Spice Model for a Dynamic Liquid Crystal Pixel Capacitance

Herbert De Smet, Jean Van den Steen,

and Dieter Cuypers

Department ELIS-TFCG, Ghent University and IMEC,

Sint-Pietersnieuwstraat 41, B-9000 Gent, Belgium

SEEDS FOR TOMORROW'S WORLD

Overview

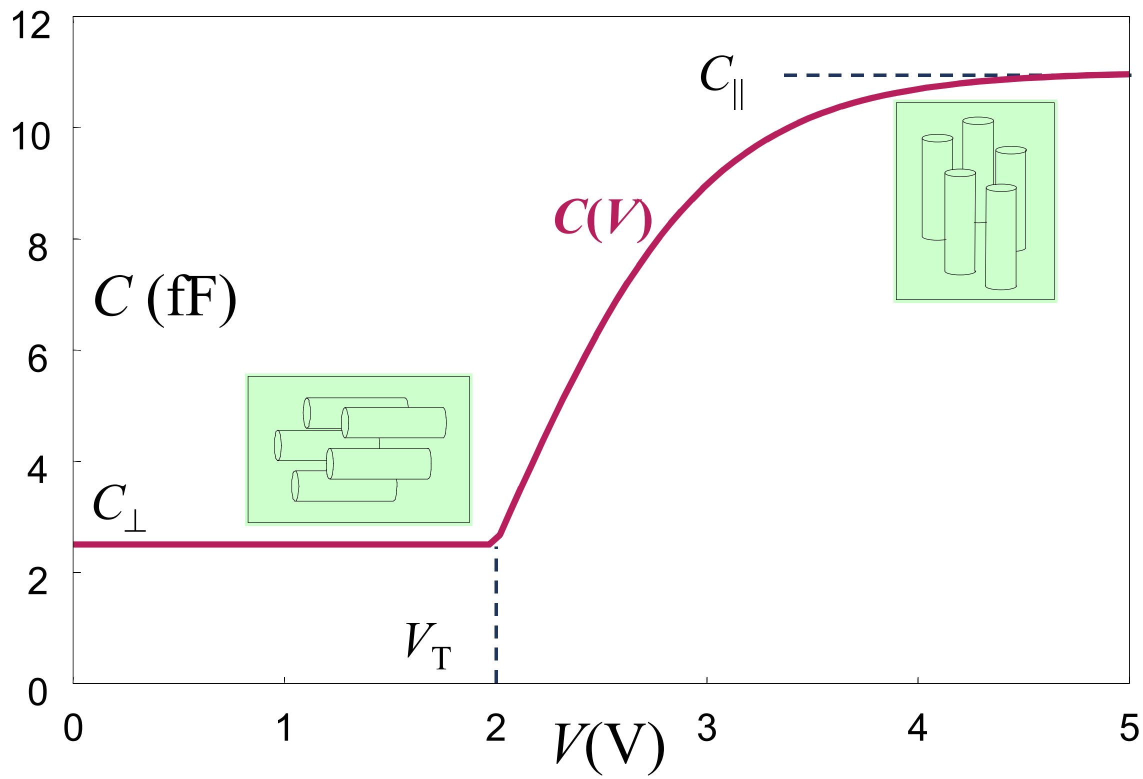
- Introduction
- Observations
- Physics
- Model
- Spice implementation
- Optical behaviour
- Results
- Conclusion
- Acknowledgements

