10/10 excellent

Laboratory 2: Time-Domain Reflectometry (TDR)

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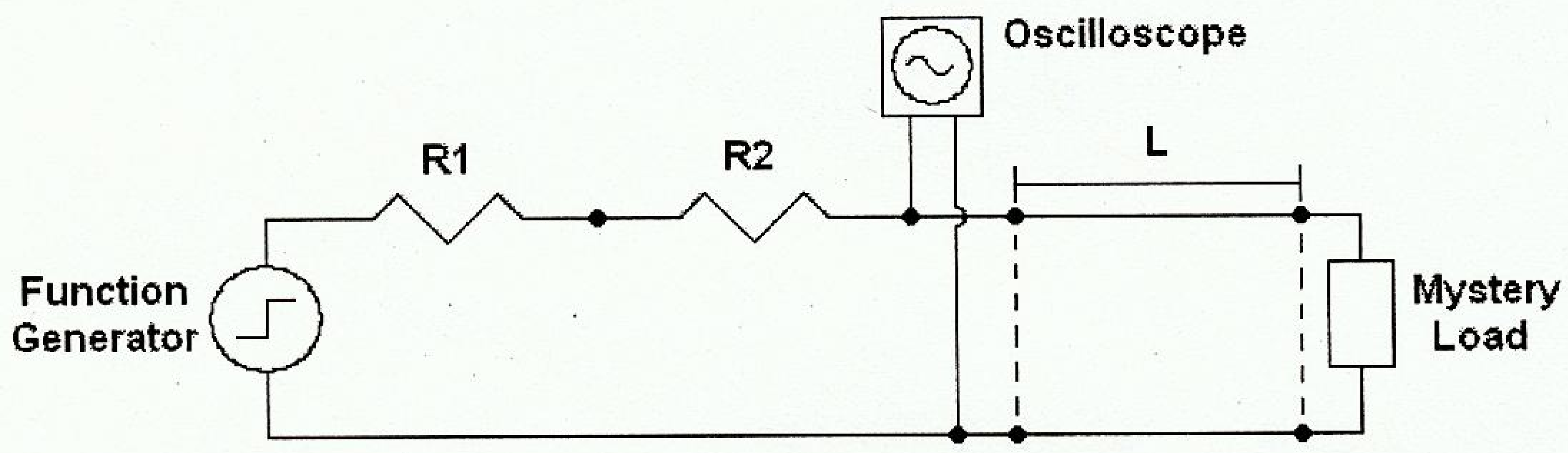
good! +1 extra

In this lab, an electrical step function, in the form of a 1kHz square wave on a coaxial transmission line, was used to characterize four unknown loads. A frequency of 1kHz gave a long enough pulse for the signal to settle for all tested loads. The circuit diagram of the TDR setup can be seen below. The rise time as measured on the oscilloscope was found to be approximately 9ns. The velocity of the signal was calculated using a test cable of known length, and found to be $2(10)^8$ m/s. Analysis of each load includes necessary equations, circuit diagrams, simulation results using HSPICE and photographs of the waveforms from the oscilloscope.
The oscilloscope used in this experiment is an equivalent-time sampling oscilloscope. In case of a time base with more periods of the wave than data points across the screen "aliasing" occurs which makes the signal look like a signal of lower frequency. A resistor of 220 Ω was used to suppress overshoot oscillations of the signals.

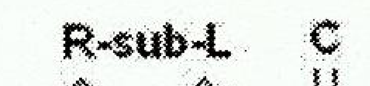
+1 ringing due to impedance mismatch, show why it helps.



$R_1 = 50\Omega$,
$R_2 = 220\Omega$,
$R_{oscilloscope} = 50\Omega$

Fig. 1 - TDR setup.

Port 1 – The unknown load is a capacitor.



