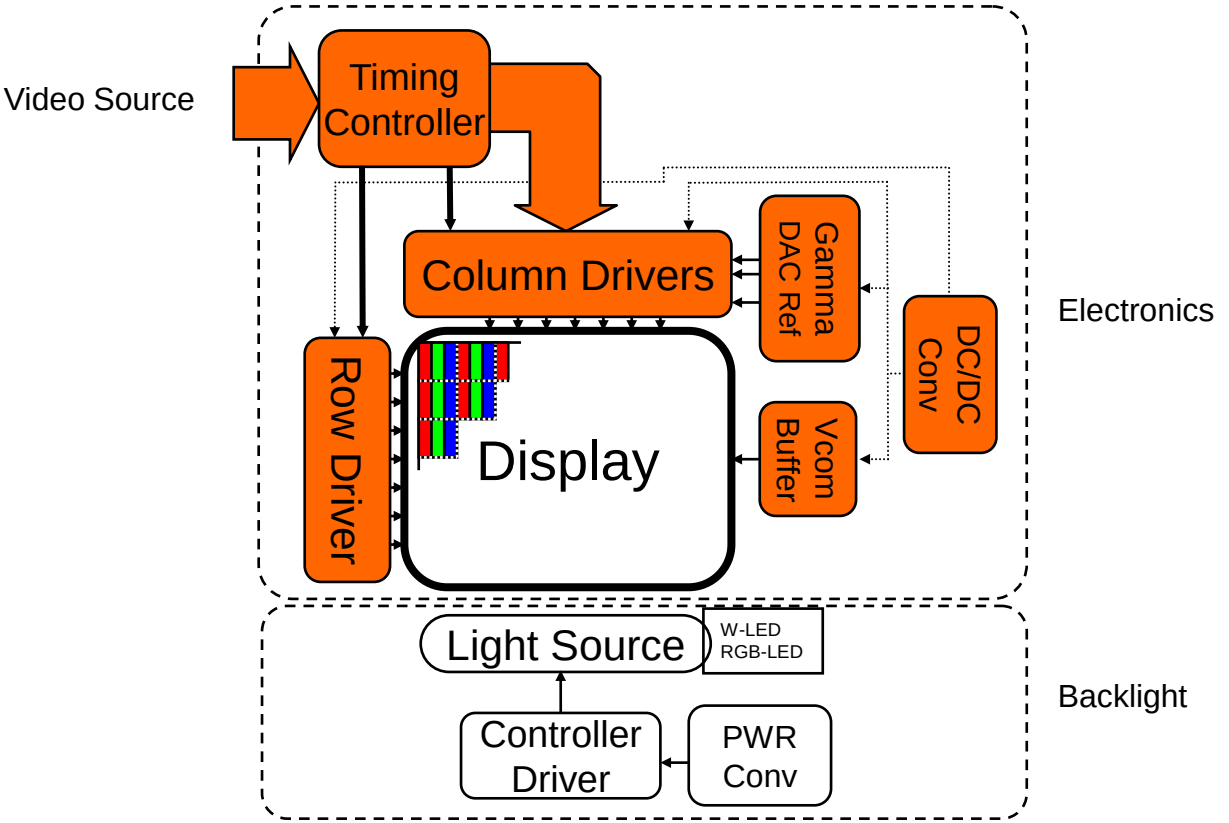
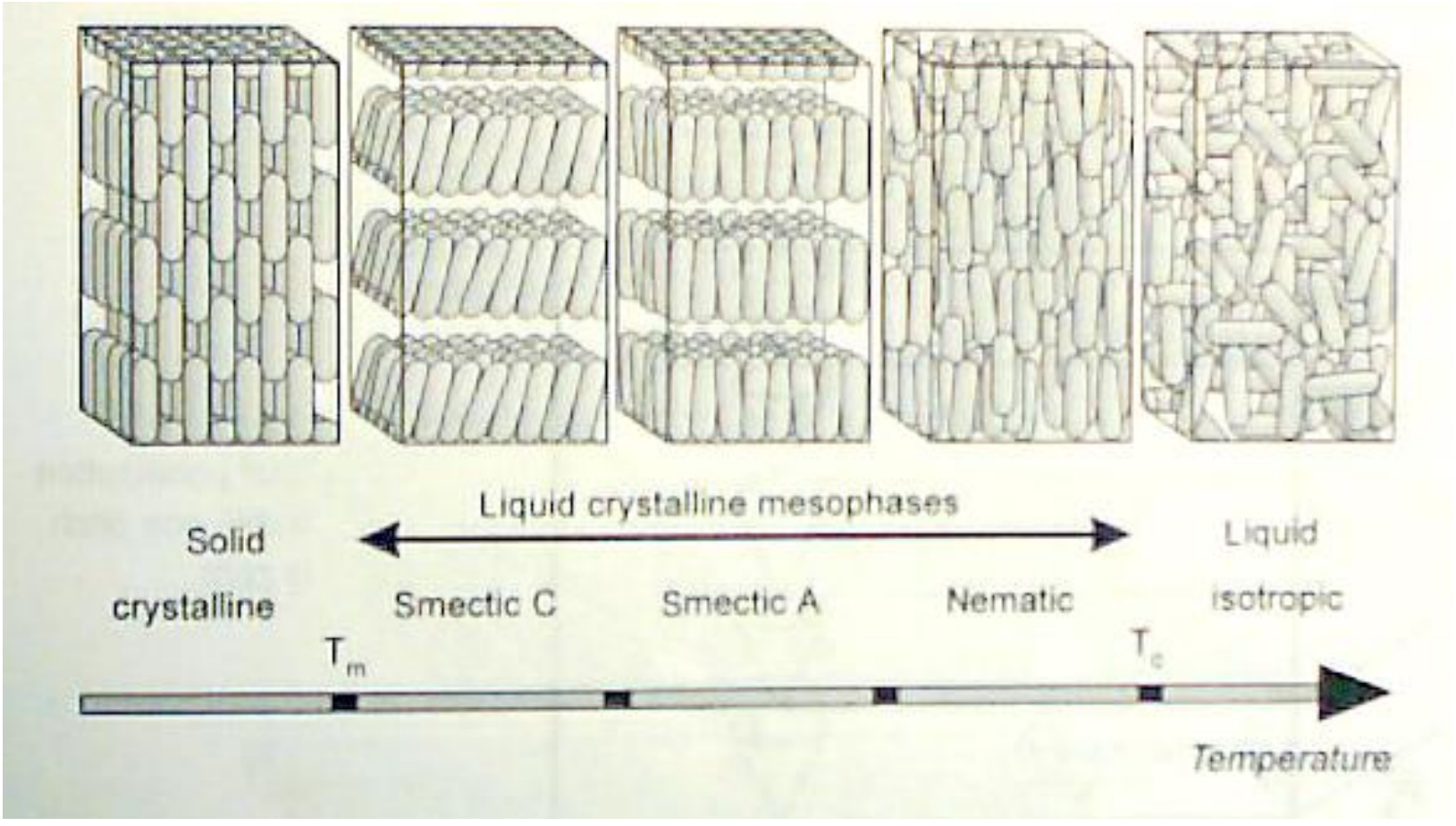
LCD Electronics Theory of Operation

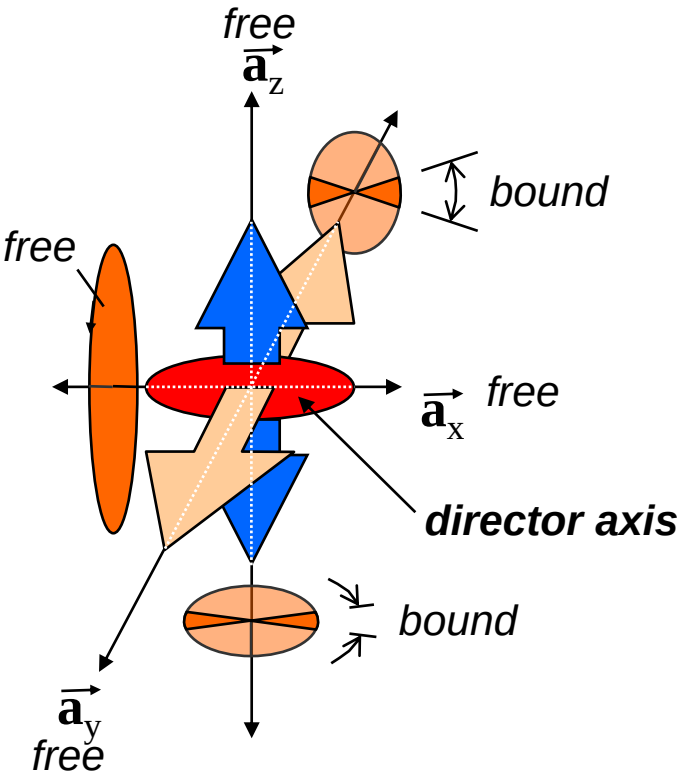
LCD Functional Diagram





Ernst Lueder, "*Liquid Crystal Displays : Addressing Schemes and Electro-Optical Effects (Wiley Series in Display Technology)*", John Wiley & Sons, 22 June, 2001.

Liquid Crystal Nematic Order

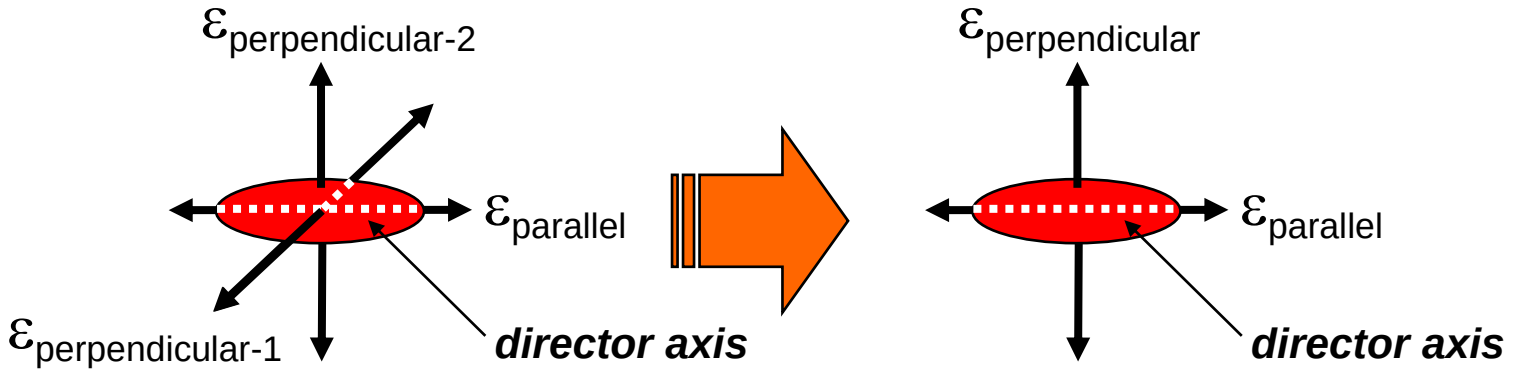


Nematic Order:

- **Free to translate in x,y and z directions**
- **Free to rotate about the major (director) axis**
- **Restricted rotation of the director axis**

Dielectrics and Nematic Order

Dielectric Property

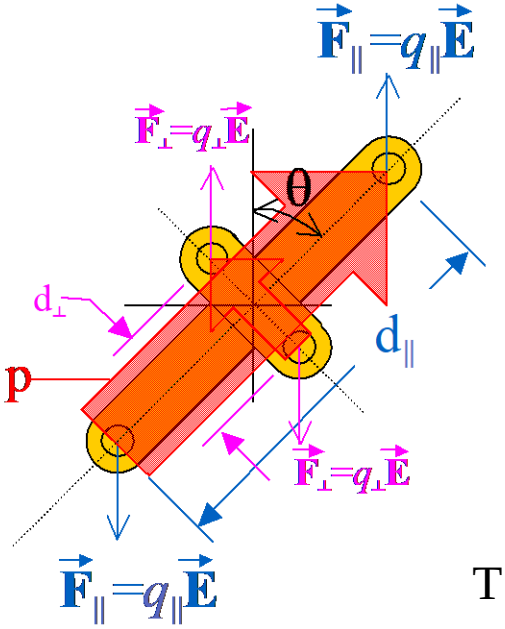


Nematic Order reduces a 3-dimensional dielectric property to two dimensions.

$$\varepsilon_{perpendicular} = \frac{\varepsilon_{perpendicular-1} + \varepsilon_{perpendicular-2}}{2}$$

Due to spin about the director axis.

Torque Depends on V_{RMS}



$$T = 2[(\tfrac{1}{2}\cdot d_{\parallel})\cdot q_{\parallel}\cdot E\cdot\sin(\theta)]-2[(\tfrac{1}{2}\cdot d_{\perp})\cdot q_{\perp}\cdot E\cdot\cos(\theta)]$$

$$T = [d_{\parallel}\cdot q_{\parallel} E\sin(\theta)]-[d_{\perp}\cdot q_{\perp} E\cos(\theta)]$$

$$T = [p_{\parallel}\cdot E\sin(\theta)]-[p_{\perp}\cdot E\cos(\theta)]$$

$$p_{\parallel} = d_{\parallel}\cdot q_{\parallel} = \chi_{\parallel}\cdot\varepsilon_o\cdot E\cdot\cos(\theta)$$

$$p_{\perp} = d_{\perp}\cdot q_{\perp} = \chi_{\perp}\cdot\varepsilon_o\cdot E\cdot\sin(\theta)$$

$$\varepsilon_r = \chi_e + 1$$

$$T = [\chi_{\parallel}\varepsilon_o E\cos(\theta)\, E\sin(\theta)]-[\chi_{\perp}\varepsilon_o E\sin(\theta)\, E\cos(\theta)]$$

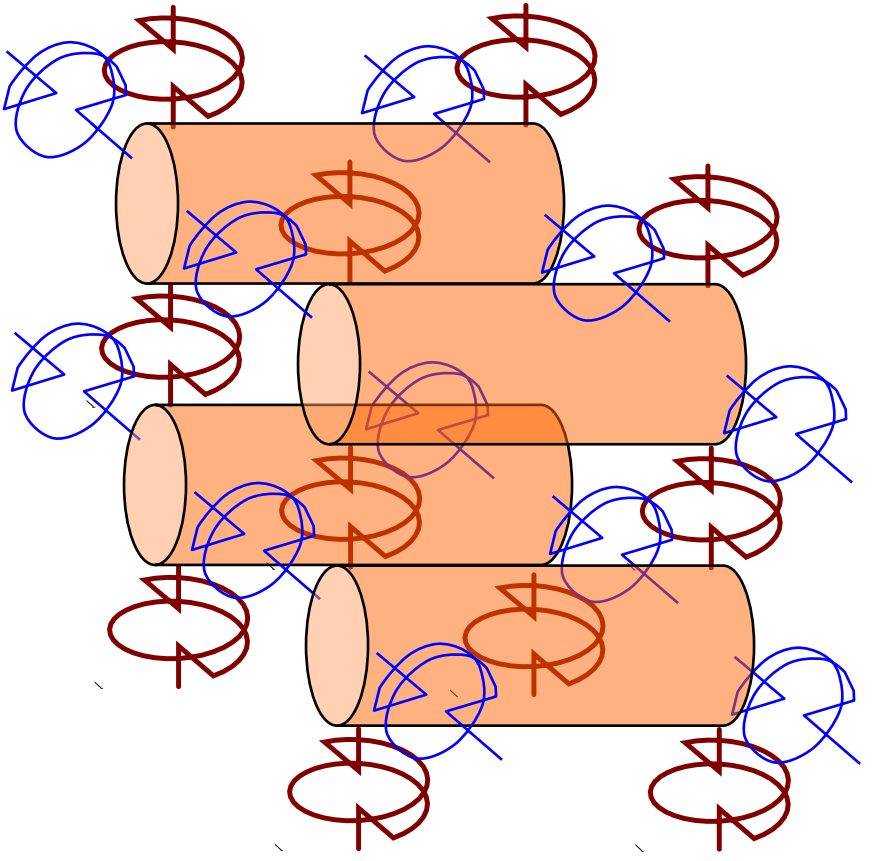
$$\boxed{T = \tfrac{1}{2}\cdot\varepsilon_o(\varepsilon_{\parallel}-\varepsilon_{\perp})\cdot E^2\cdot\sin(2\cdot\theta)}$$

Temperature dependency

RMS dependency

dielectric anisotropy

Order Depend on Springs

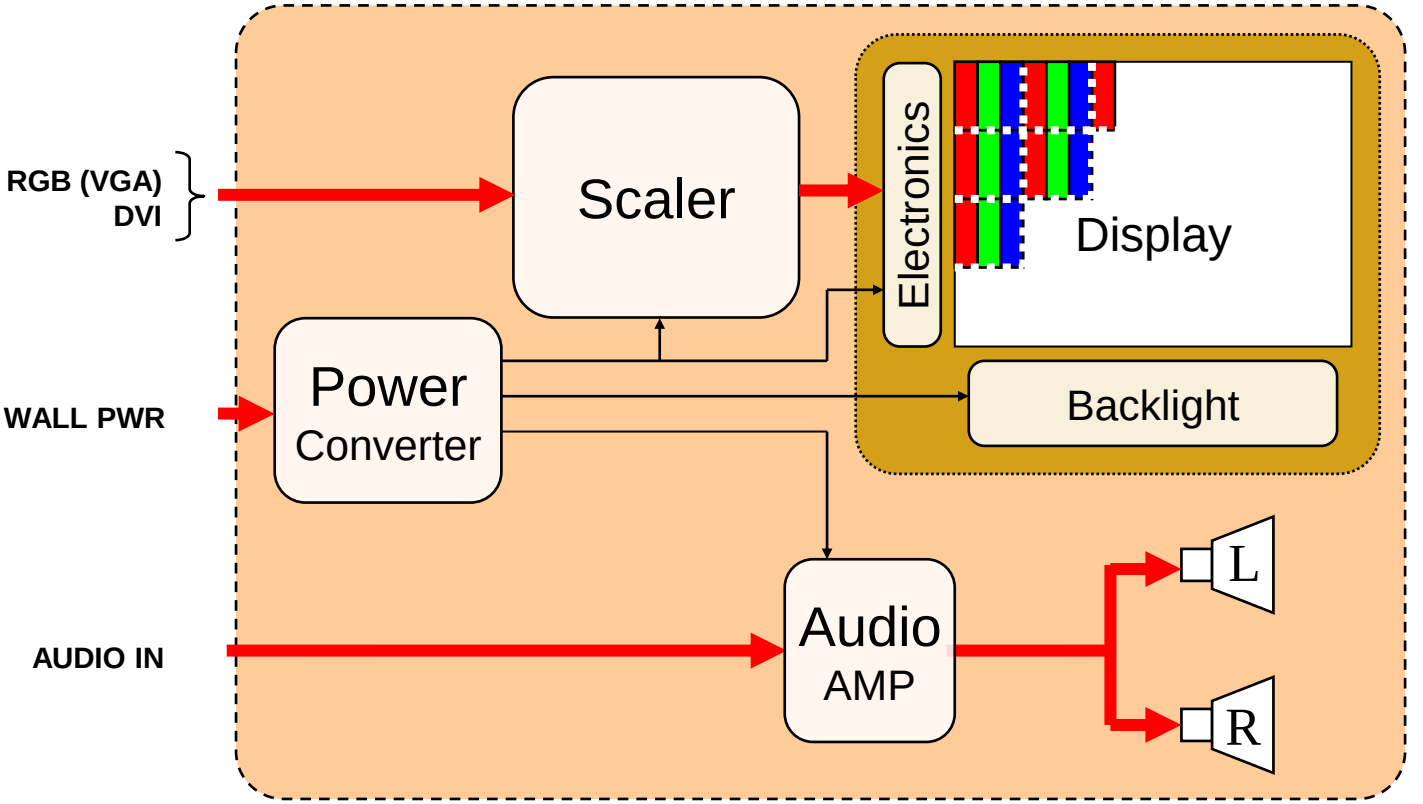


Nematic order is maintained by intermolecular forces which are macroscopically characterized as spring constants for the material.

