

Boğaziçi University

Introductory Phys Labs

CHARACTERISTICS OF A CAPACITOR

PHYL 201

THEORY AND APPARATUS

CHARACTERISTICS OF A CAPACITOR

When you connect a capacitor and a resistor in series and apply a specific waveform, the behavior of the circuit can be understood by applying the Kirchoff's voltage law:

$$R\frac{dq}{dt}+\frac{q}{C}=V_{app}$$

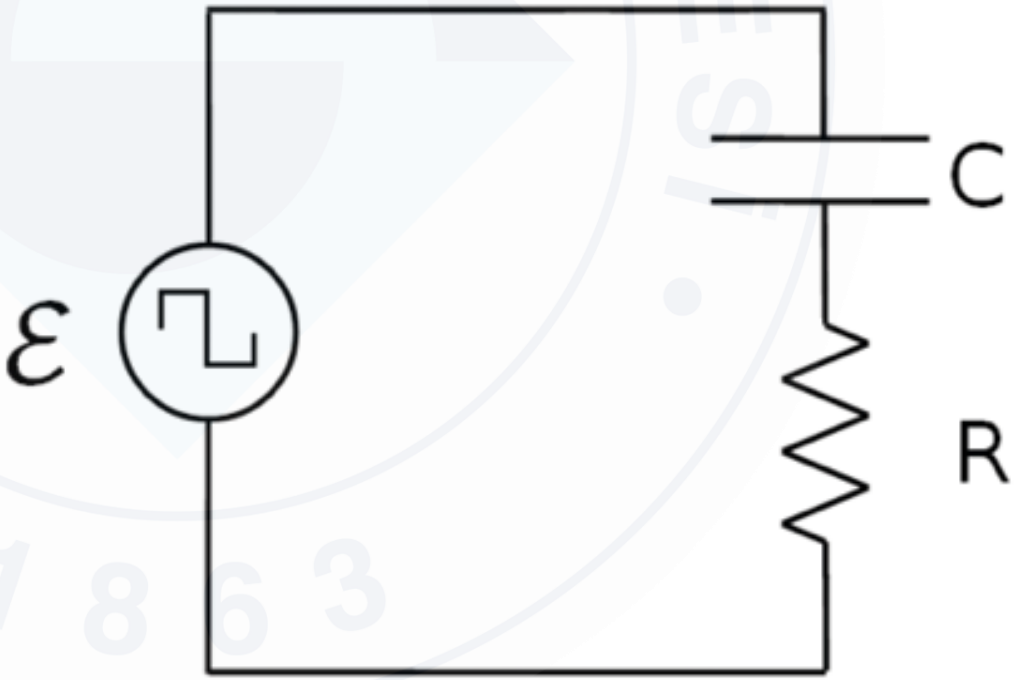
$V_c = V_0\, e^{-t/RC}$

when $V_c=V_0/2$

$t = t_{1/2} = \ln 2\, R_{tot}\, C$

RC is the time constant

here R is the total resistance in the circuit



CHARACTERISTICS OF A CAPACITOR

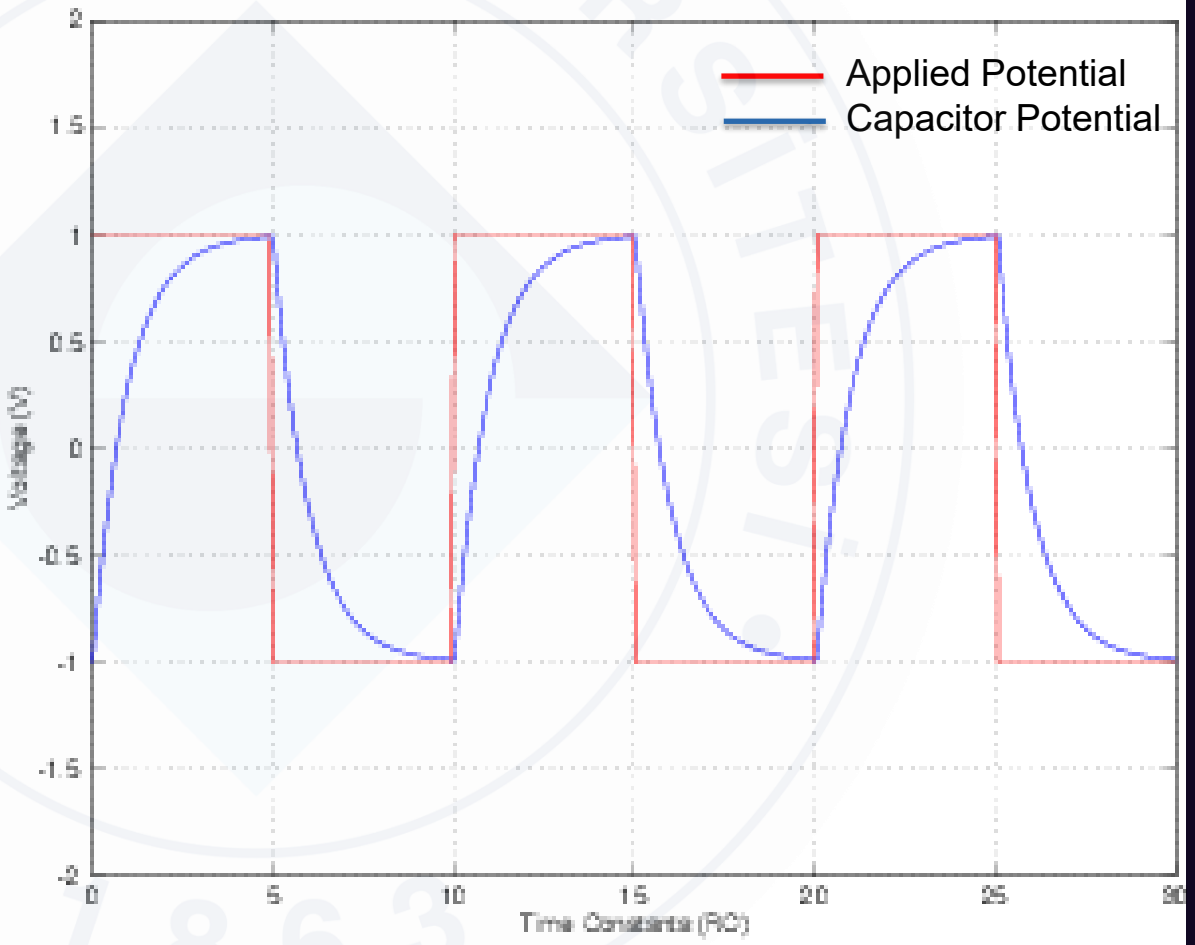
If we apply a square wave signal, choosing a period T much longer than the half-life of the RC circuit or

the RC time constant,

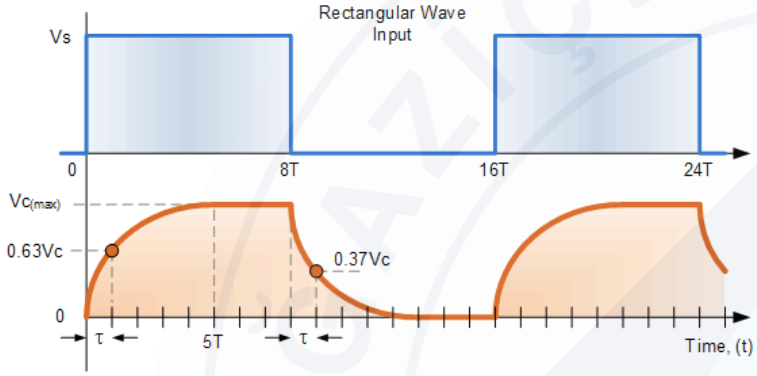
$$t_{1/2} = (\ln 2) R_{tot} C$$

we get a waveform repeatedly displaying the charging and discharge of the capacitor when the square wave goes up and down.

