Boğaziçi University

Introductory Phys Labs

CHARACTERISTICS OF A CAPACITOR

PHYL 201

THEORY AND APPARATUS

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:

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

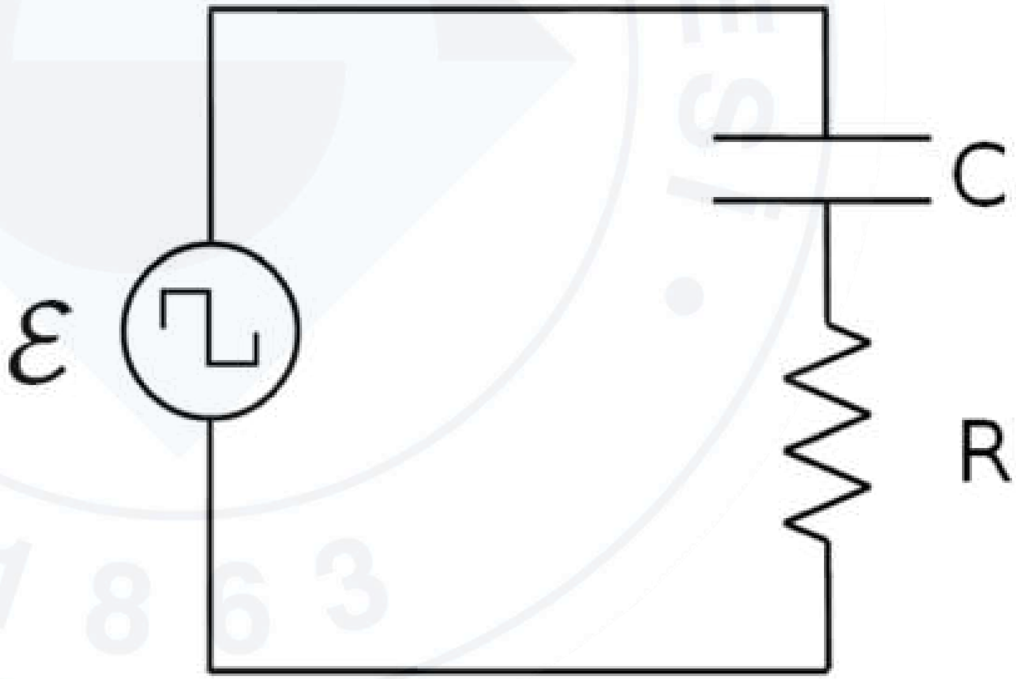
$V_c = V_0\, e^{-t/RC}$

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

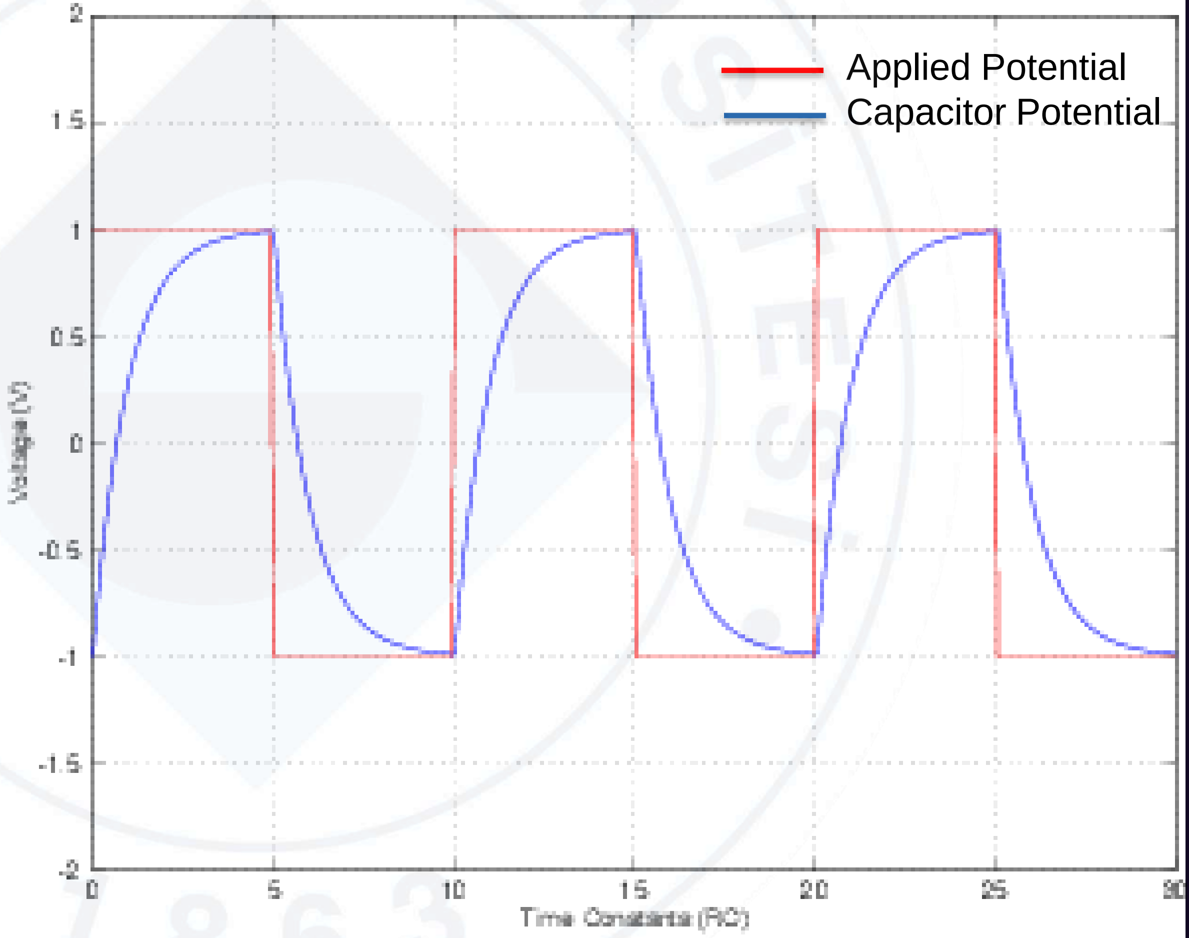
If we apply a square wave signal, choosing a period T much longer than the half-life of the RC circuit or

