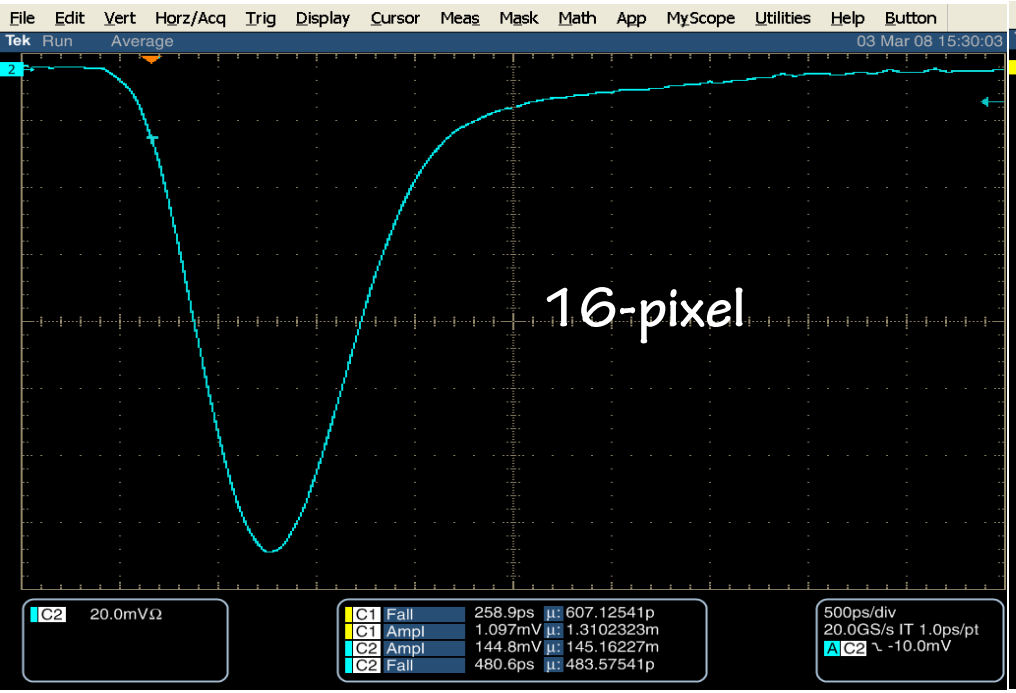
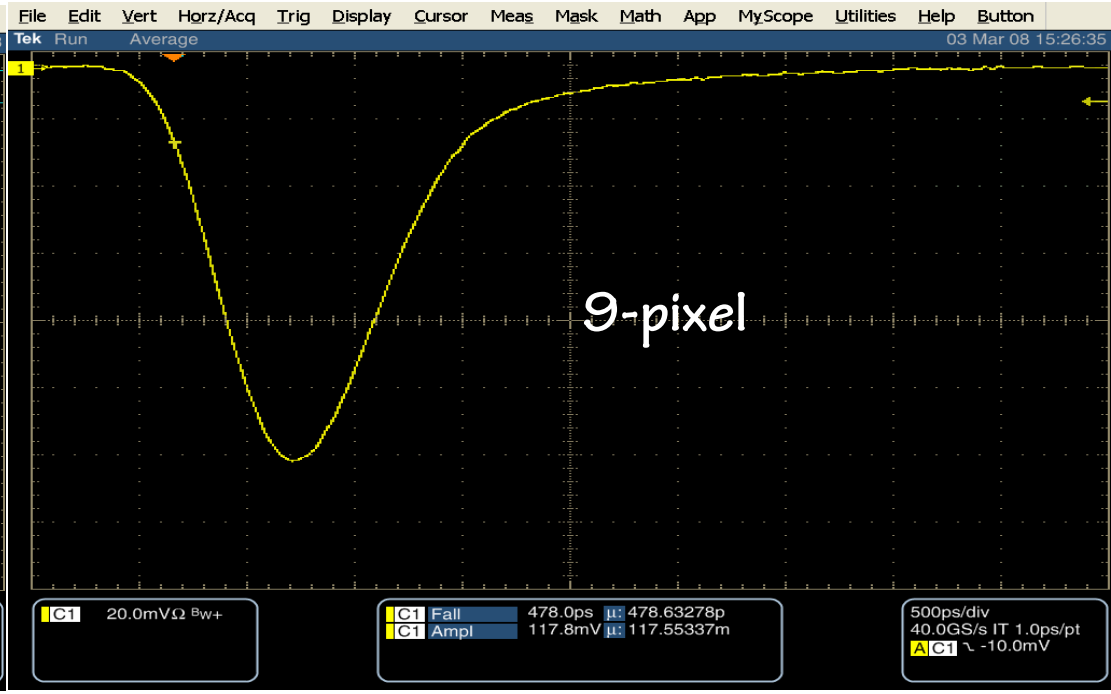
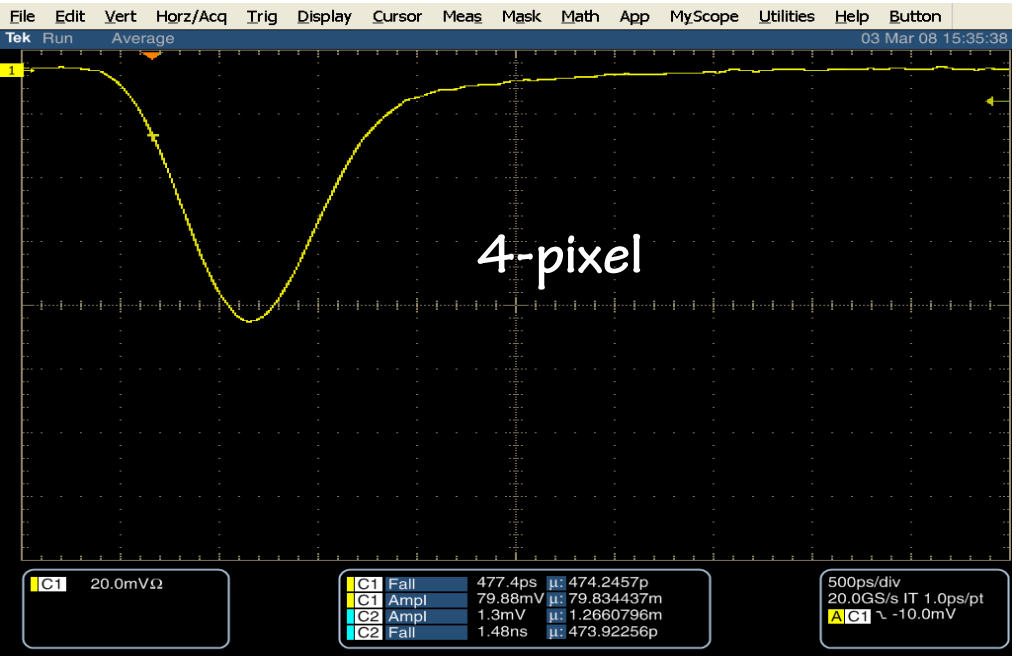
Modeling for MCP-PMT Output Signal