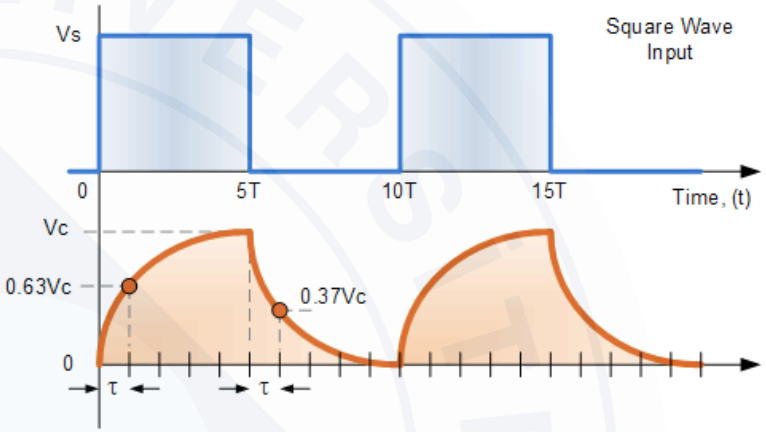
T >> RC



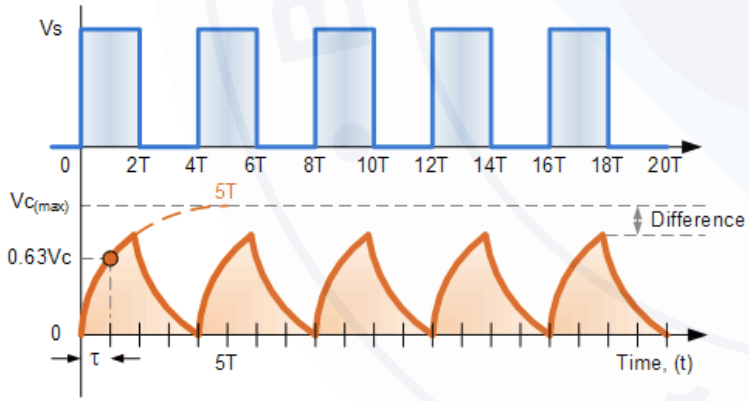
CHARACTERISTICS OF A CAPACITOR



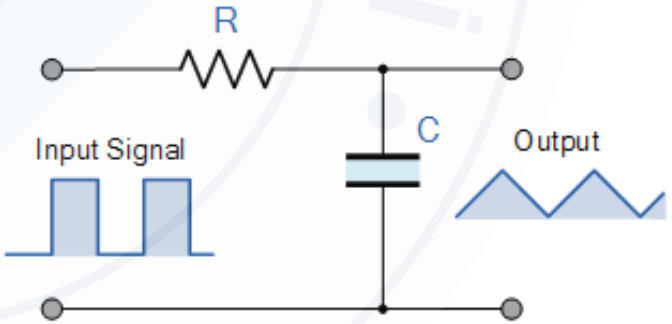
Period = 16 RC, T>RC



Period = 10 RC, T>RC



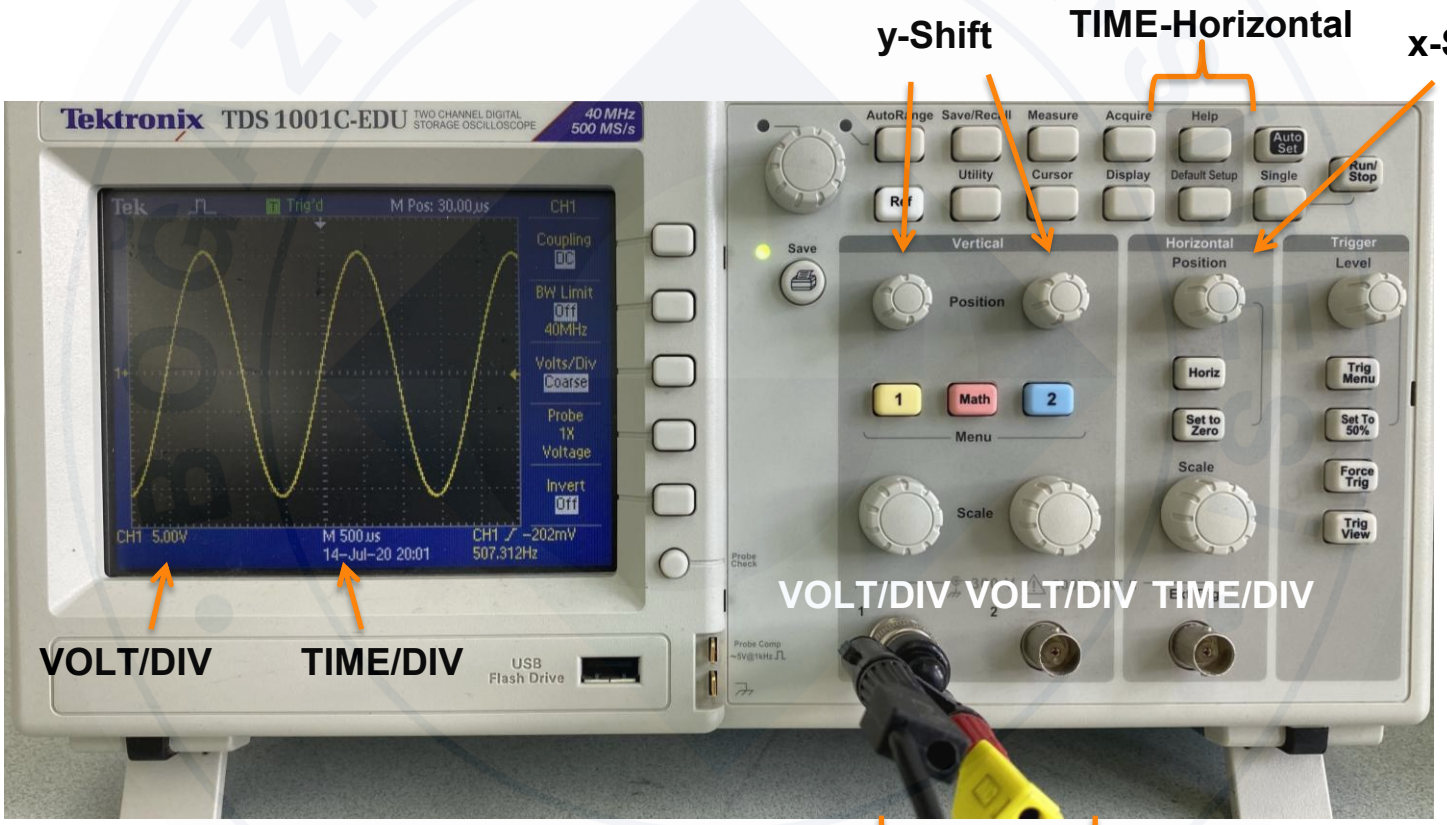
Period = 4 RC, T>RC



T<<RC

CHARACTERISTICS OF A CAPACITOR

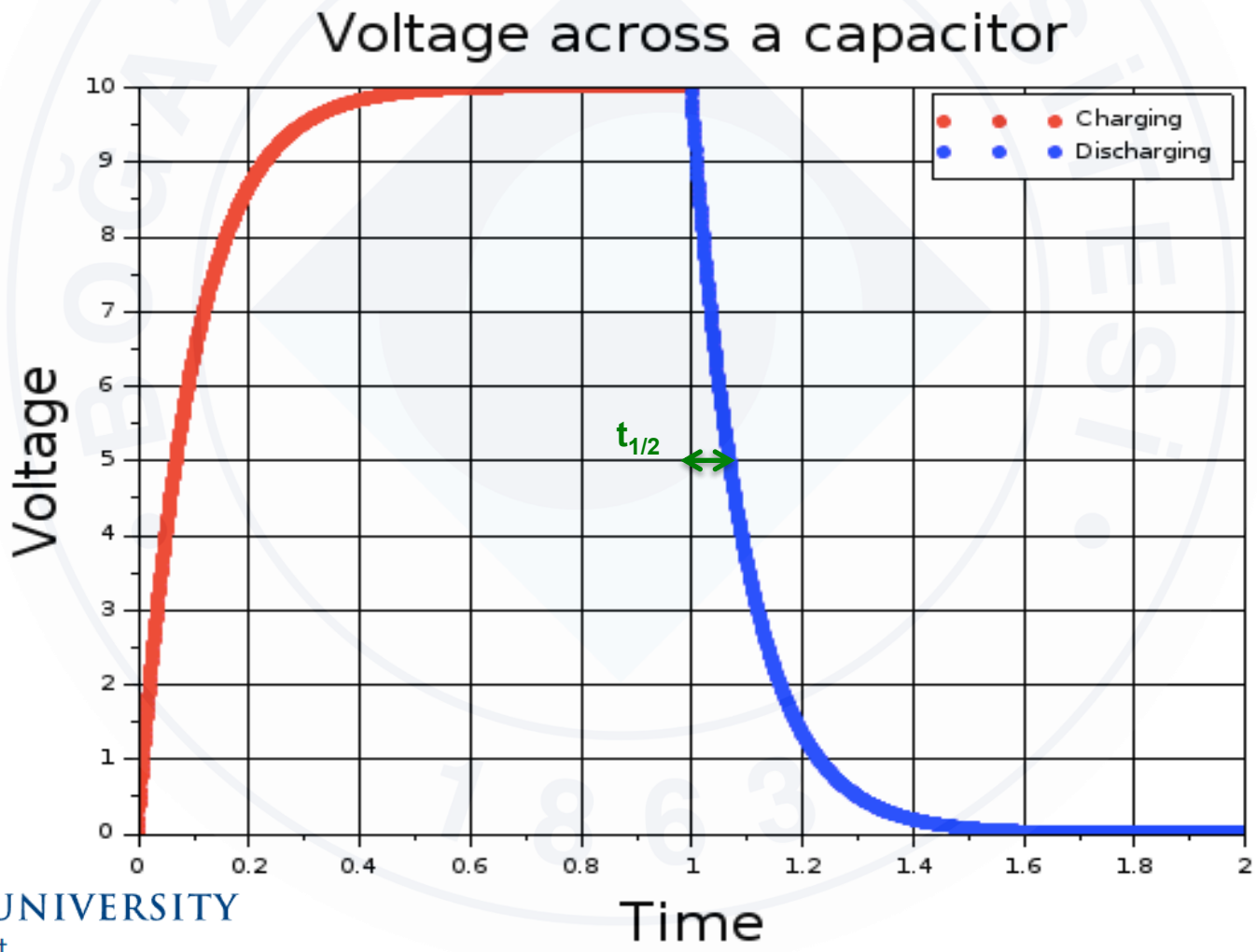
Oscilloscopes display the change of an electrical signal over time, with voltage and time as the Y- and X-axes, respectively, on a calibrated scale.



CHARACTERISTICS OF A CAPACITOR

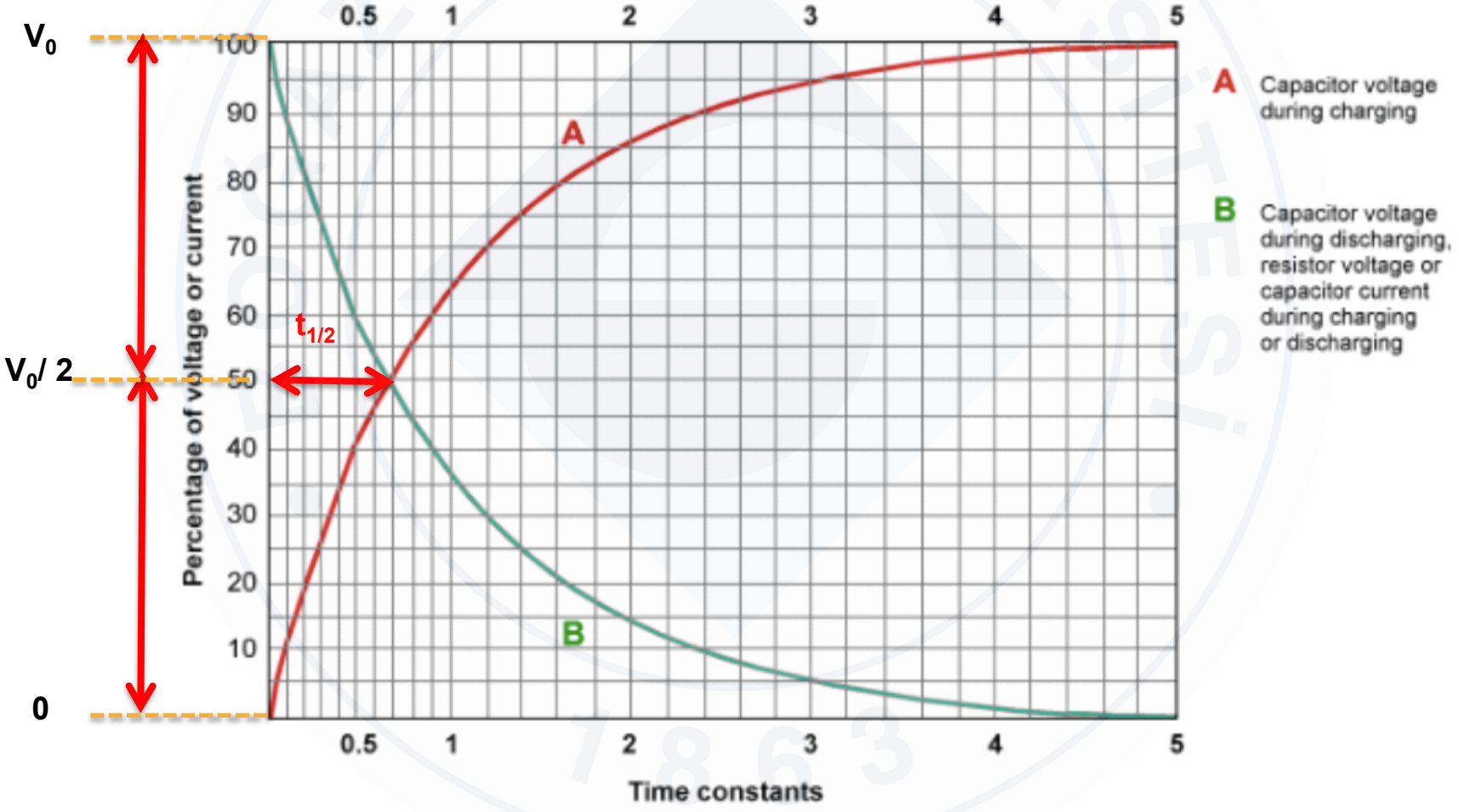
Measurement of half life of the capacitor:

time needed to discharge half of the capacitor potential



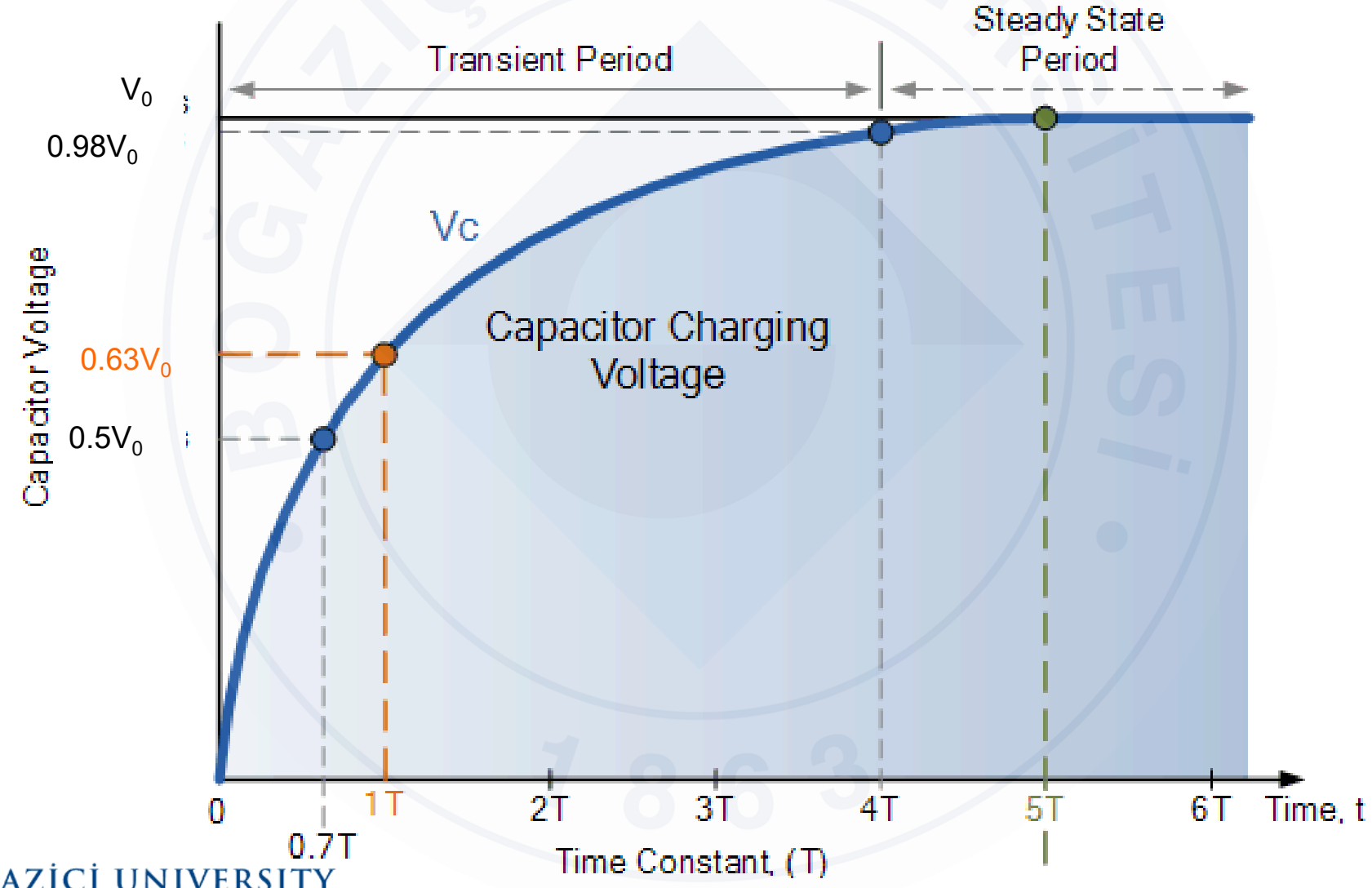
CHARACTERISTICS OF A CAPACITOR

Half-life of the Capacitor



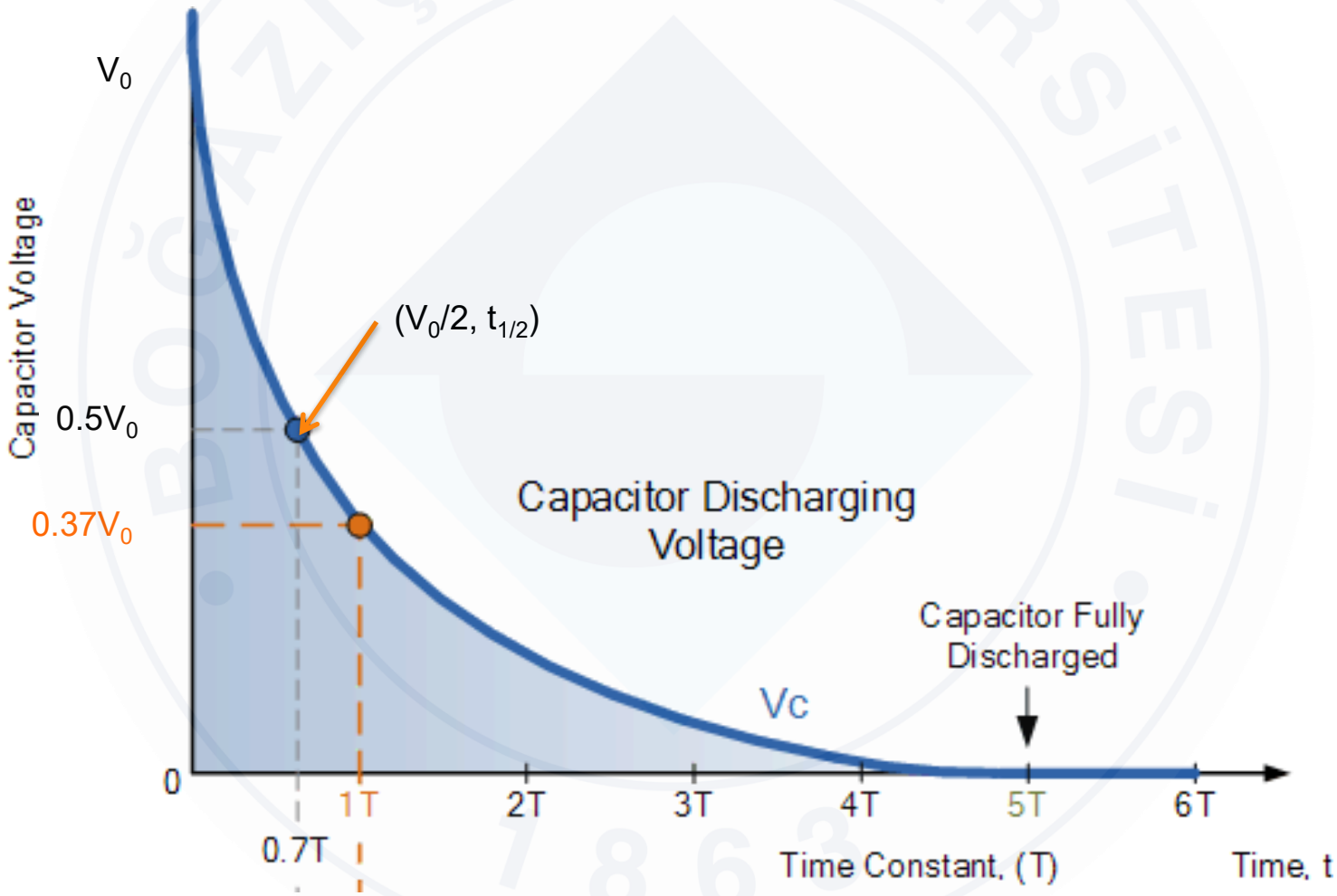
CHARACTERISTICS OF A CAPACITOR

Charging of the Capacitor



CHARACTERISTICS OF A CAPACITOR

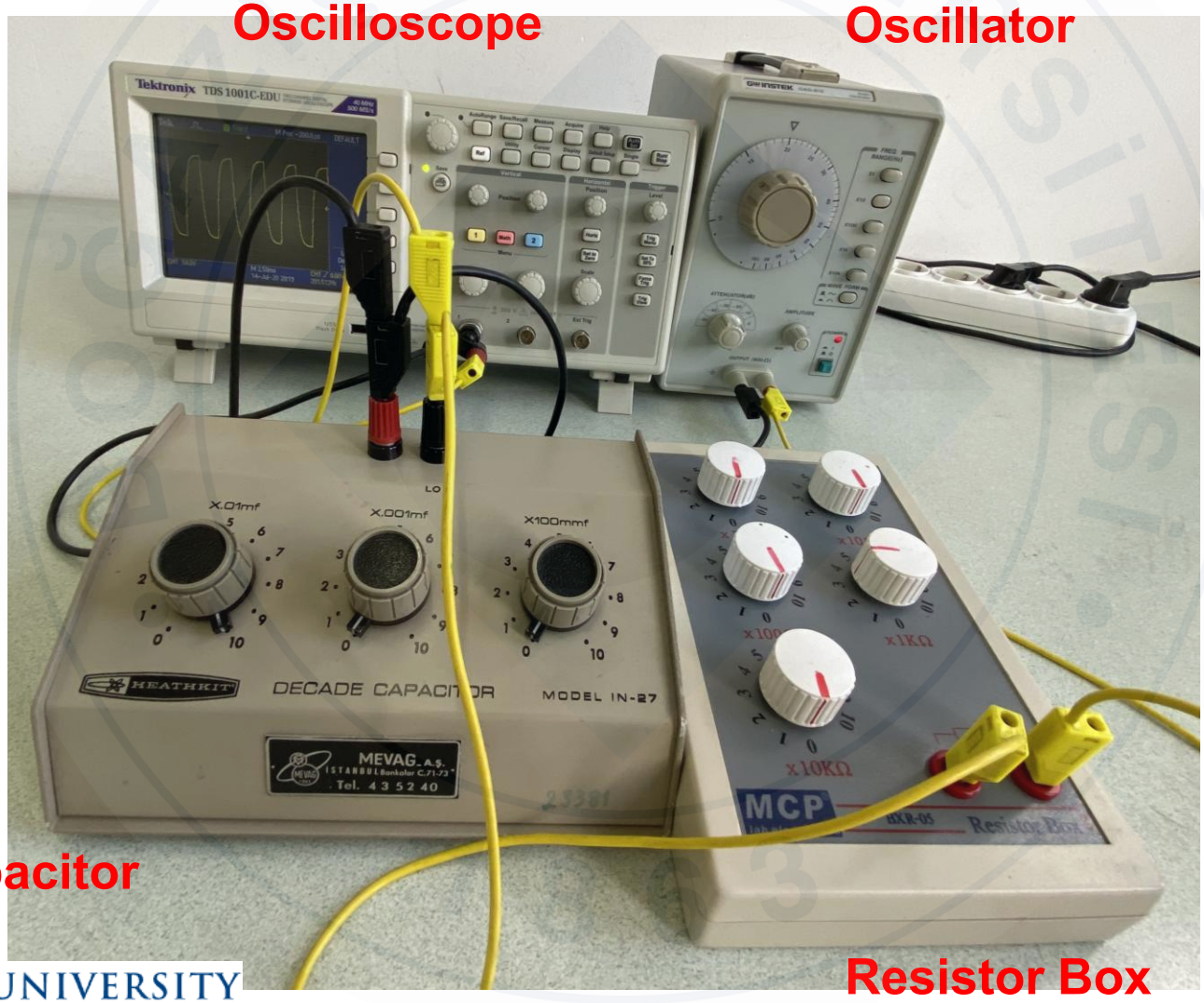
Discharging of a Capacitor



SETUP AND EXPERIMENT

CHARACTERISTICS OF A CAPACITOR

CIRCUIT



PART 1:
DISCHARGING CHARACTERISTICS

PREVIOUS EXPERIMENT

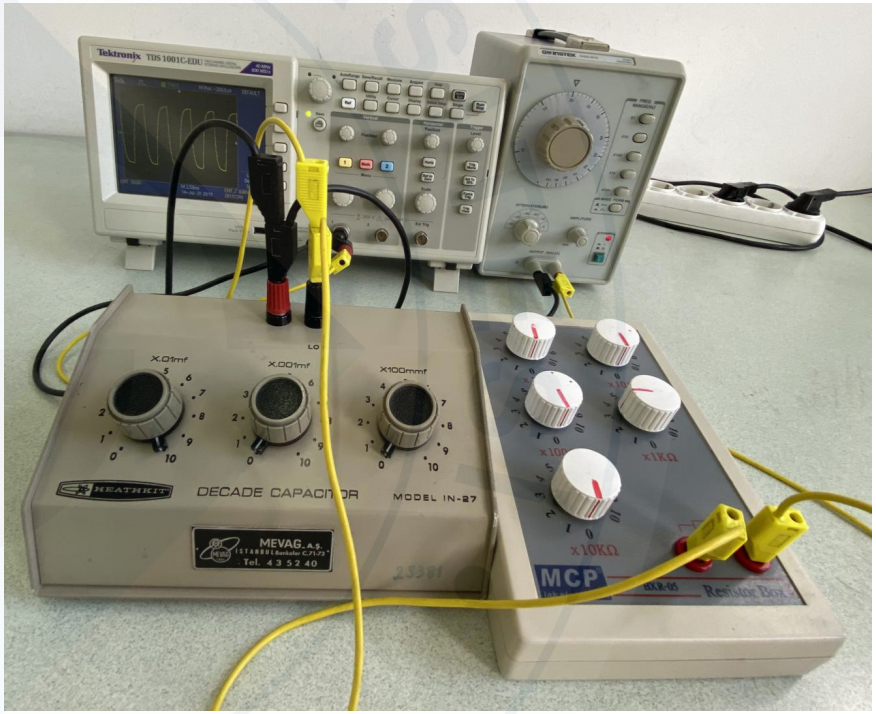
CHARACTERISTICS OF A CAPACITOR

An overview

Given: Resistance to set on Resistance box, R; Internal resistance of SWG, R_{SWG}; Capacitance, C.