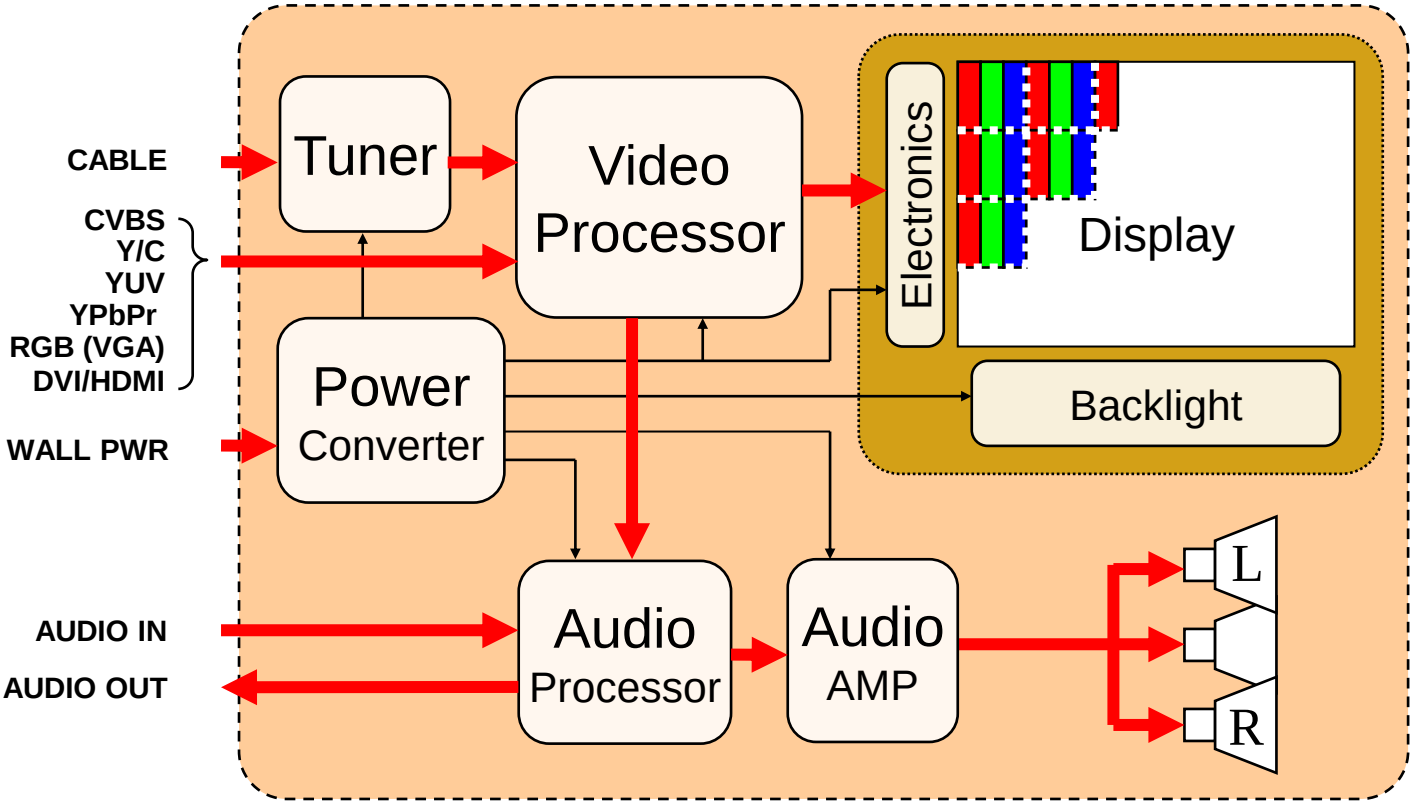
*The **bend**, **twist** and **splay** spring constants restore order in a perturbed system. E-field inducted torque works against these springs*.