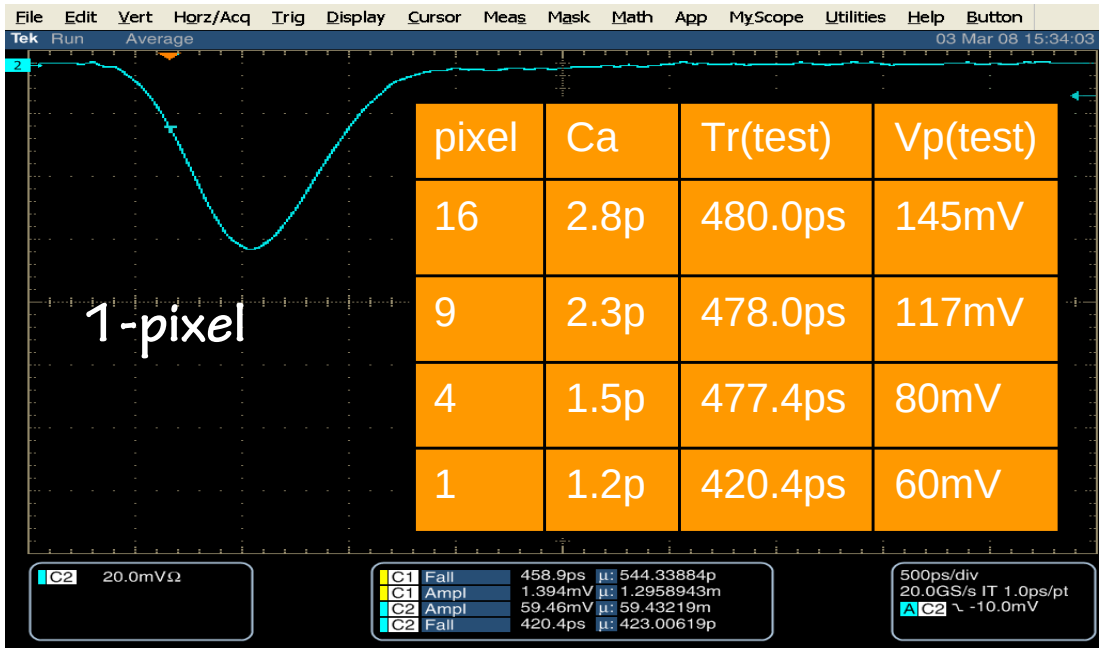
1. Modeling with RC Load
   - Mathematic modeling
   - Spice simulation with linear-rise Impulse force
   - Spice simulation with 2-τ exponential force
   - Comparison between simulation and test
2. Modeling with RLC Load (and includes T-line)
   - Mathematic modeling
   - Spice simulation
   - Comparison between simulation and test
3. Summary

Camden's Test



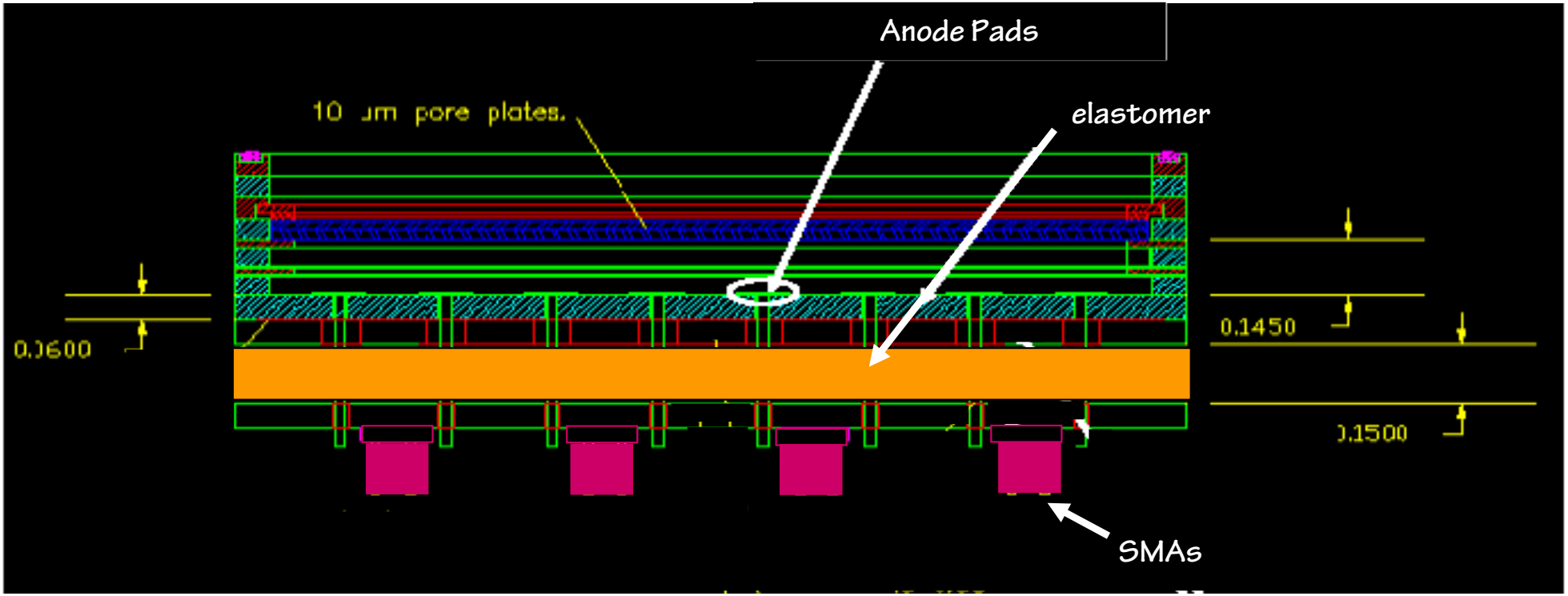






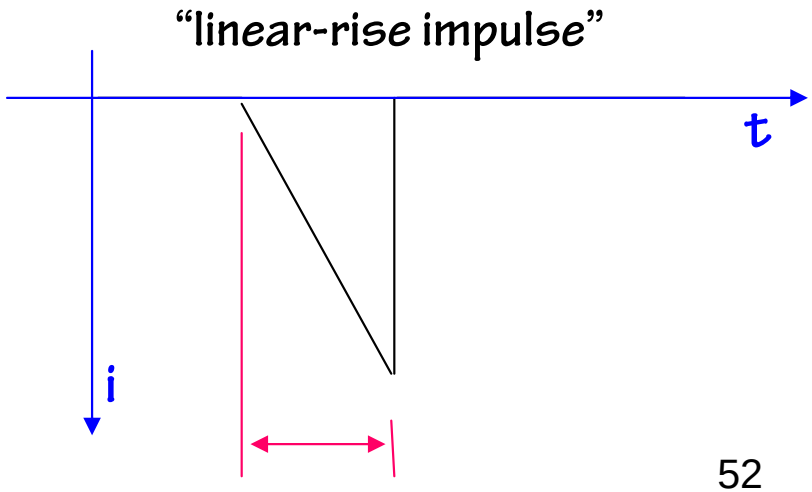
pixel	Ca	Tr(test)	Vp(test)
16	2.8p	480.0ps	145mV
9	2.3p	478.0ps	117mV
4	1.5p	477.4ps	80mV
1	1.2p	420.4ps	60mV

