303 – Physics for Engineers II - Laboratory

UNIVERSITAT JAUME•I

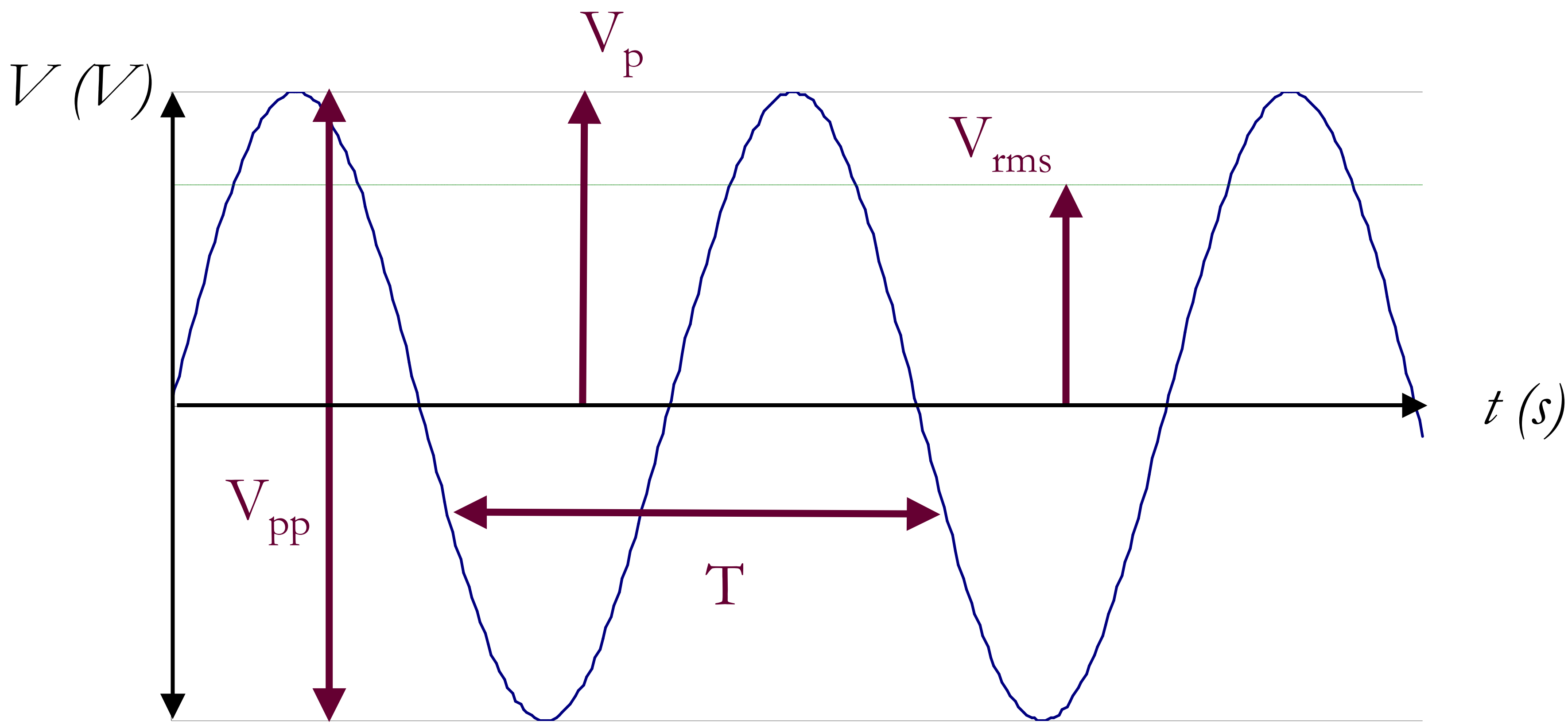
Experiment # 2: Digital oscilloscope. RC Circuit

- **Introduction to oscilloscopes:** measuring transient and periodic signals. Digital oscilloscope
- **Condensers and capacitance**
- **Making measurements with the oscilloscope:** probe attenuation factor, automatic measurements, cursor measurements, main and delayed sweep, trigger, ambient signals, signals from function generator
- **Discharging a capacitor in an RC Circuit:** time constant
- **RC integrator and differentiator**

Periodic signals

Multimeter: measures V, I, R (only DC signals or low frequency, ~50 Hz / kHz)

Oscilloscope: signals V(t), V_1(t) vs. V_2(t), up to very high frequency (60 MHz and more)



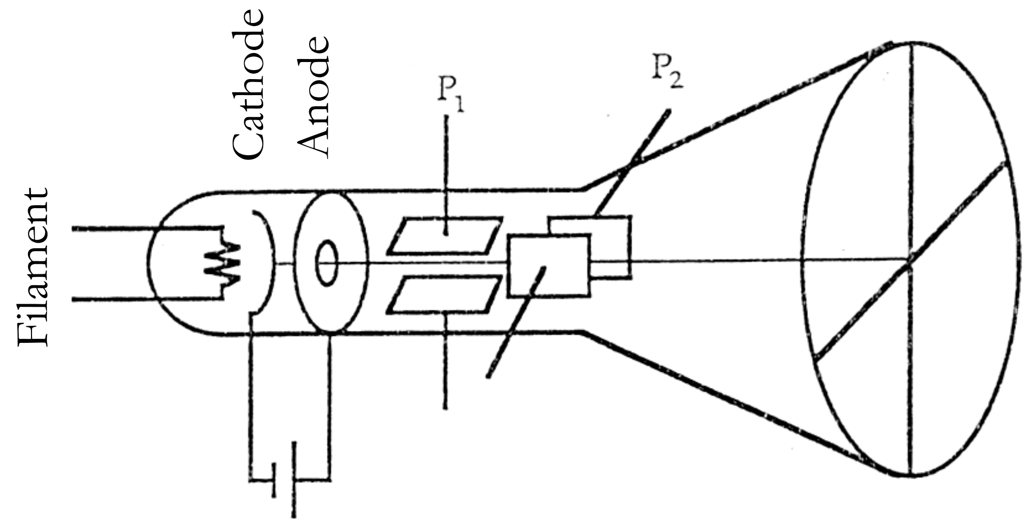
$$T = \frac{1}{\nu} = \frac{2\pi}{\omega}$$