Introduction

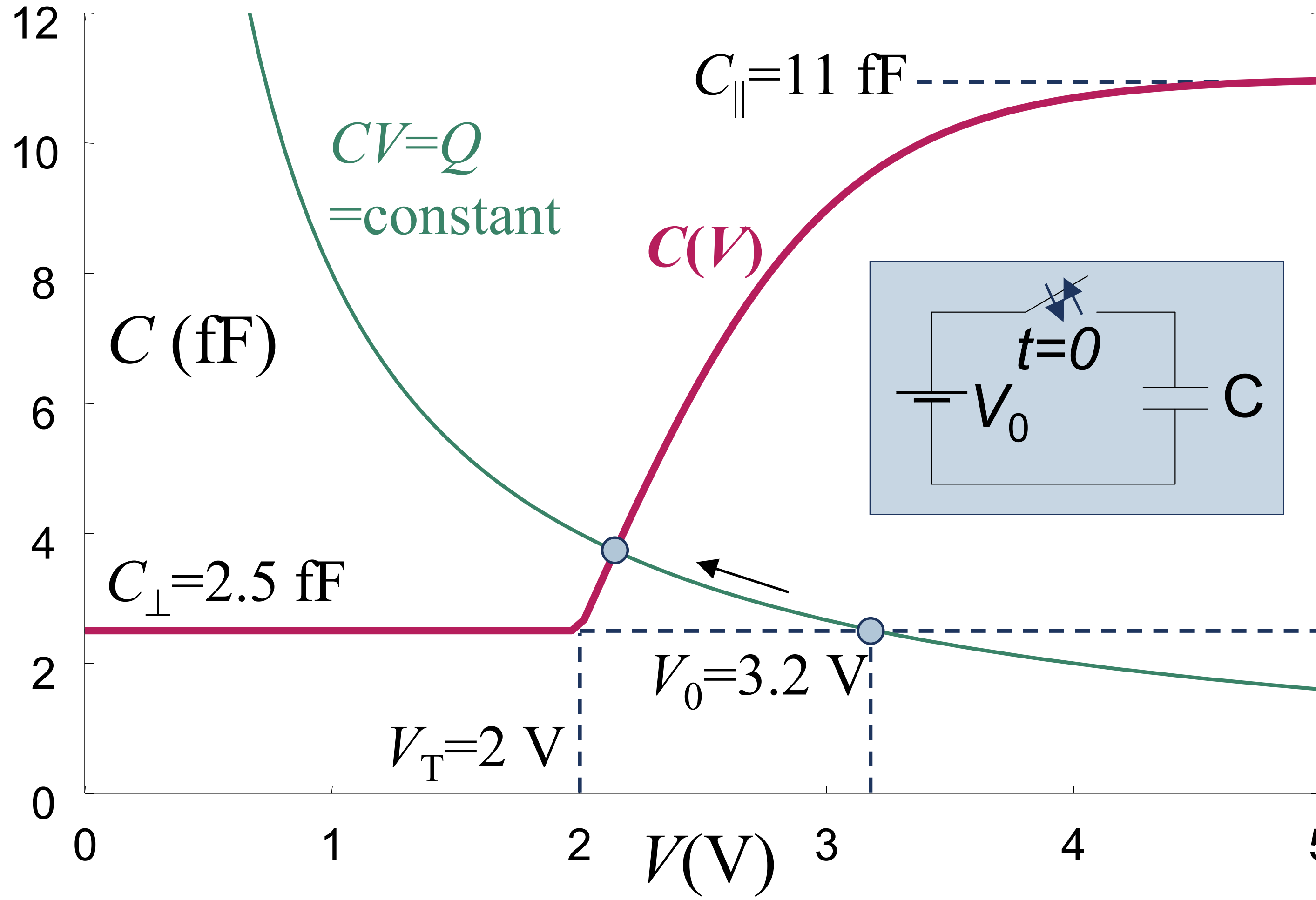
- Video rates
- Colour sequential operation
- Transition time gets more and more important
- Voltage overdrive
- Smart pixels (frame buffering)
- Operation dependent on value of pixel capacitance But pixel capacitance not constant
- Need for good electrical model

Observations

- Variable capacitor: from $C_\perp$ to $C_{||}$
- Static: C = C(V) (well known)
- Dynamic: C = C (history (V)): ???
- Rms response
- Voltage drop