Tube and Anodes



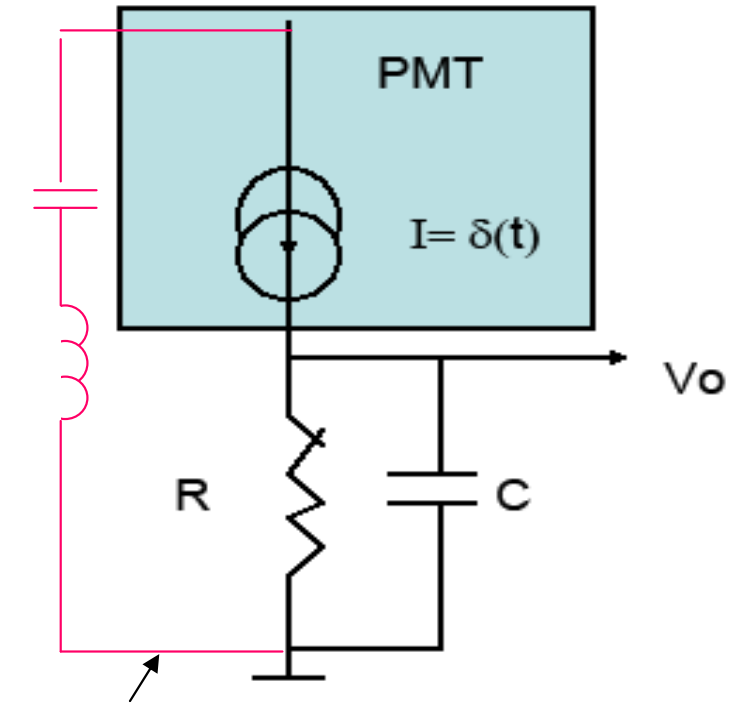
From Jean-Francois' calculation:

The tube current source should be linearly rise in a time interval of 75ps-225ps, which is related to tube structure and the field between MCP_out to anode, then suddenly stops, we call it as "linear-rise impulse"



F.Tang

Modeling for Tube's Output with RC Load



Ignore slow current path

Laplace transforms:

$I = \delta(t) \rightarrow 1$

$R//C \rightarrow \dfrac{1}{C\left(s + \dfrac{1}{RC}\right)}$

Frequency domain:

$Vo(s) = \dfrac{1}{C\left(s + \dfrac{1}{RC}\right)}$

Time domain:

$Vo(t) = \delta(t)\ (R//C) \rightarrow \dfrac{u(t)}{C} e^{-\frac{t}{RC}}$

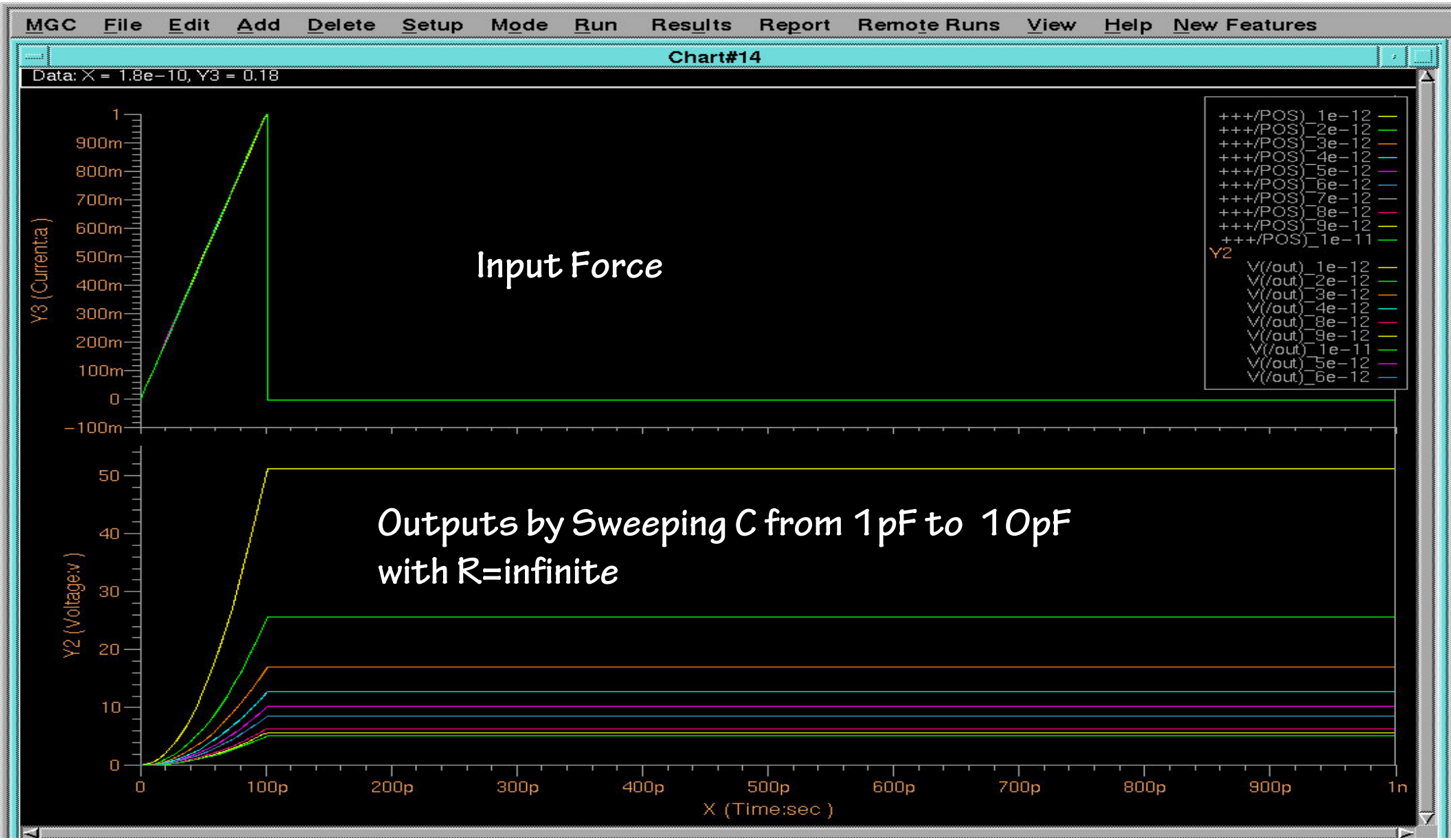
Where u(t) is a step pulse

If the current source is a impulse, then rise time of output pulse is a step function, amplitude is proportional to 1/C, then decay with τ=RC.

Rise Time is Nothing Dependent If Input is a Impulse Current Source!