+2

Using a measured rise time of $2.2R_{eff}C = 320ns$ where $R_{eff} = 50 \parallel (50 + 220)$, we estimate $C = 3.45nF$. The reflection coefficient of the capacitor for the first reflection is not -1, and is estimated from the waveform to be about -0.9, which corresponds to a parasitic resistance of 2.6Ω. $\frac{R_L-50}{R_L+50} = -0.9$, which implies $R_L = 2.6\Omega$. We used cables of different length to connect the oscilloscope to the unknown load. The picture below shows the reflection of the capacitor using a long cable.

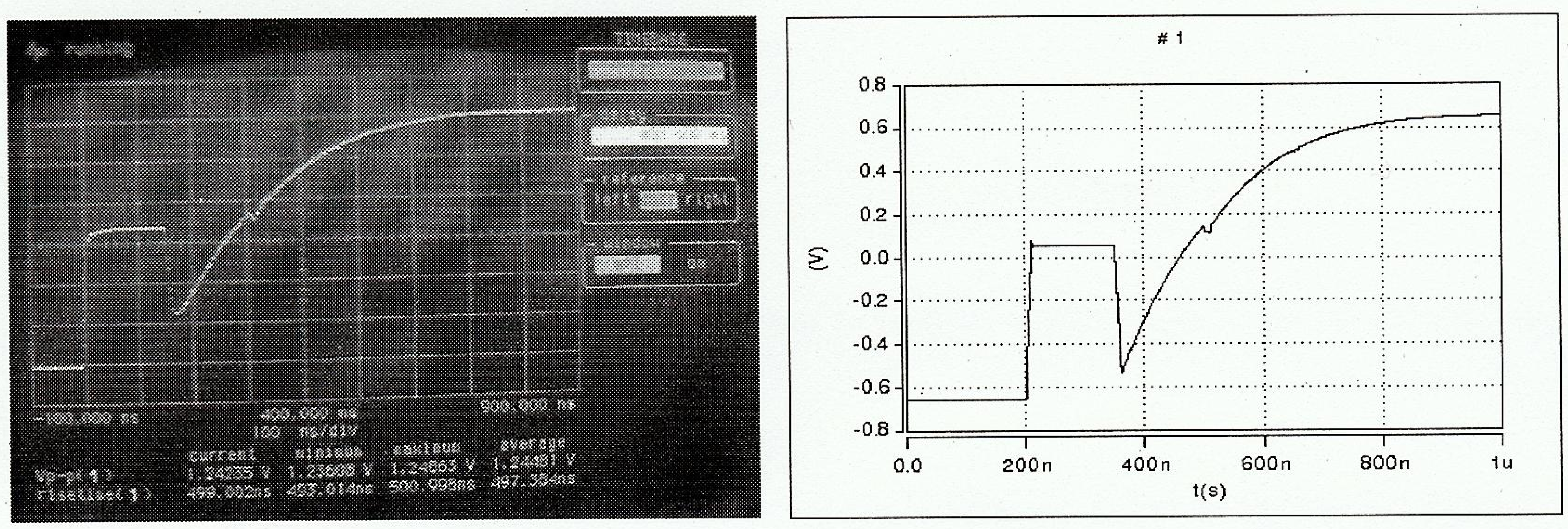
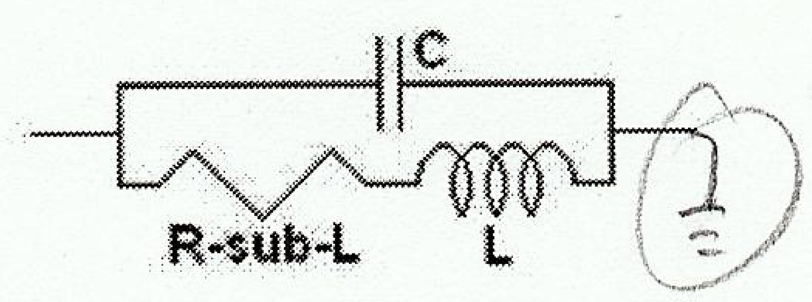


Fig. 2 Measured waveform (left) and simulation using calculated values (right) for port 1.