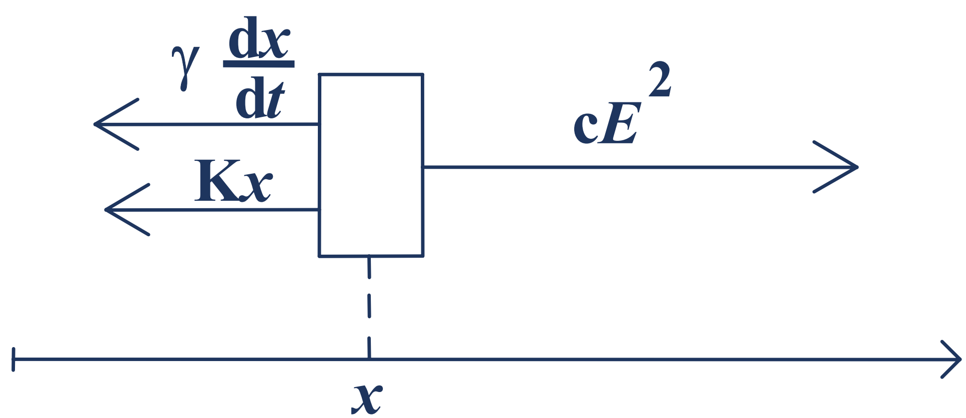


Observations: Voltage drop



Physics

- Average director orientation: represented by 1-D variable "*x*"
- 3 forces to consider:
  - Electrical force: $\sim E^2$: tries to maximize ε by rotating molecules
  - Elastic force: K*x*: molecules want to stay parallel to each other and to alignment layer
  - Friction (viscosity): γ d*x*/d*t*



- Equilibrium :

$$cE^2 = Kx + \gamma \frac{\mathrm{d}x}{\mathrm{d}t}$$

$$x = \frac{\frac{cE^2}{K}}{1 + \mathrm{p}\tau}$$

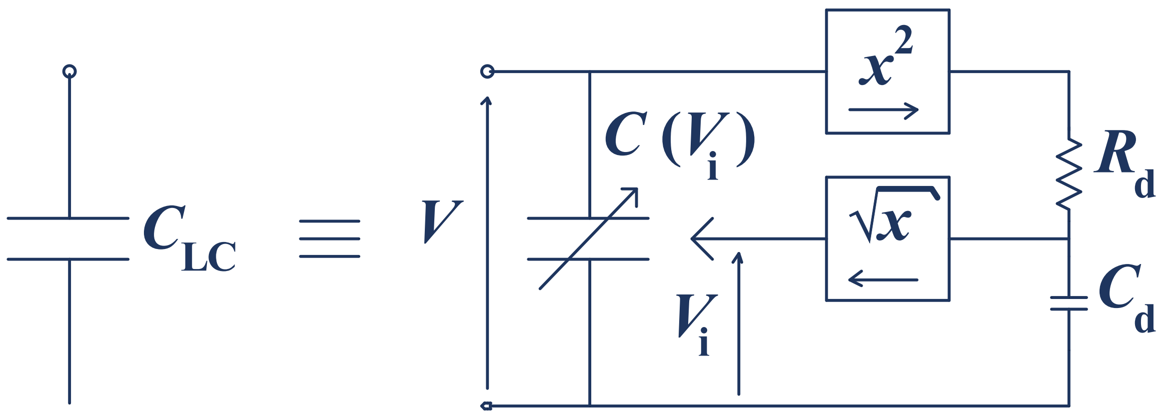
1st order system (time constant τ)

Model

- 1^{st} order system represented by RC filter
- (time constant $\tau = R_d C_d$)
- 1D variable "x" is $V_i^{\,2}$ (V_i = "internal voltage")

→ V_i is root-mean-square (rms) value of applied voltage, with integration constant τ