$$V_{rms} = \sqrt{avg\left(V^2\right)}$$

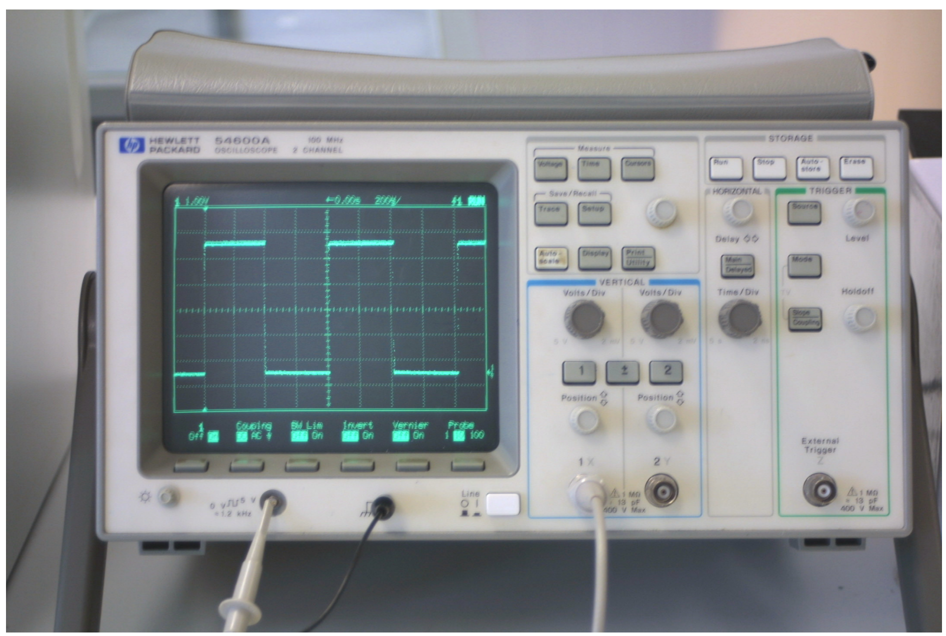
for a sinusoidal signal: $V_{rms} = \frac{V_p}{\sqrt{2}} = \frac{V_{pp}}{2\sqrt{2}}$