Port 2 – The unknown load is equivalent to a RLC network as shown.



We used the measured waveform to estimate the values of the circuit elemesnt. The circuit is described in frequency space by

$$V(s) = \frac{A(s)}{\left(LCs^2 + s\left(RC + \frac{L}{R_{eff}}\right) + \left(1 + \frac{R}{R_{eff}}\right)\right)}, \text{ where } R_{eff} = 50 \parallel (50 + 220).$$

At steady state we know $\frac{V_{steady\ state}}{R \| 50} = \frac{V_{pulse} - V_{steady\ state}}{(50+220)}$, which implies $R \simeq 2\Omega$. From the waveform, we estimate the resonant frequency, $f_R = \frac{1}{2\pi\sqrt{LC}} \simeq 50kHz$ and decay constant of the envelope

RLC discharged into $Z_0 \to 50\,\Omega$

$\alpha = \left(\frac{R}{2L} + \frac{1}{2R_{eff}C}\right) = 1.5(10^5)s^{-1}$. Together, these two conditions give $L = 135\mu H, C = 74nF$. 100μH 100nF +2

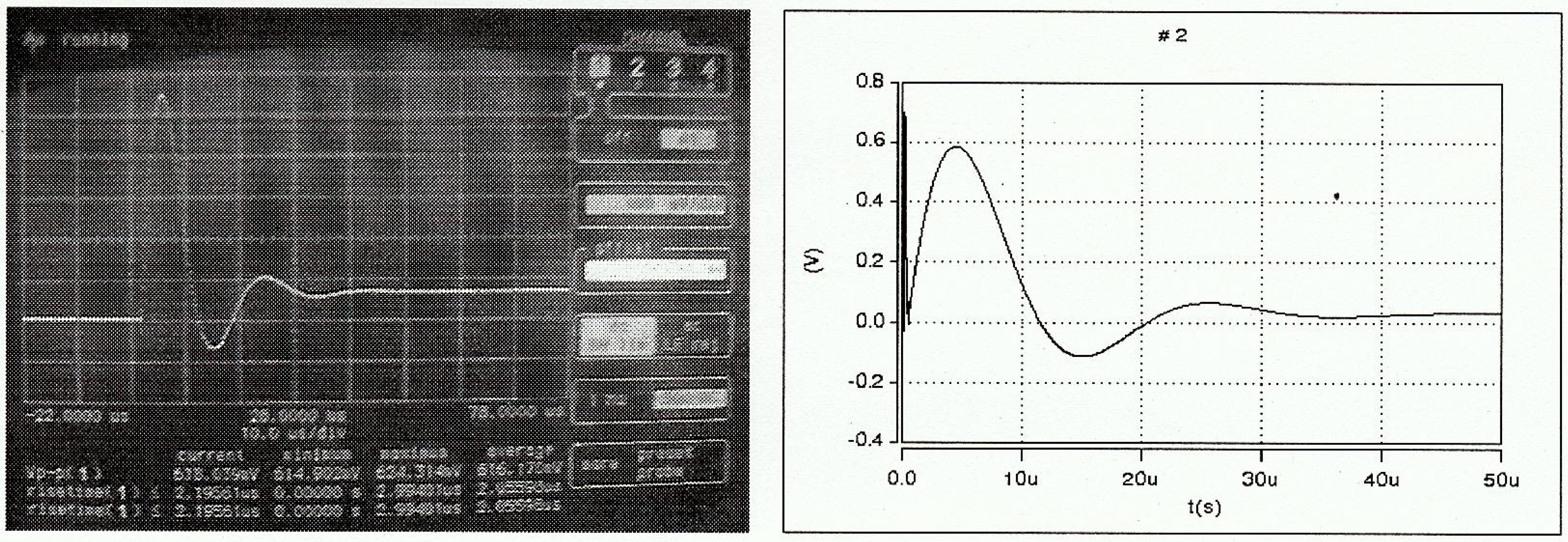
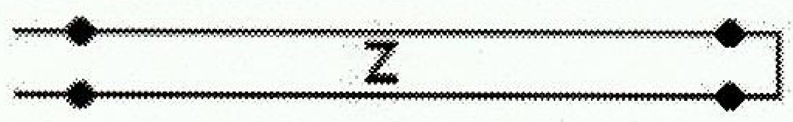