the RC time constant,

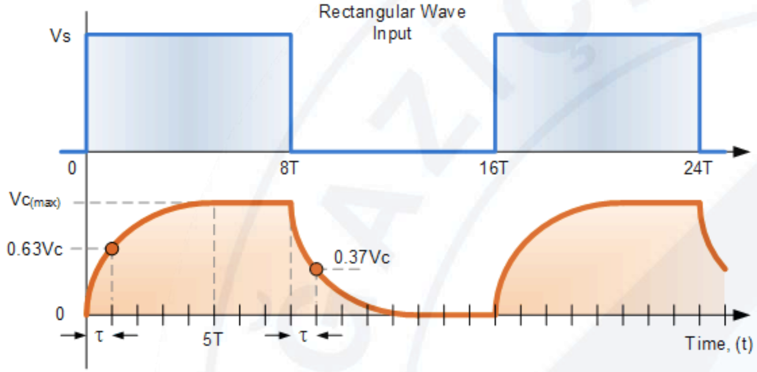
$$t_{1/2} = (\ln 2) R_{tot}\, C$$

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

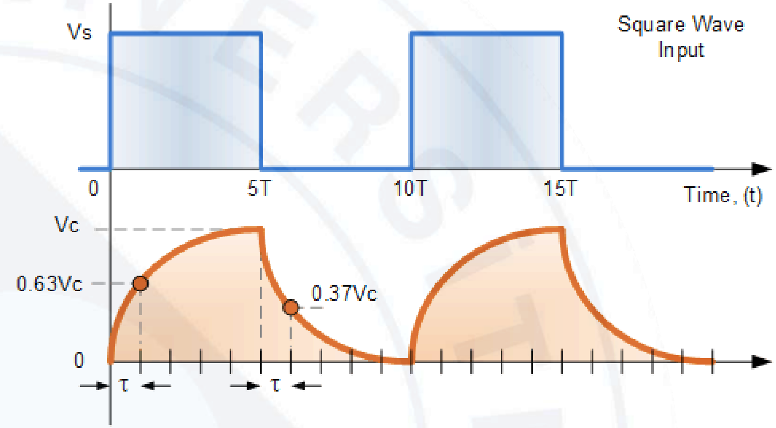
T >> RC



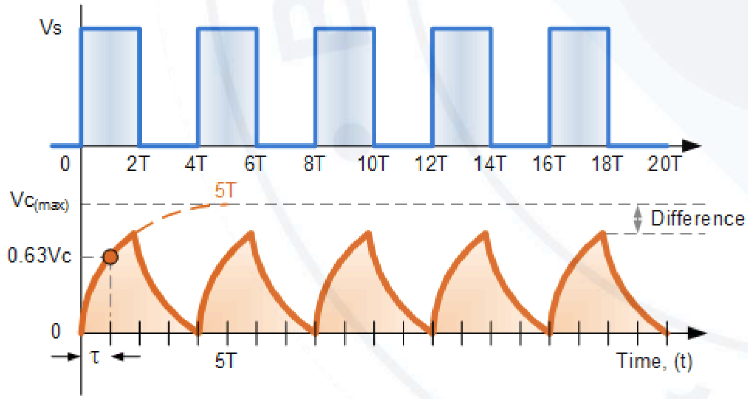
CHARACTERISTICS OF A CAPACITOR