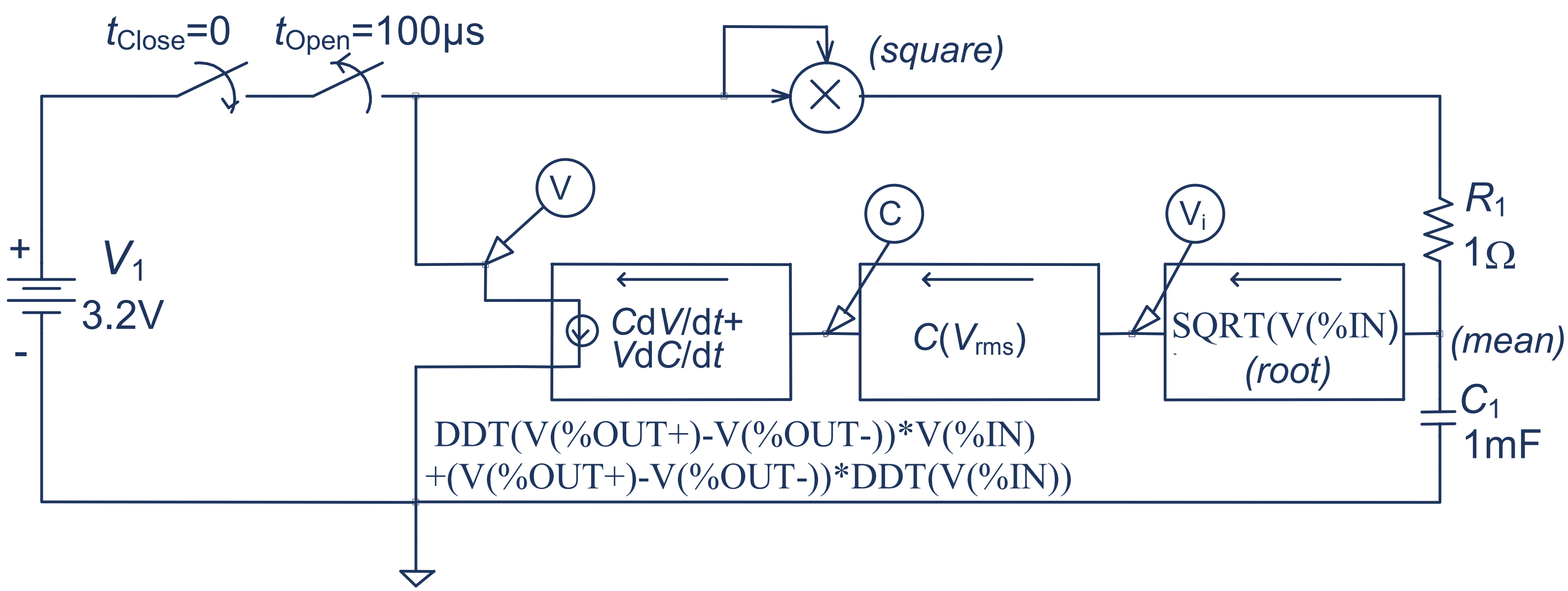
- Momentary C value is $C(V_i)$, using static $C(V)$ function
- Steady-state: $V_i = V$