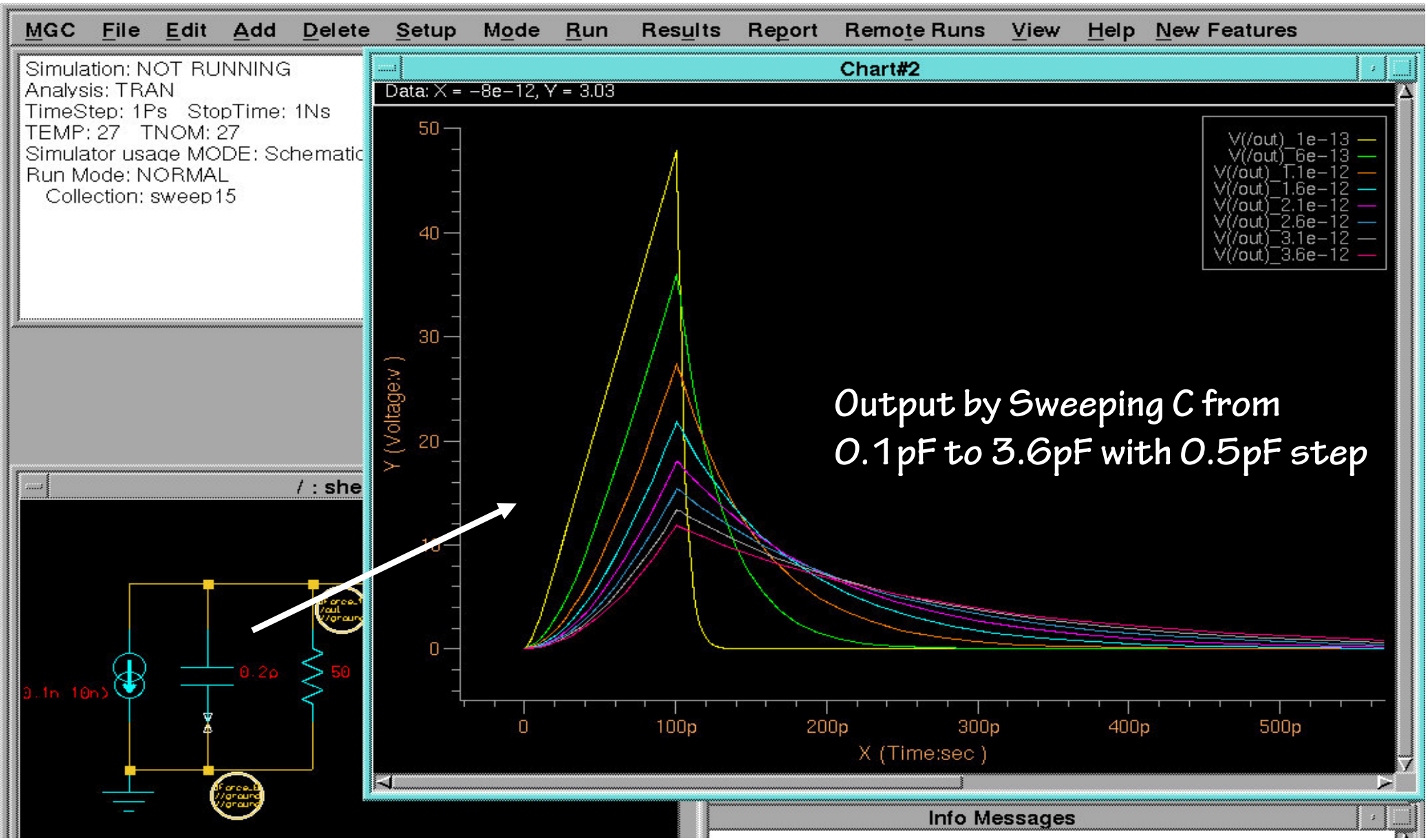
Effect of C_anode to the Rise Time of Output Signal (1)

Input force: Linear-rise Impulse Current Source (tr=100ps, tf=1ps, Ip=1A)



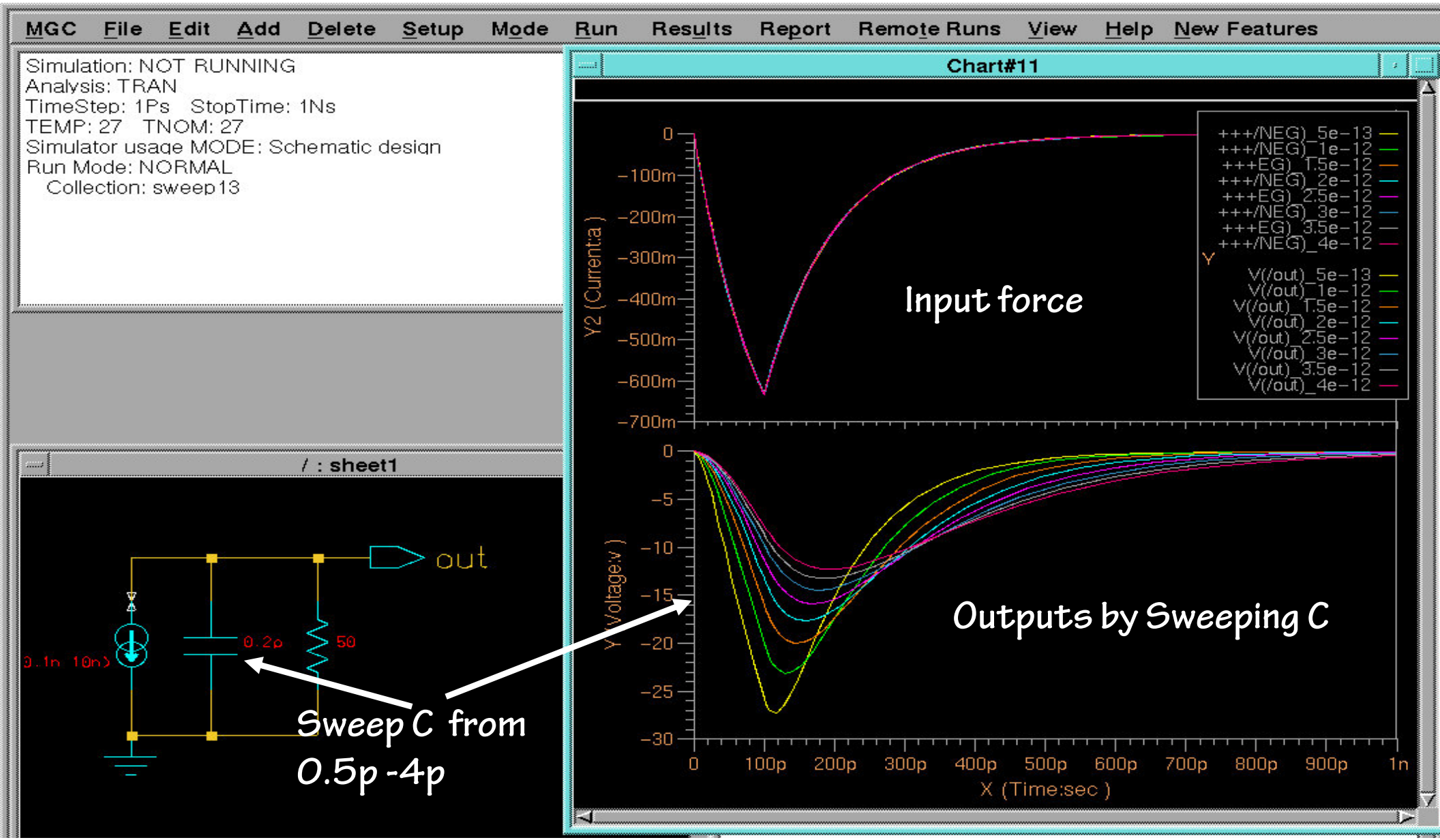
Effect of C_anode to the Rise Time of Output Signal (2)