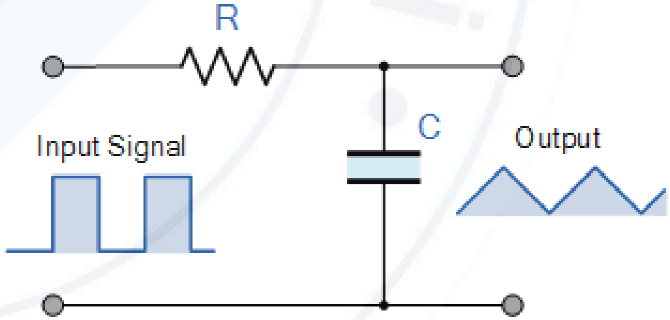
Period = 16 RC, T>RC



Period = 10 RC, T>RC

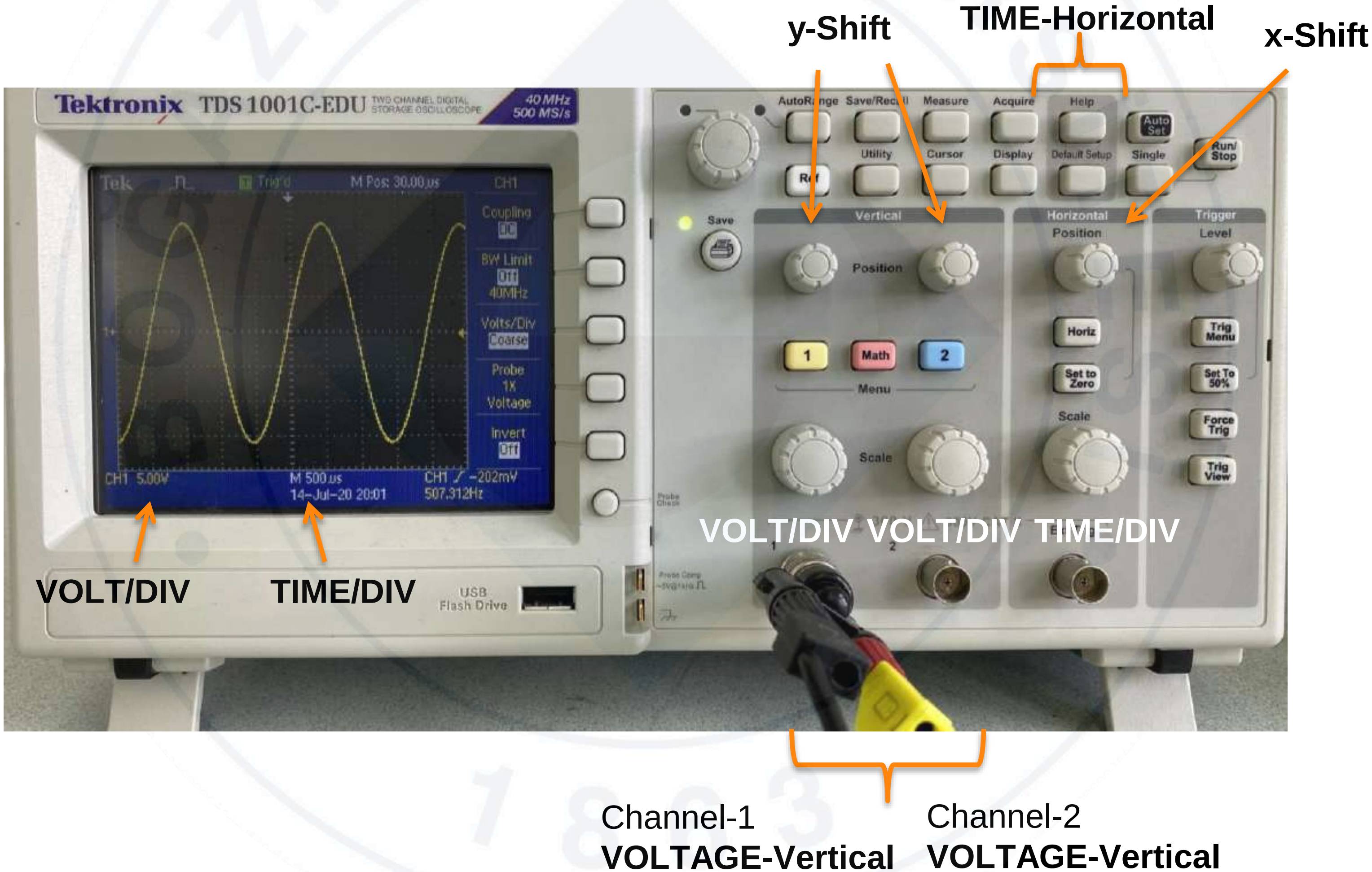


Period = 4 RC, T>RC



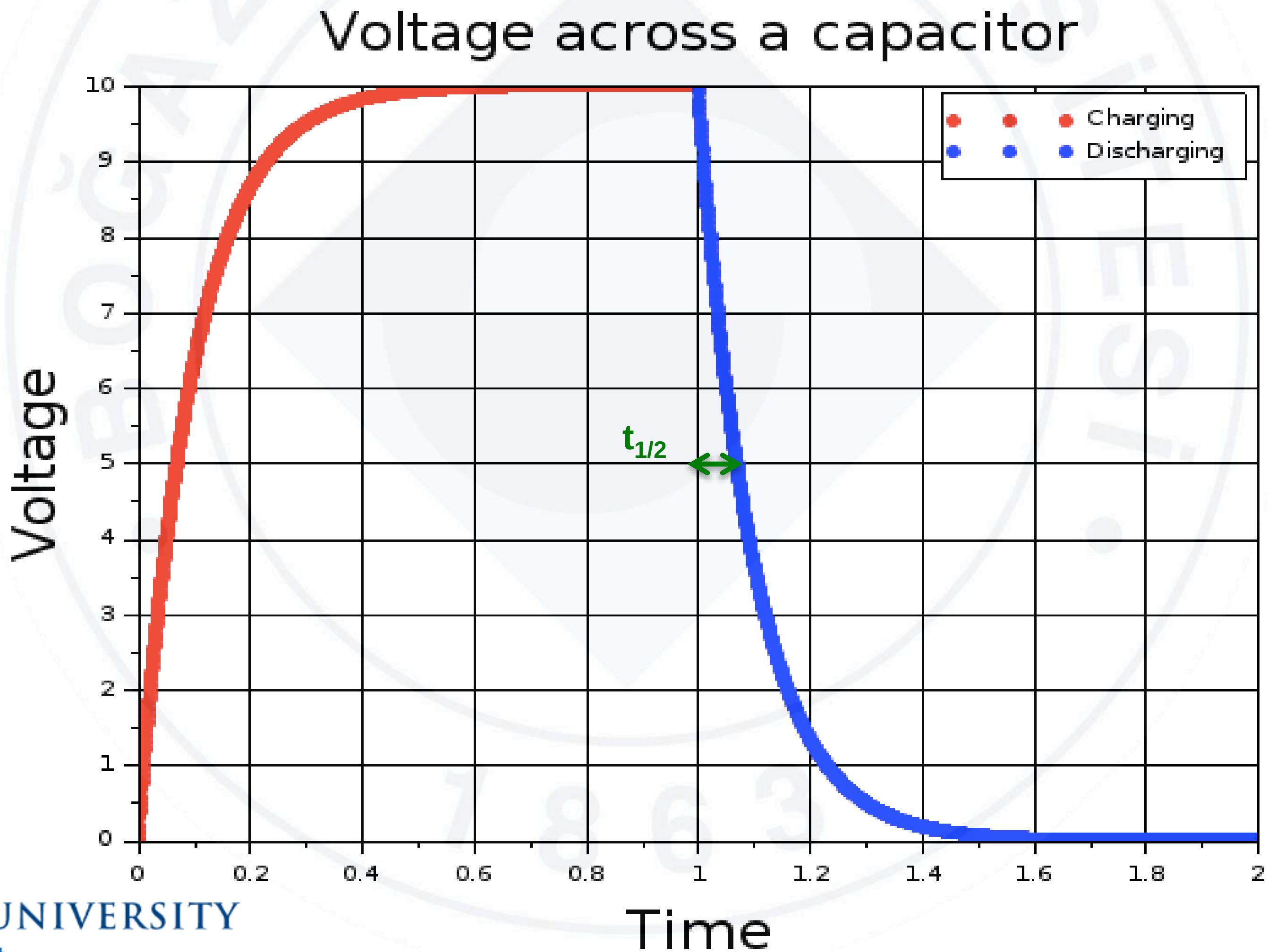
T<<RC

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.