The spring constants also depend on temperature

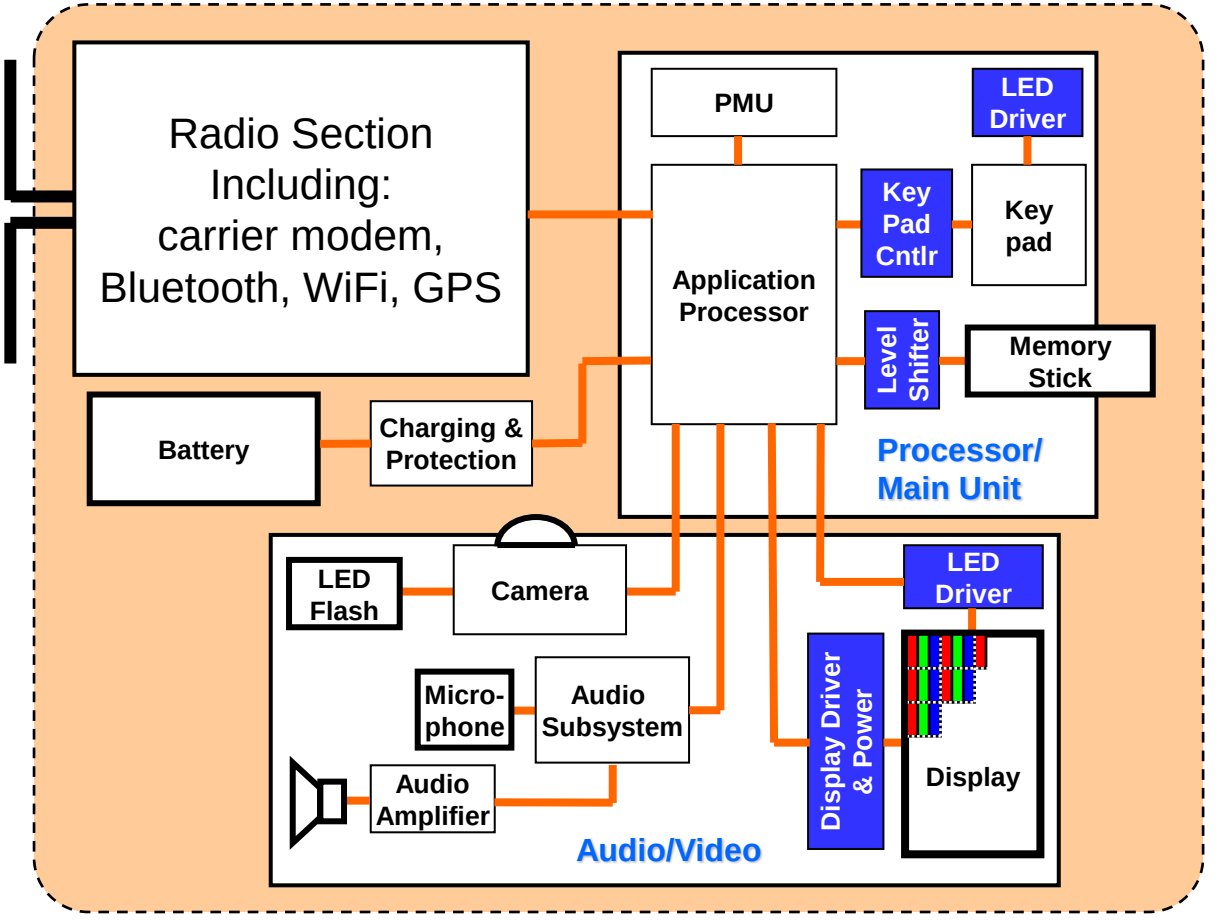
LCD Monitor Block Diagram



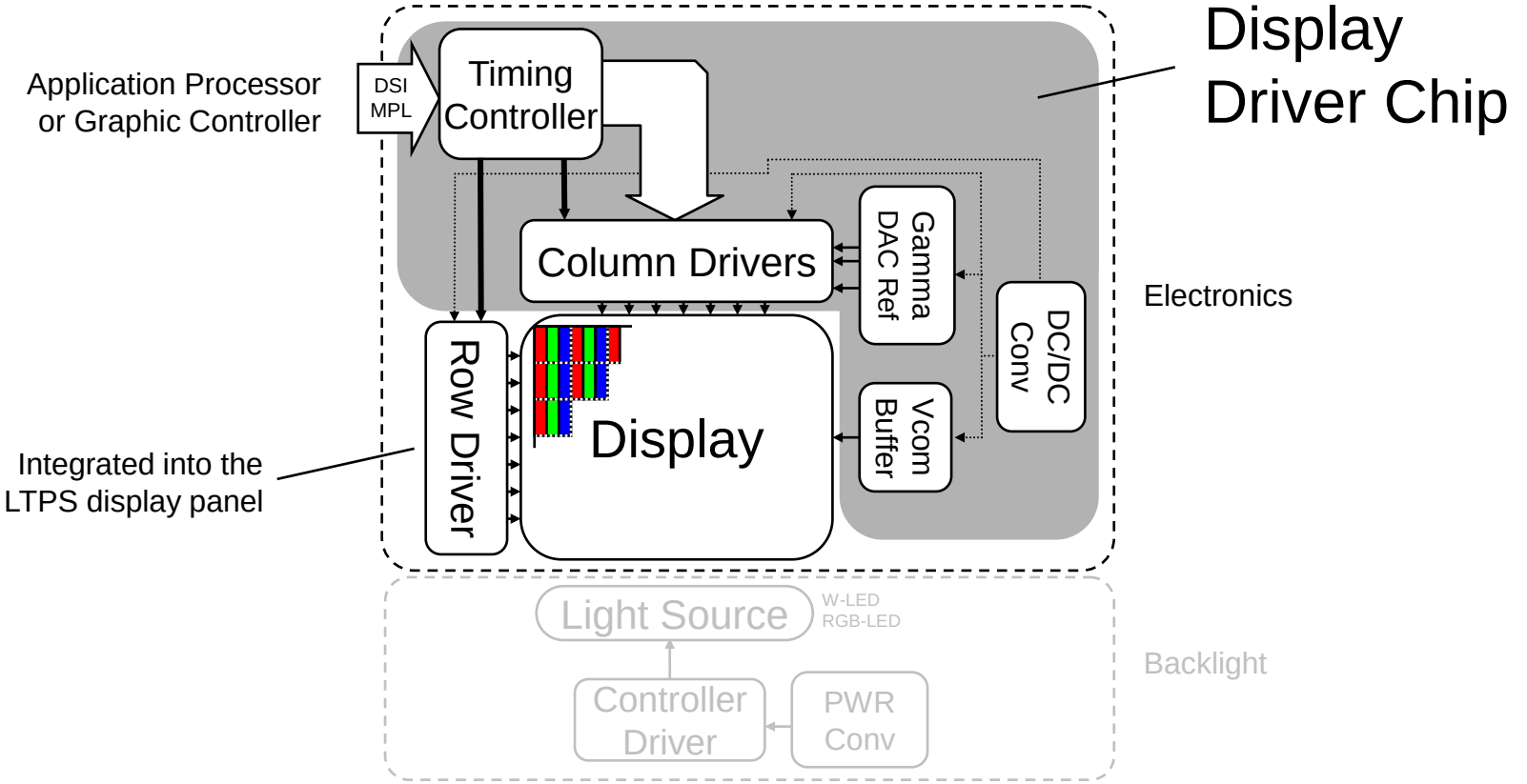
LCD TV Block Diagram



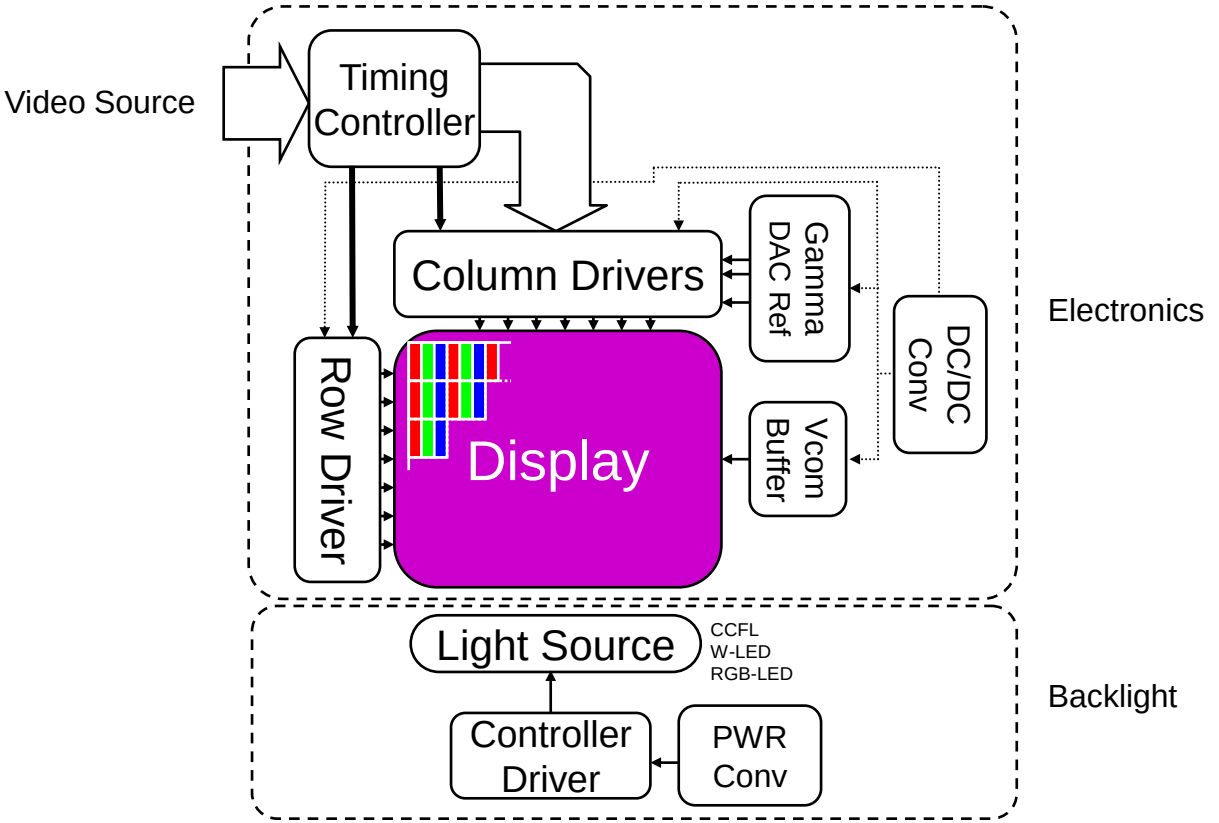
Representative Smart Phone System



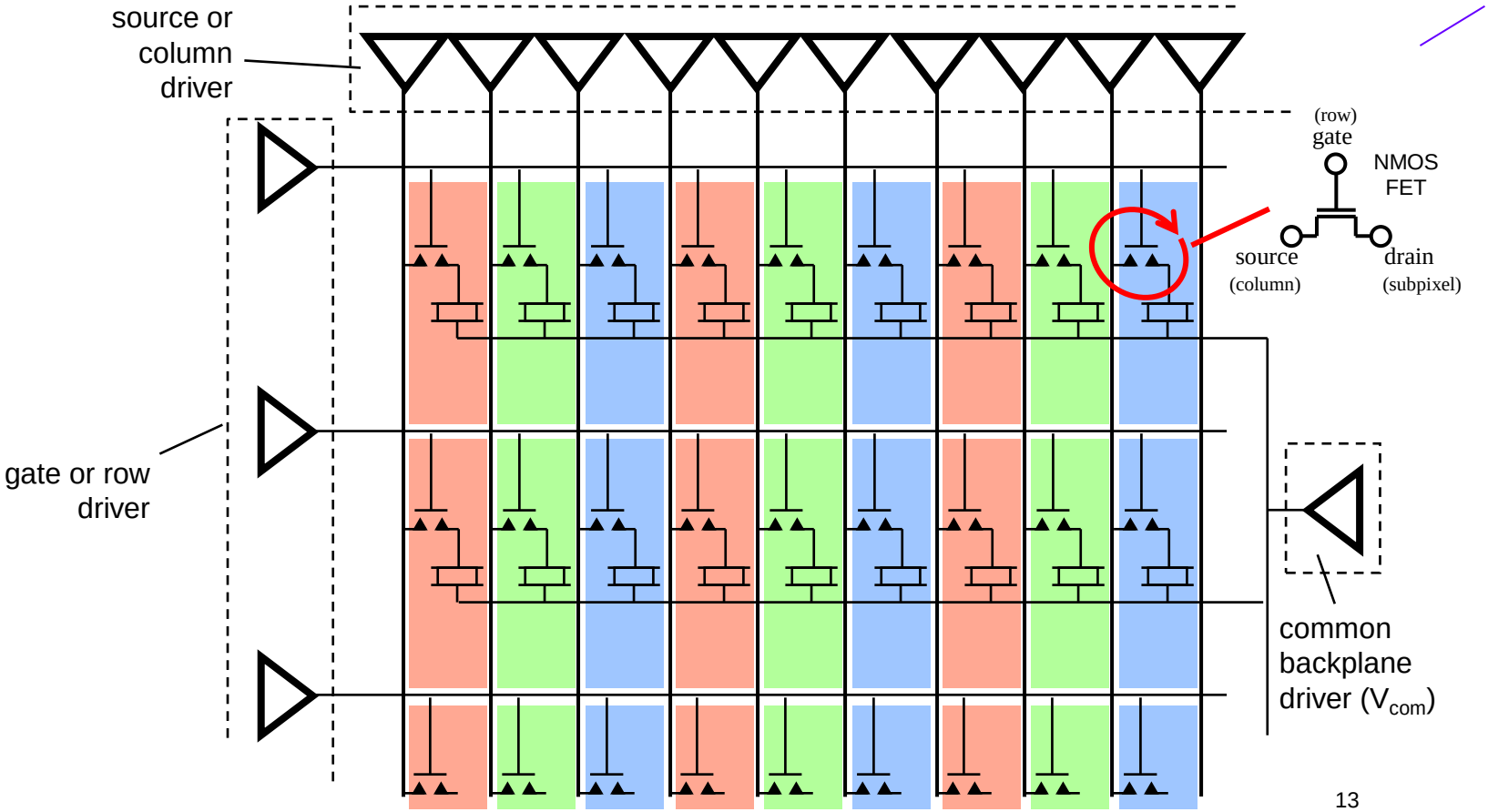
LTPS LCD Functional Diagram



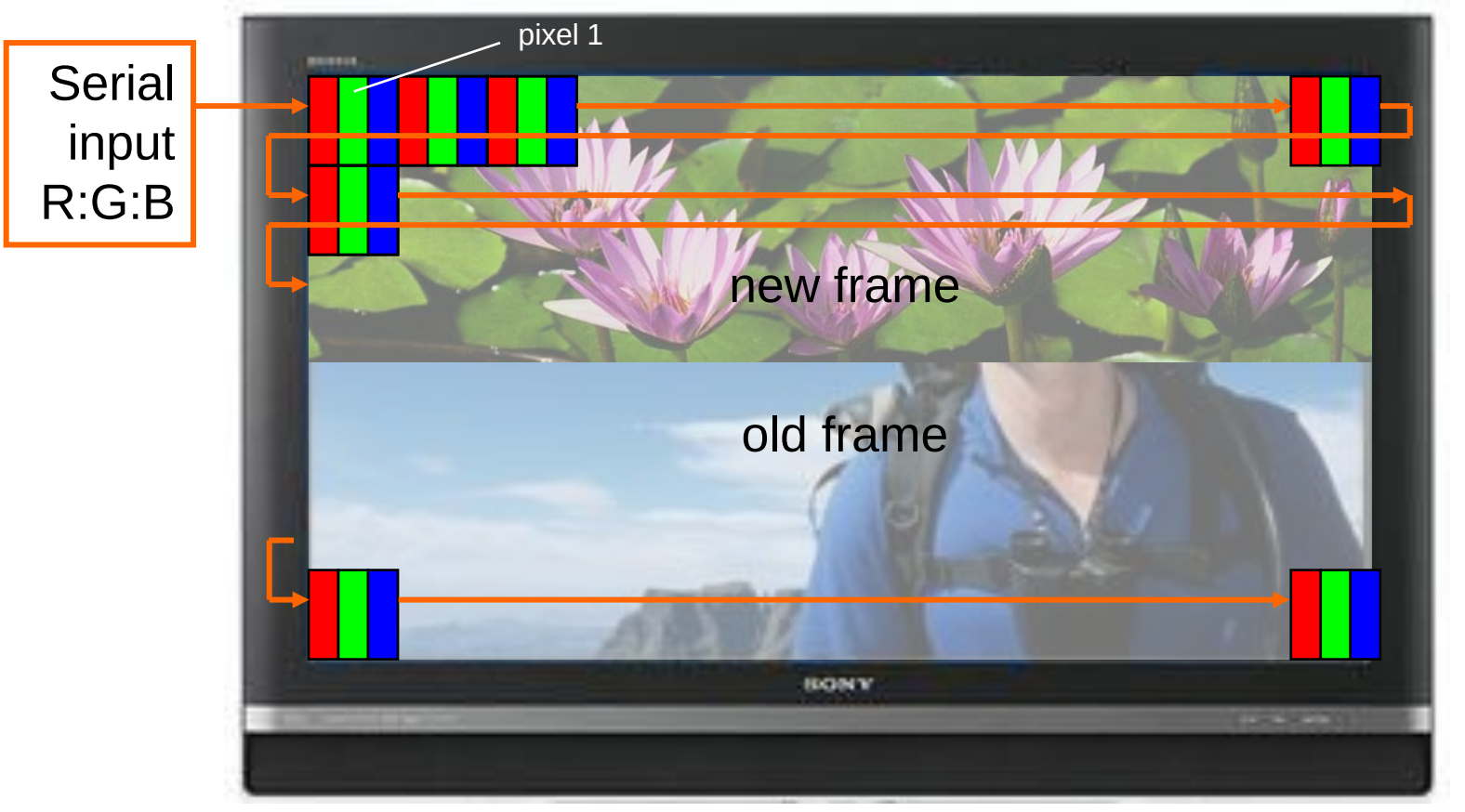
LCD Device Operation



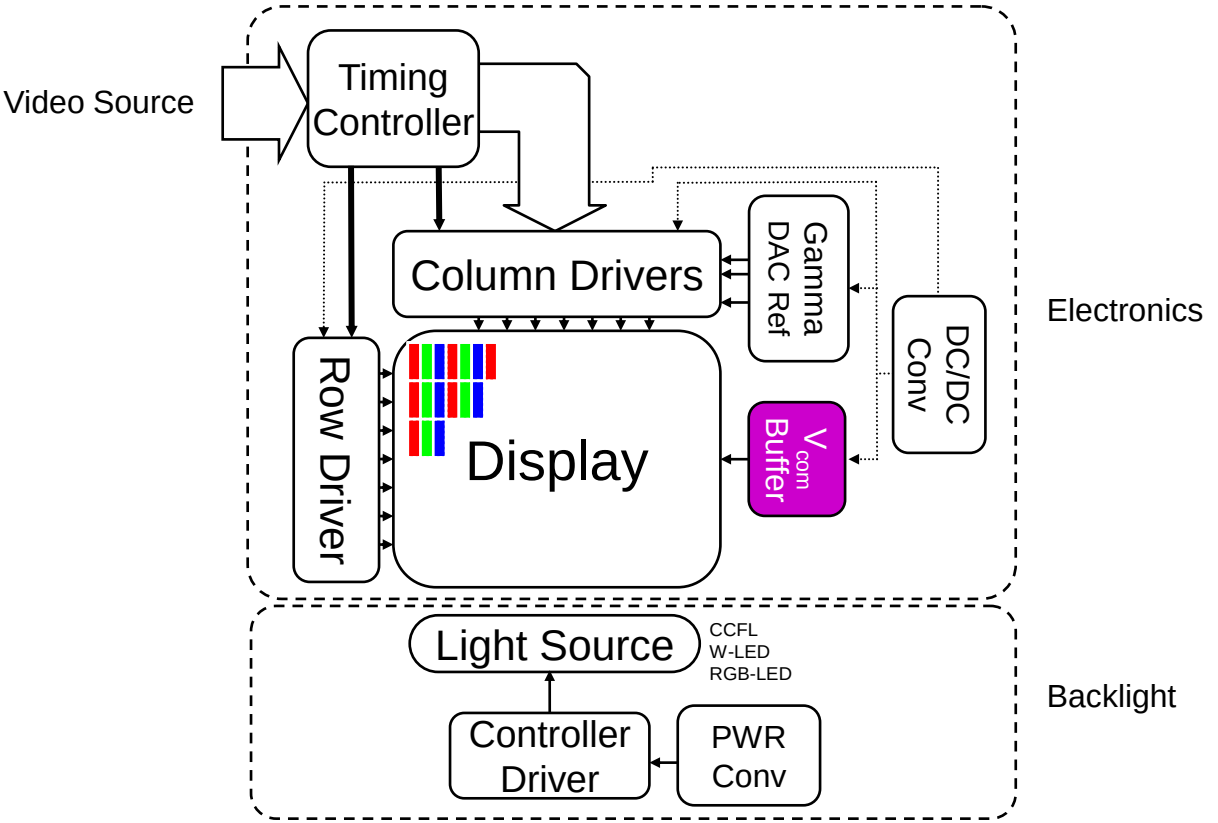
Active Matrix



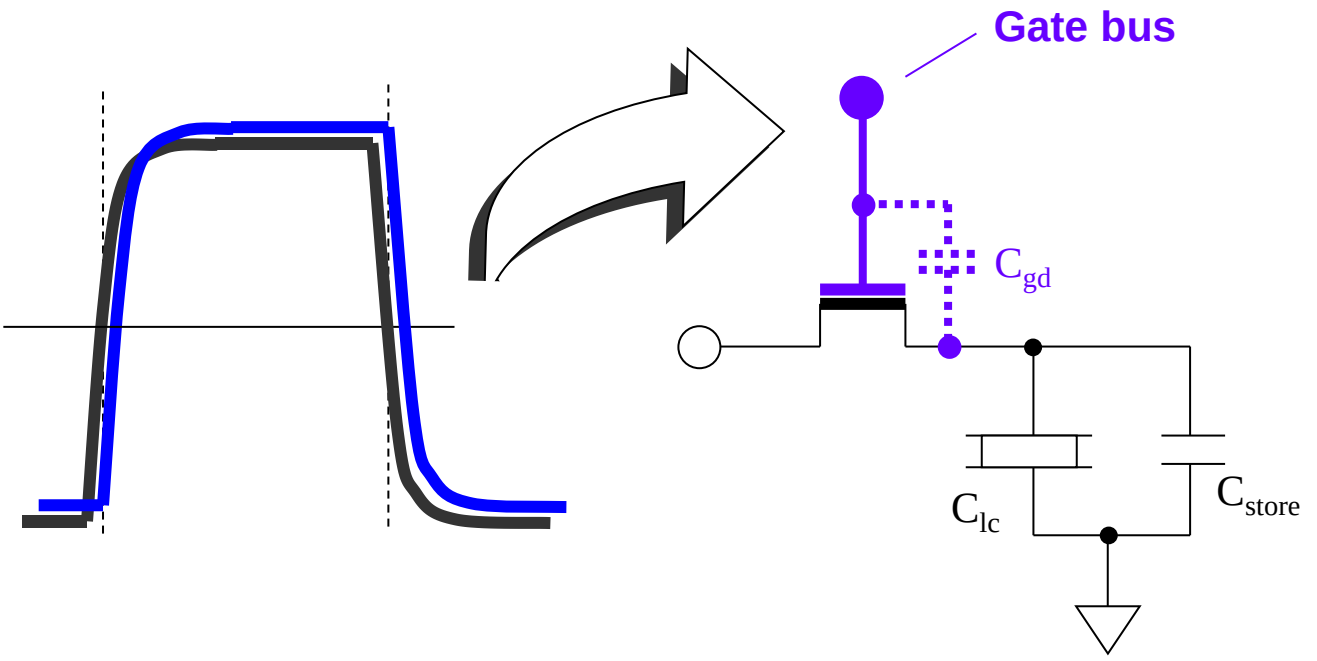
Serial Data Scan Pattern Converted to Row-by-Row



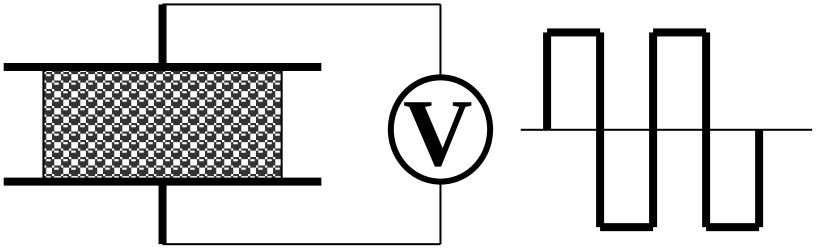
V_{com} Function

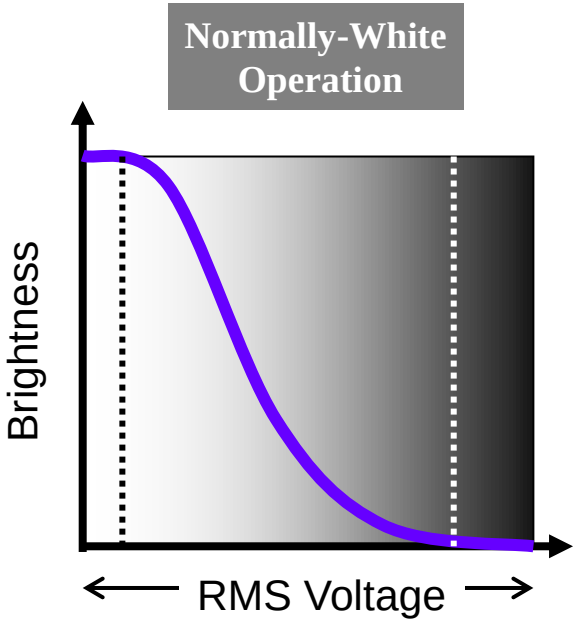


Gate Line Charge Injection



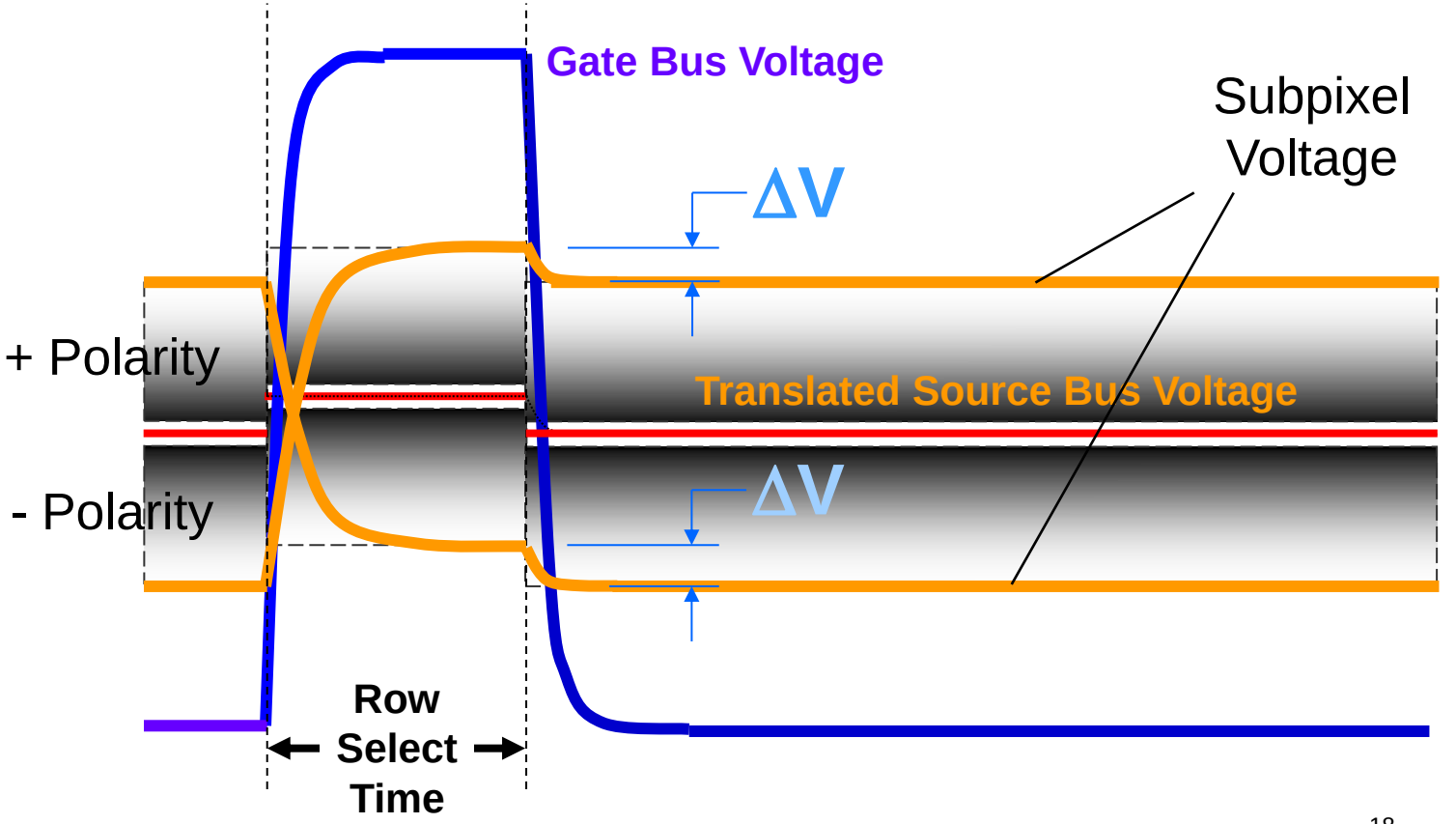
Alternating Voltage Drive



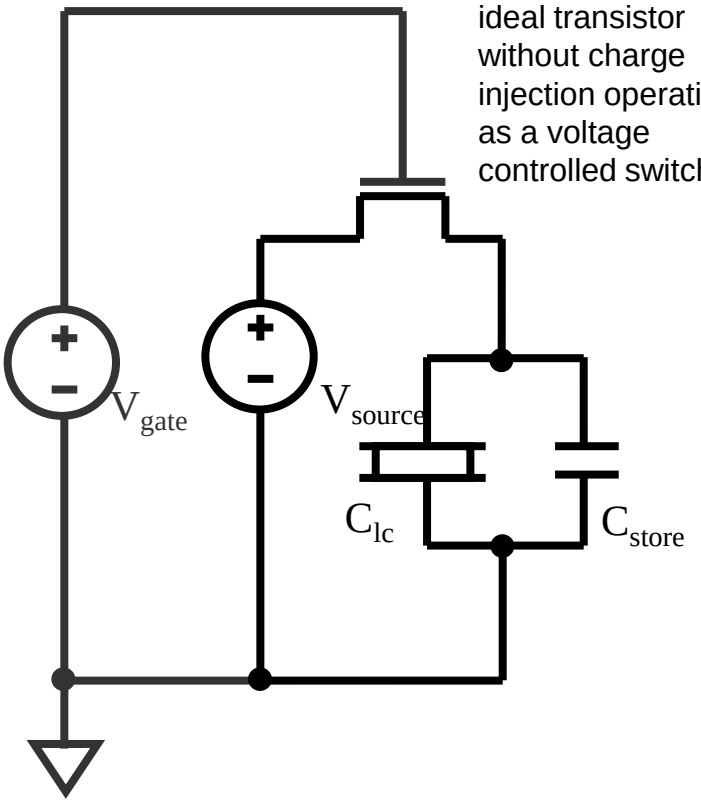


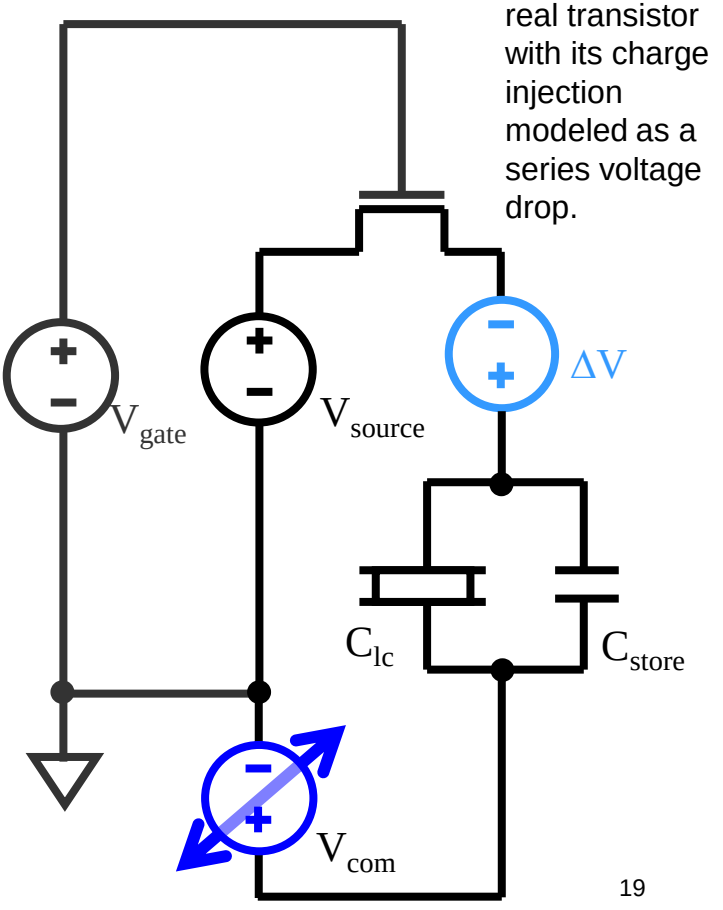
Alternating polarity is used to keep the average voltage value across the LC at zero. This prevents electroplating of ion impurities in the liquid crystal onto the electrodes. Electroplating of contaminants is a major source of image retention (sticking image).