Input force: Linear-rise Impulse Current Source (tr=100ps, tf=1ps, Ip=1A)



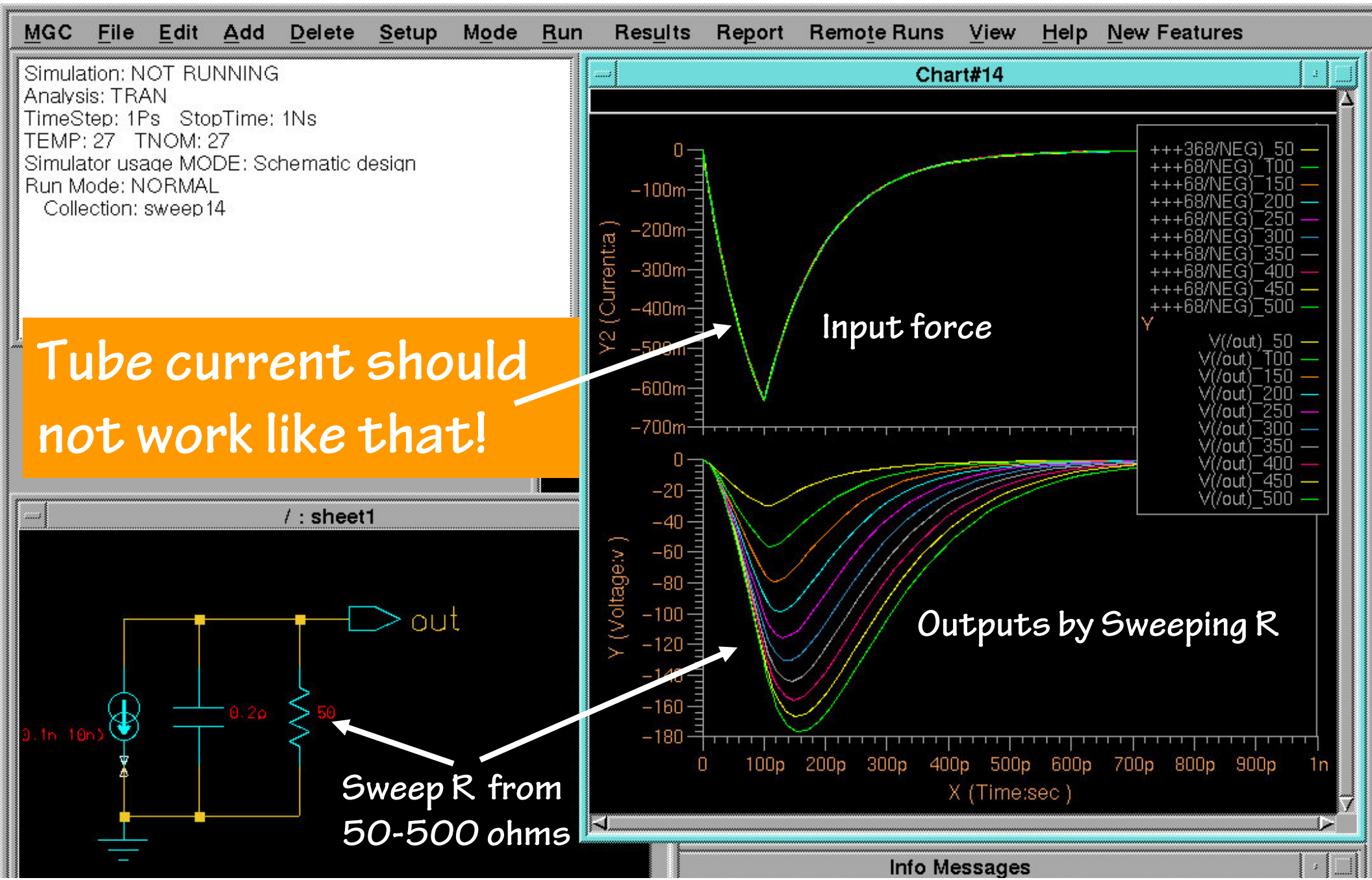
Effect of C_anode to Rise Time of Output Signal (1)

Input force: 2-τ Exponential Current Source (tr=100ps, tf=300ps)



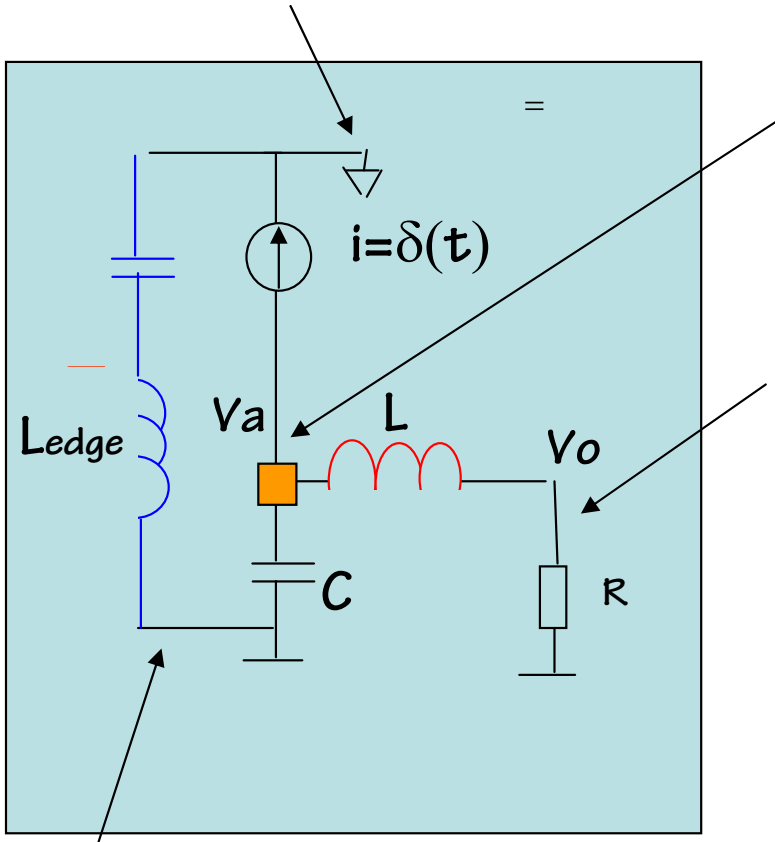
Effect of C_anode to Rise Time of Output Signal (2)