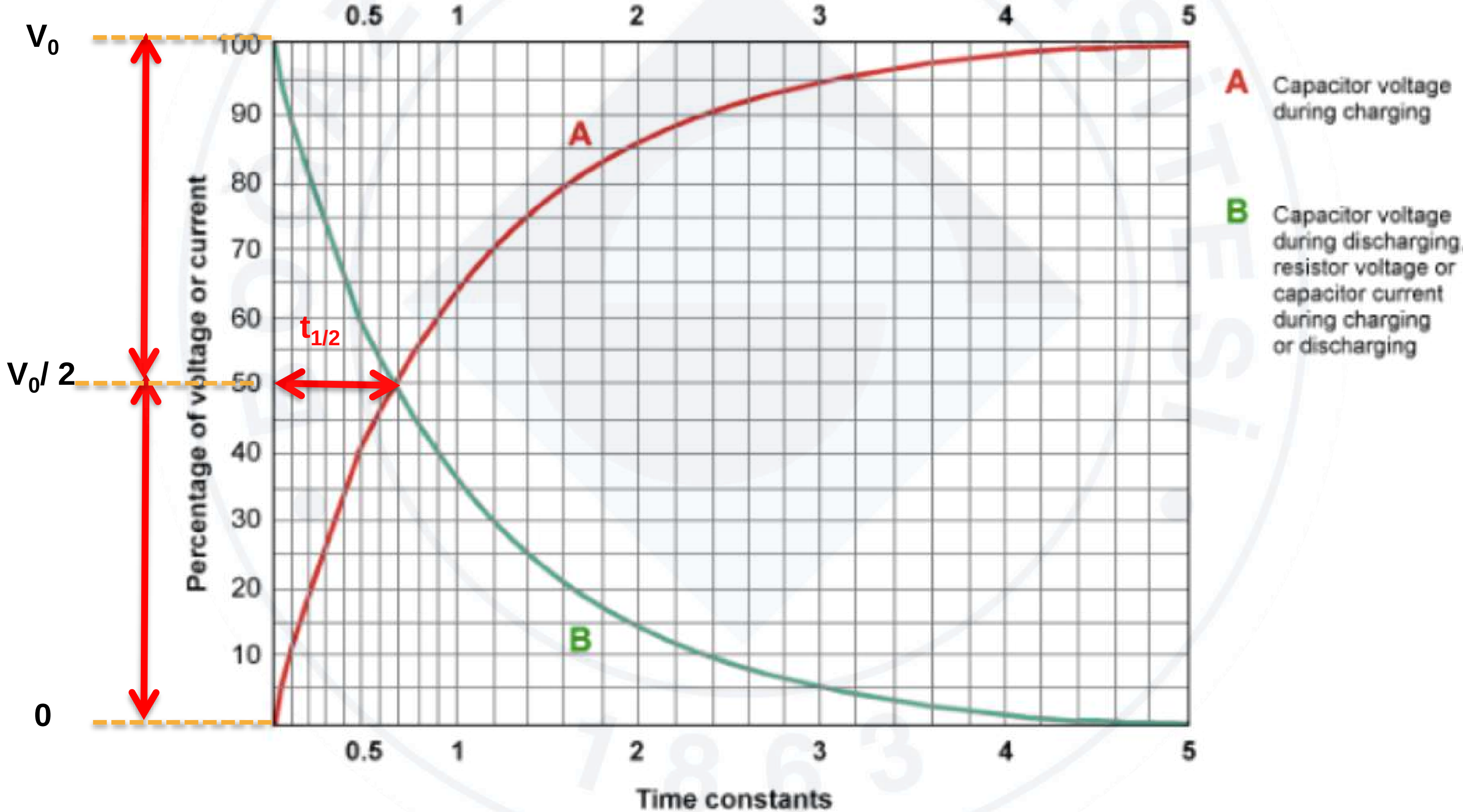


Measurement of half life of the capacitor:

time needed to discharge half of the capacitor potential

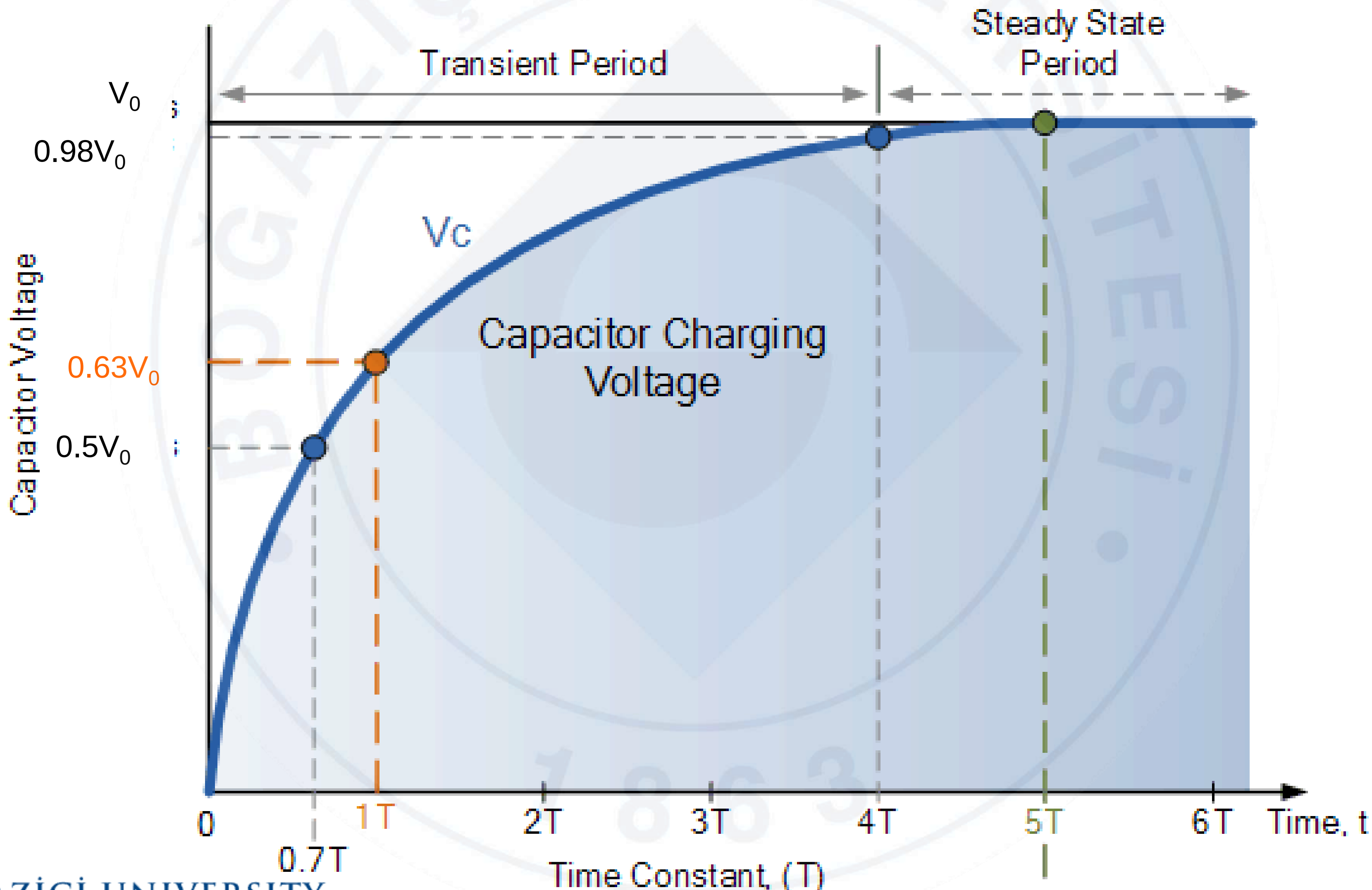


Half-life of the Capacitor



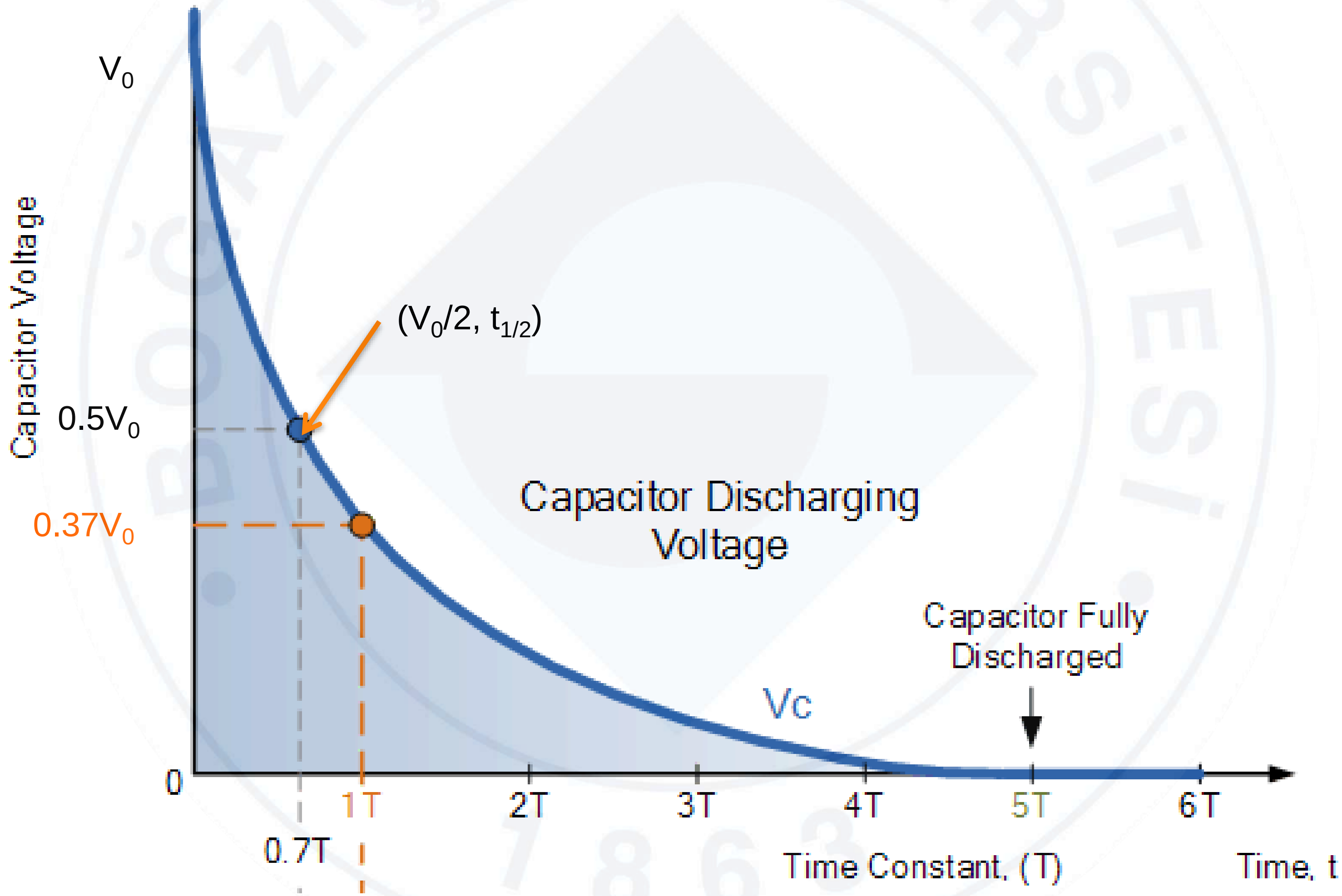
CHARACTERISTICS OF A CAPACITOR

Charging of the Capacitor



CHARACTERISTICS OF A CAPACITOR

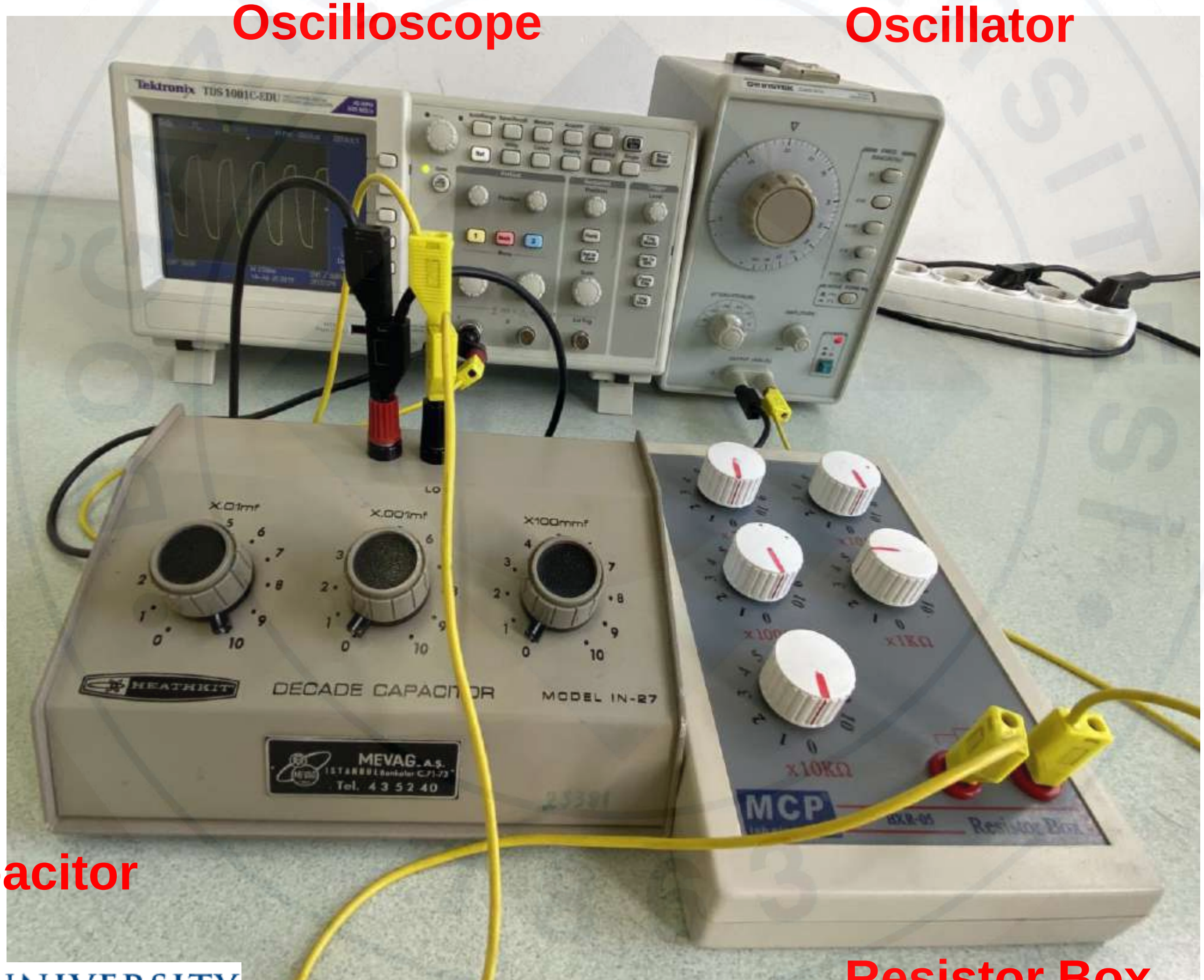