Subpixel Voltage Translation

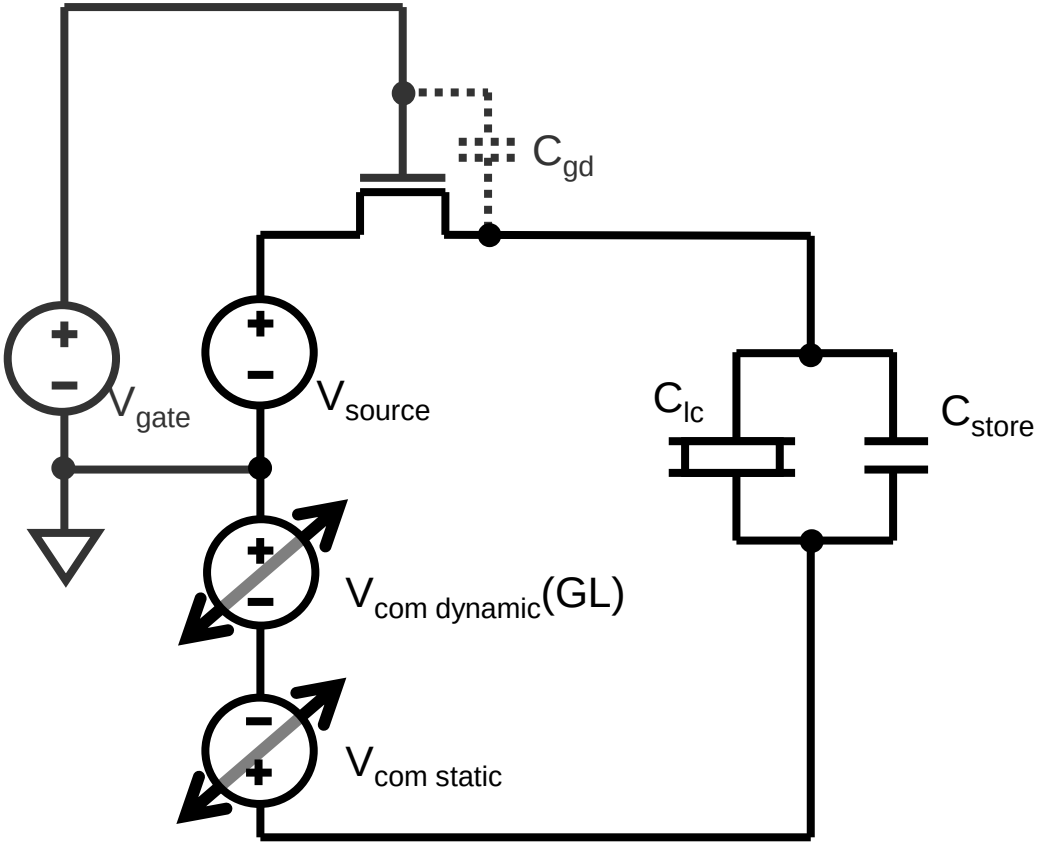


V_{com} Equivalent Circuit at the Subpixel Level

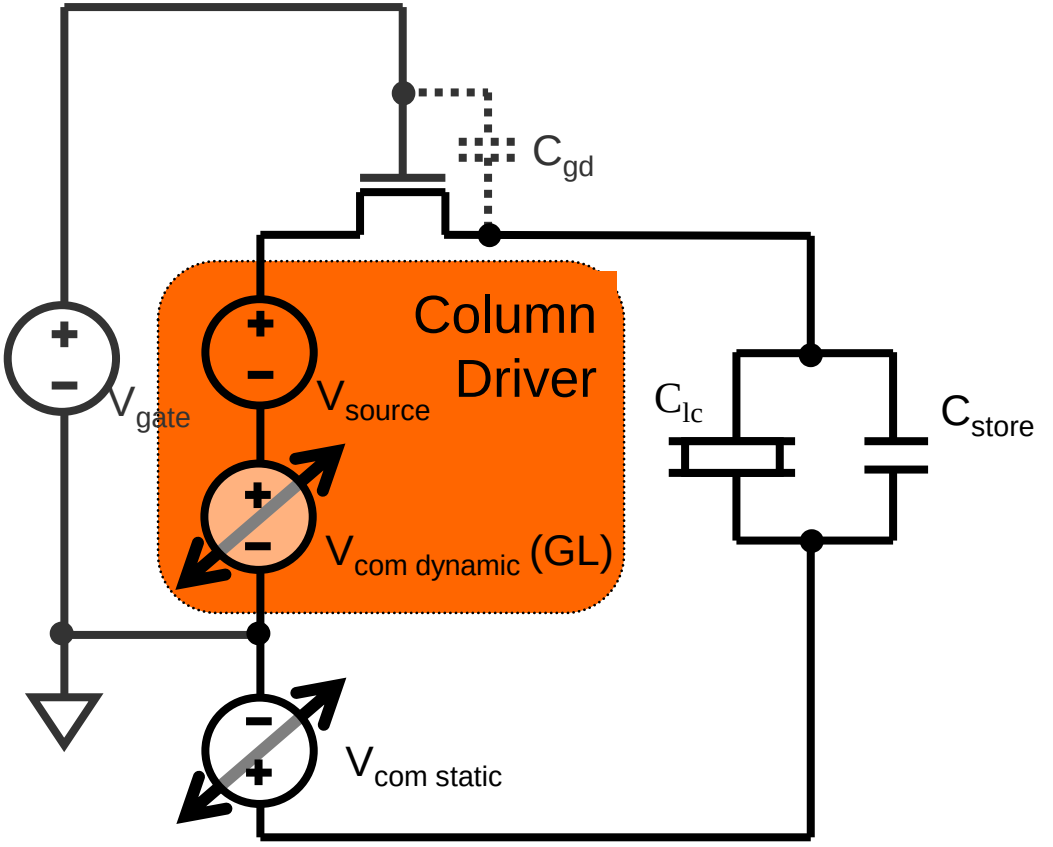




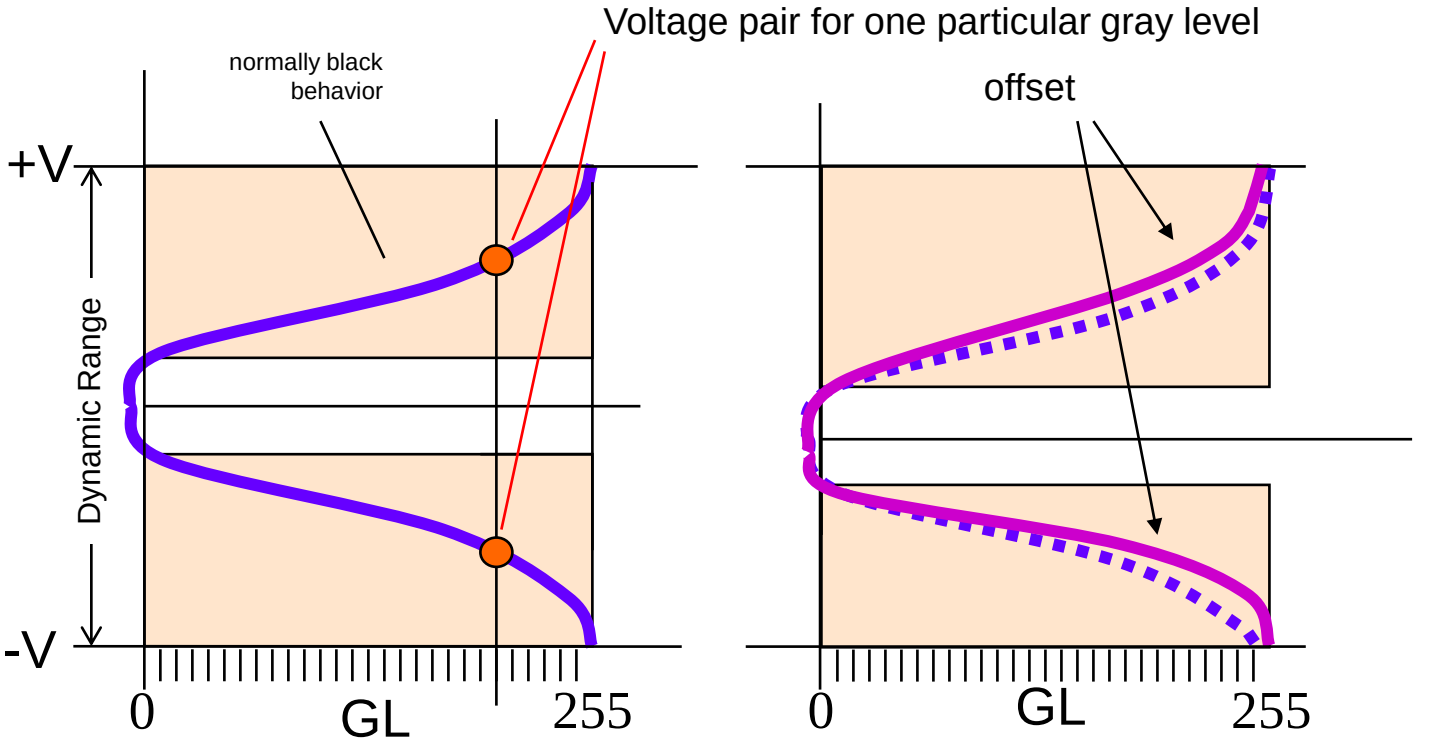
Static and Dynamic Vcom



Grayscale Dependent Offset



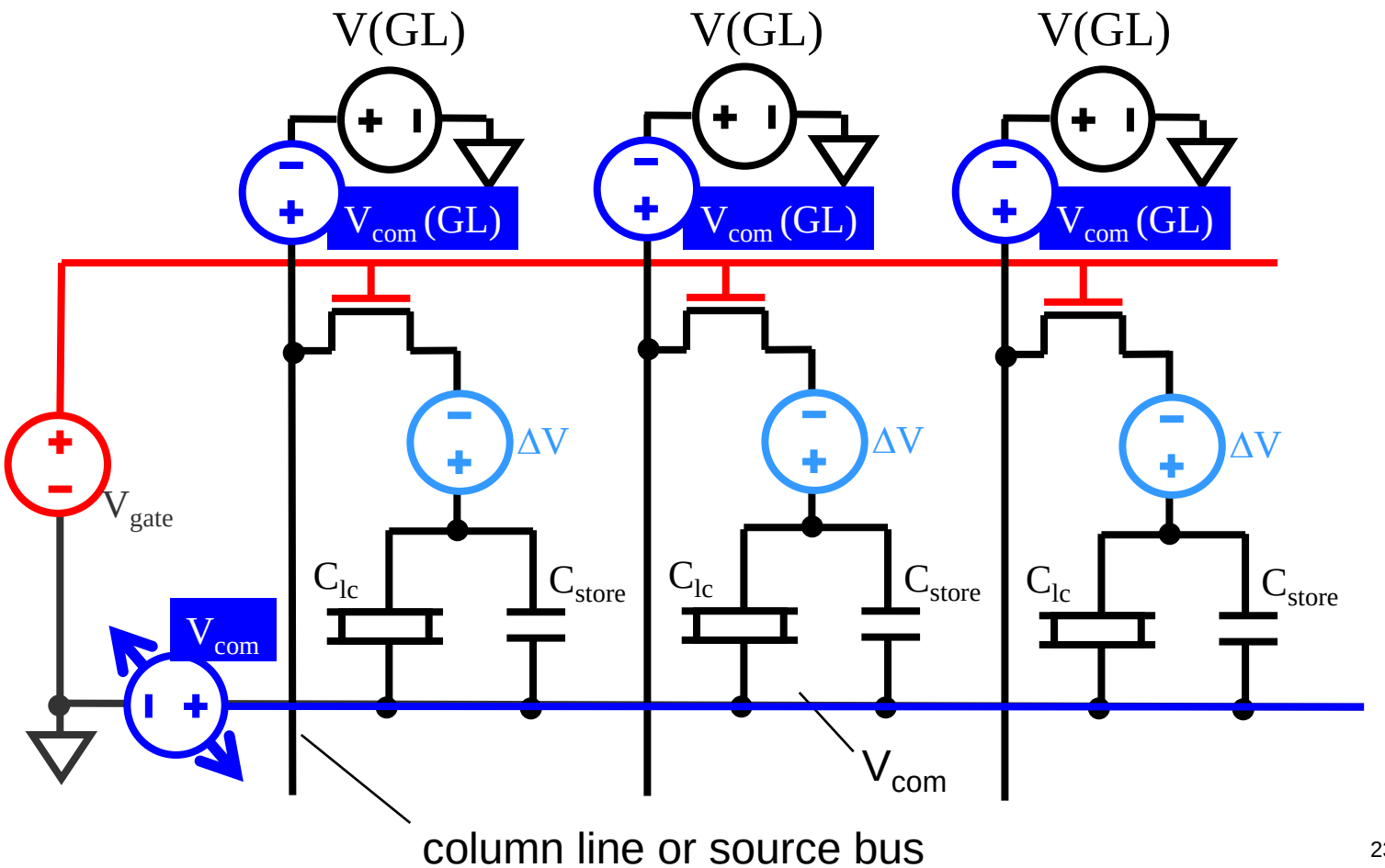
Adding Dynamic V_{com} to each gray level of the Column Driver