Input force: 2-τ Exponential Current Source (tr=100ps, tf=300ps)



Modeling for Tube's Output With LRC Load

MCPOUT is an AC ground for fast signal



Ignore slow current path

Transfer Function:

Laplace transform with impulse current force:

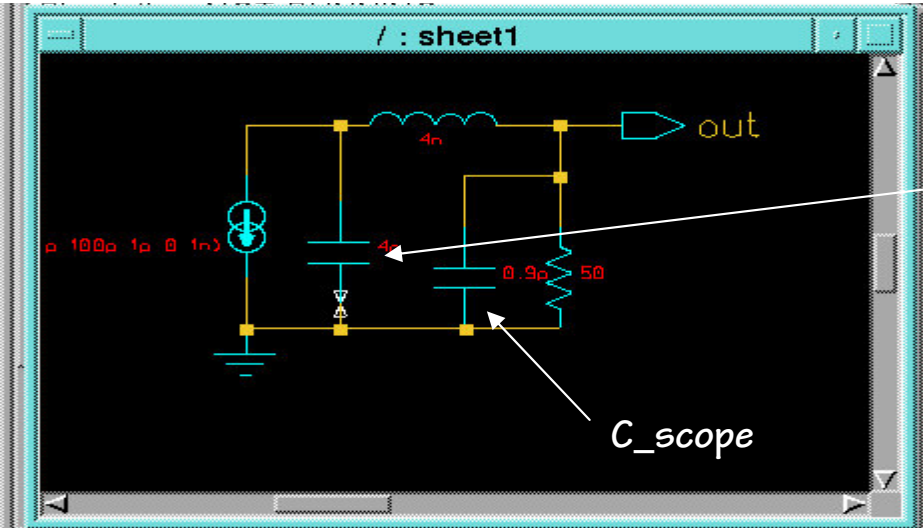
$$Va(s) = \frac{sL + R}{s^2 LC + sRC + 1}$$

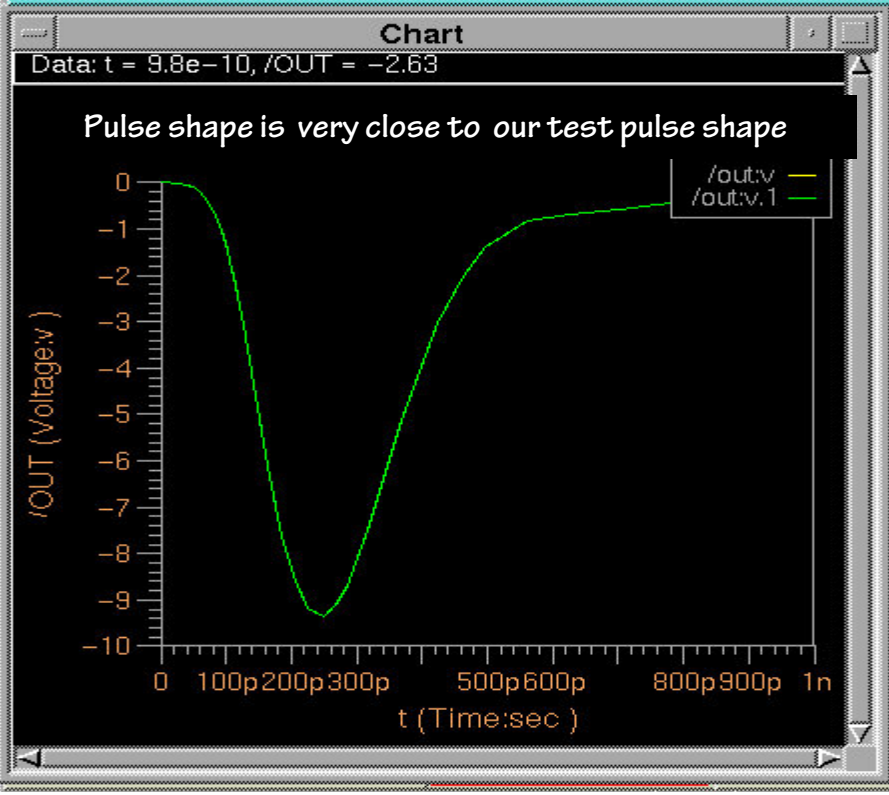
$$Vo(s) = \frac{sL + R}{s^2 LC + sRC + 1} \bullet \frac{R}{sL + R}$$