Discharging of a Capacitor



SETUP AND EXPERIMENT

CHARACTERISTICS OF A CAPACITOR

CIRCUIT

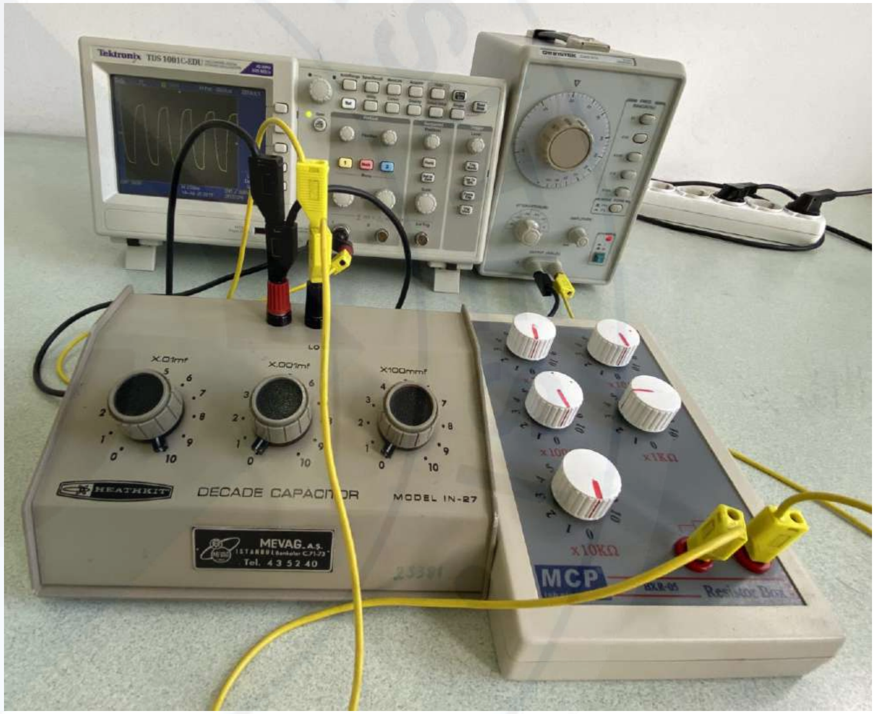


PART 1: DISCHARGING CHARACTERISTICS

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).**

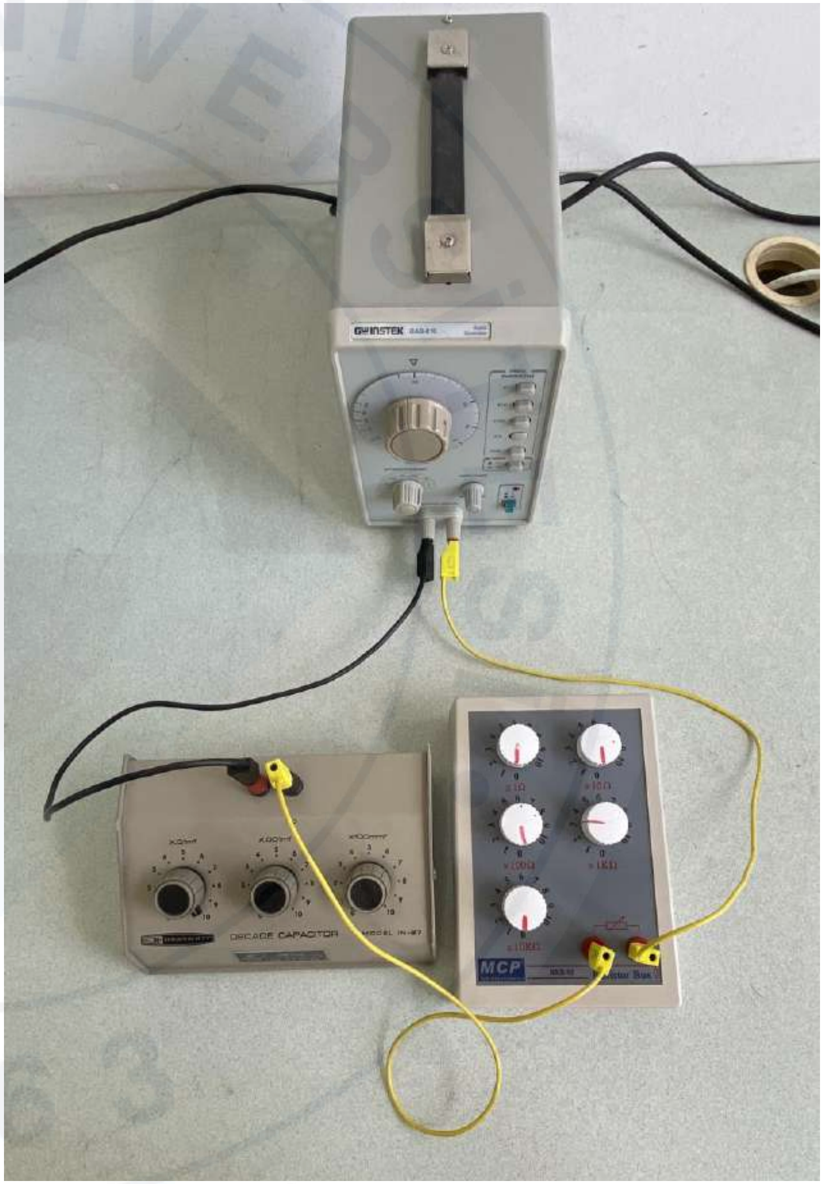
CIRCUIT:

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.

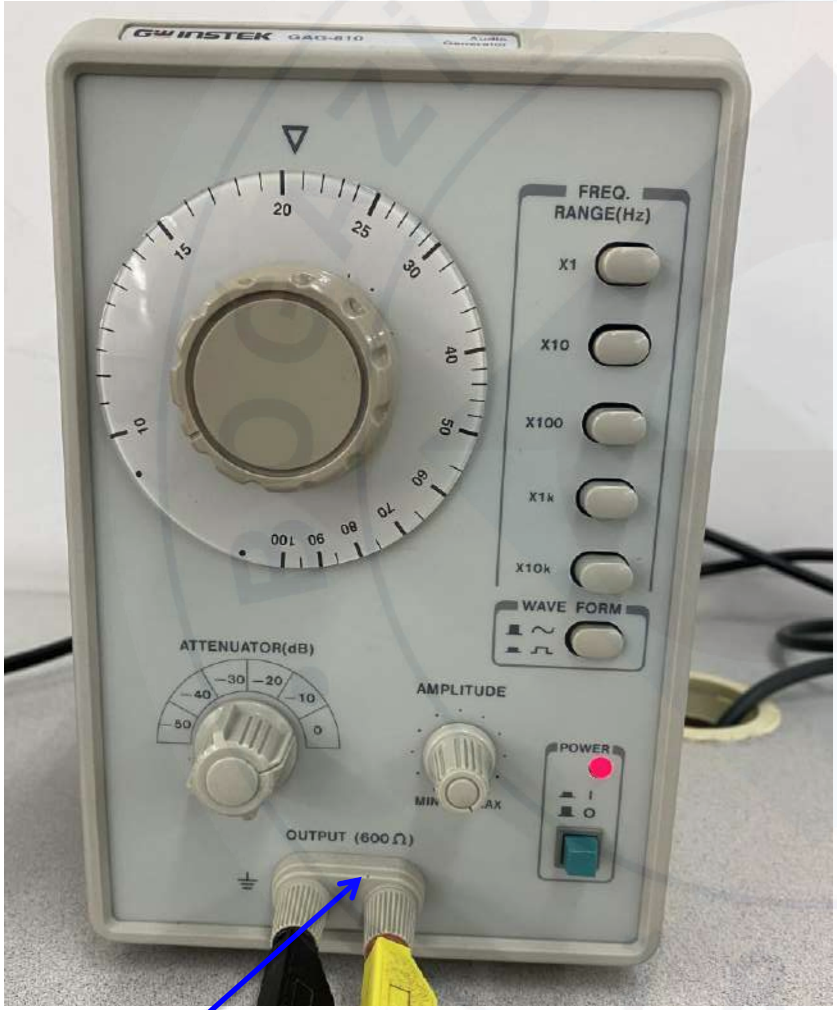
Calculate the true value of the half-life of the RC circuit and determine the square wave frequency to set.



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

CHARACTERISTICS OF A CAPACITOR

Oscillator (SWG)