What to read: half-life in cm, $t_{1/2EV}$(cm); [VOLT/DIV]; [TIME/DIV].

What to calculate: Period of the SWG to be set, T; frequency of the SWG, f_{TV}; half-life in sec, $t_{1/2}$(s); % error for half-life in sec $t_{1/2}$(s).



CHARACTERISTICS OF A CAPACITOR

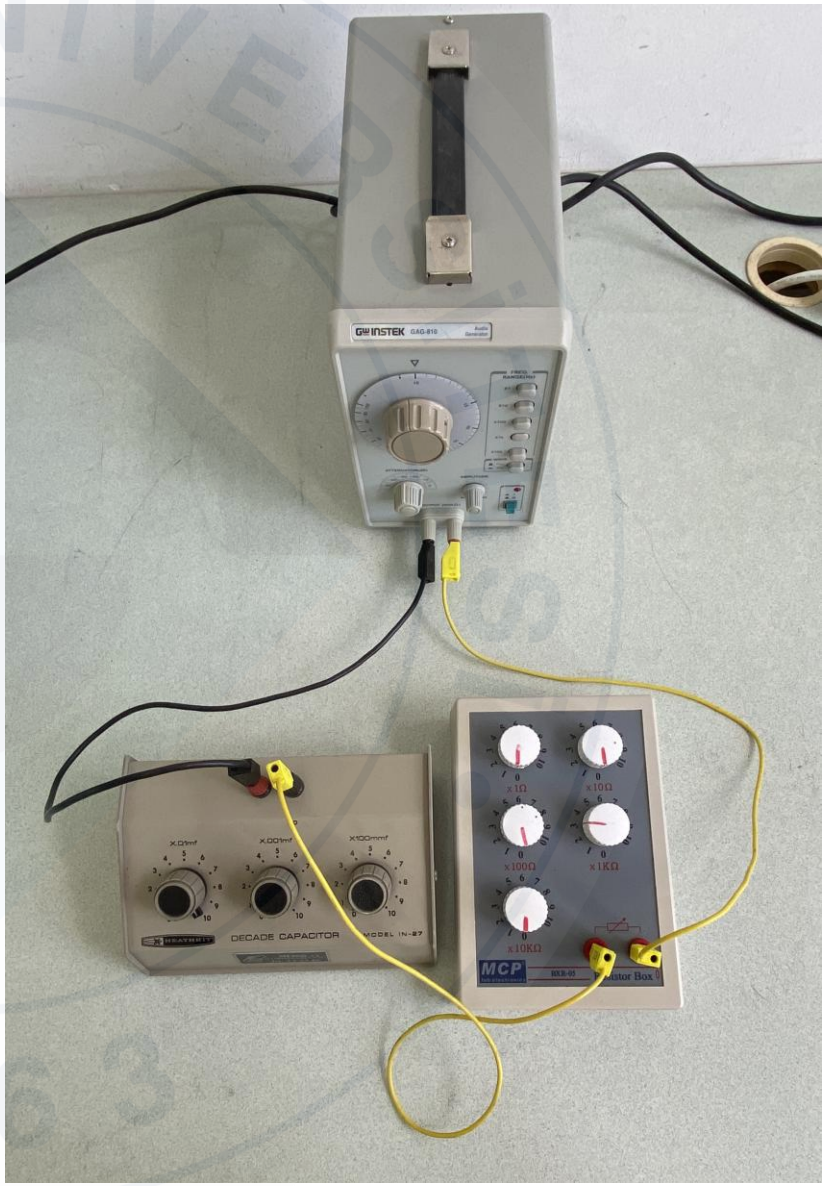
CIRCUIT:

R and C are given in the Lab Report.

Internal resistance of Oscillator (Square Wave Generator) is 600Ω.

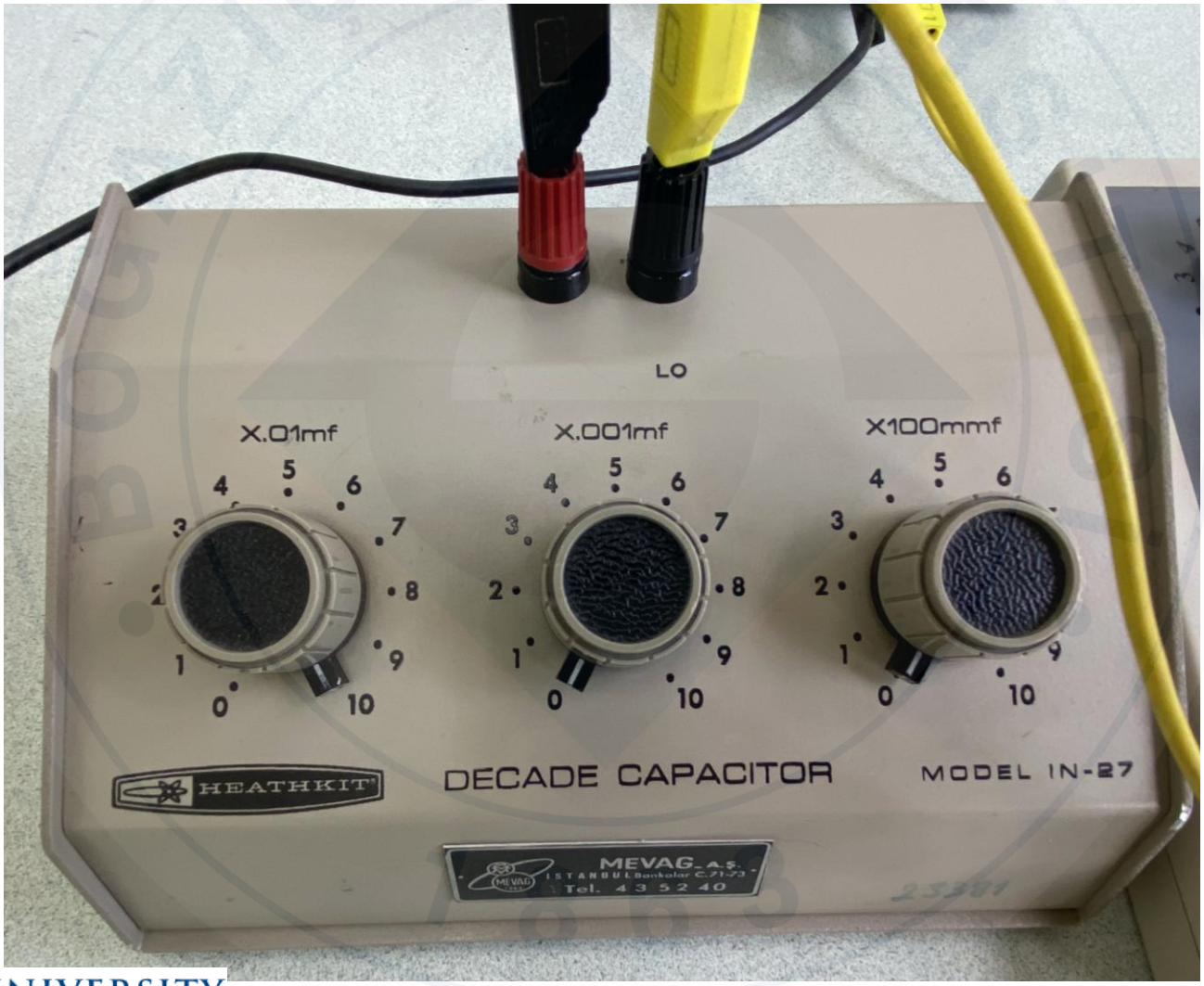
The resistance of the circuit will be the total resistance, the sum of R (resistor) and the internal resistance of the SWG.