Digital oscilloscope

Analog oscilloscope

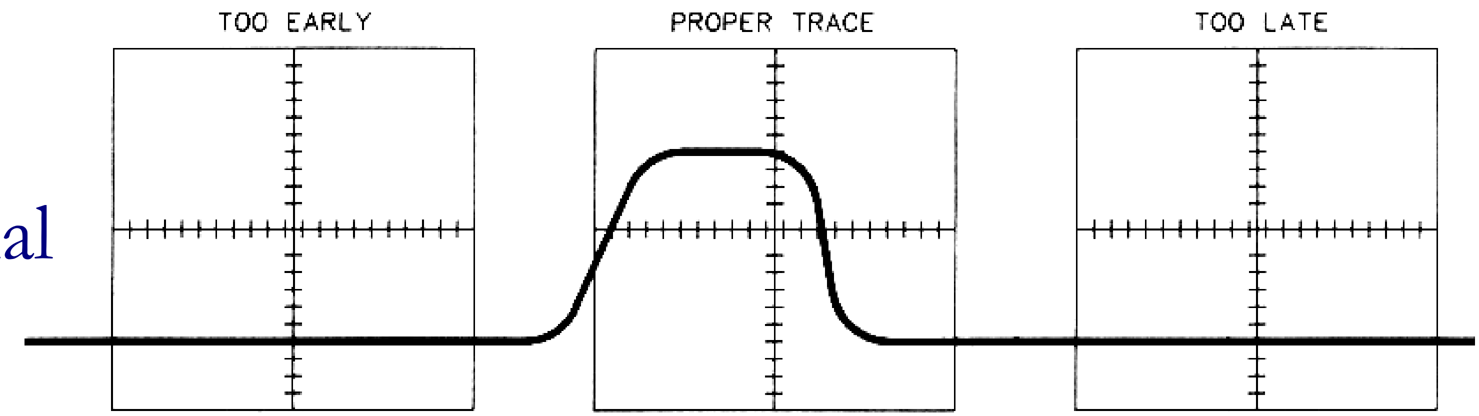


Digital oscilloscope

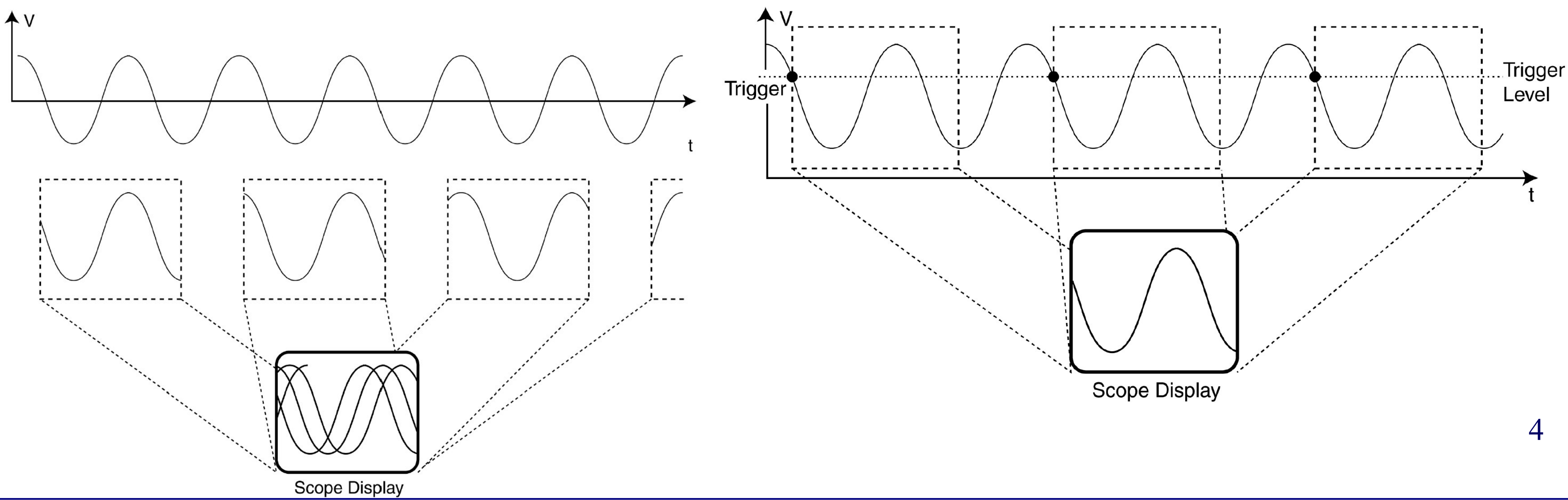


Scope trigger

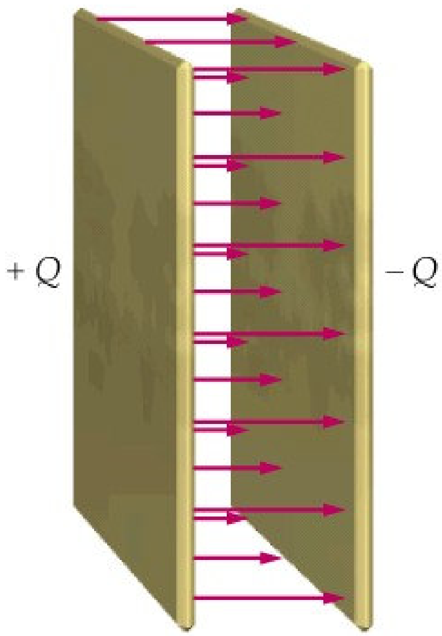
Transient signal



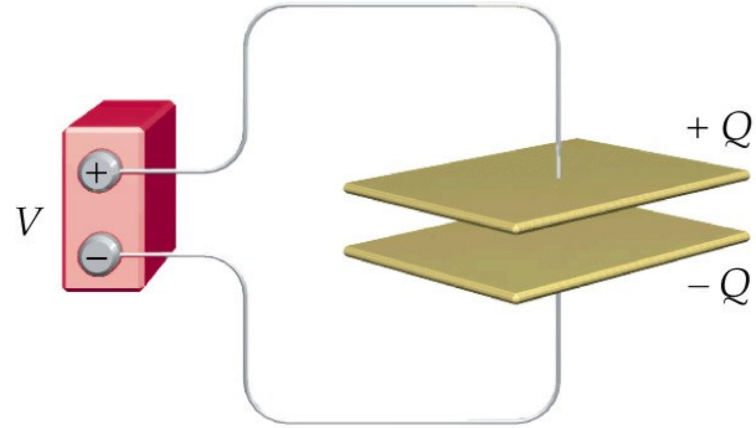
Periodic signal



Condensors



(a)



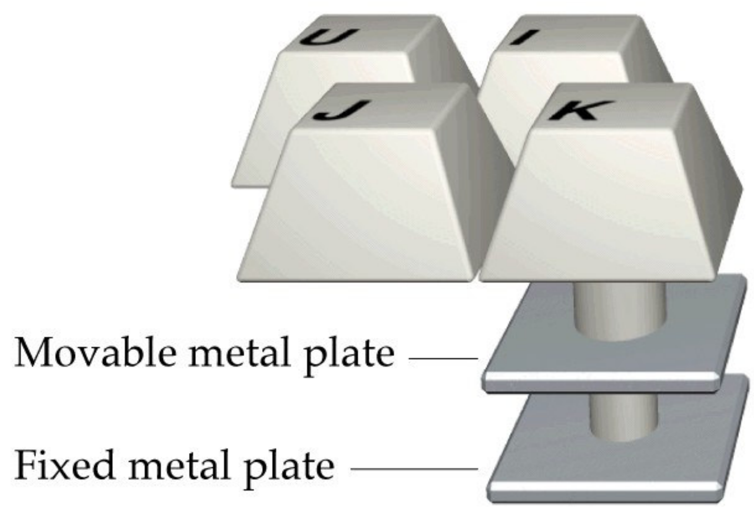
$$C = \frac{Q}{V}$$

Applications:

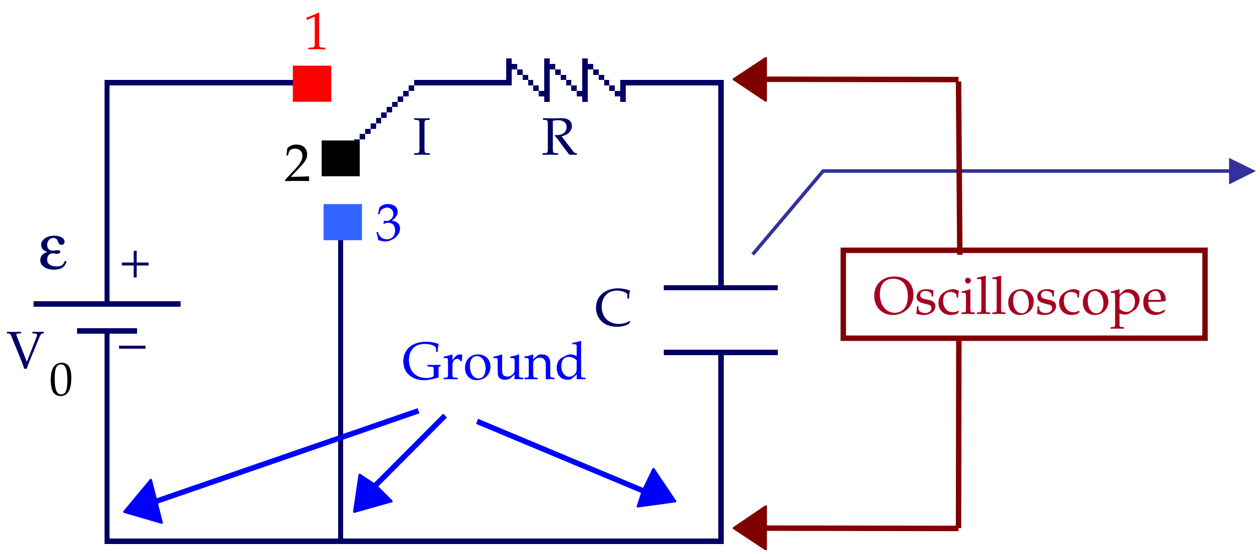
Electronics, low-pass and high-pass filter

Keyboards: capacitance switch

Camera flash



RC Circuit: Discharging a capacitor (1/2)



$$dq = -i\,dt$$

$$V(t) = \frac{q(t)}{C} = i(t)\,R$$

$$\frac{dq}{q} = -\frac{1}{RC}dt$$

$$\frac{q(t)}{C} = -R\frac{dq}{dt}$$

$$\int_{Q_0}^{Q}\frac{dq}{q} = -\frac{1}{RC}\int_0^t dt$$

RC Circuit : Discharging a capacitor (2/2)

$$\int_{Q_0}^{Q} \frac{dq}{q} = -\frac{1}{RC}\int_0^t dt \qquad Q(t) = Q_0\, e^{-\frac{t}{RC}}$$