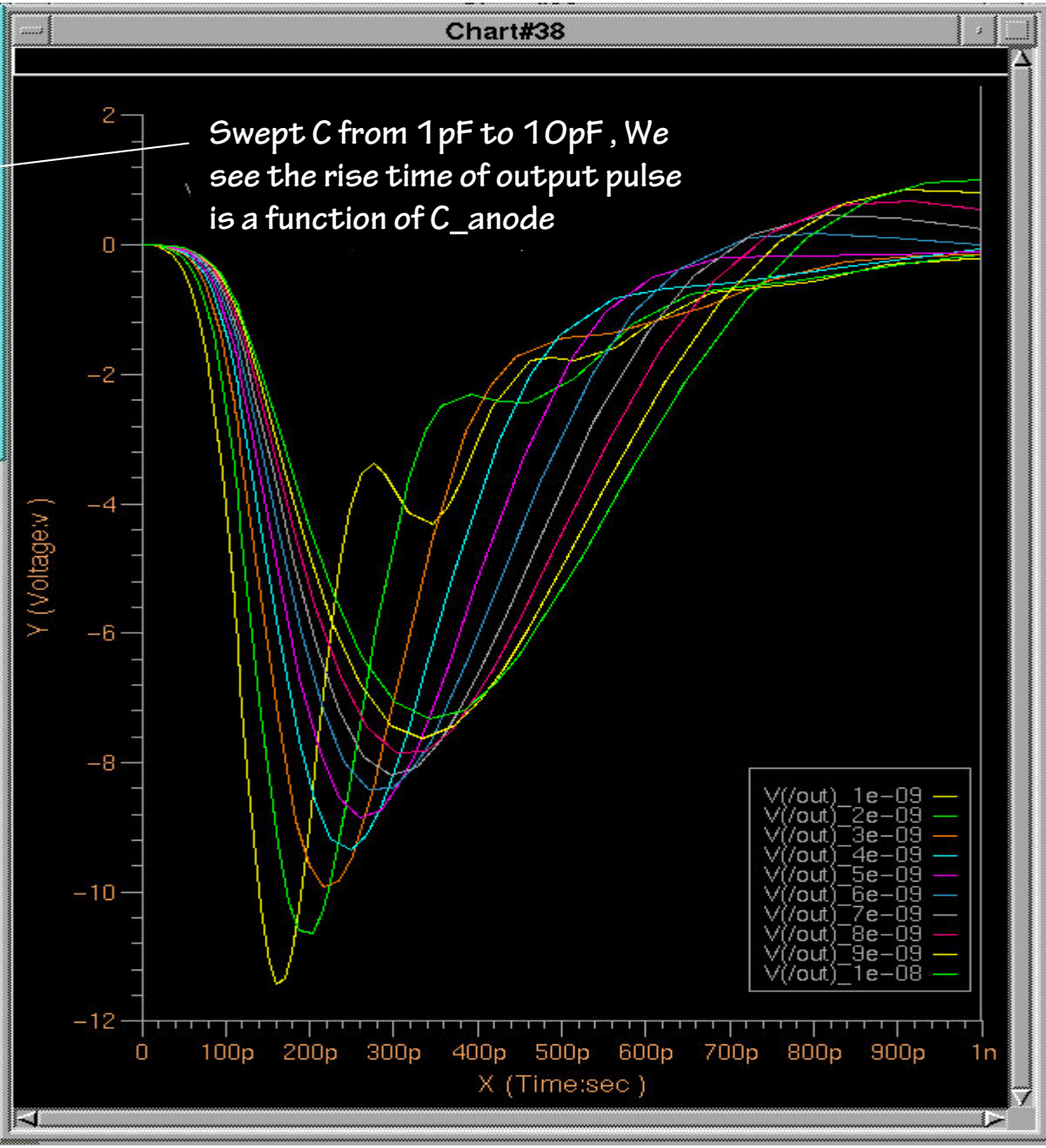
$$= \frac{R}{s^2 LC + sRC + 1}$$

Fast signal components: 2-Pole!