Spice implementation

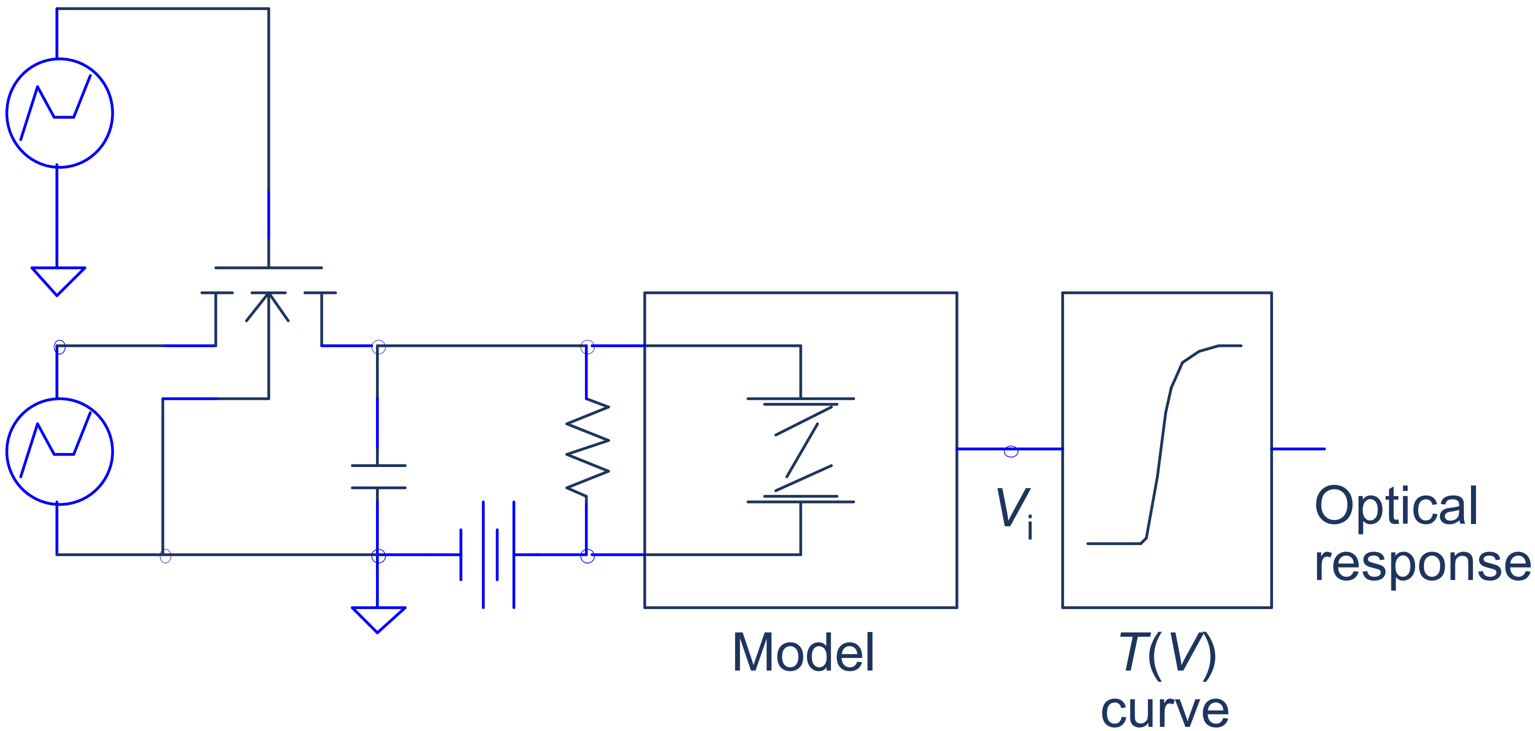
- C implemented in PSpice as current source using ABM block (Analog behavior Modeling).