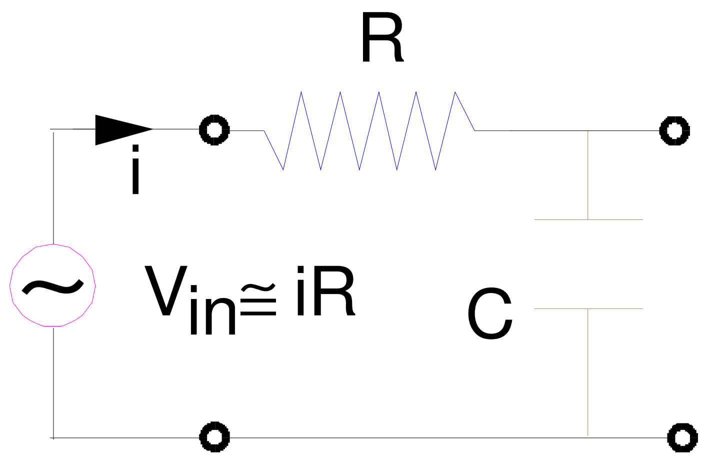
$$\tau = RC$$

$$V(t) = \frac{Q(t)}{C} = \frac{Q_0}{C}\, e^{-\frac{t}{RC}} = V_0\, e^{-\frac{t}{RC}}$$

$$\ln V = -\frac{t}{RC} + \ln V_0$$

$$pendent = -\frac{1}{RC}$$

RC integrator



$$V_{out} \cong \frac{1}{RC}\int V_{in}\,dt$$

$$(w >> 1/RC)$$

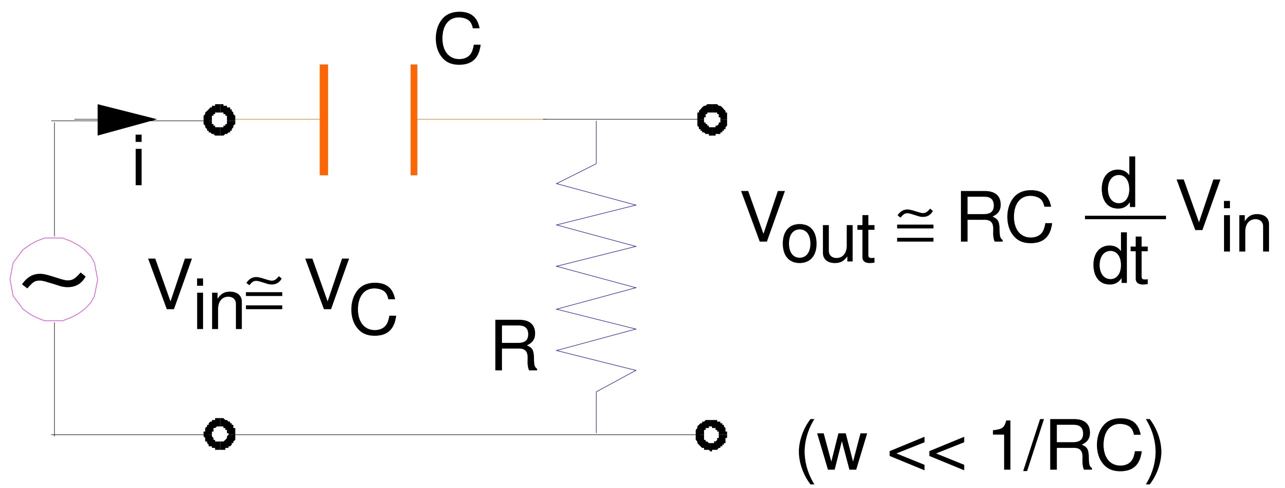
$$V_{in} = I\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$$

$$\omega C >> R \quad \Rightarrow \quad V_{in} \cong IR$$

$$V_{out} = \frac{Q}{C} = \frac{1}{C}\int I\,dt \cong \frac{1}{C}\int \frac{V_{in}}{R}\,dt$$

$$V_{out} = \frac{1}{CR}\int V_{in}\,dt$$

RC differentiator

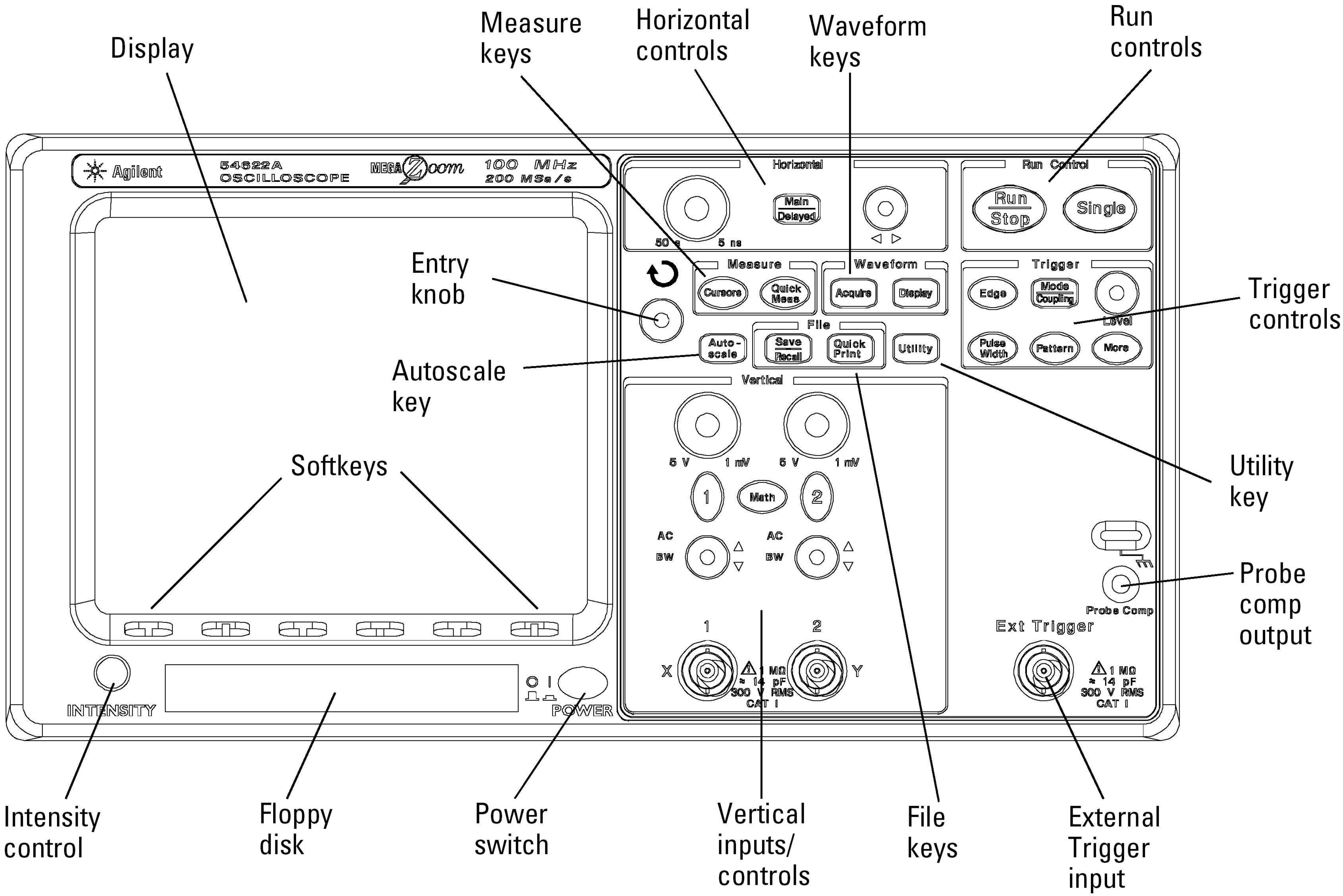


$$R << \frac{1}{\omega C} \quad \Rightarrow \quad V_{in} \cong \frac{I}{\omega C} = V_C$$

$$V_{out} = RI = R\frac{dQ}{dt} = R\frac{d}{dt}CV_c = RC\frac{dV_c}{dt}$$

$$V_{out} \cong RC\frac{d}{dt}V_{in}$$

Experimental procedure (1/10)