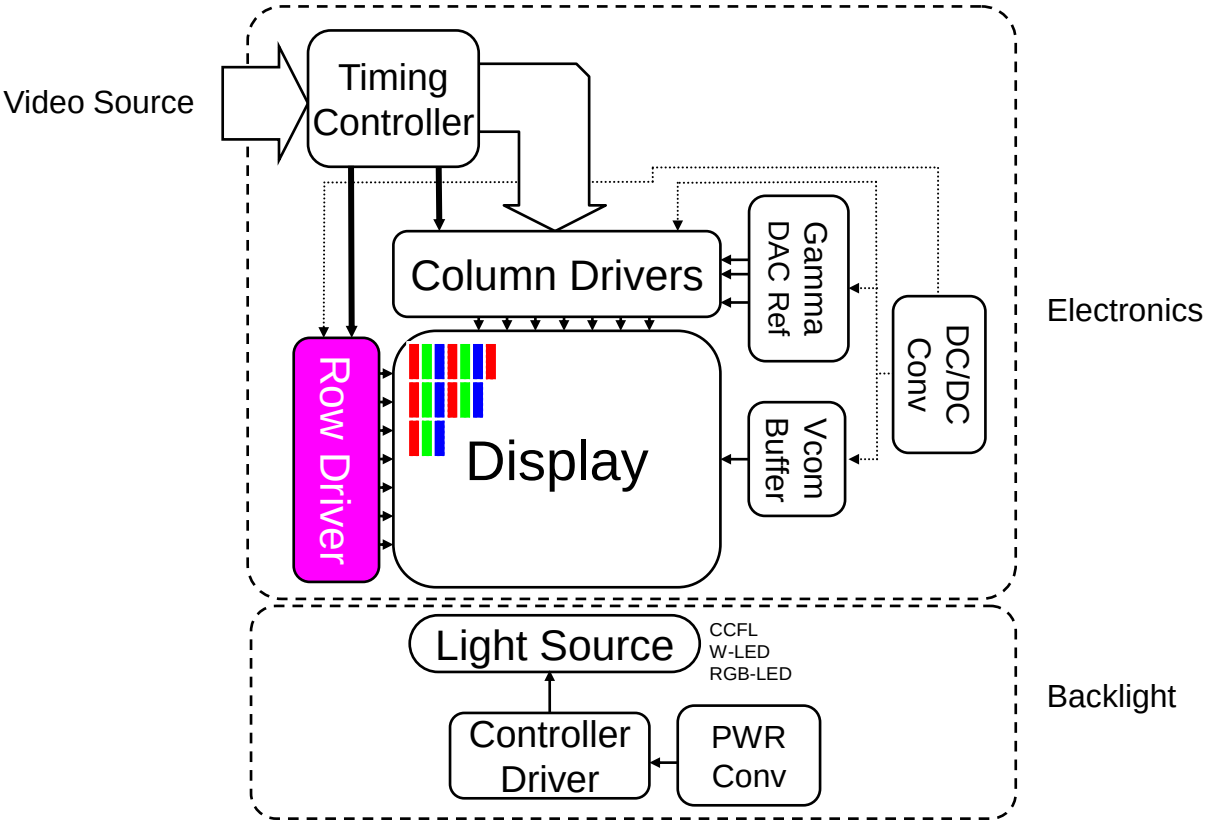
Symmetric
Inverse Gamma Curve

Asymmetric
Inverse Gamma Curve Correcting for ΔV

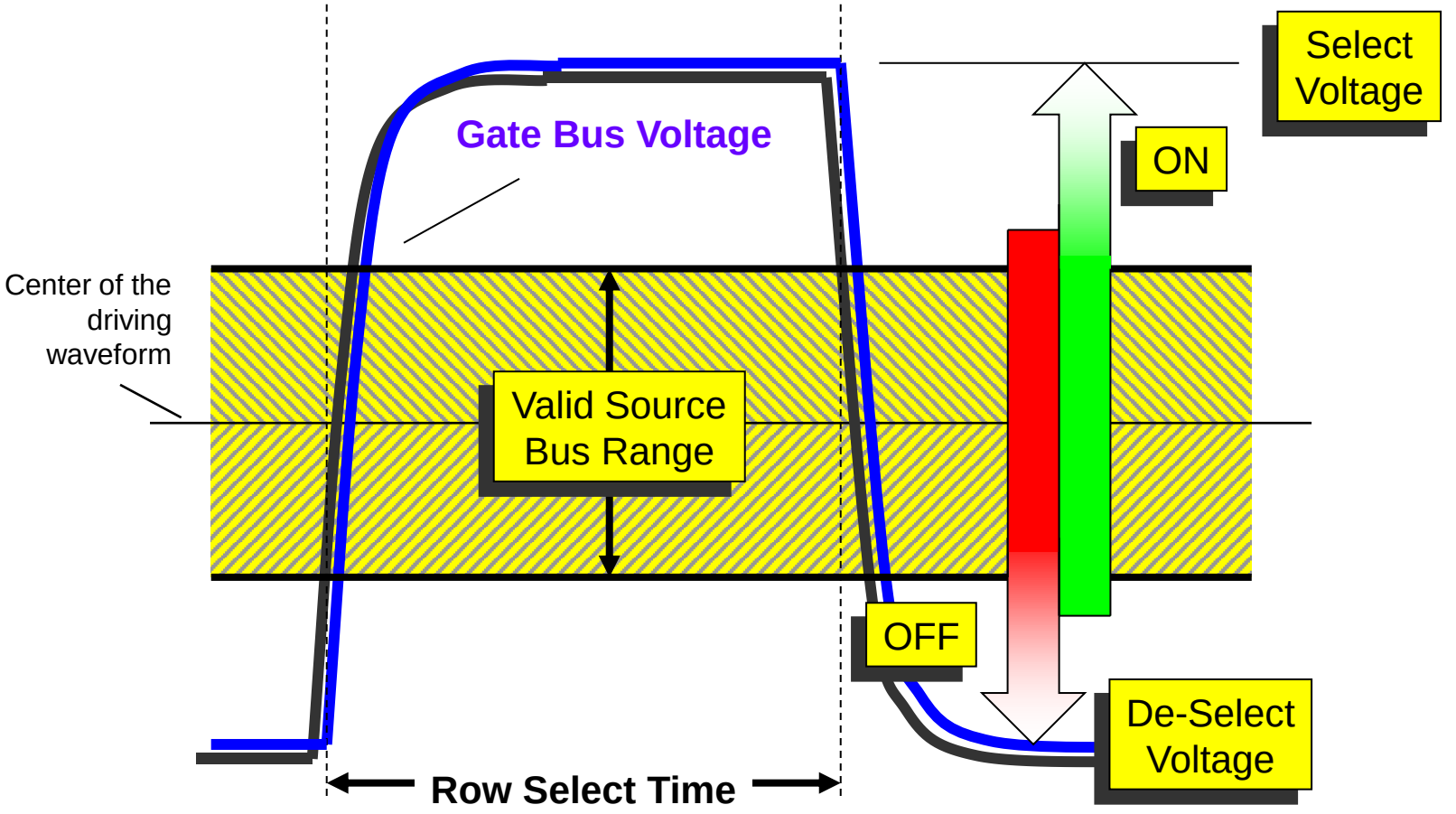
Corrected Matrix



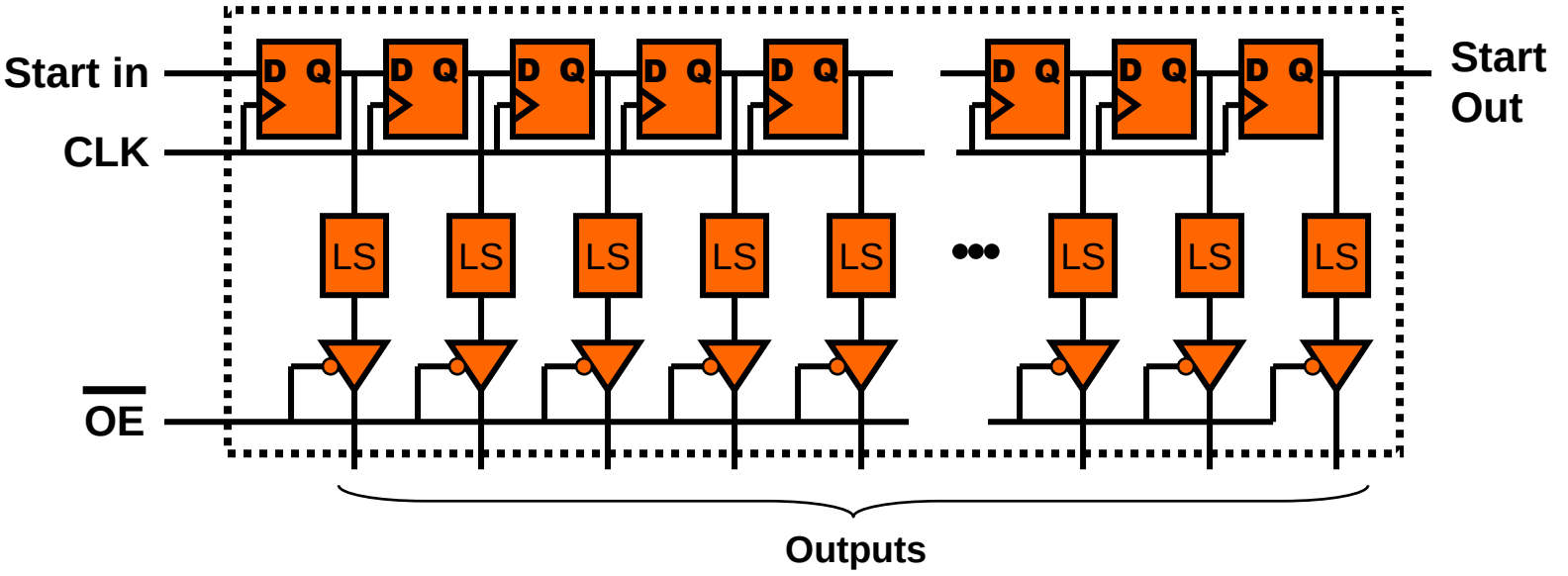
Row Driver Operation



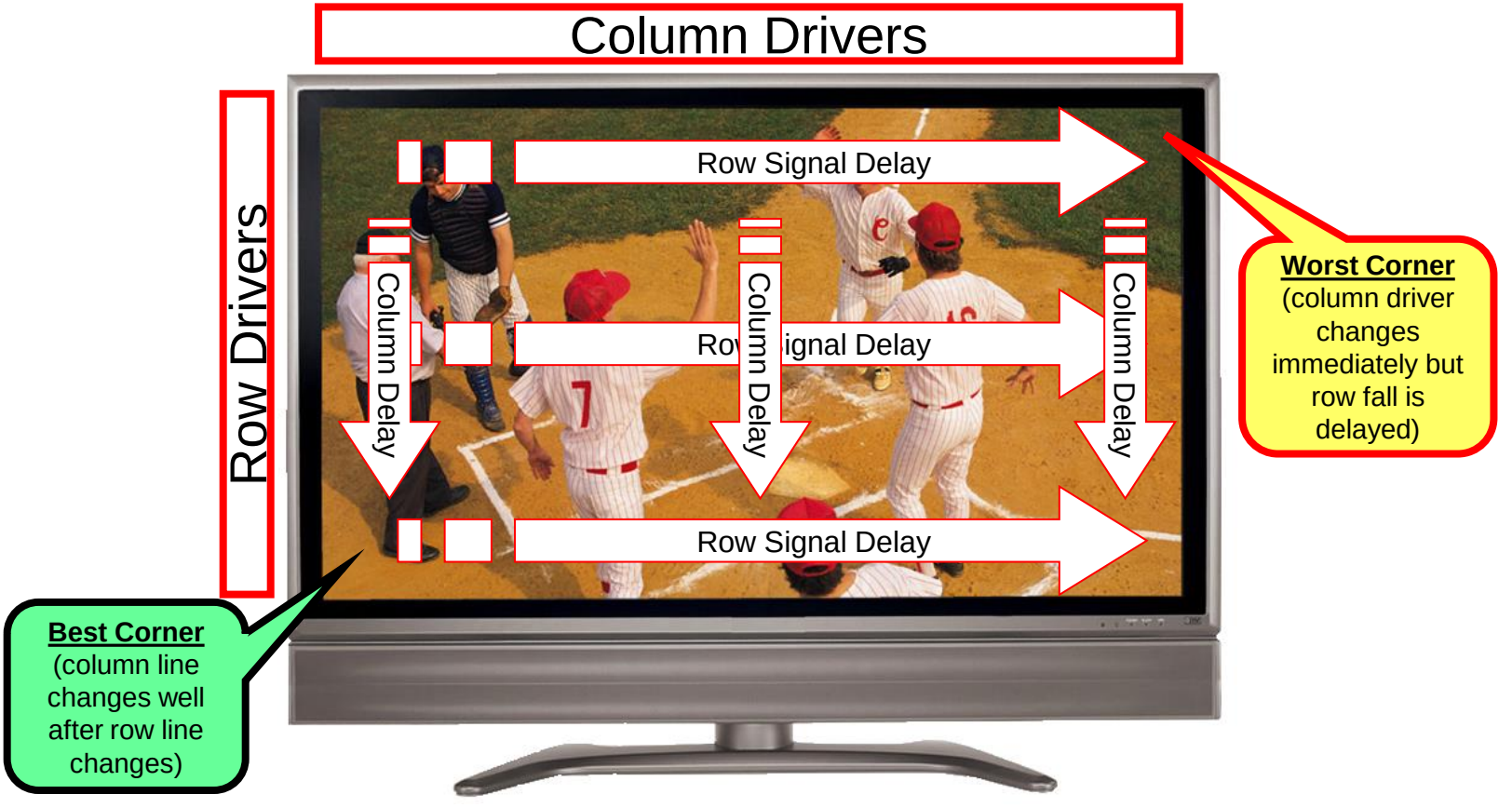
Gate and Source Voltages



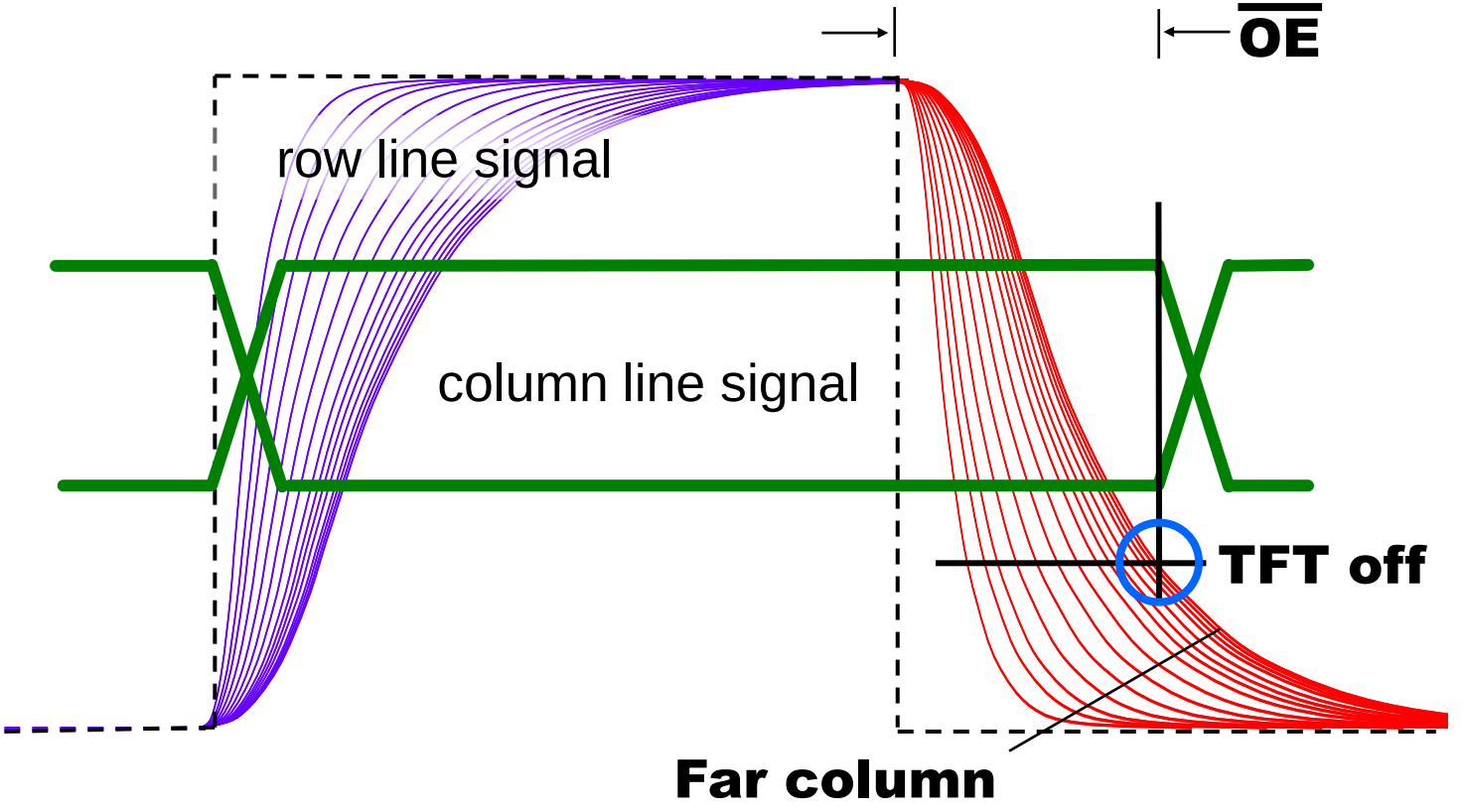
Row Driver Block Diagram



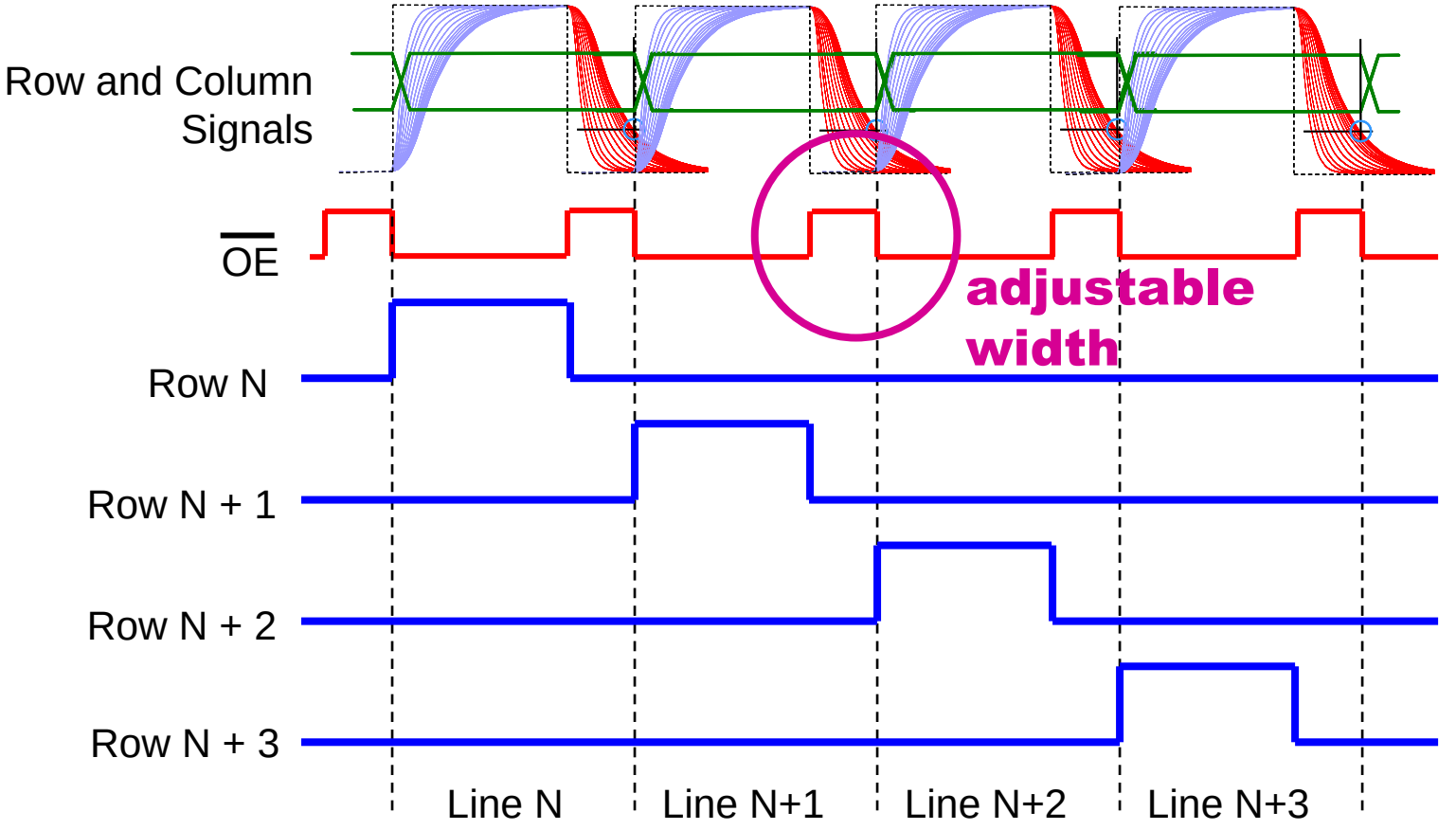
AMLCD Address Signal Propagation



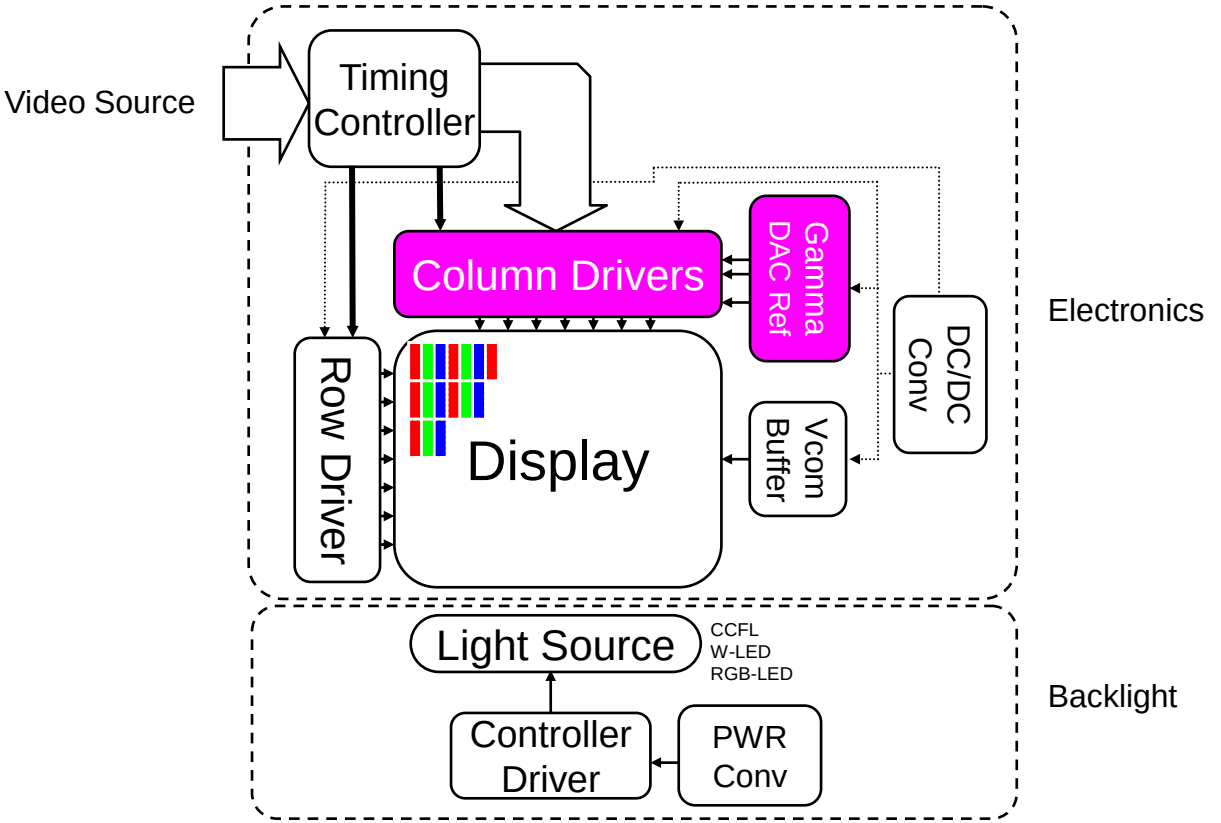
Required Row Select Pulse for both Near and Far Column