Calculate the true value of the half-life of the RC circuit and determine the square wave frequency to set.



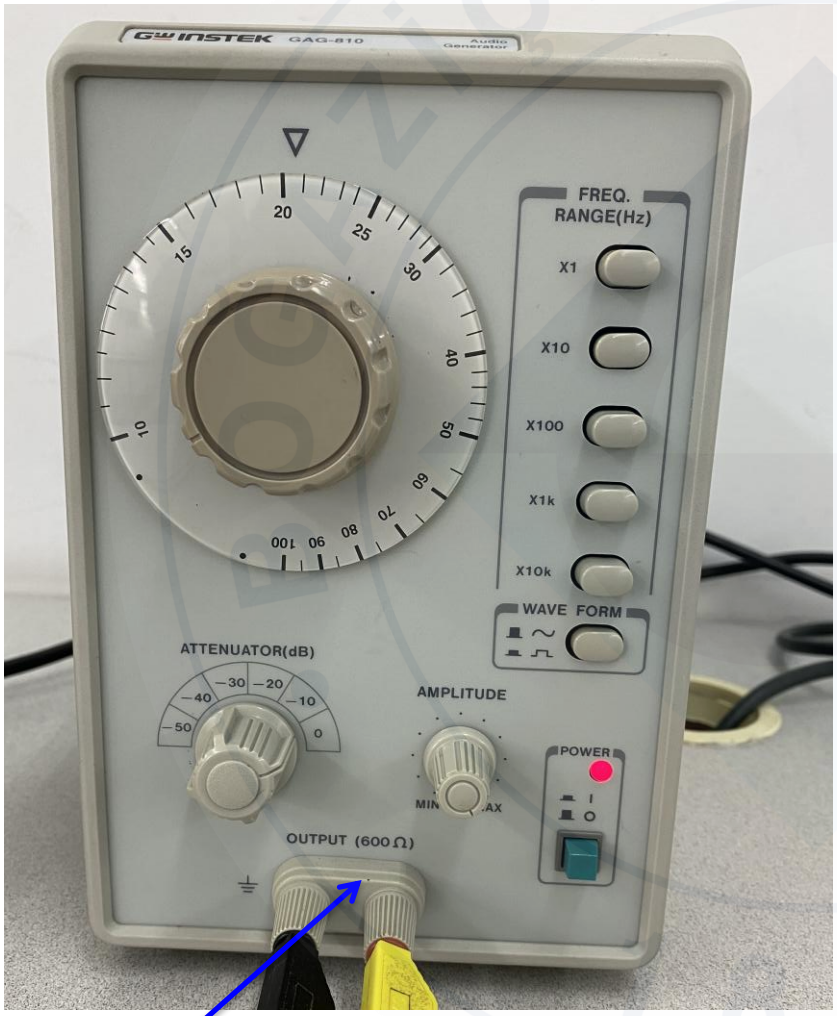
CHARACTERISTICS OF A CAPACITOR

CAPACITOR: Set to 0.1μF (here on the device **mf means μF**).



CHARACTERISTICS OF A CAPACITOR

Oscillator (SWG)



Internal resistance, R_{SWG} = 600 Ω

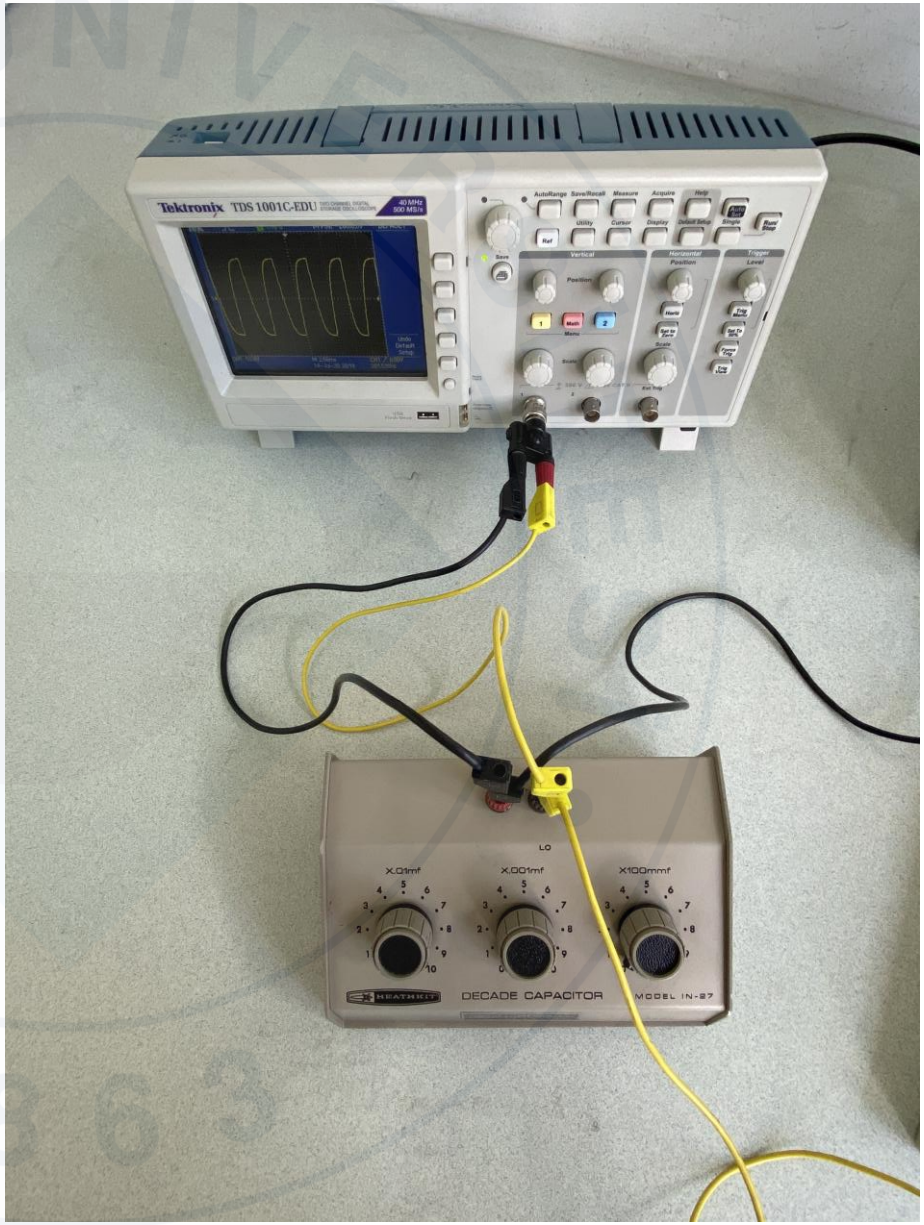
Resistor Box



R= 3000 Ω is set

CHARACTERISTICS OF A CAPACITOR

Oscilloscope is connected across (in parallel to) the capacitor to display the capacitor potential.

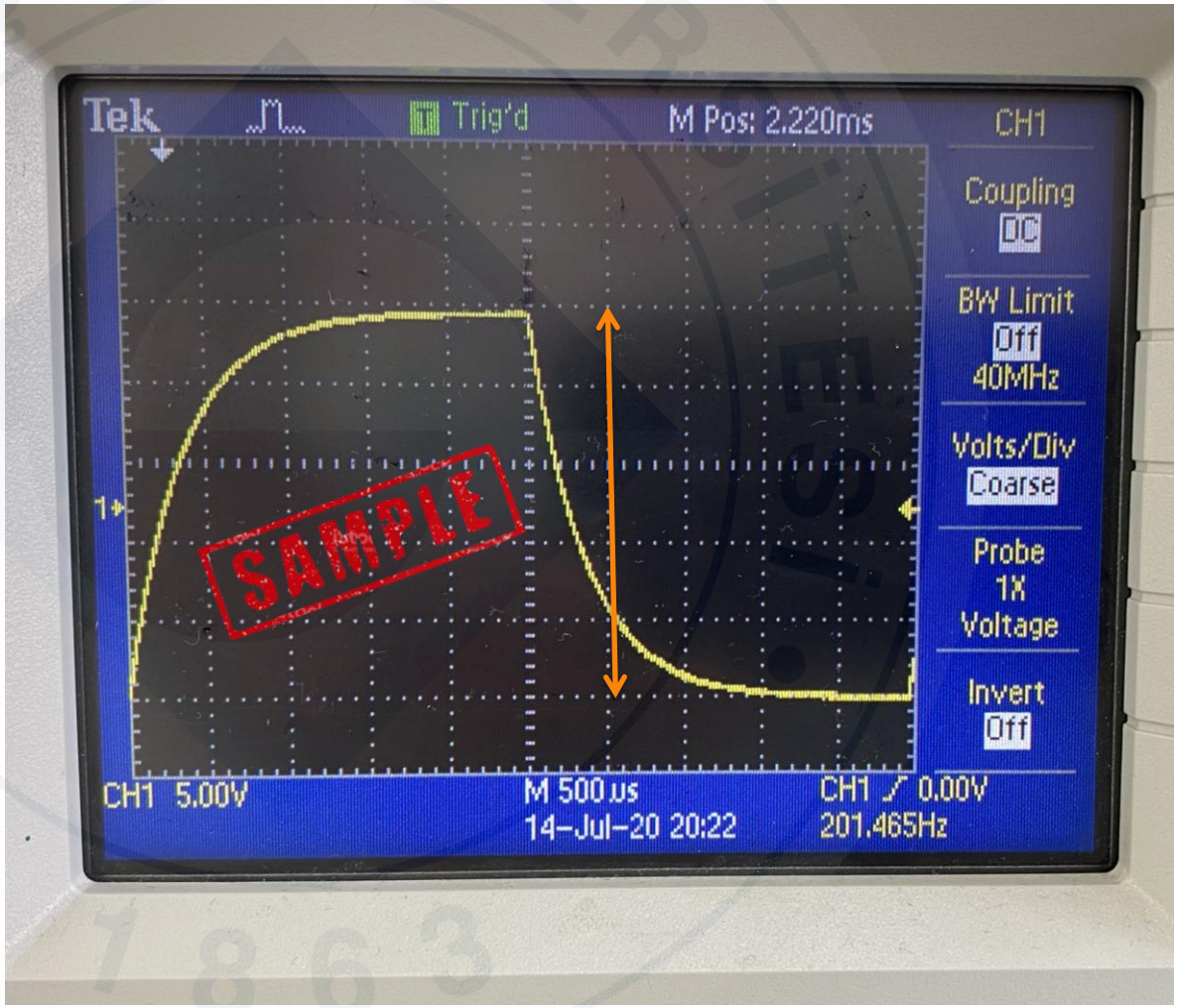


CHARACTERISTICS OF A CAPACITOR

- **Calculate the square wave frequency to set to the oscillator.**

  R_T, C is known.
  Calculate $t_{1/2}$. T=20 $t_{1/2}$ is given. Determine T and f.