Fig. 3- Measured waveform (left) and simulation using calculated values (right for port 2).

Port 3 – The unknow load is a ~~15m~~ 7.5m long high impedance ($Z_L = 93\Omega$) transmission line terminated by a short.



The reflection coeffecient at the load is $\frac{Z_L - 50}{Z_L + 50} = \frac{200mV}{687mV}$, implying $Z_L = 93\Omega$. The effective resistance of the load is given by $4.2V \times \left(\frac{R_{eff}}{R_{eff}+50+220}\right) = 15mV$, implying for the shorted end $R_{eff} \simeq 1\Omega$. The velocity of the signal in a standard 93Ω cable is $0.83c = 2.5(10^8)m/s$ so the delay of $30ns$ corresponds to a cable length of $7.5m$.

where did you get this?

well done +2

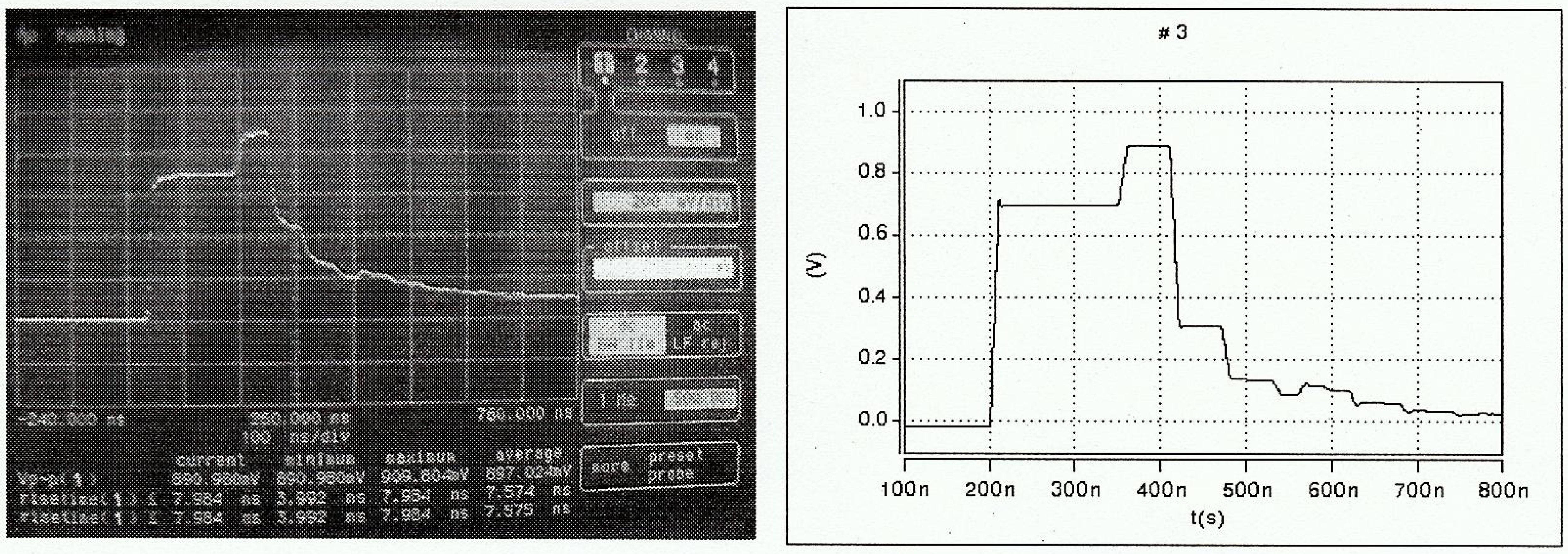
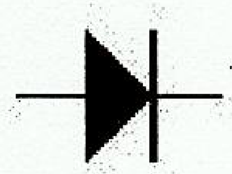