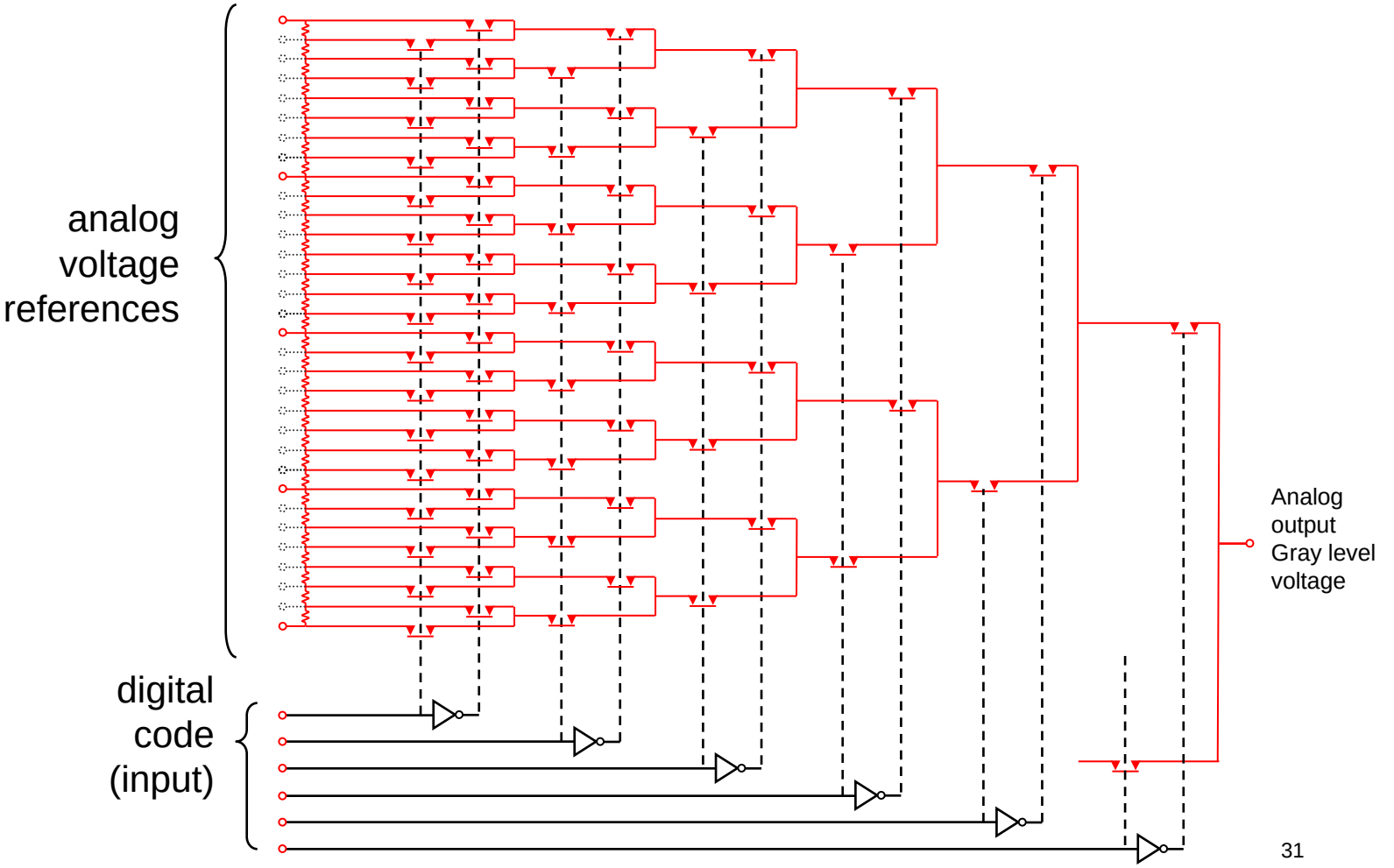
Conventional Solution



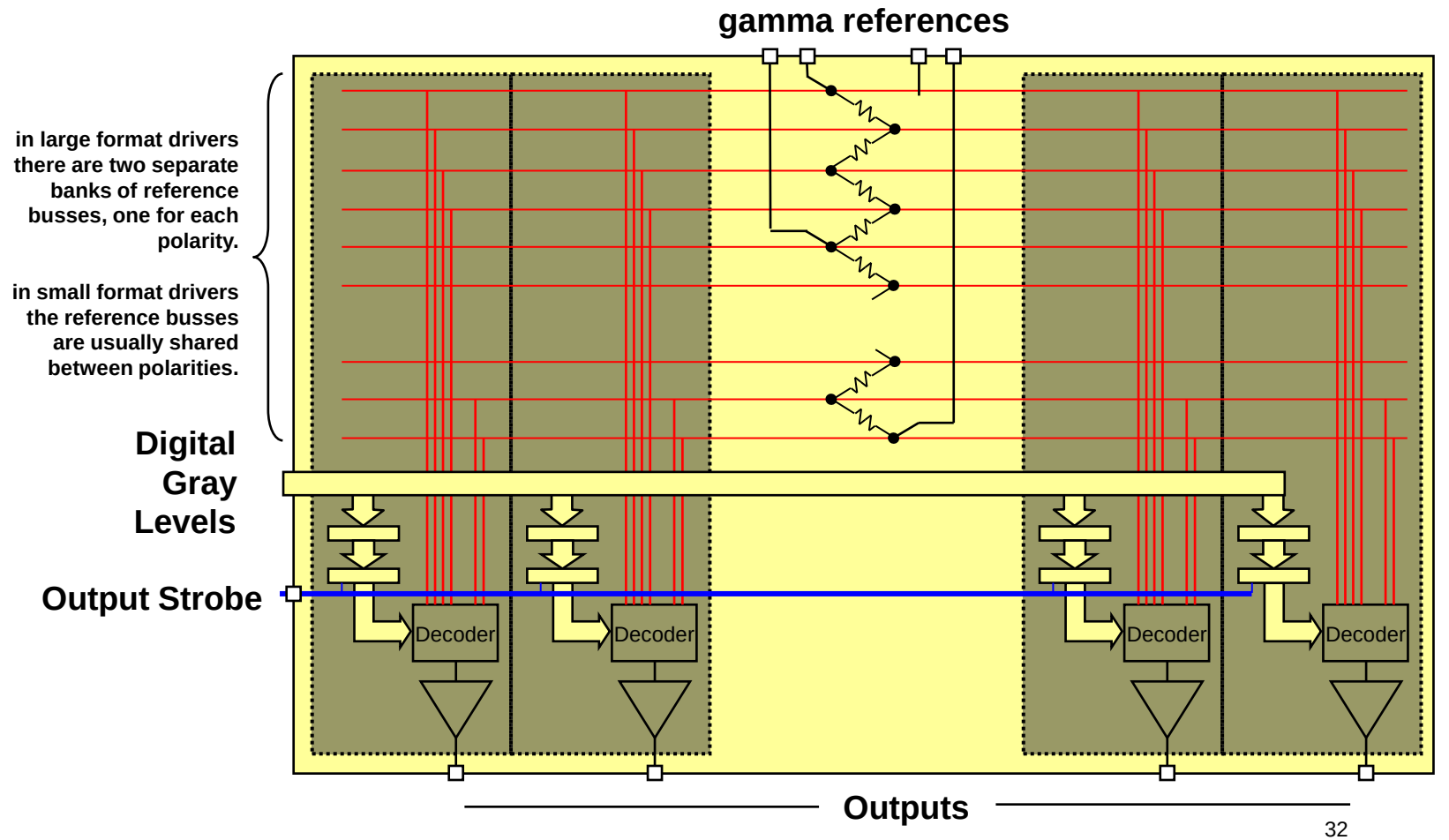
Column Driver Operation



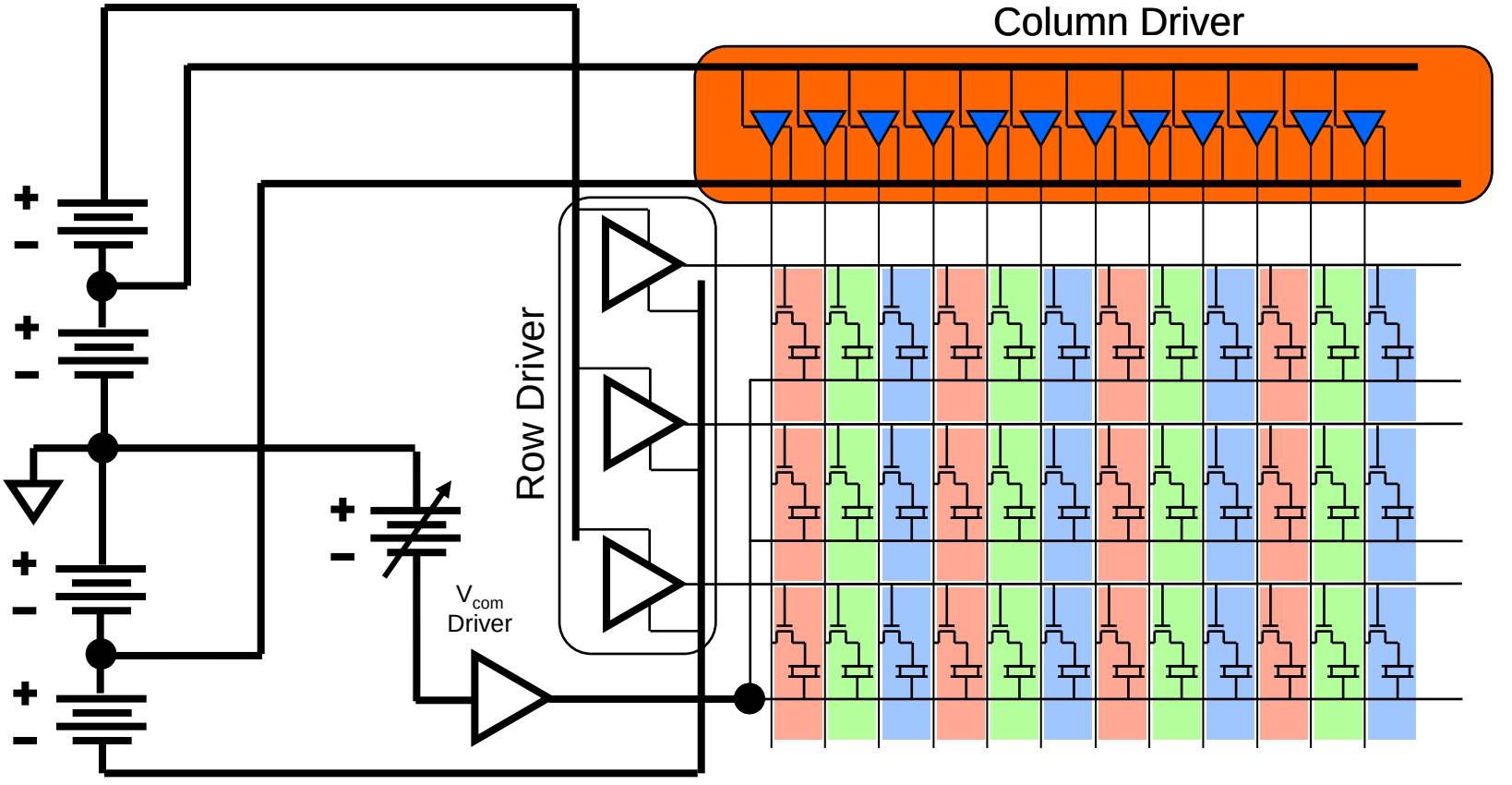
Simplified, 6-bit (64:1), R-DAC



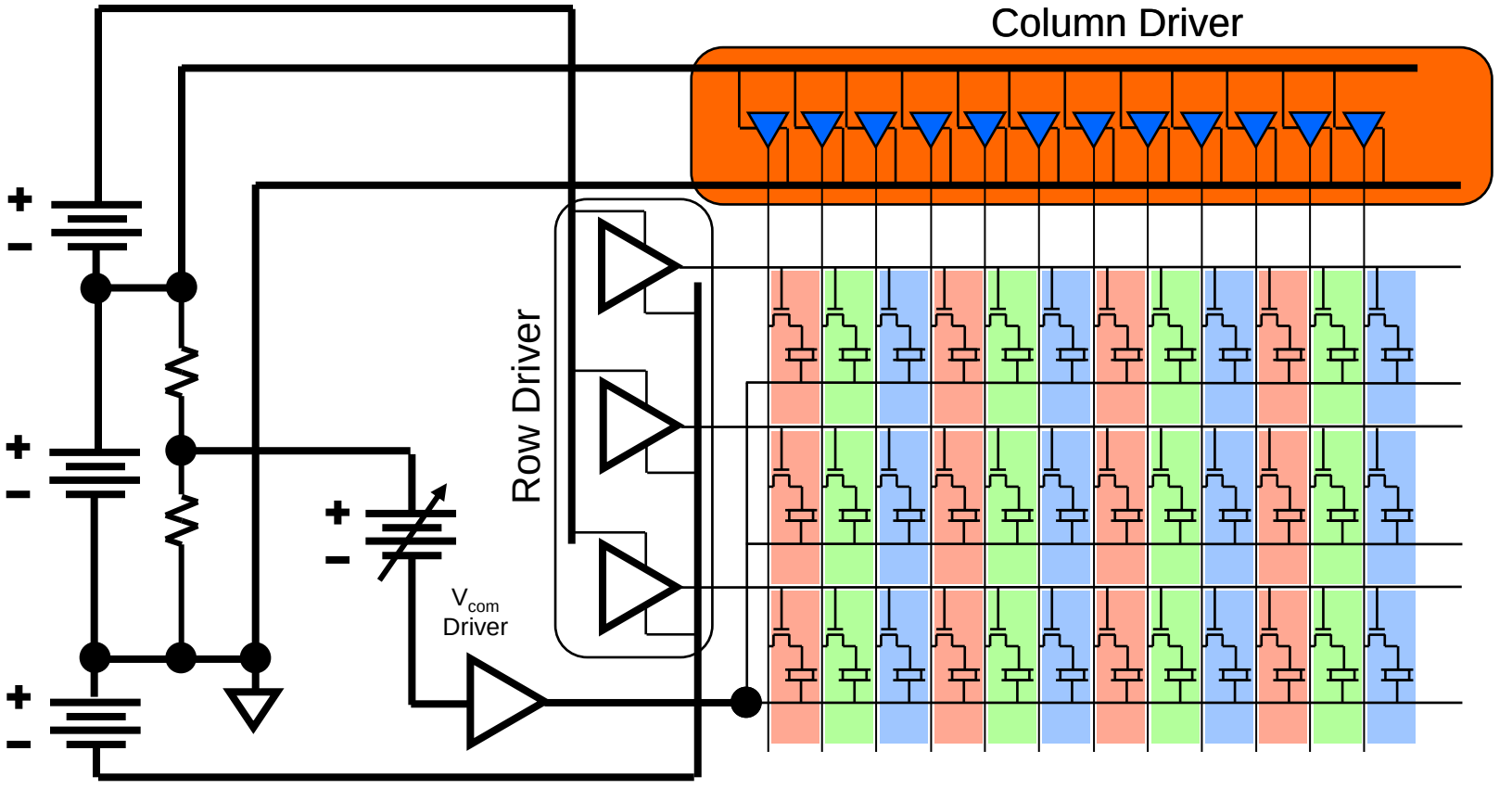
Column Driver Block Diagram



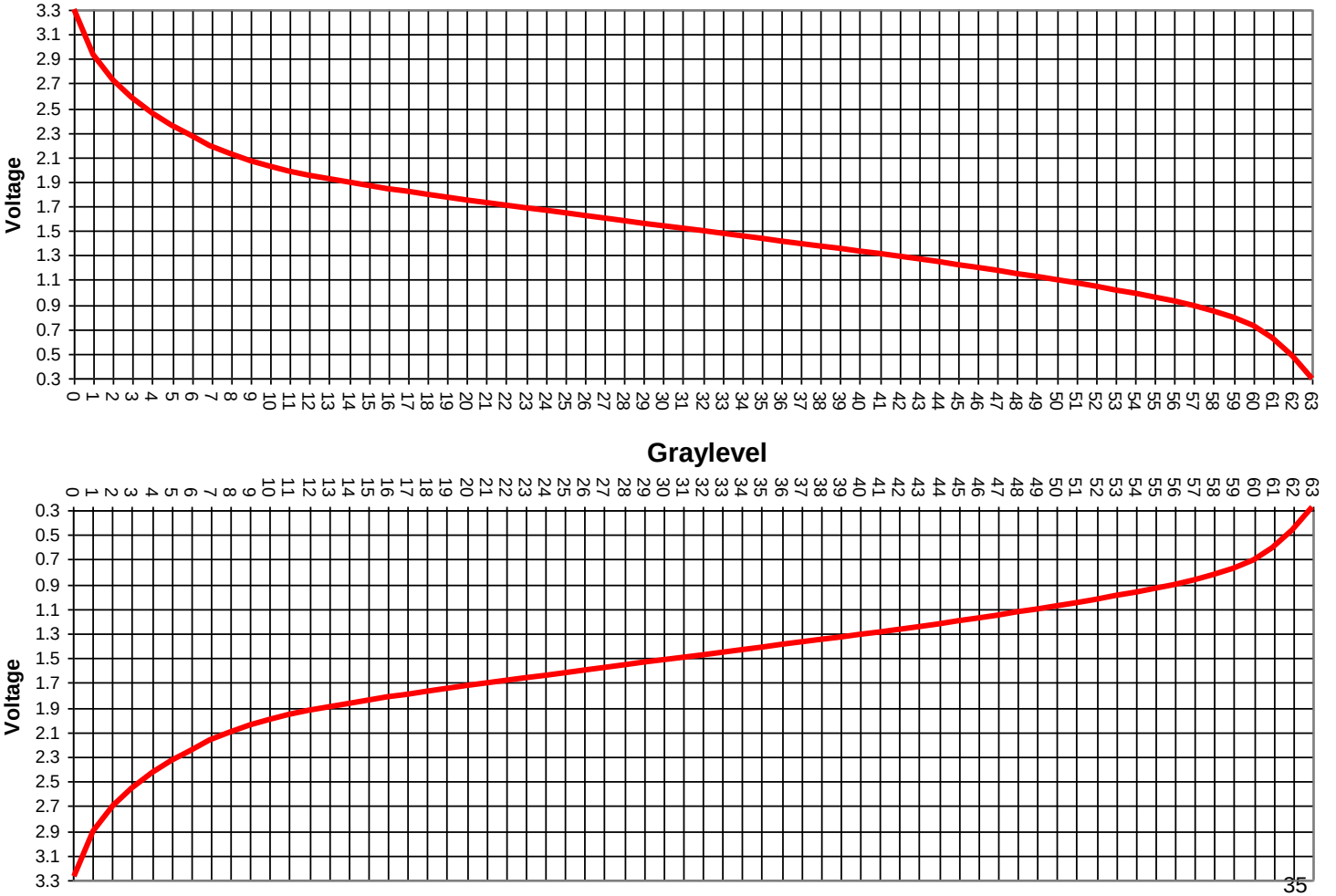
Direct Drive Column Driver



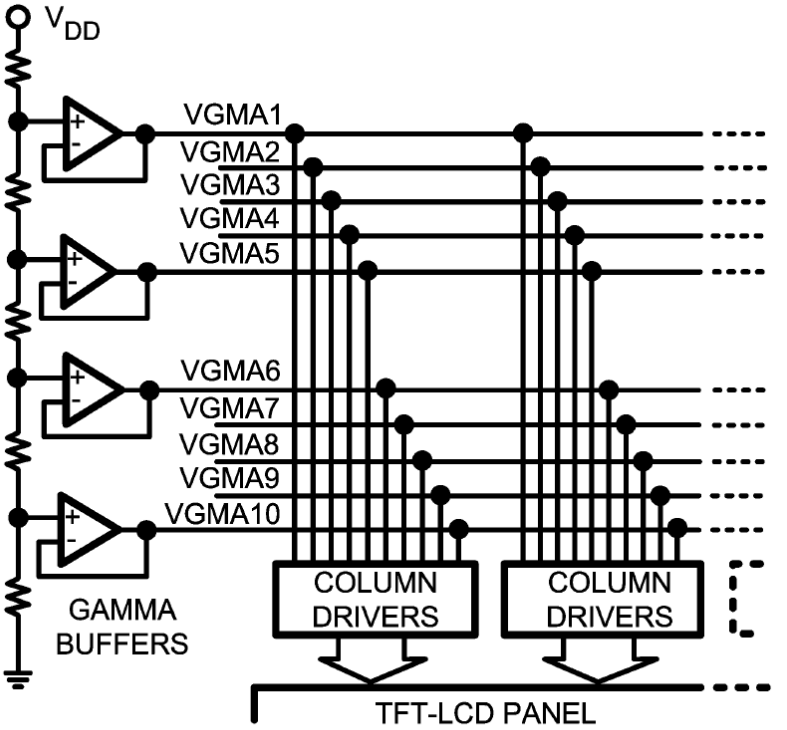
Direct Drive Column Driver



Normally-White Direct Drive

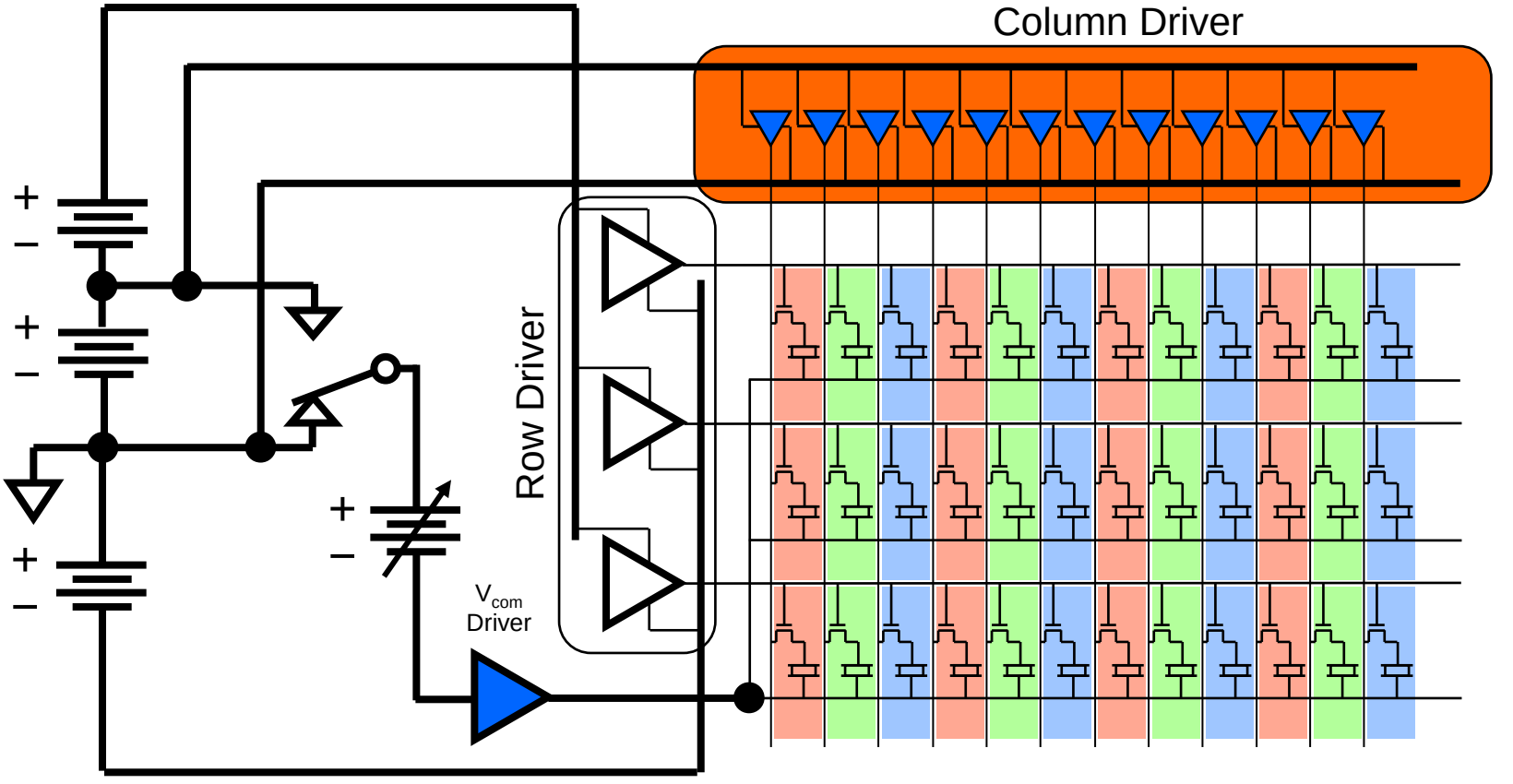


Gamma References

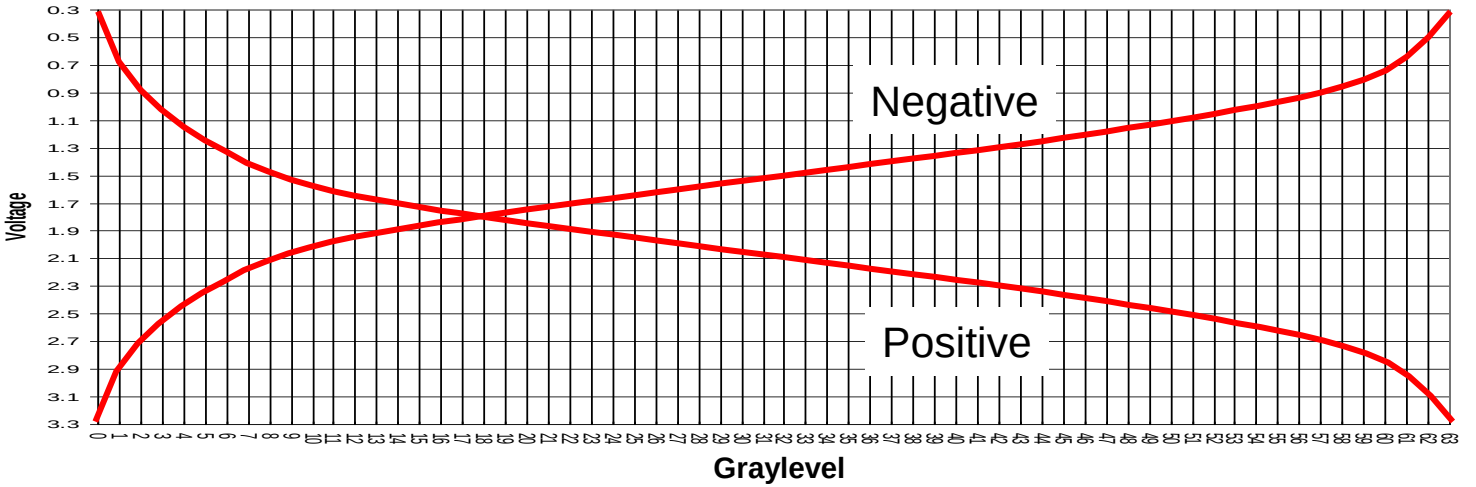


20059234

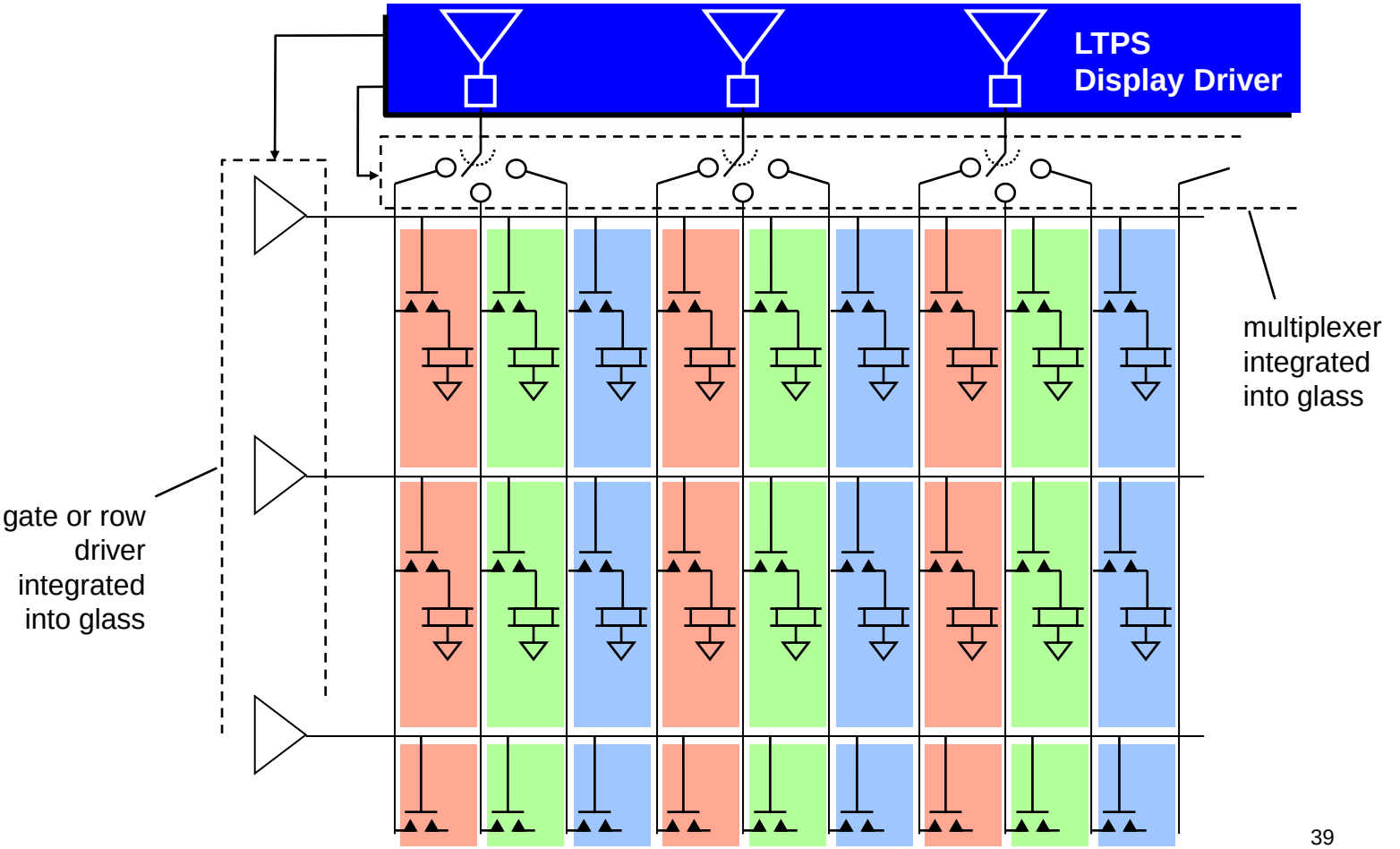
V_{com} Modulation (AC V_{com})



