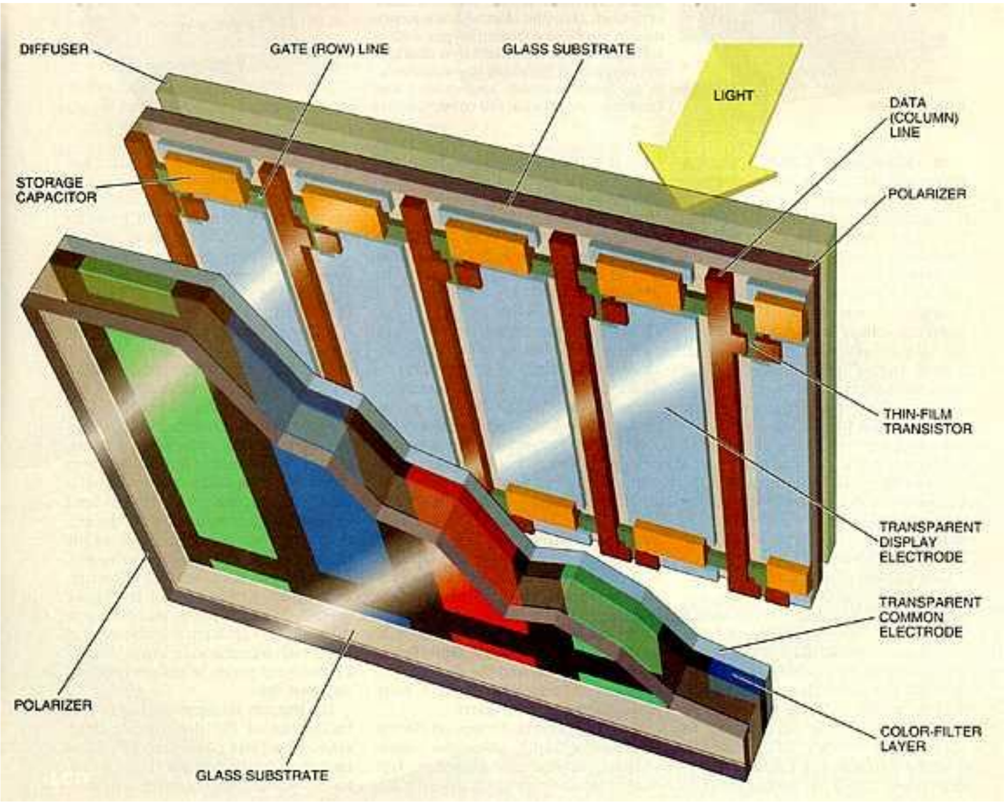
- **3. ‘New’ LC-Modes: Multidomain ECB (VAC), IPS**
  - (nearly) perfect viewing angle
  - Non standard technologies, require better cell-gap control and specific
  - LC mixtures
  - higher driving voltage = higher power consumption)
  - IPS: low transmission = about 2x higher power consumption

Large Viewing Angle - Trends

Application	Technology	Challenge
Laptop	Standard TN	Price, Power Consumption
PC-Monitor	IPS (Hitachi, NEC,...)	Cell gap uniformity
	VAC (Futjisu,...)	Cell gap uniformity, retarder uniformity
	TN, Multidomain, ASM (Sharp,...)	manufactoring Process, LC-stability
Automotive,	Polymer LC Film	cost of retarder, evironmental stability
Video monitor	Polymer LC Film	cost, symmetry of viewing angle

LCD

TRAINING COURSE



Thank You For Your Kind Attention