Experimental procedure (2/10)

1. Measuring probe compensation signal:

Probe compensation signal

Autoscale key

Display information and adjustment of scaling and position

Vertical sensitivity
ch 1 & 2: 2 V/div

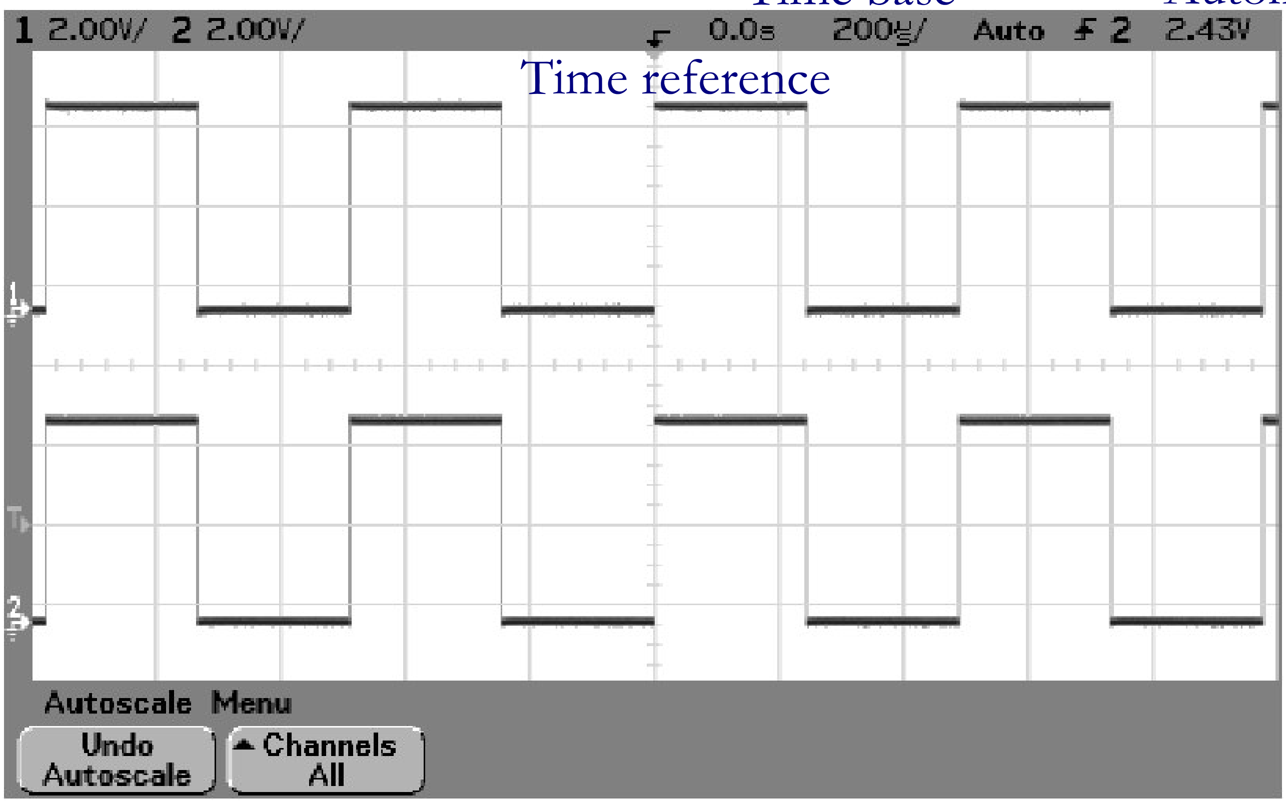
Time base

Automatic measurement

Time reference

Ch 1

Ch 2