V_{com} Modulation Inverse Gamma

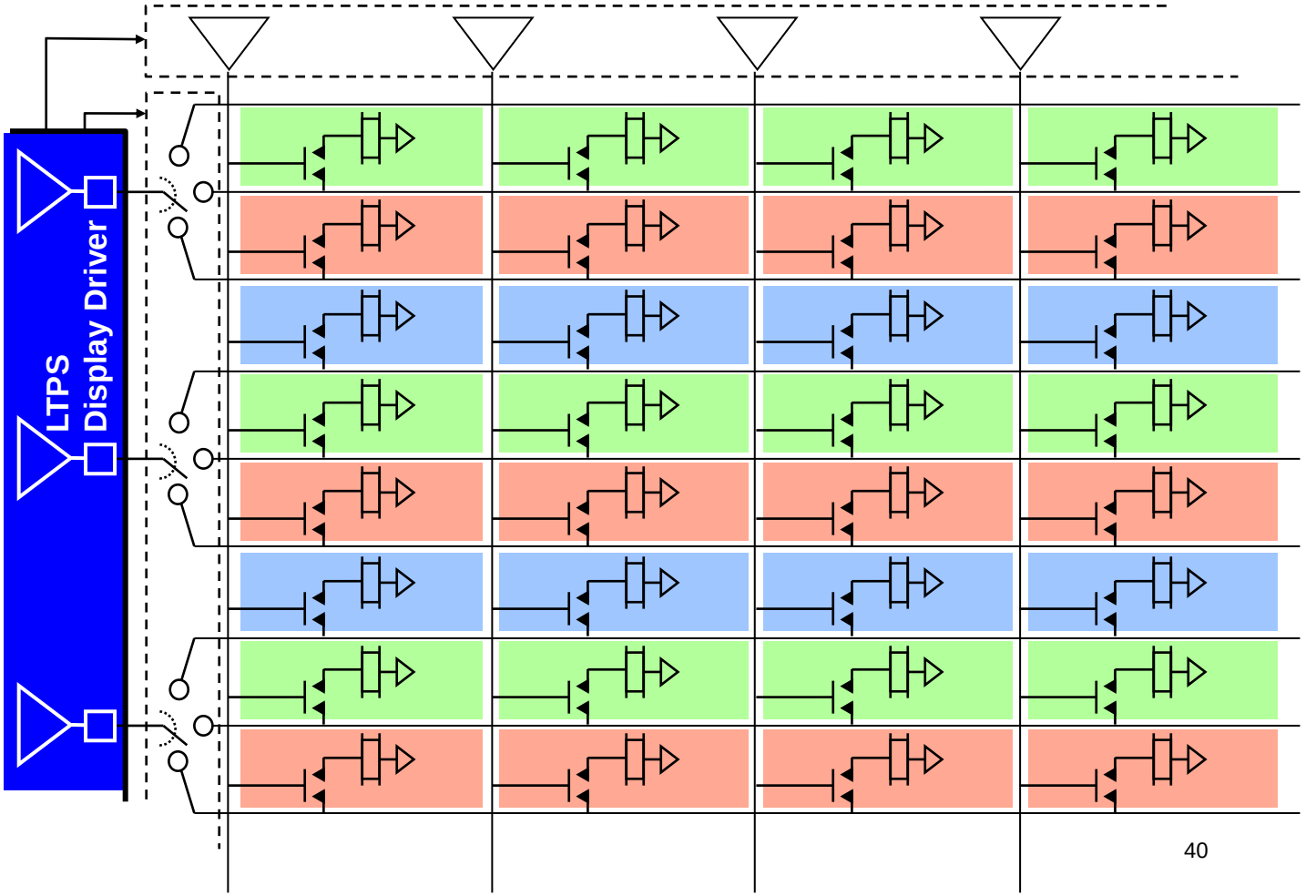


LTPS Active Matrix

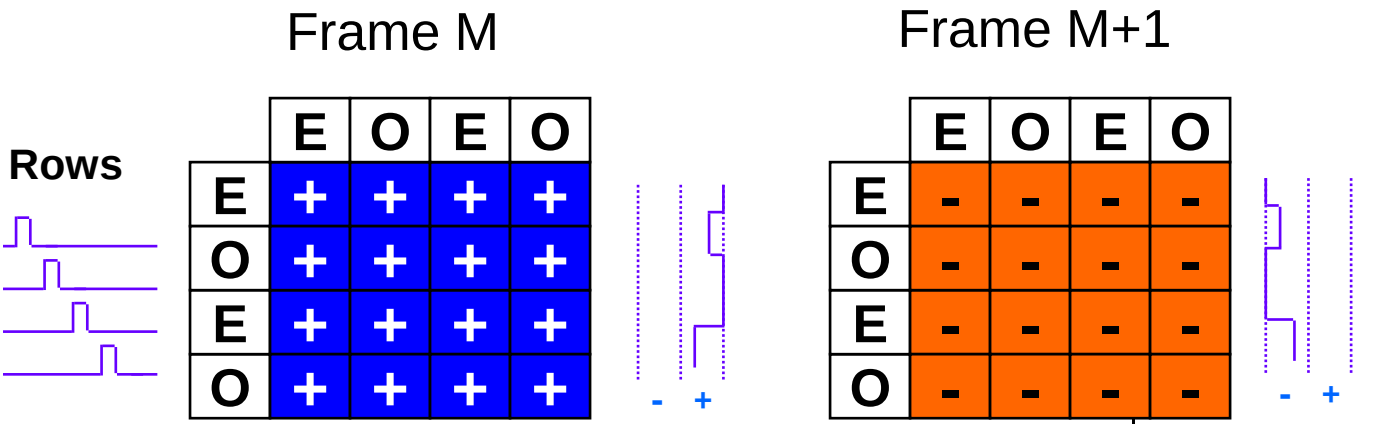


Rotated, LTPS Active Matrix

rotation permits fewer column outputs for the same h x v format

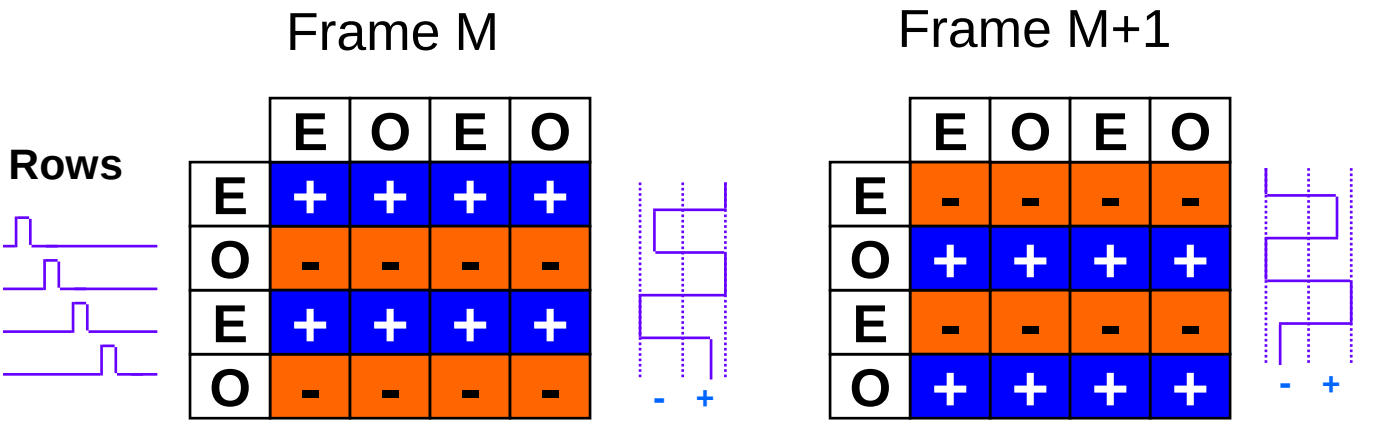


Frame Inversion



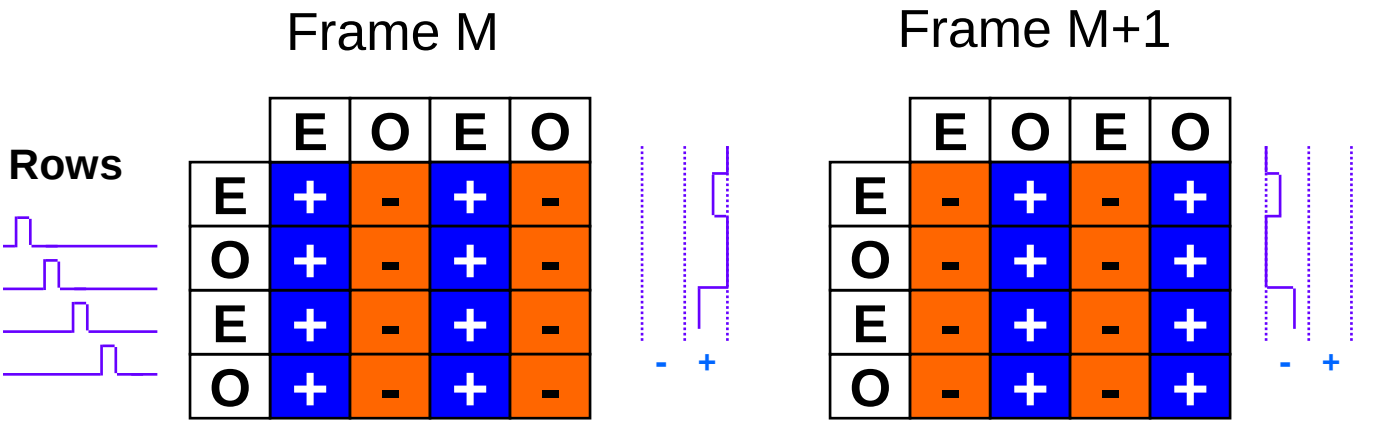
- Low Power Operation
- Sensitive to Flicker Due to Lack of spatial Averaging and Slight Transmissivity Mismatches for + and - Polarities
- Sensitive to Horizontal and Vertical Cross-talk

Line Inversion



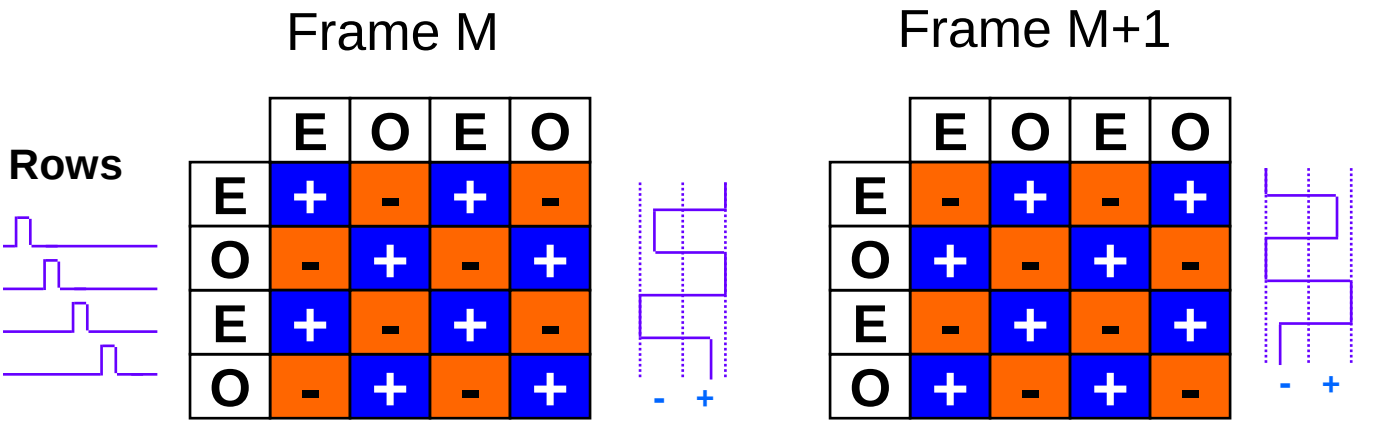
- Reduced Flicker Due to Spatial Averaging
- Reduced Vertical Cross-talk
- Compatible with Vcom Modulation Scheme
- High Power Operation: 480X Higher Power than Frame or Column Inversion
- Sensitive to Horizontal Cross-talk

Column Inversion



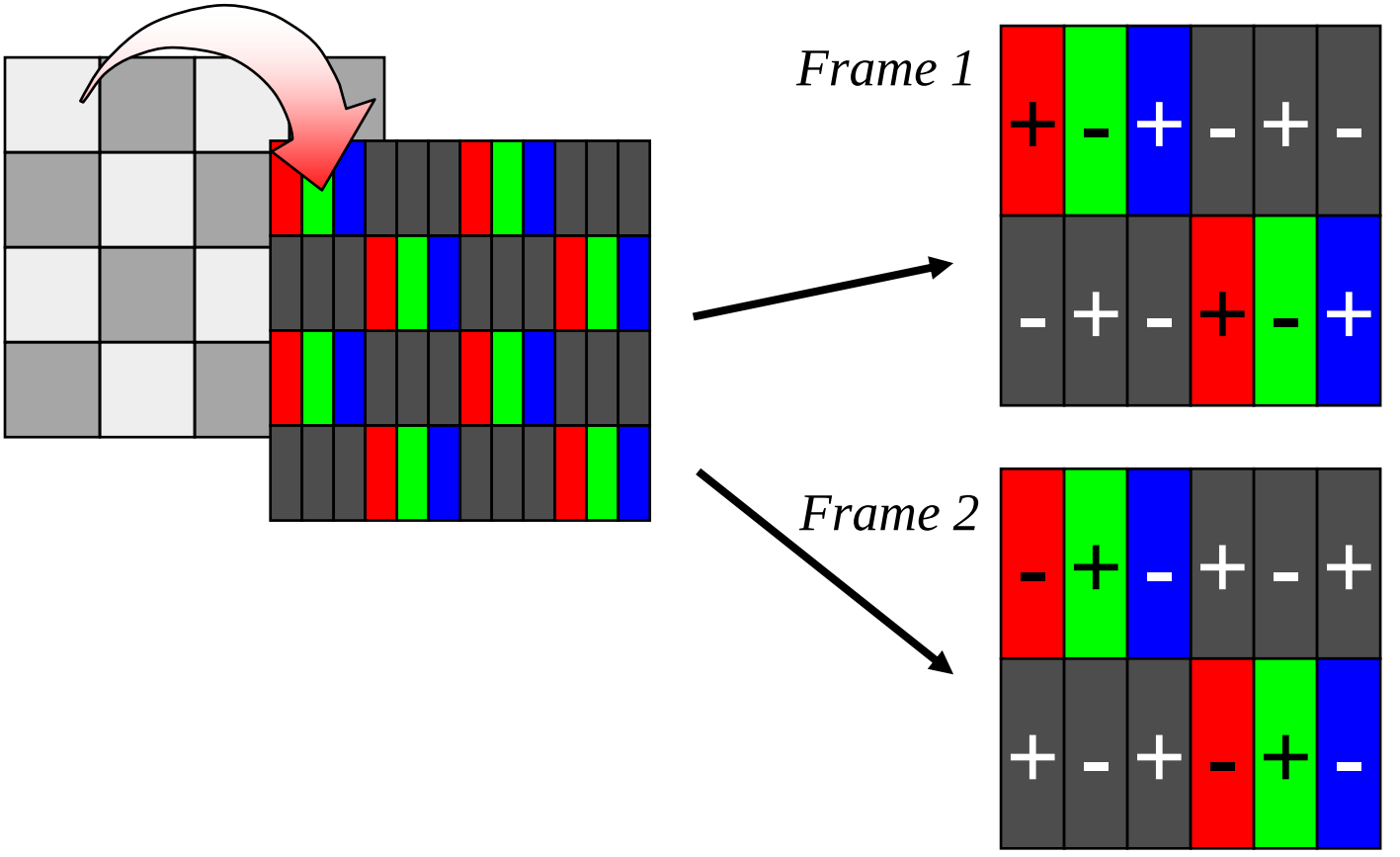
- Low Power Operation
- Further Flicker Reduction Due to Spatial Averaging
- Greatly Reduced Horizontal Cross-talk
- Requires High Voltage Source Driver
- Reduces component count and complexity
- Incompatible with Vcom Modulation

Pixel Inversion

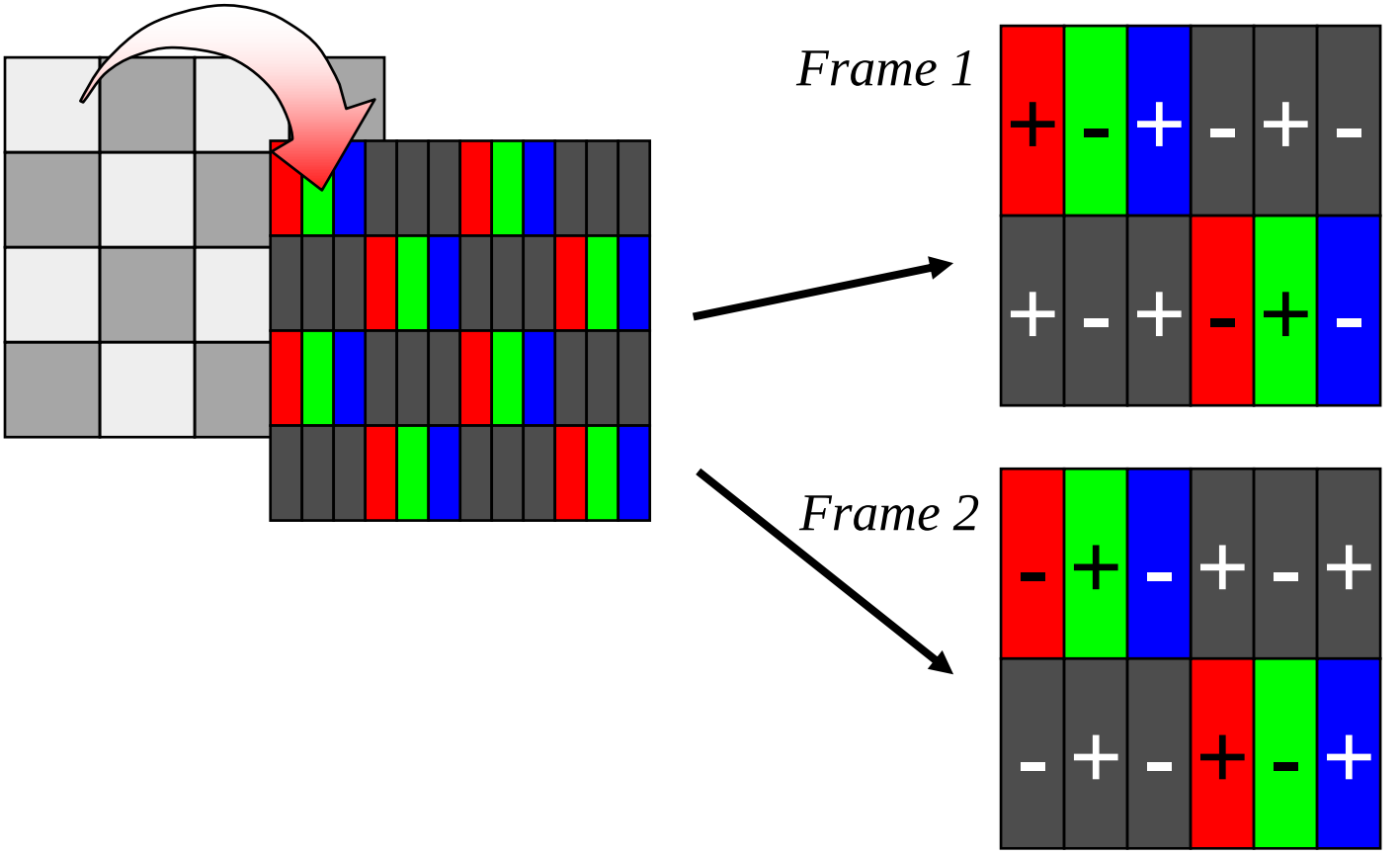


- Highest Quality Image Due to Reduction in Both Horizontal and Vertical Cross-talk
- No Flicker Due to Spatial Averaging
- Requires High Voltage Source Driver
- Incompatible with Vcom Modulation
- Higher Power Due to Line Inversion Component