MCP-PMT Model with Anode L and C

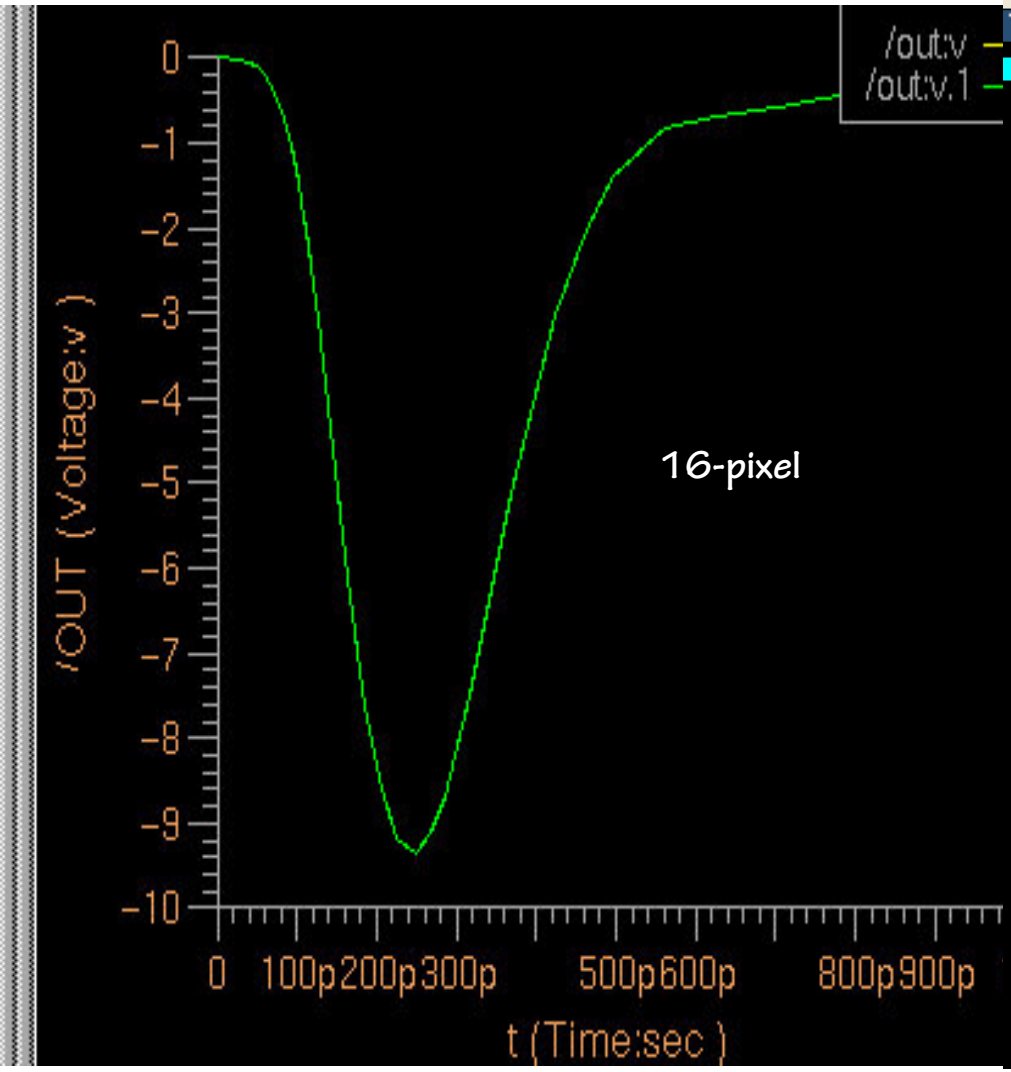




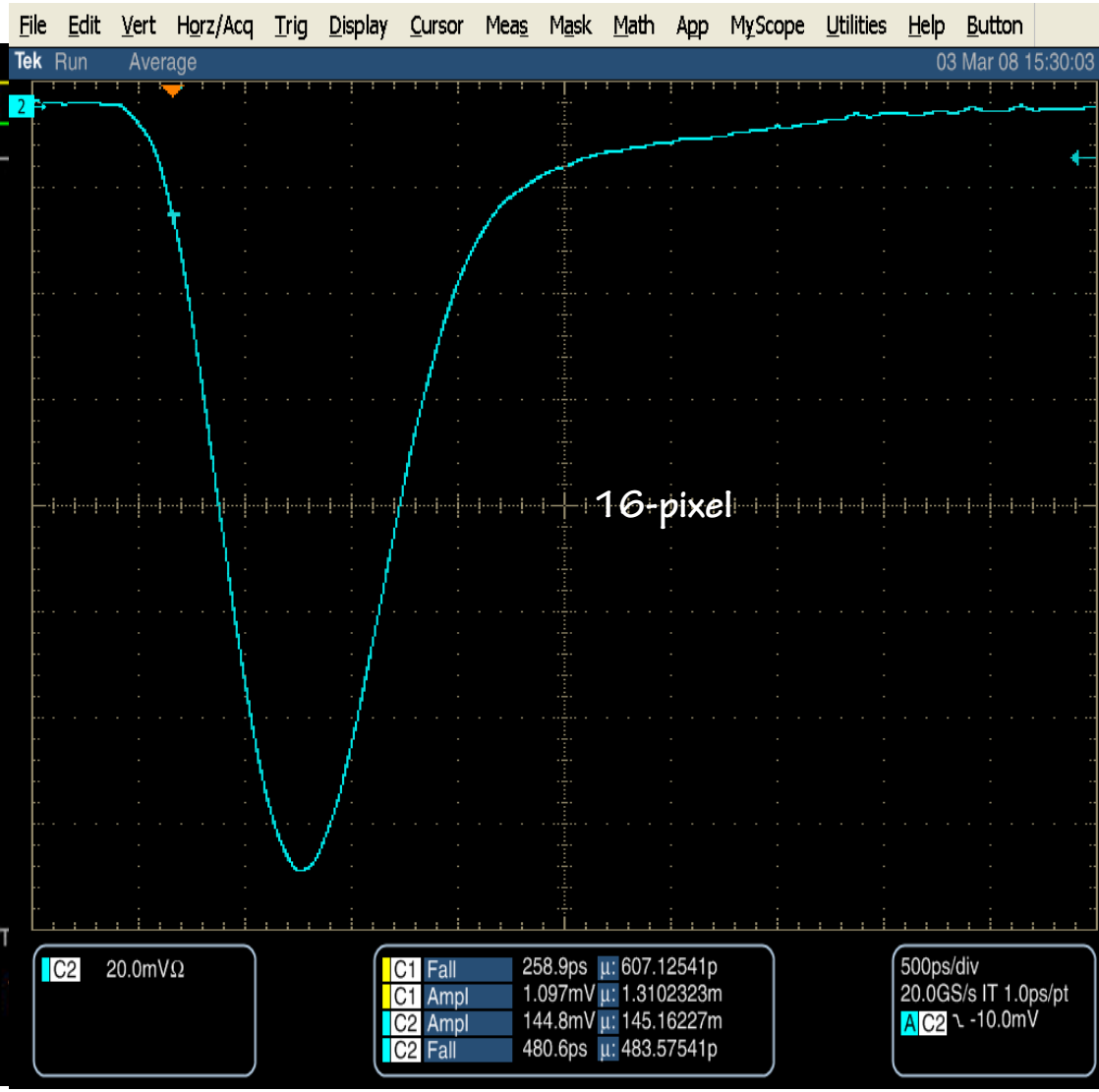


Comparison of Output Pulse Shapes

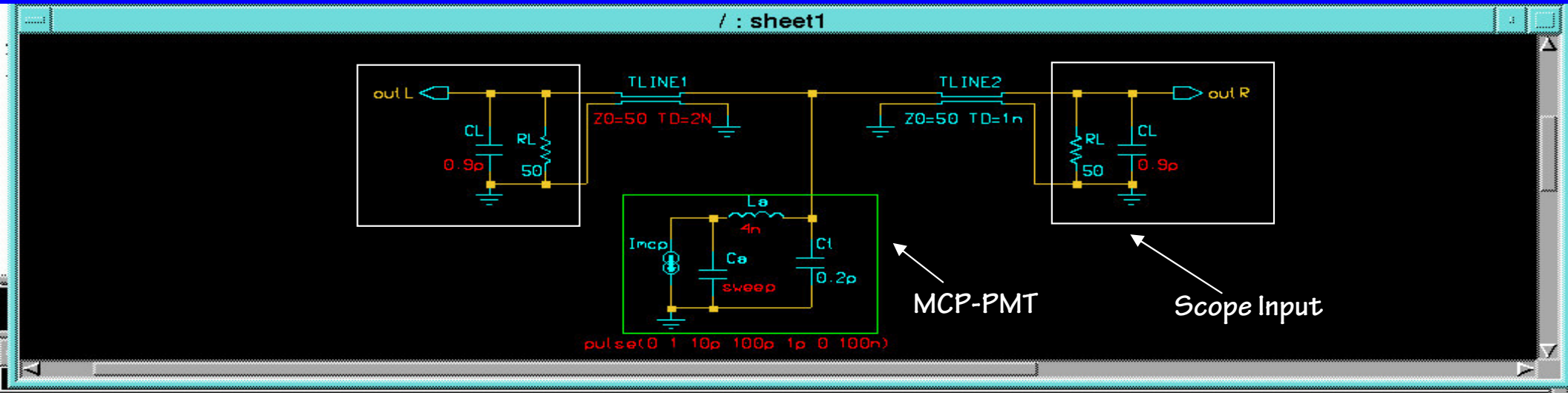
Simulation

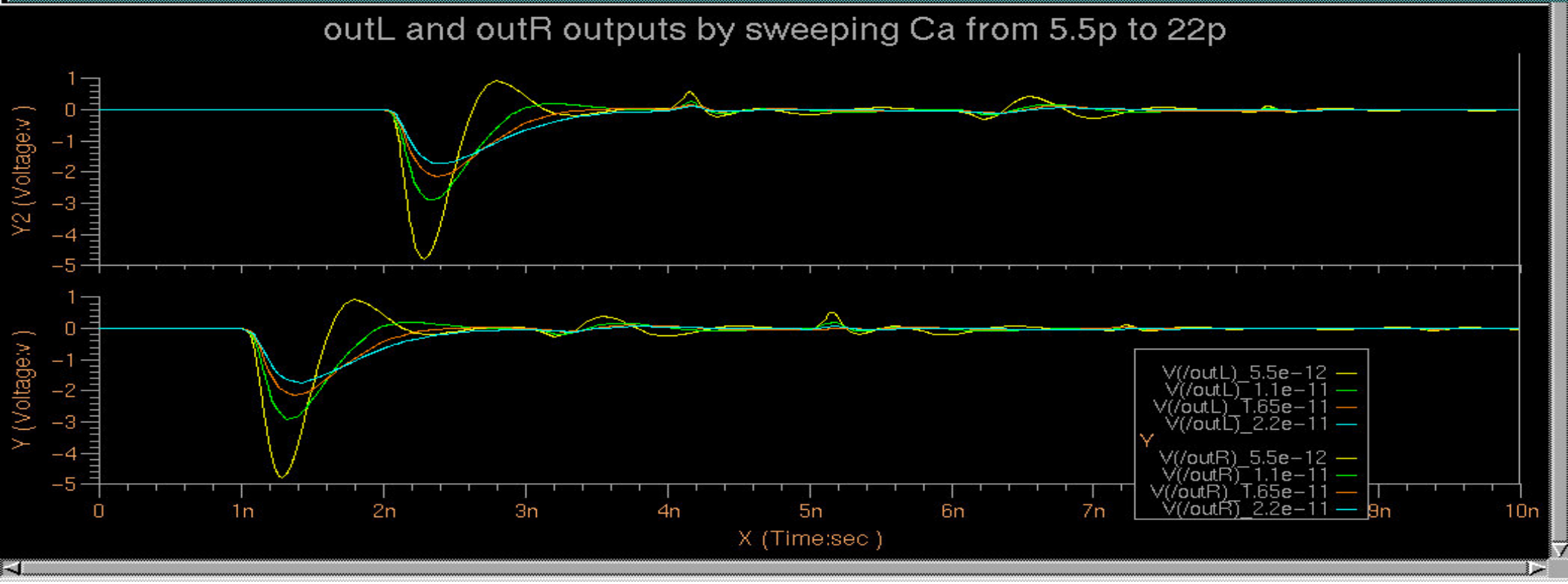


Test



Model with LRC and T-line





Summary

- Model with RLC seemed accurate.
- Output pulse shape from simulation is very consistent to the one we obtained from scope.
- Similar output behaviors have been observed from simulation as Photek obtained from their tests.
- More tunes on both model and shape of current source may be needed for further comprehensive simulations