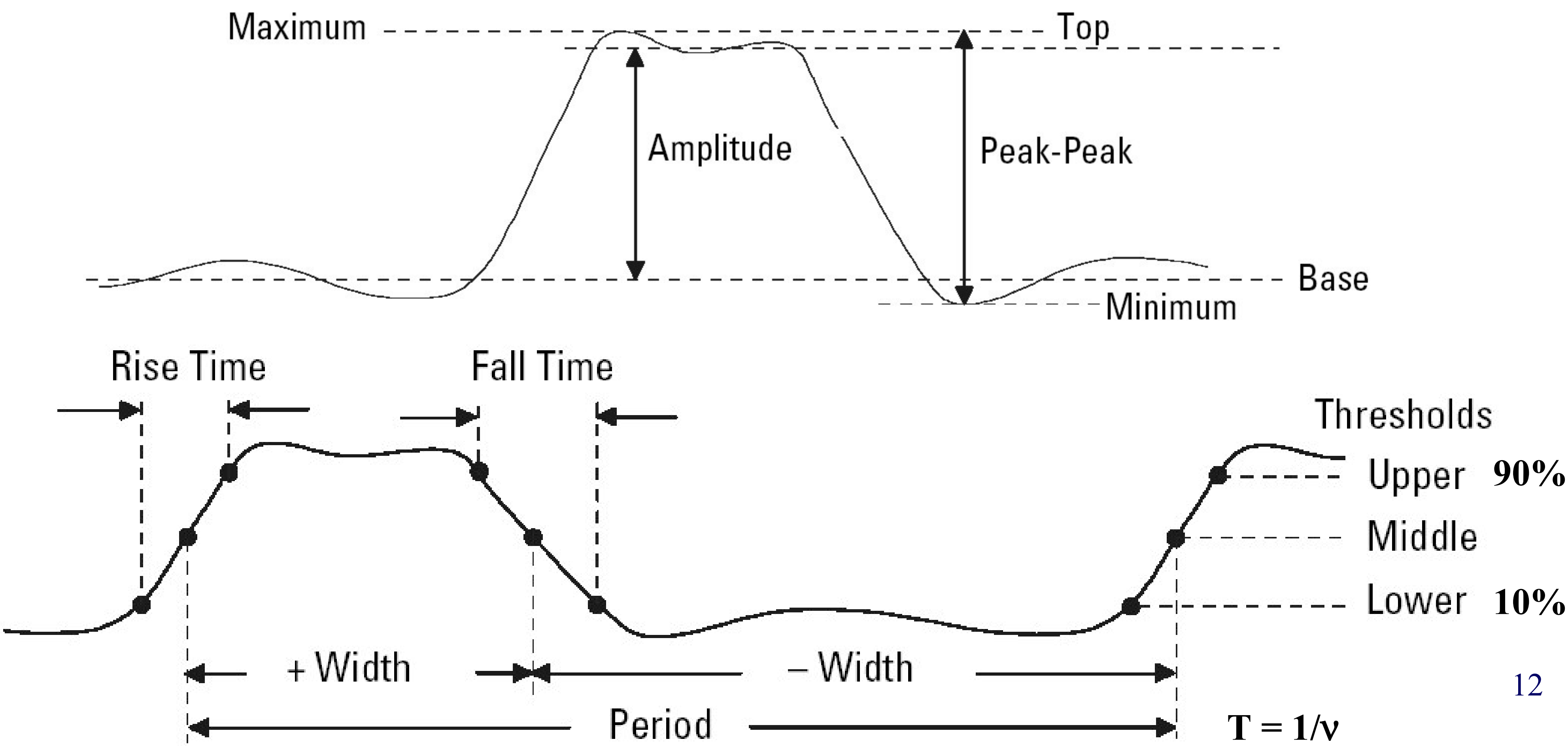


Experimental procedure (3/10)

1. Measuring probe compensation signal:

Checking probe attenuation factor

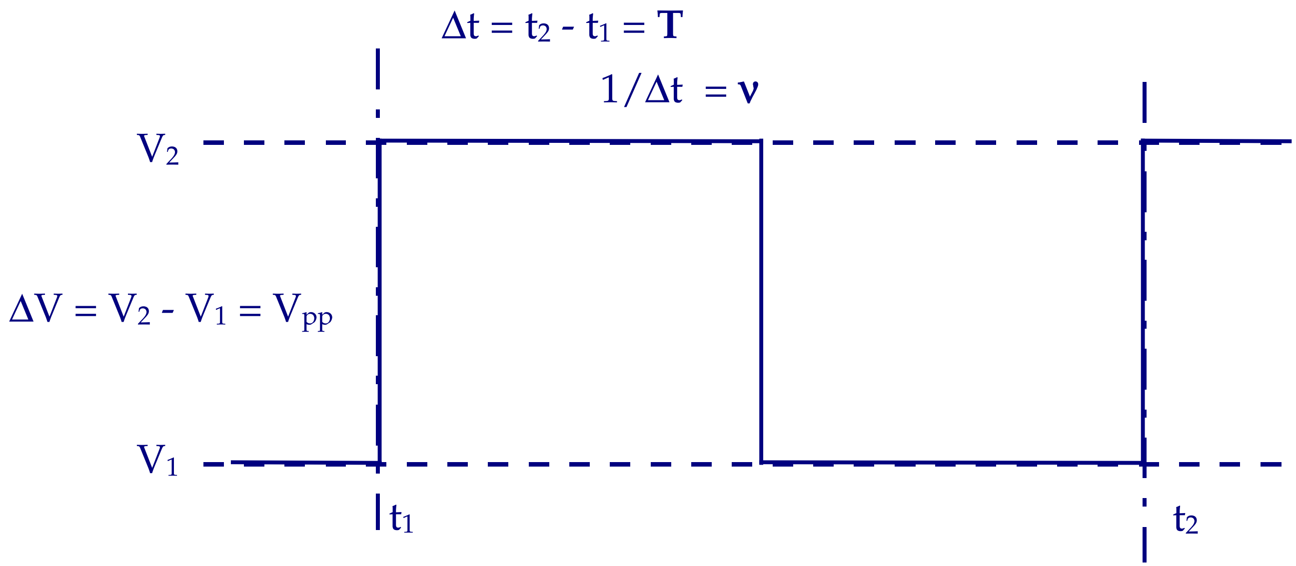
Automatic measurements of voltage and time: V_{pp}, V_{avg} (average), V_{rms} , ...

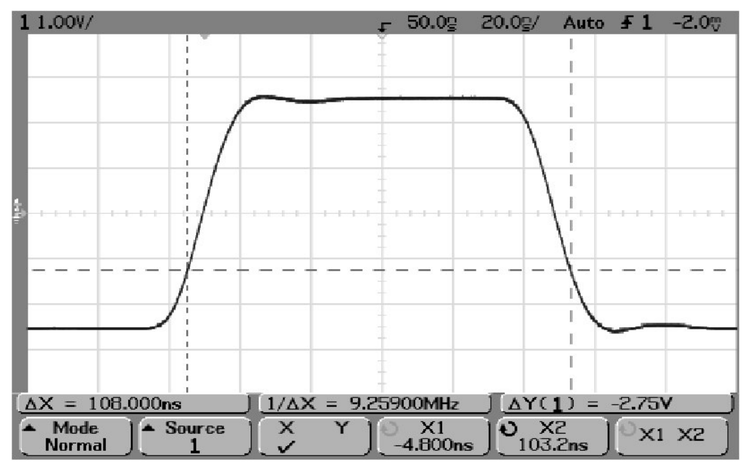


Experimental procedure (4/10)