- **TIME/DIV and VOLT/DIV knobs are set to display one charging and one discharging phase on the oscilloscope screen.**

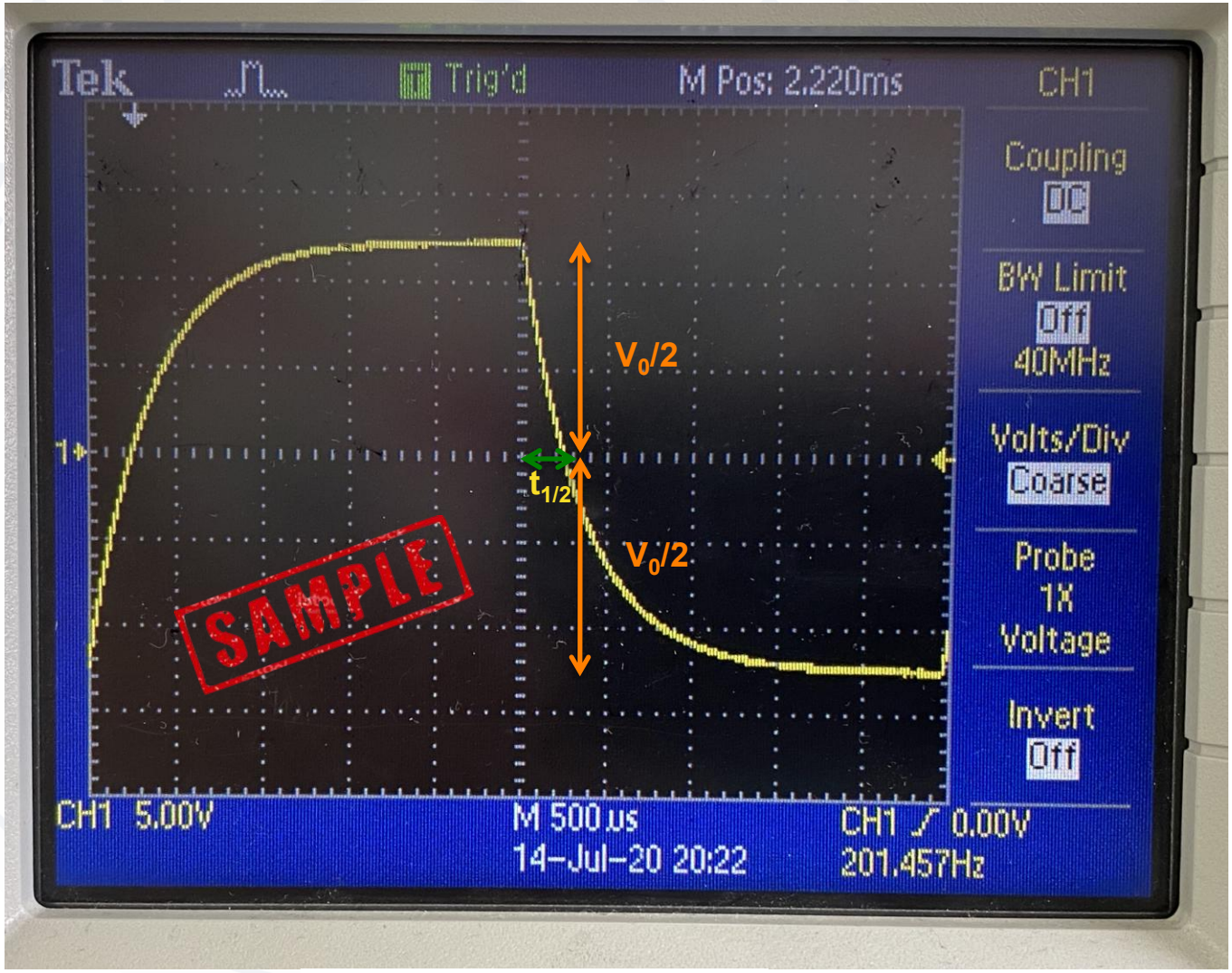


CHARACTERISTICS OF A CAPACITOR

- From the observed pattern on the oscilloscope screen, measure $t_{1/2}$.

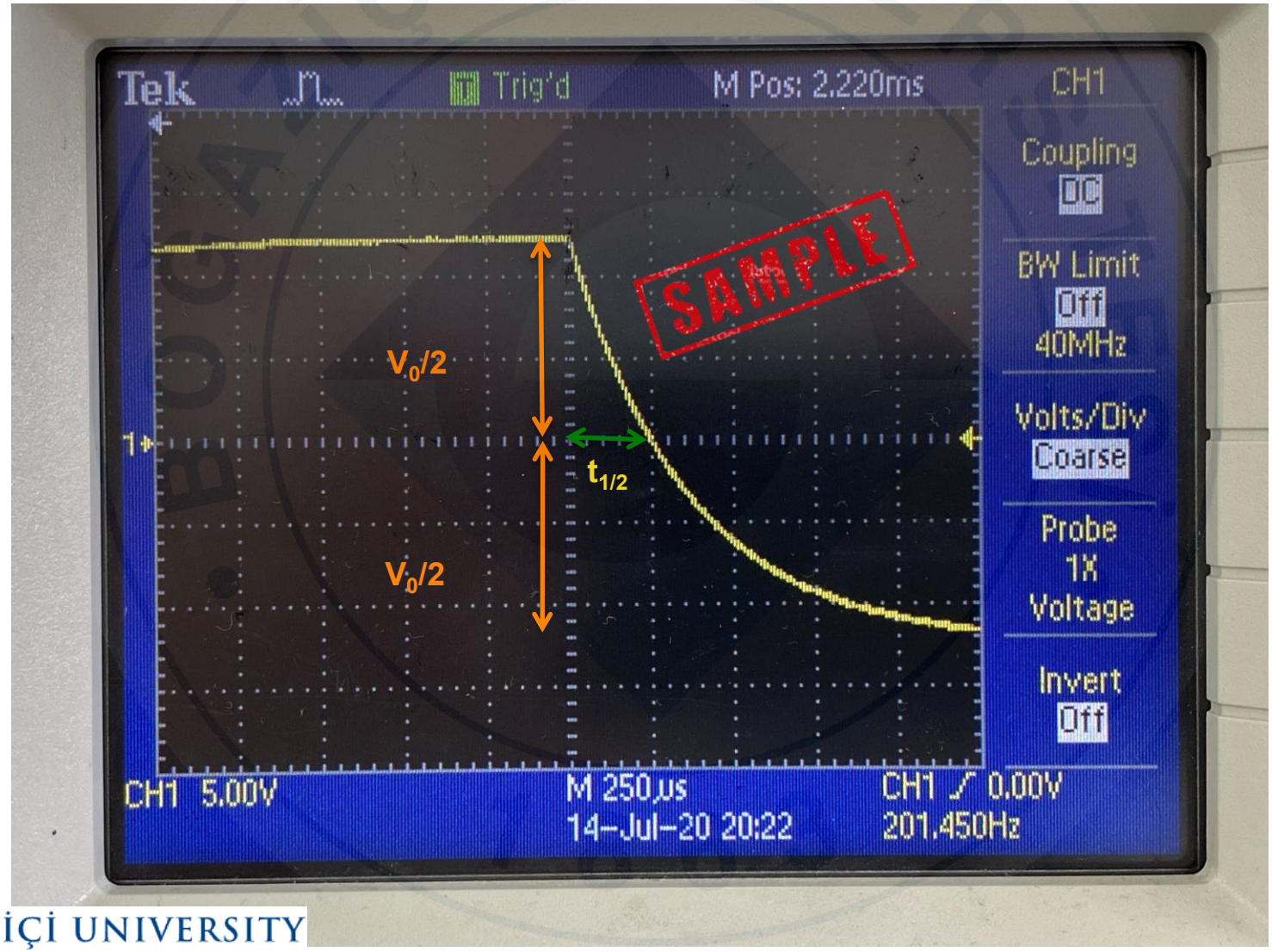
  But it is better to choose much better TIME/DIV setting.

- Calculate $t_{1/2EV}$ using this measured $t_{1/2EV}$(cm).



CHARACTERISTICS OF A CAPACITOR

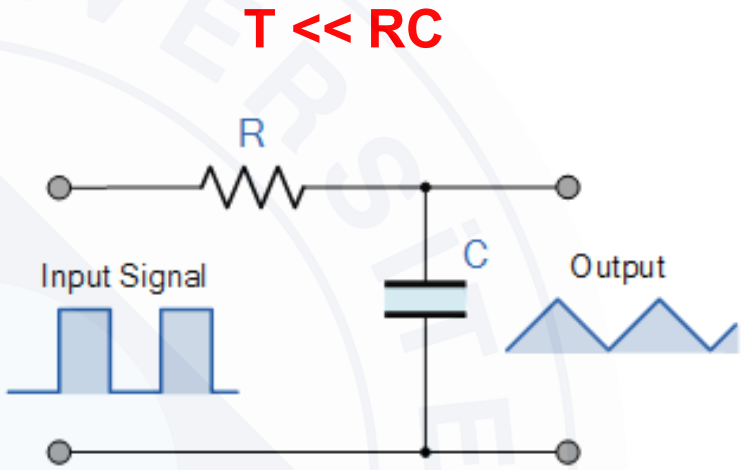
Half Life of Capacitor measurement with different TIME/DIV setting.



PART 2:
AN INTEGRATING CIRCUIT

APPLIED EXAM 2

If we go to the other extreme and choose a square wave signal with a period much shorter than the RC time constant, then the voltage across the capacitor is basically the integral of the applied potential.