$$I = \frac{\mathrm{d}Q}{\mathrm{d}t} = \frac{\mathrm{d}(CV)}{\mathrm{d}t} = C(V_\mathrm{i})\frac{\mathrm{d}V}{\mathrm{d}t} + V\frac{\mathrm{d}C(V_\mathrm{i})}{\mathrm{d}t}$$



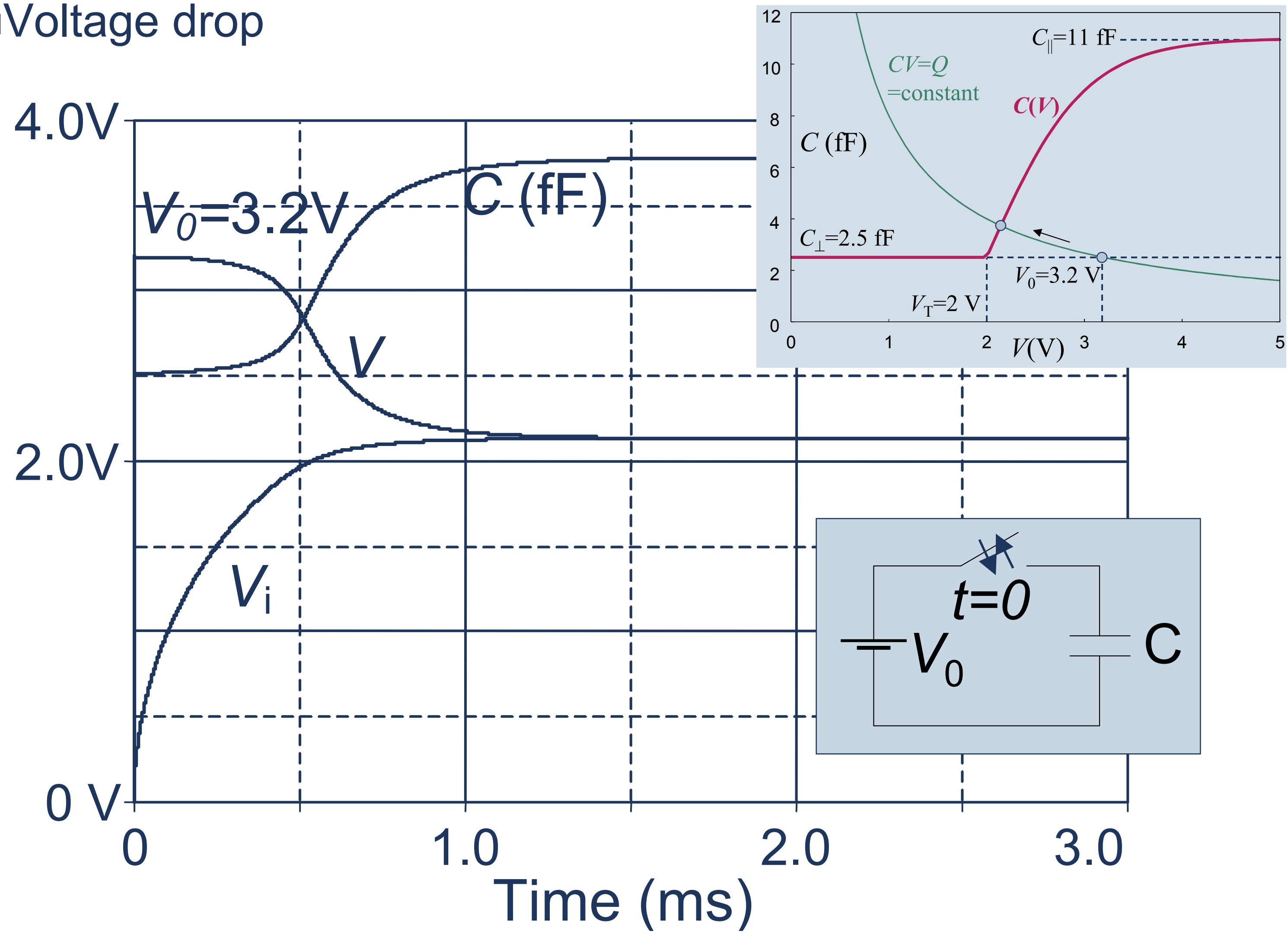
Optical behaviour

- Can be derived from V_i, using static $T(V)$ curve.