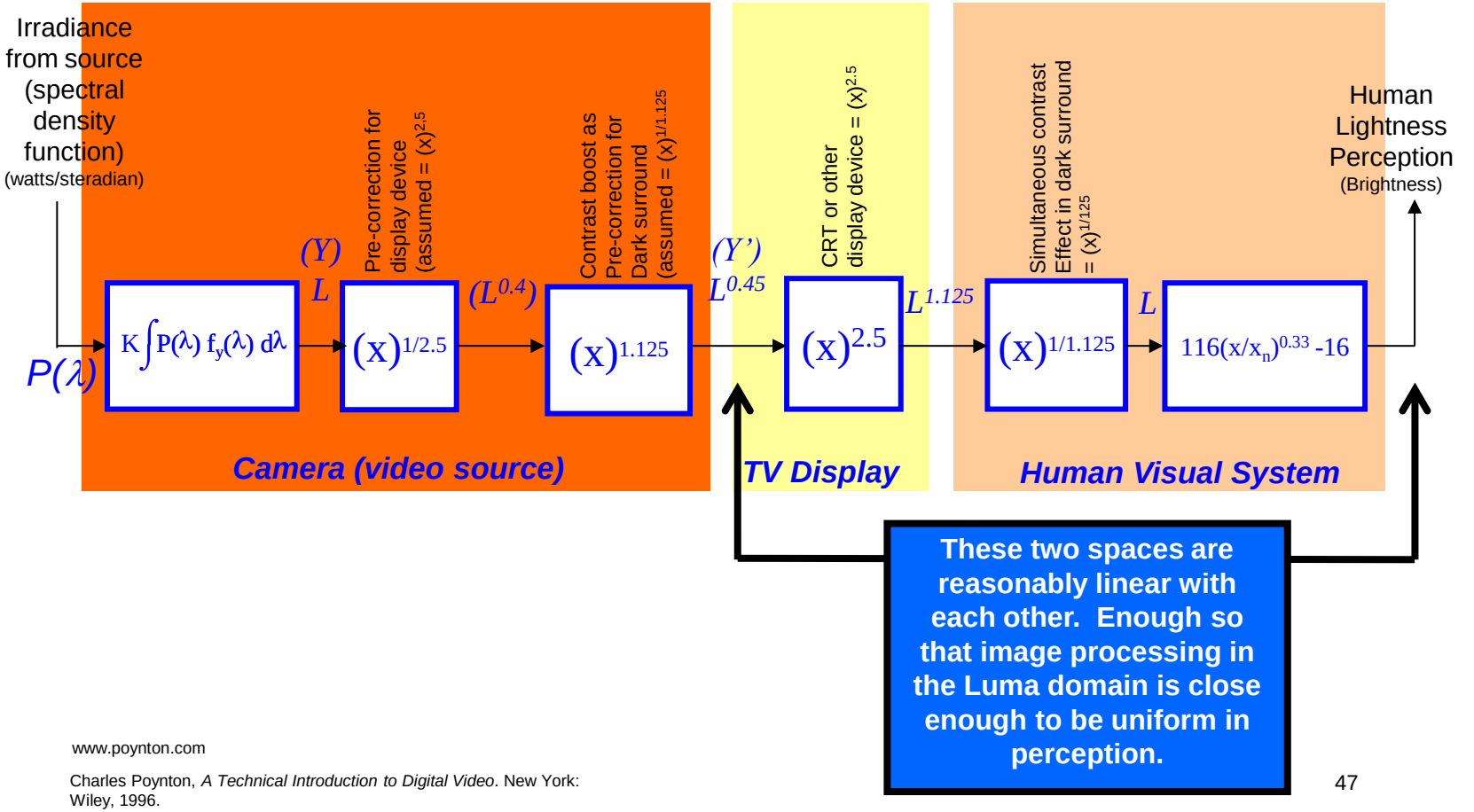
Pixel Inversion



N-Line Inversion (N=2)



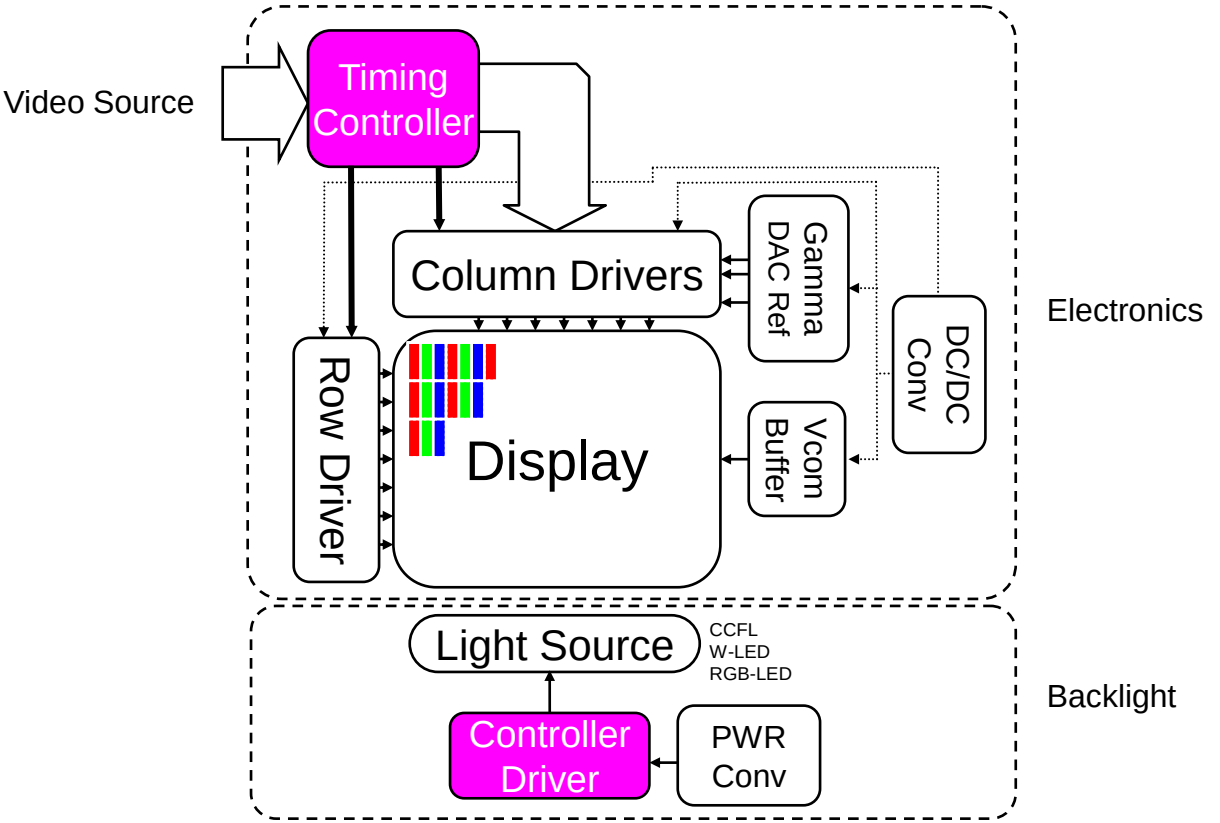
Video System Intensity Transformations (Gamma)



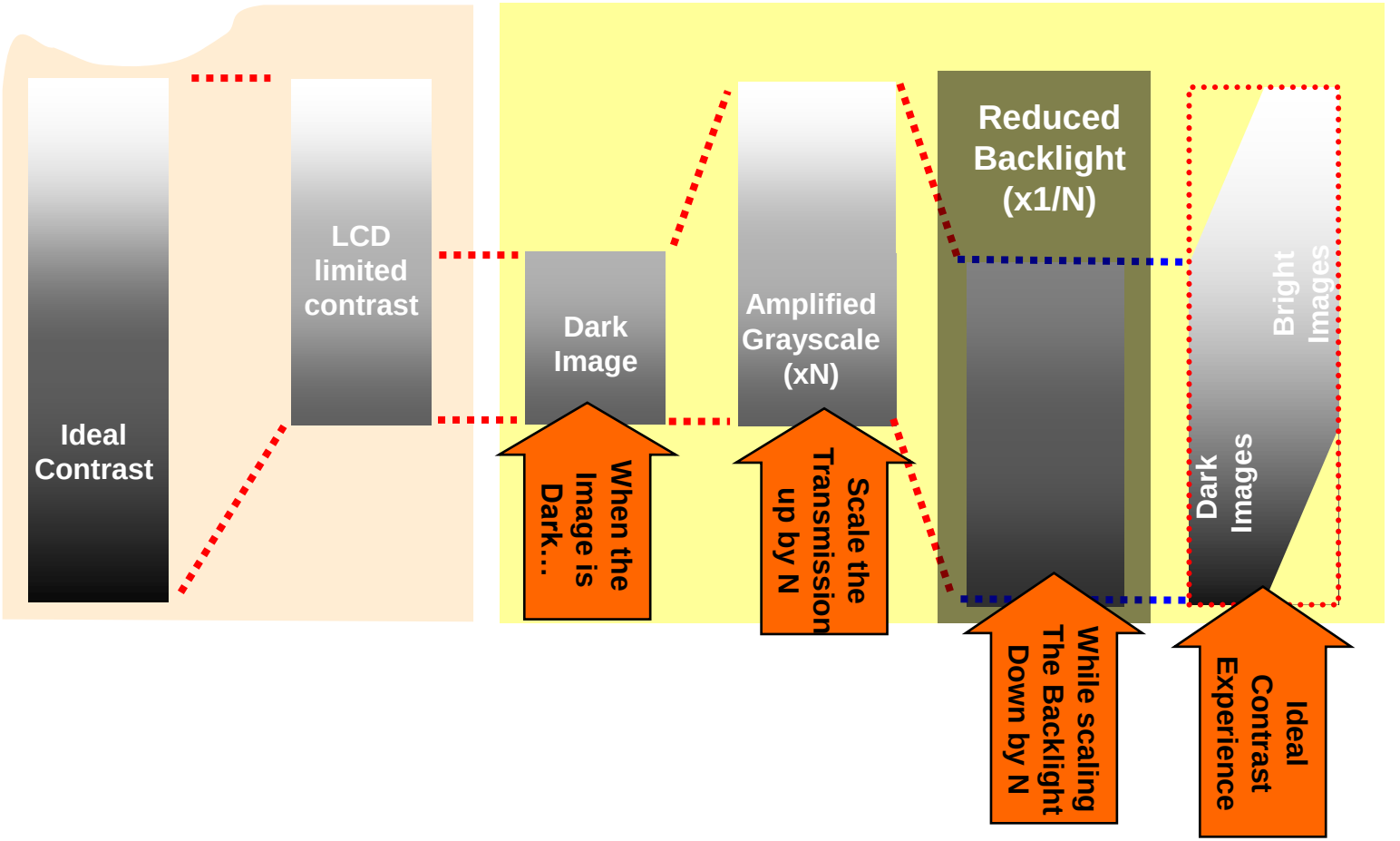
www.poynton.com

Charles Poynton, *A Technical Introduction to Digital Video*. New York: Wiley, 1996.

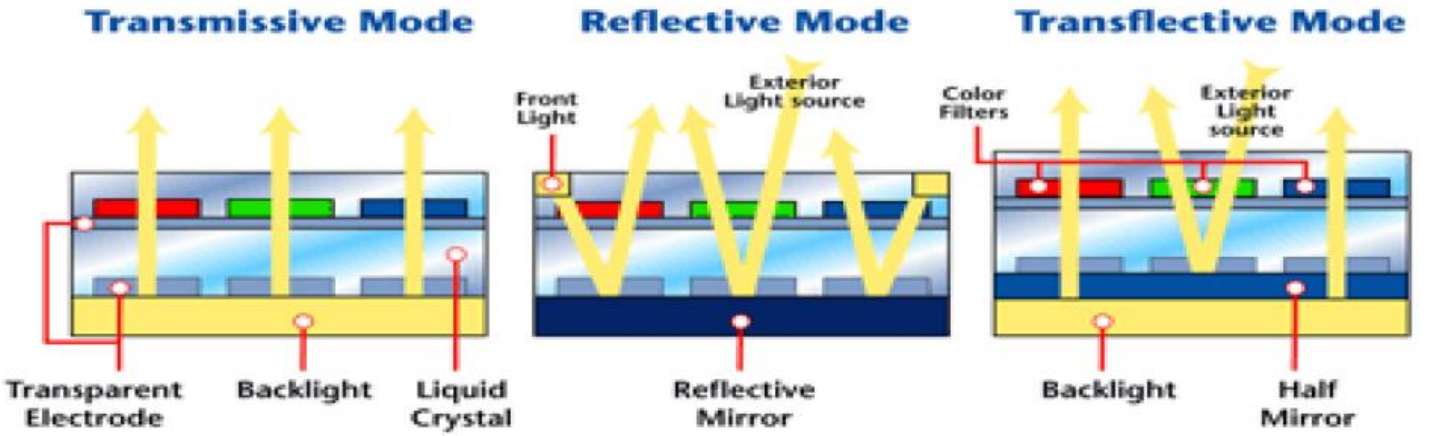
Advanced Features



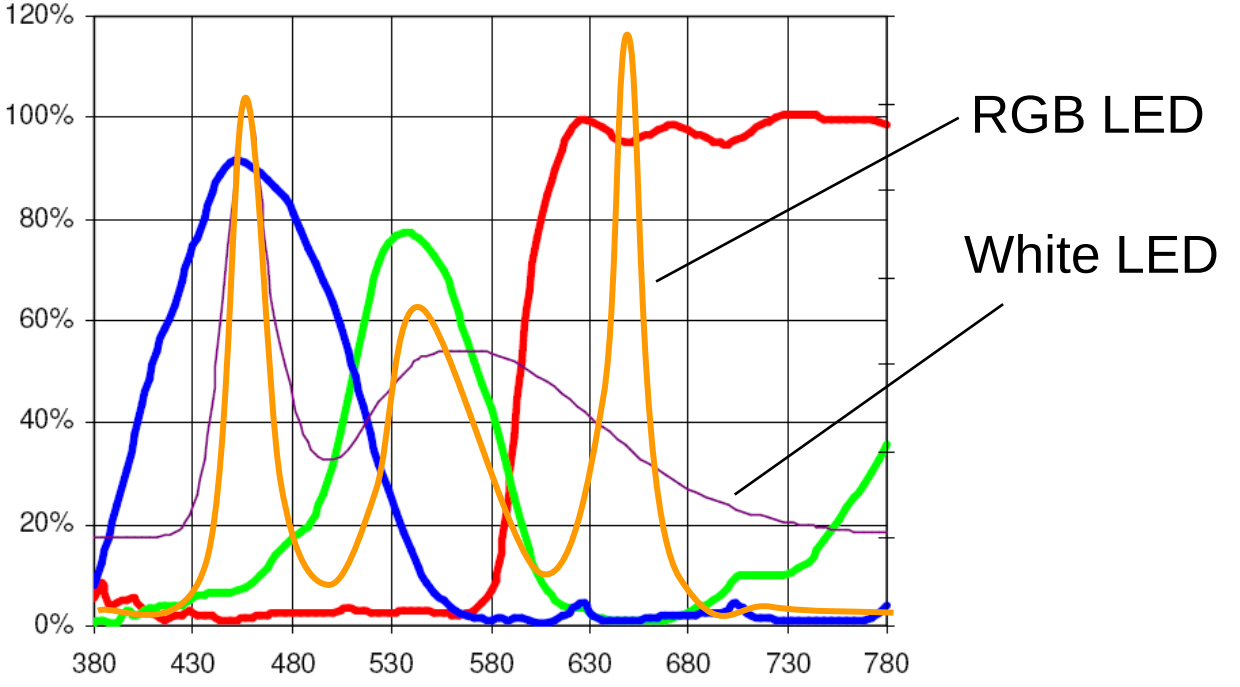
Dynamic Contrast Expansion



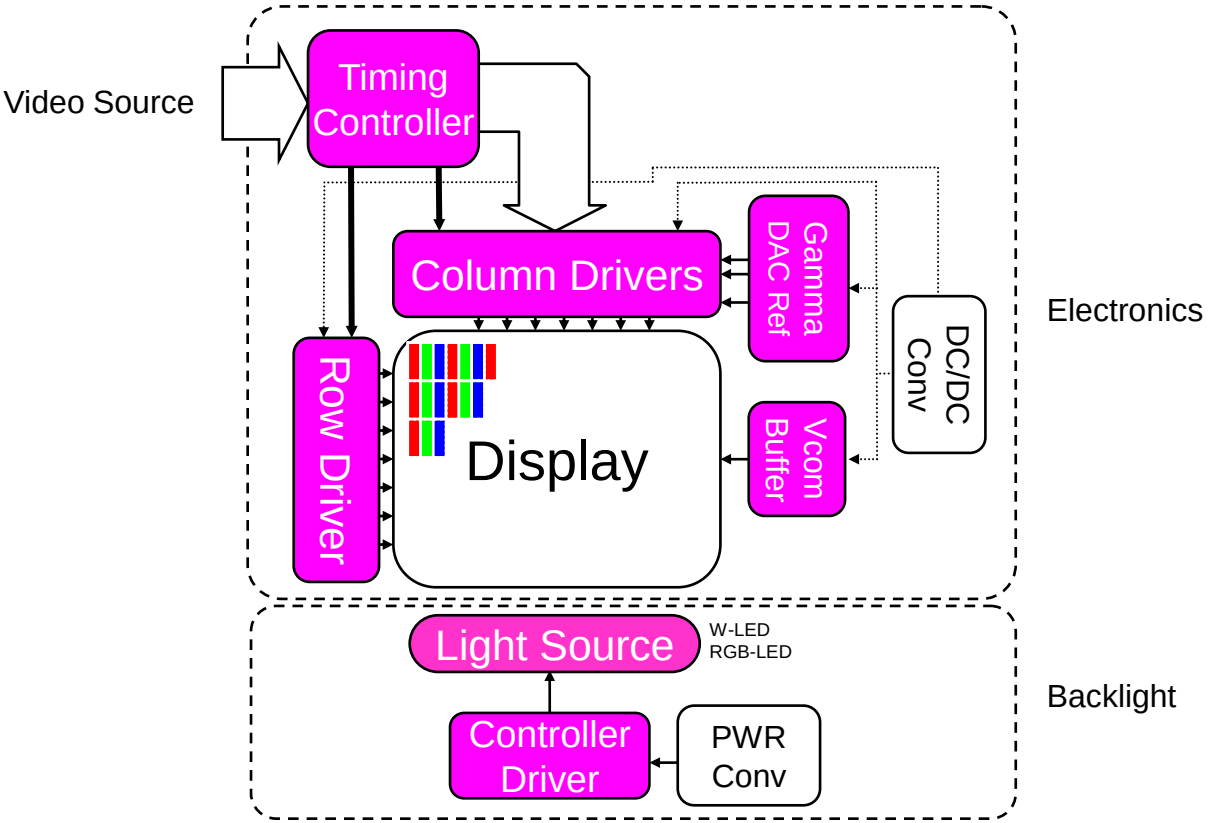
LCD Lighting Modes



Matched RGB-LEDS
vs
White LED



Reviewed Operations



Summary of LCD Electronics

- LCD operation is essentially the same across applications
- Different driving strategies and tactics are used in different applications
- Different back-lighting strategies are used in each application
- Innovation and technology advancement continue to extend the size, format, contrast, color performance and portability of LCDs moving them into whole category of products