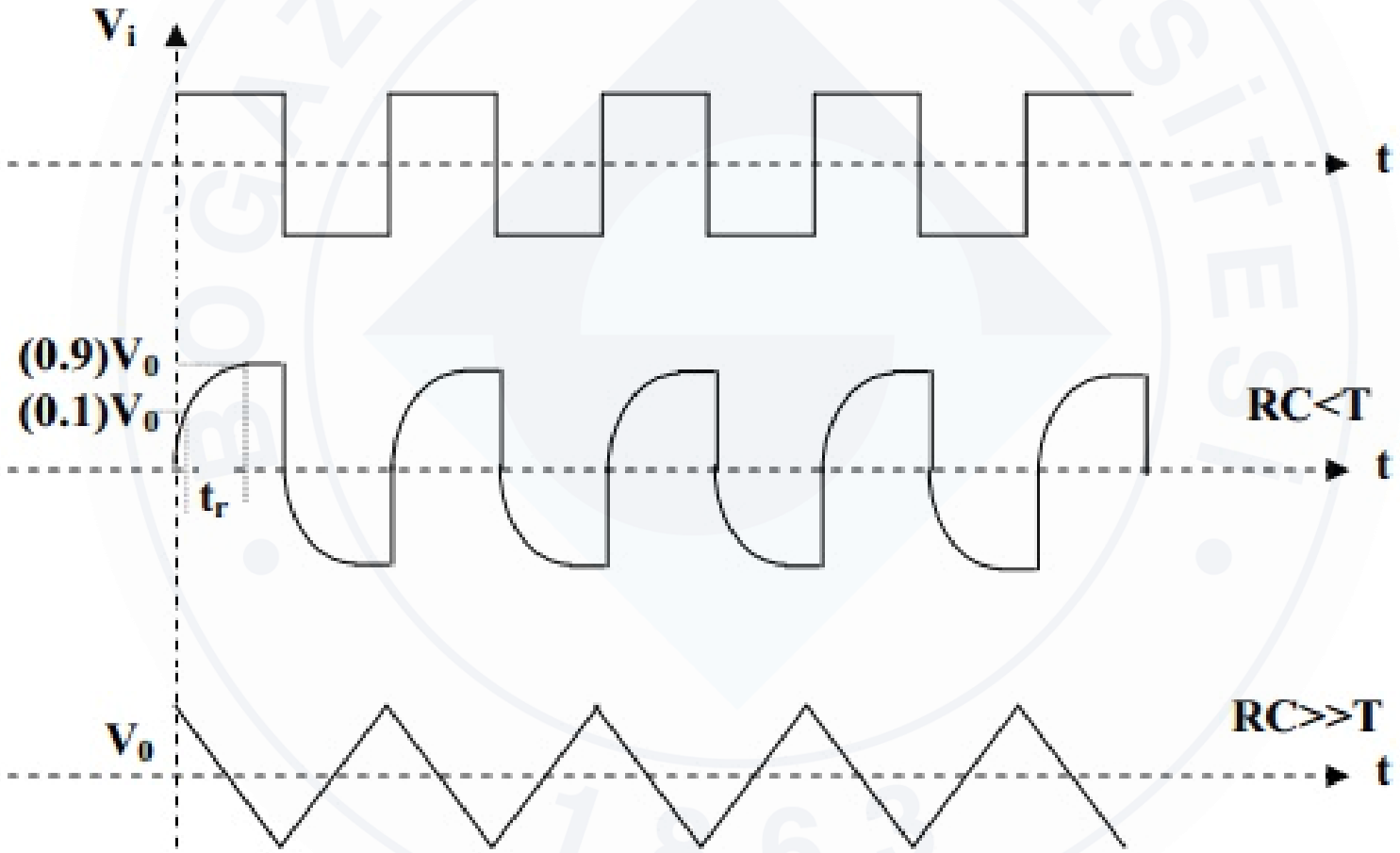


since $V_C << V_R$

$$R\frac{dq}{dt} \approx V_{app} \Rightarrow \frac{dq}{dt} = \frac{V_{app}}{R} \quad \rightarrow \quad V_c = \frac{q}{C} = \frac{1}{RC}\int V_{app}\,dt$$

CHARACTERISTICS OF A CAPACITOR

In this part we will study the case RC >>T. In this case, the frequency of the oscillator (SWG) is set to a very high value. At high frequency circuit becomes an integrating circuit.



CHARACTERISTICS OF A CAPACITOR

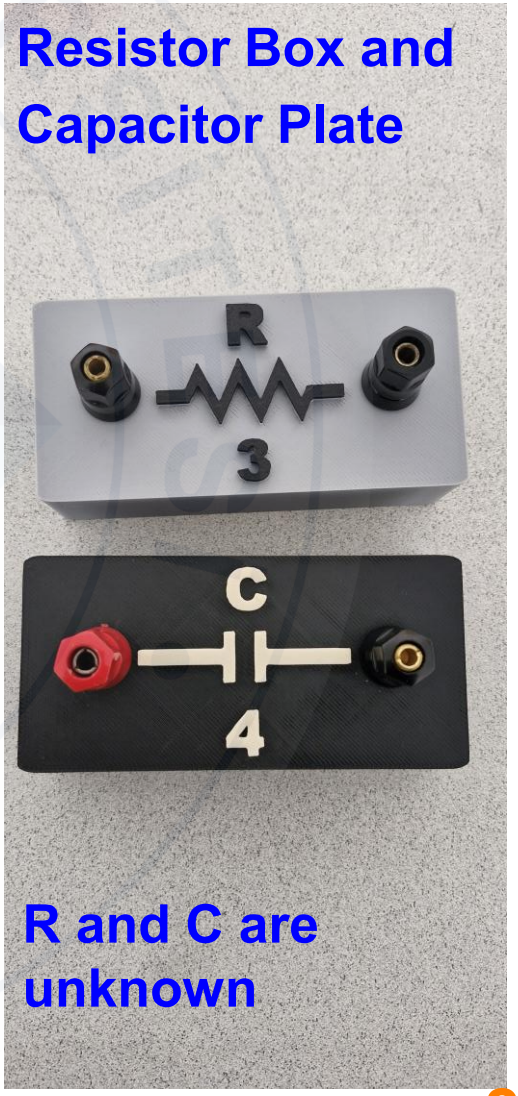
Oscillator (SWG)