1. Measuring probe compensation signal:

Voltage and time cursor measurement: V_{pp}, T and ν



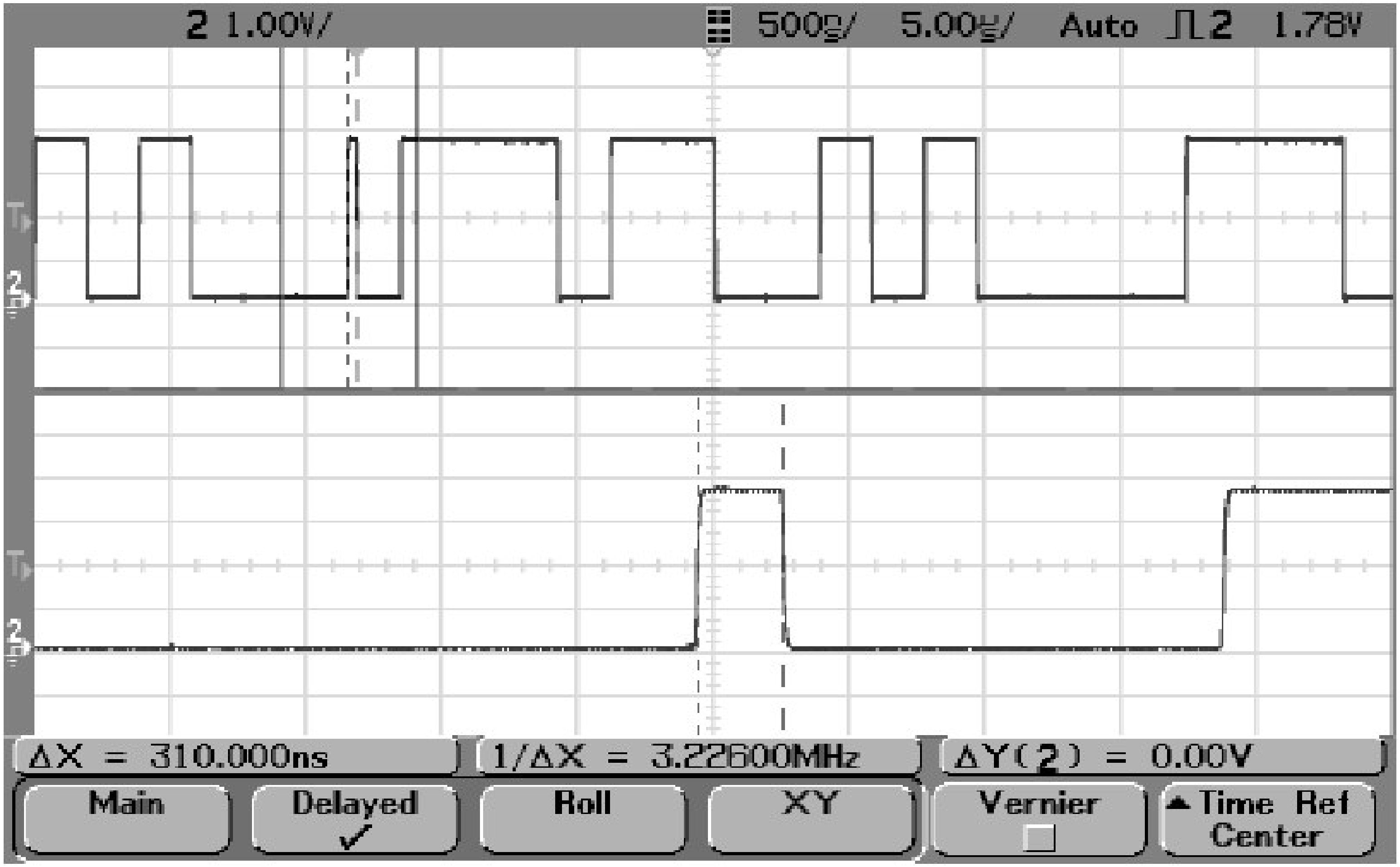


Experimental procedure (5/10)

1. Measuring probe compensation signal:

Main and delayed sweep

Trigger



Experimental procedure (6/10)

1. **Measuring probe compensation signal.**
2. **Measuring ambient signals.**
3. **Measuring signals from function generator:**

   Coaxial cable attenuation factor

   7 kHz and 7 Hz signals

   Adjust amplitude and offset

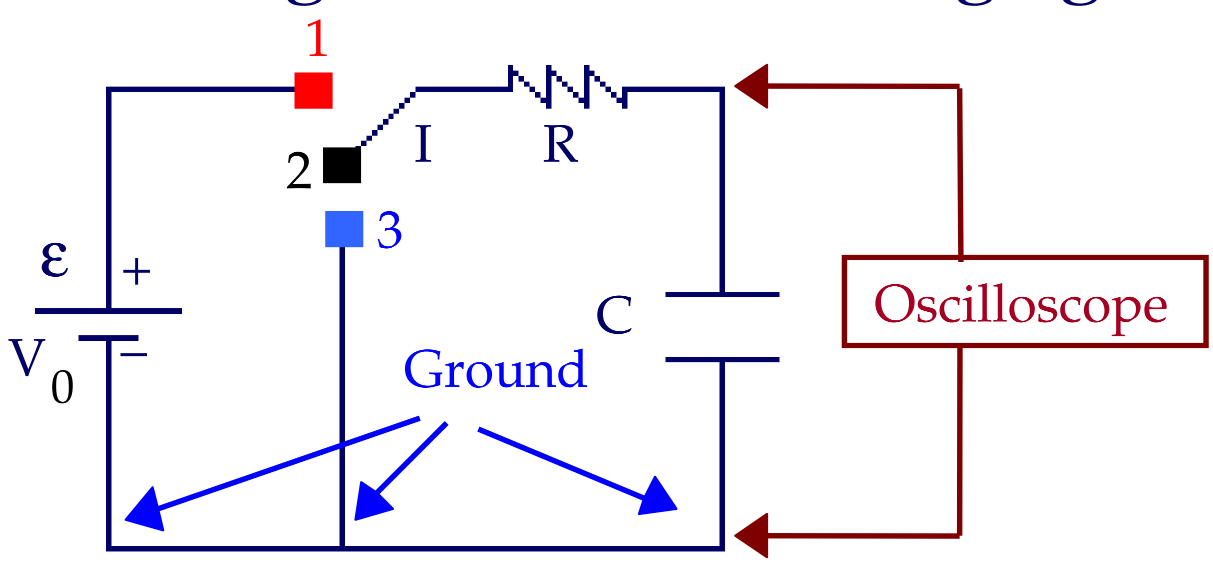
Experimental procedure (7/10)

4.1 Measuring transients: outputs 9 & 10, training signal board

9: Trigger: Single, mode Normal, ↗, level 5.0 V. Time base: Left, 20 μs/div, 2V/div

10: as previous, but Trigger level 2V, sensitivity 1V/div

4.2 Measuring transients: Discharging a capacitor



R = 10 kΩ, measure it!