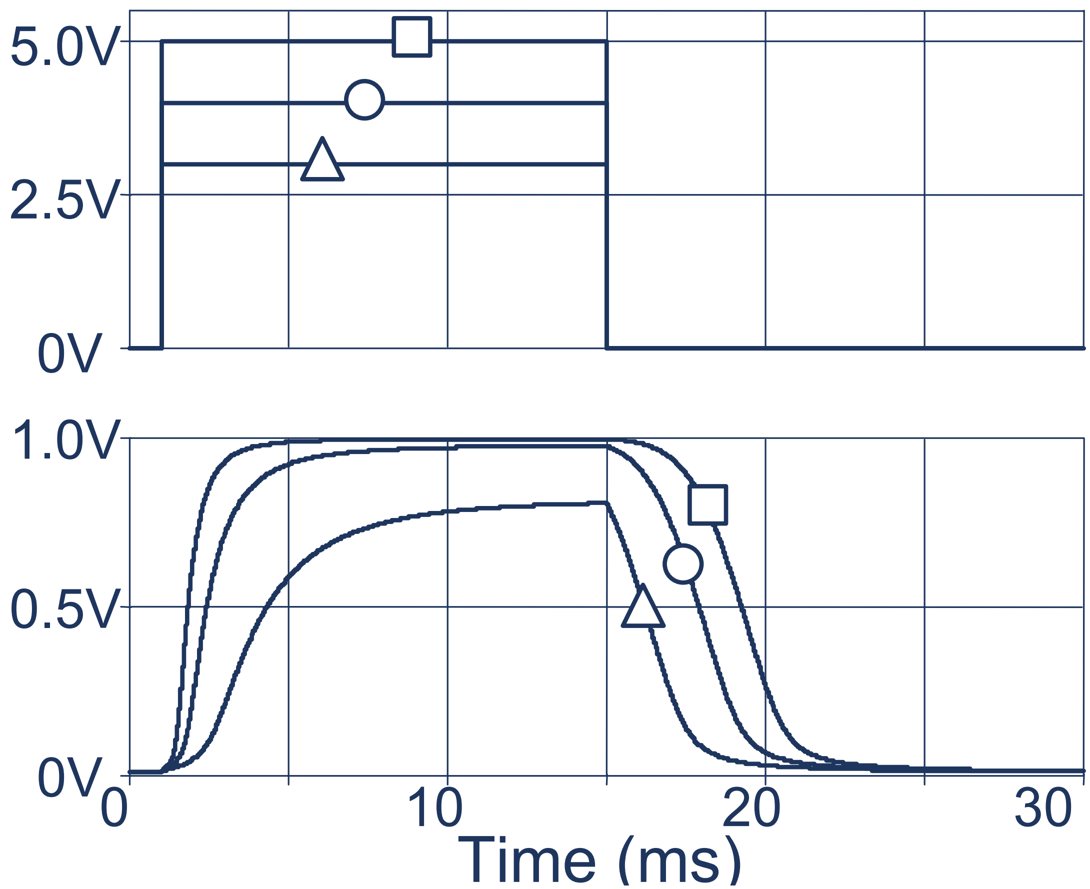
Results

- Voltage drop



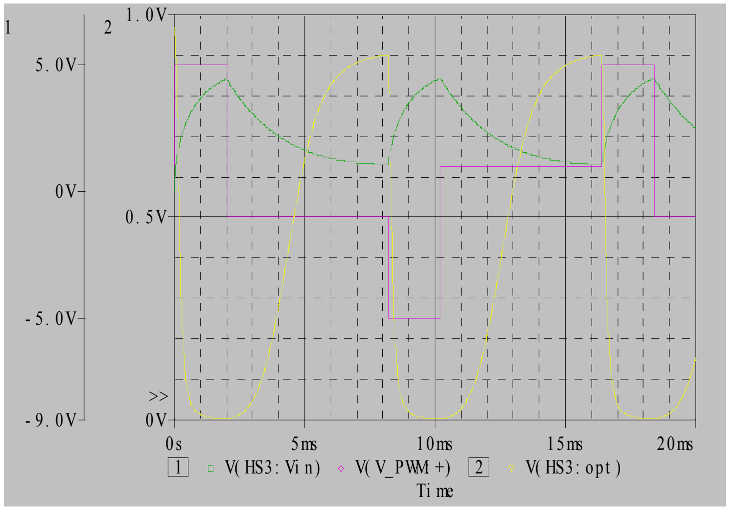
Results (2)

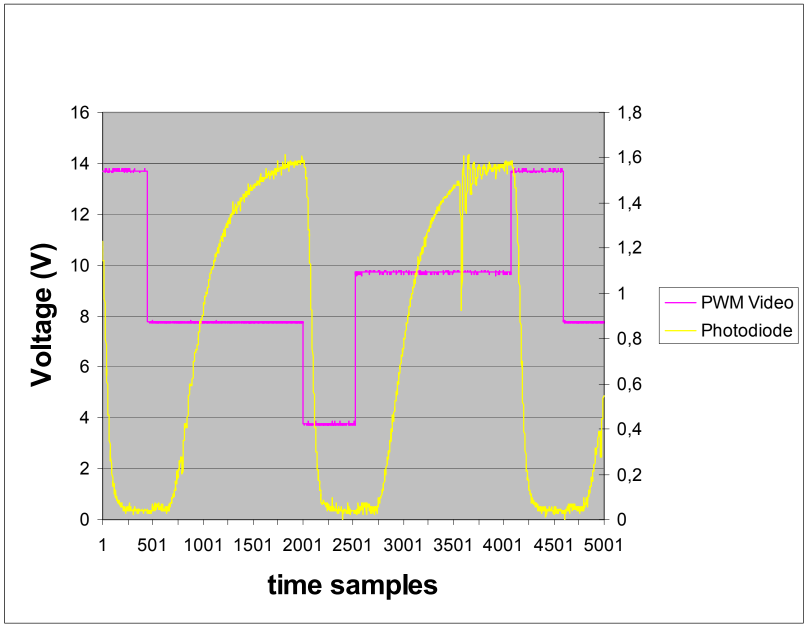
- Rise and fall times



Results (3)

- Confrontation with experiment
  - Pulse-width modulation response





- Simulation (Spice)
- Measurement

Conclusion

- Spice model for dynamic LC pixel capacitance
- Based on simple 1D first order system
- Internal voltage V_i represents voltage history
- Implemented in PSpice
- Correctly predicts voltage drops
- Can be used to predict optical response
- Good agreement with experimental data

Acknowledgements

This work was carried out with support from the European Commission under the Framework 5 program,

project LCOS4LCOS, N° IST-2001-34591

information society technologies

www.lcos4lcos.info