Set the frequency to 20. x 1KHz

SAMPLE

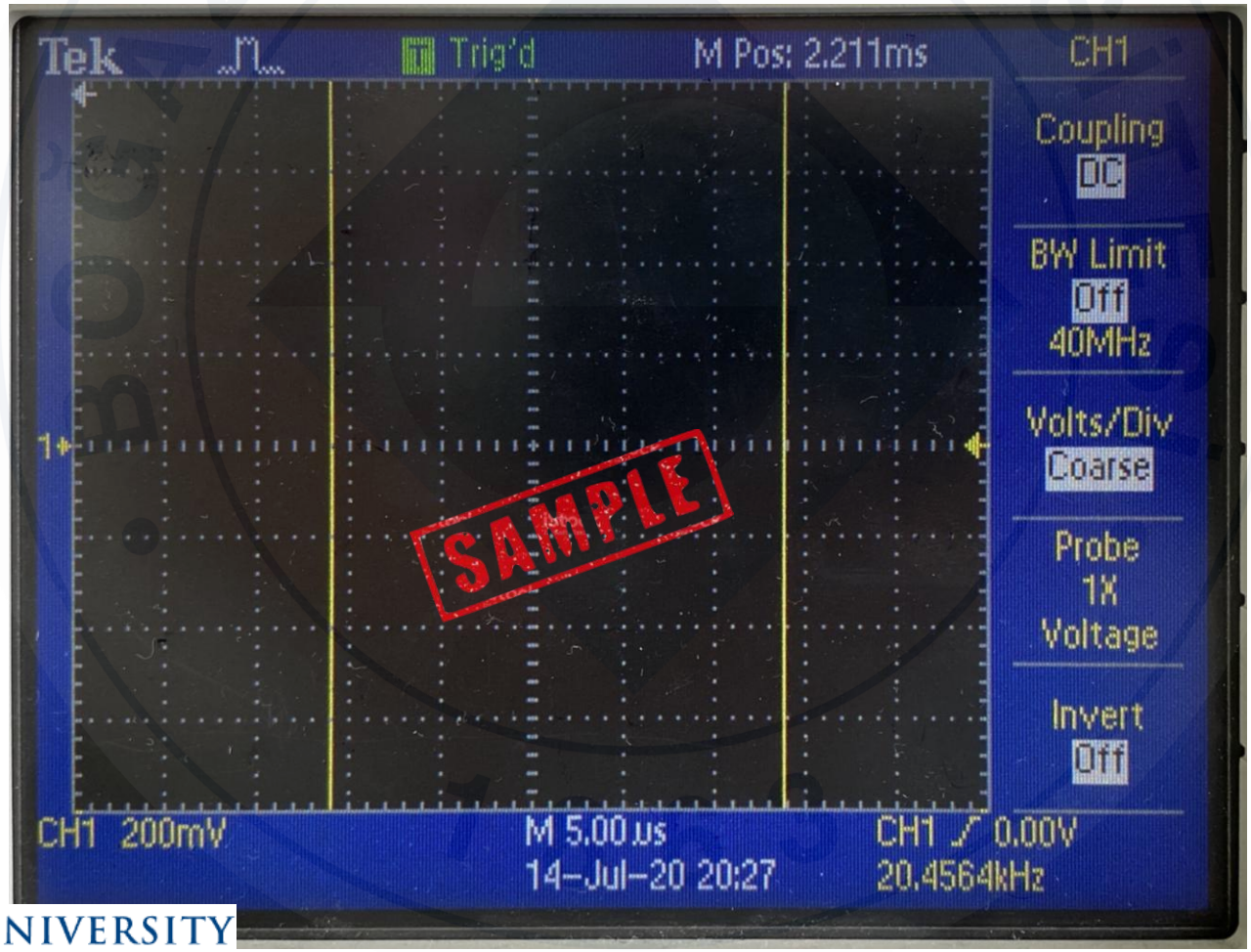
Resistor Box and Capacitor Plate



R and C are unknown

CHARACTERISTICS OF A CAPACITOR

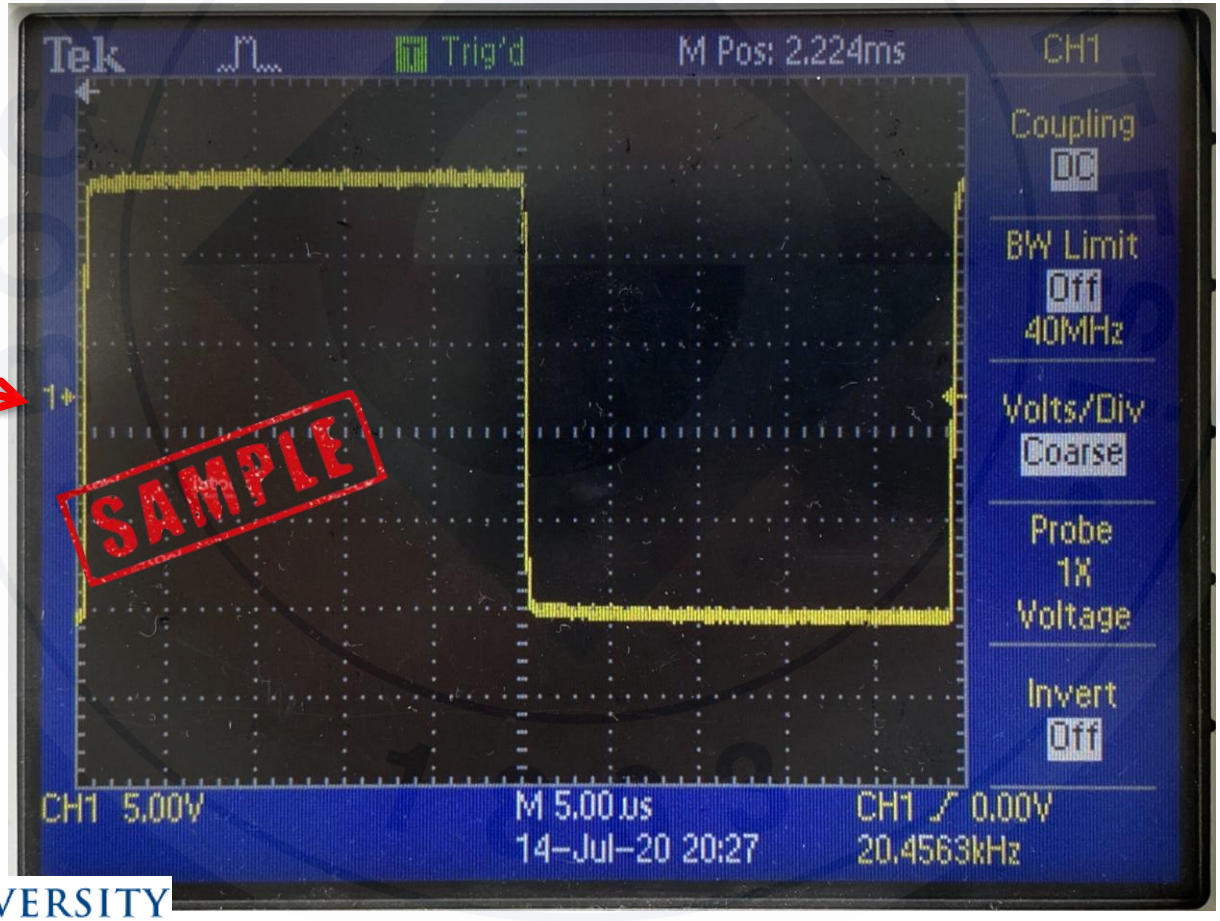
Now, connect the oscilloscope directly to the square wave generator in order to observe the applied voltage.



CHARACTERISTICS OF A CAPACITOR

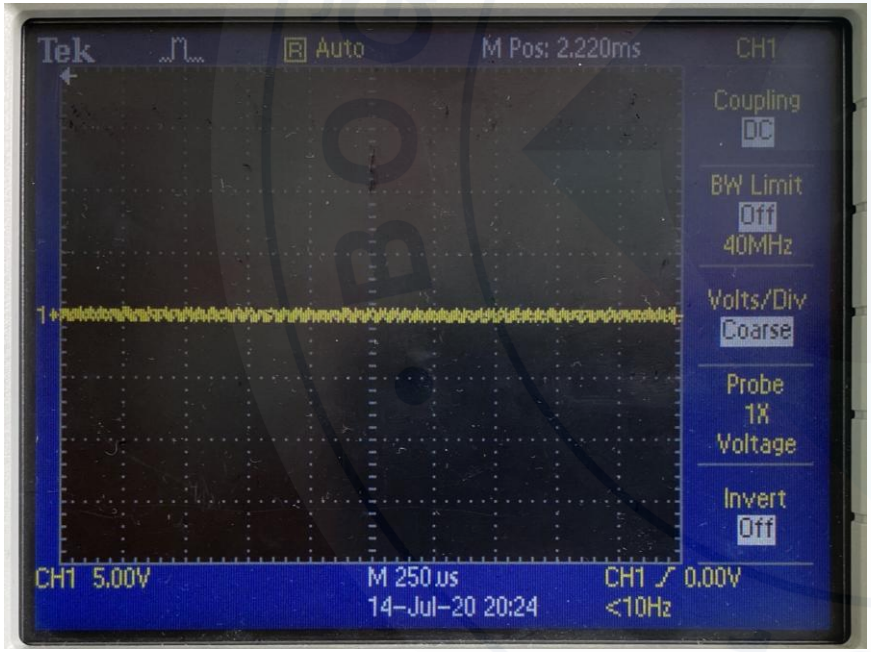
Draw one period of the applied square wave voltage

Indicates the horizontal axis where the signal is zero.



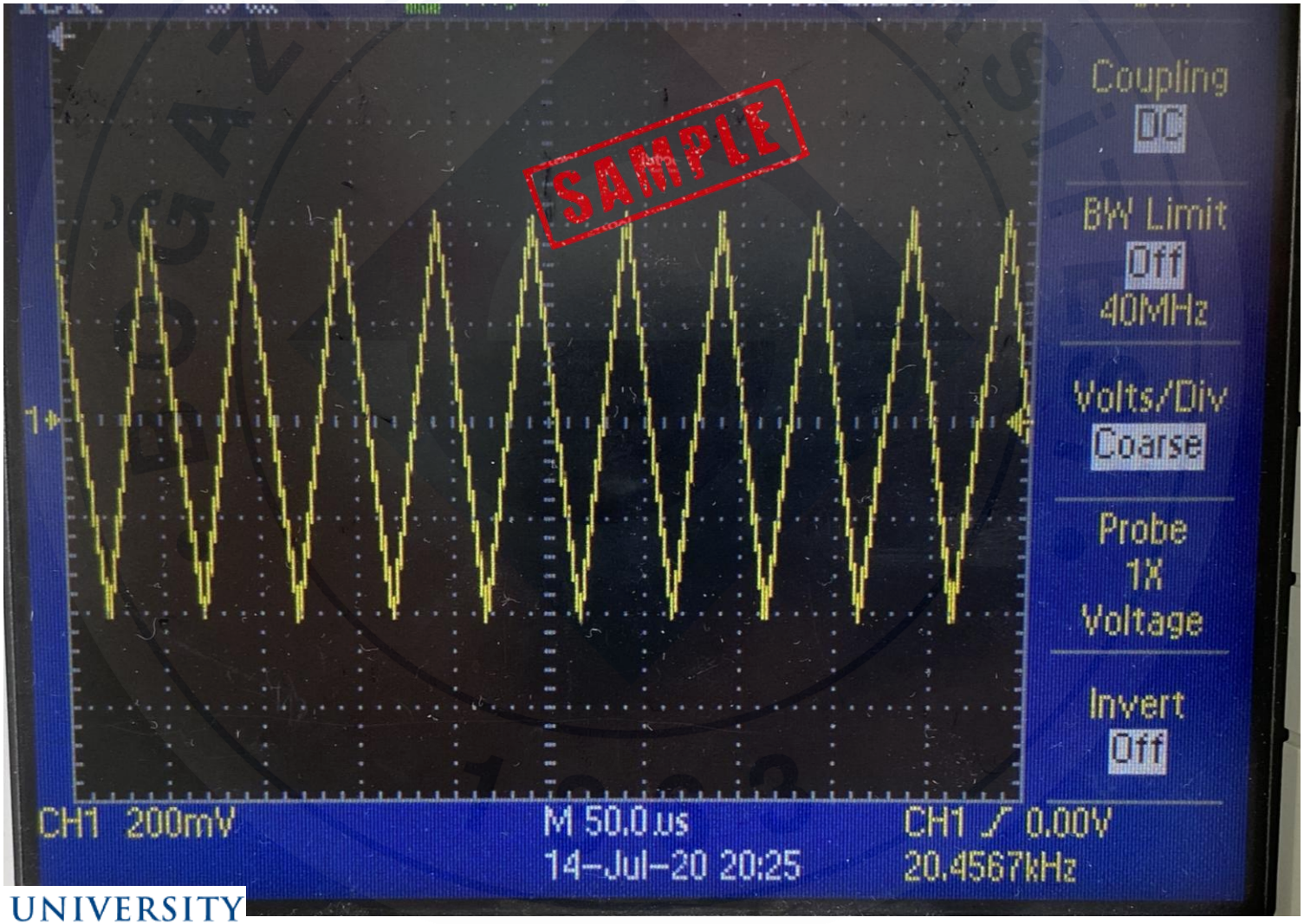
CHARACTERISTICS OF A CAPACITOR

Use the same circuit constructed in the previous experiment (but apply much higher frequency on the Square Wave Generator) .





The controls (TIME/DIV and VOLT/DIV) are adjusted to for optimum focus. Since $V_{app} >> V_c$ we need to adjust the VOLT/DIV setting.



CHARACTERISTICS OF A CAPACITOR

Draw one period of the voltage across the capacitor by using the same scale you drew the corresponding pattern for the applied square wave (V_{app}). Show that the capacitor voltage is proportional to the integral of the applied square wave voltage in your report.

Indicates the horizontal axis where the signal is zero.

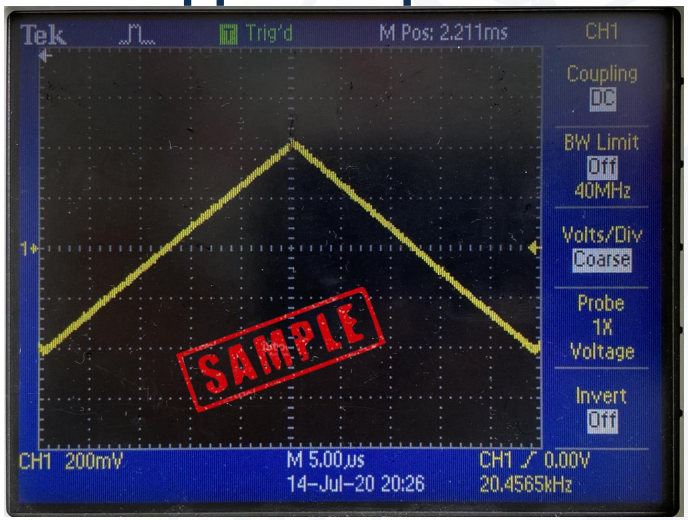


CHARACTERISTICS OF A CAPACITOR

Show that the capacitor voltage is proportional to the integral of the applied square wave voltage.

V_{c2}

V_{c1}



t_1 t_2

V_{app}

$-V_{app}$



$$V_c = V_{c2} - V_{c1}$$

$$V_c = \frac{q}{C} = \frac{1}{RC}\int V_{app}\,dt$$

$$\int V_{app}\,dt = (t_2 - t_1)\,V_{app}$$

The integral is equal to the area under the signal (function) over x-axis!