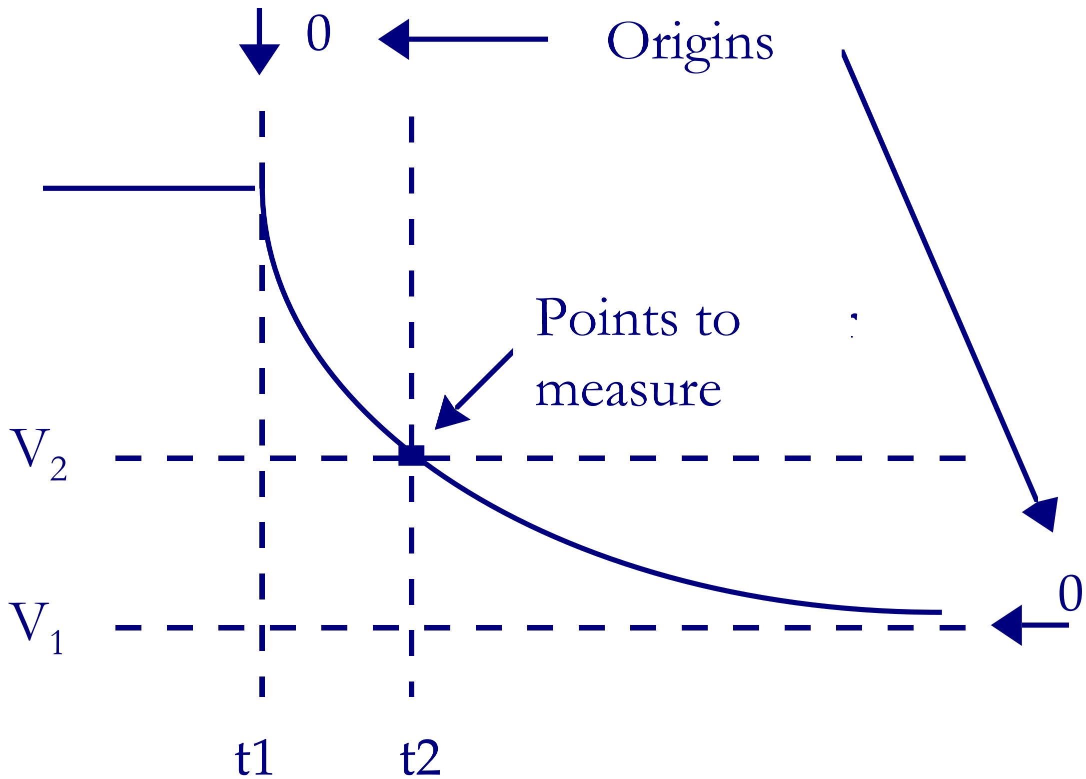
C = 1 μF

Source 4 V

Trigger: Single, Level < 4 V, Slope ↘, 1 V/div, 5 ms/div, t Left

Experimental procedure (8/10)

4.2 Discharging a capacitor



t (s)	V (V)	ln V

$$\ln V = -\frac{t}{RC} + \ln V_0$$

$$y = ax + b \qquad a = \frac{-1}{RC}$$

Results: Calculation of τ, C i V_0, and their uncertainty

Experimental procedure (9/10)

5.1 RC integrator

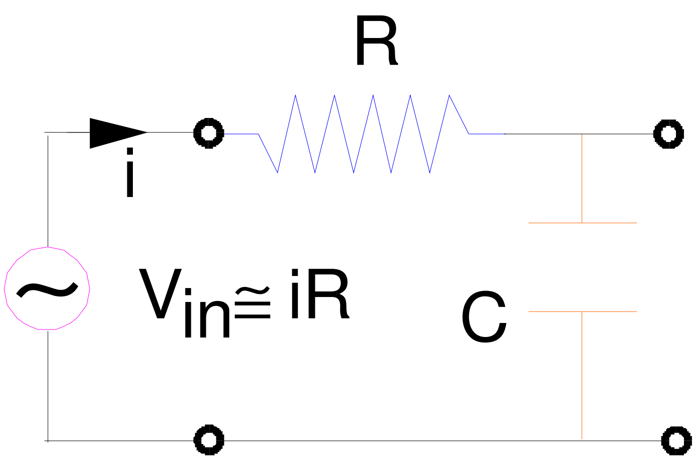
Circuit set-up: C=1 nF and R=10 kΩ.

Function generator: high frequency square wave ($\nu \approx 400$ kHz)

Channel 1, measuring input voltage.

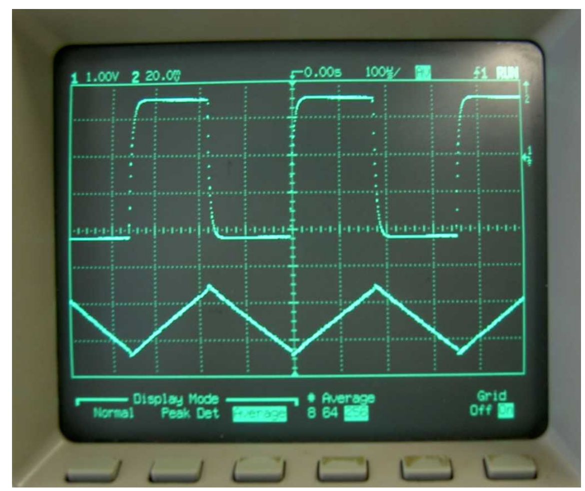
Channel 2, measuring voltage across capacitor.

Probe ground leads should be connected to the same point in the circuit



$$V_{out} \cong \frac{1}{RC}\int V_{in}\, dt$$

(w >> 1/RC)



Experimental procedure (10/10)

5.2 RC differentiator

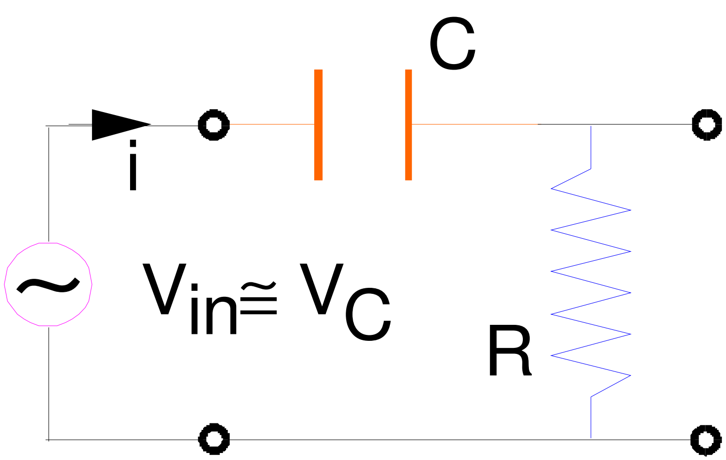
Circuit set-up: C=470 nF i R= 10 kΩ.

Function generator: low frequency triangle wave (ν≈100 Hz)

Channel 1, measuring input voltage.

Channel 2, measuring voltage across resistor.

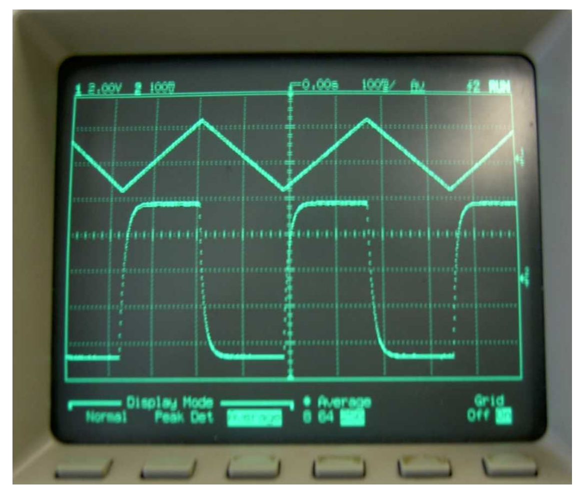
Probe ground leads should be connected to the same point in the circuit



$V_{in} \cong V_C$

$$V_{out} \cong RC \frac{d}{dt} V_{in}$$

$(w << 1/RC)$



Questions

1.- What is the physical meaning of the time constant $\tau = RC$ that appears in equation (9) in lab manual?

2.- Bearing in mind the input signal, justify the shape of the integral and derivative obtained in the oscilloscope from the RC circuit.