Fig. 4 - Measured waveform (left) and simulation using calculated values (right) for port 3.

Port 4 – The unknown load is a silicon diode whose turn-on voltage is nearly 0.8V.



Changing the peak-to-peak voltage of the input pulse we determined the ~~the~~ turn-on voltage of the diode. +2

sketch?

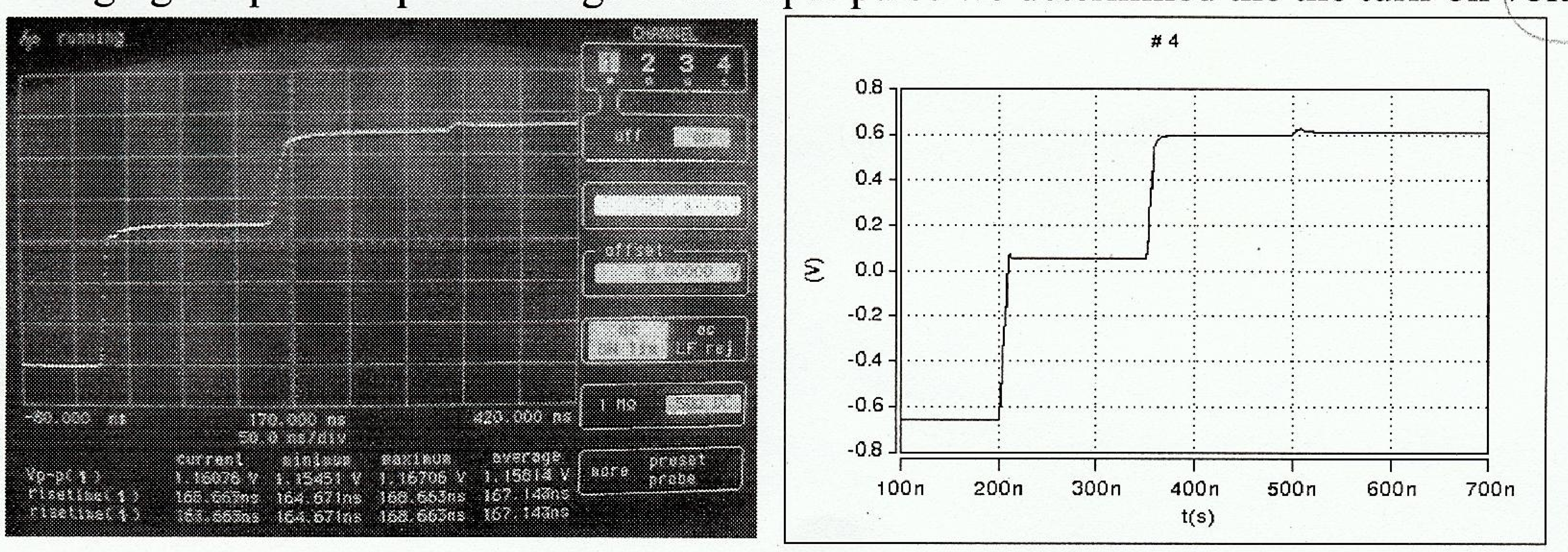


Fig. 5 - Measured waveform (left) and simulation using calculated values (right) for port 4.

Conclusion: The 4 unknown loads were quantitatively determined using TDR. All the lumped element values reported are accurate only in the order of magnitude.