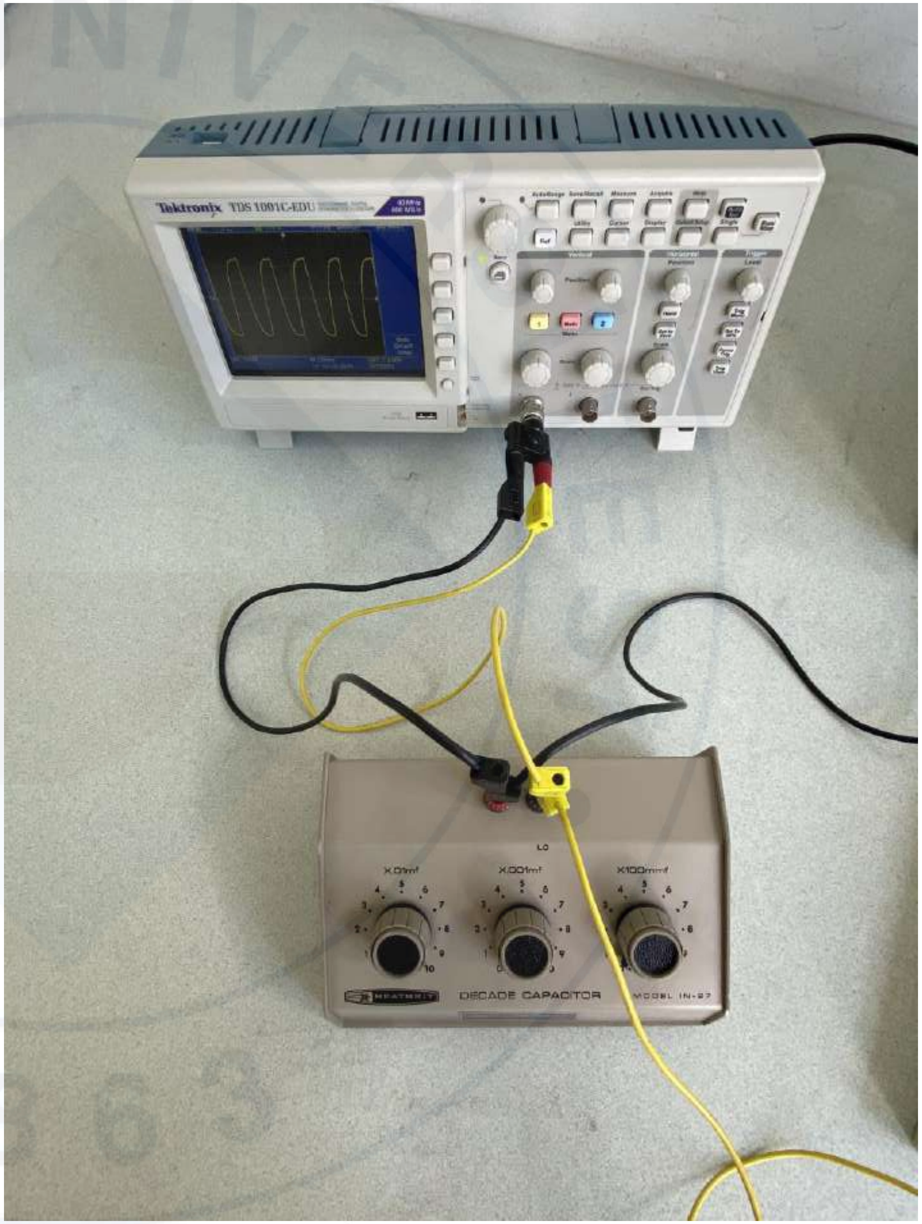


Internal resistance, R_{SWG} = 600 Ω

Resistor Box

R= 3000 Ω is set

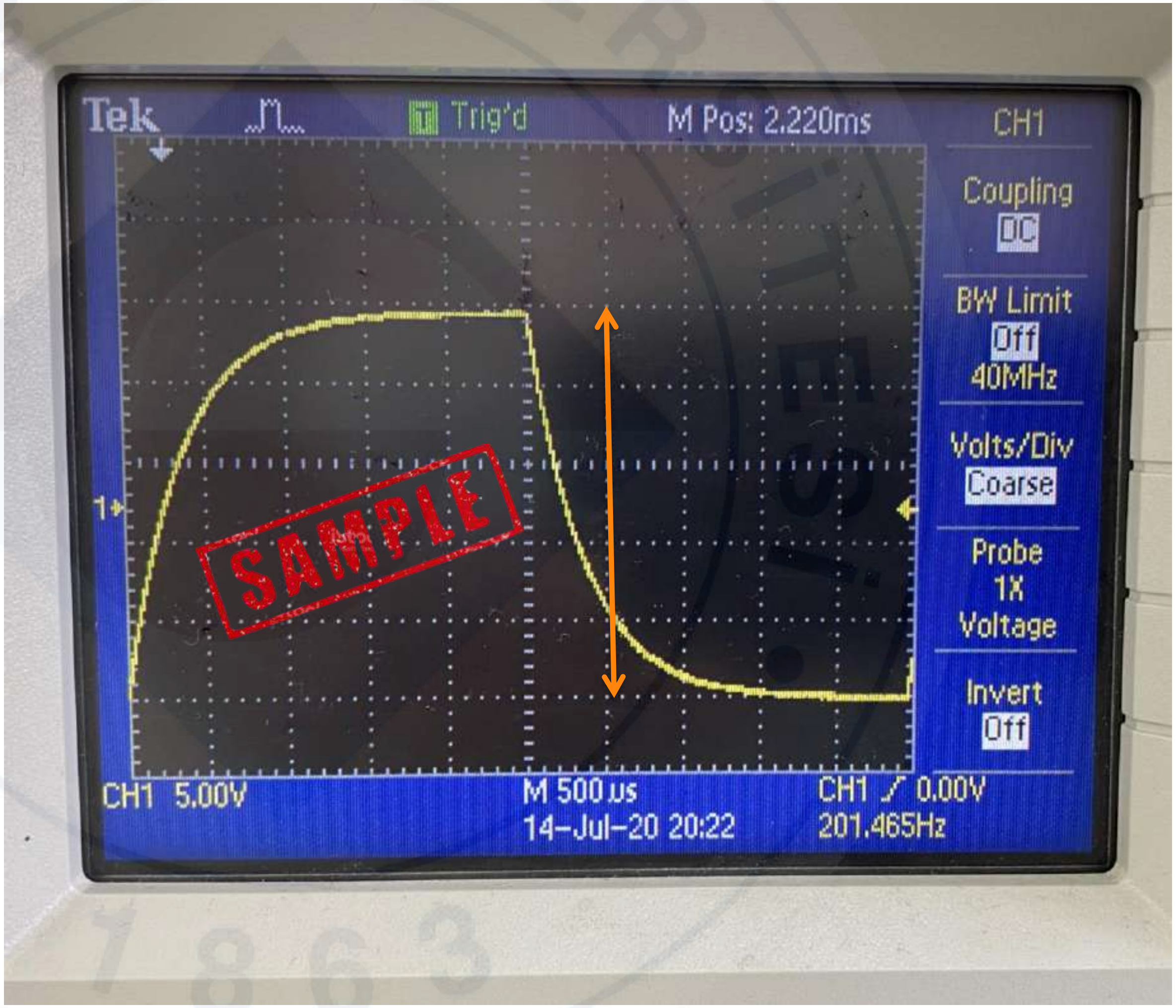
Oscilloscope is connected across (in parallel to) the capacitor to display the capacitor potential.



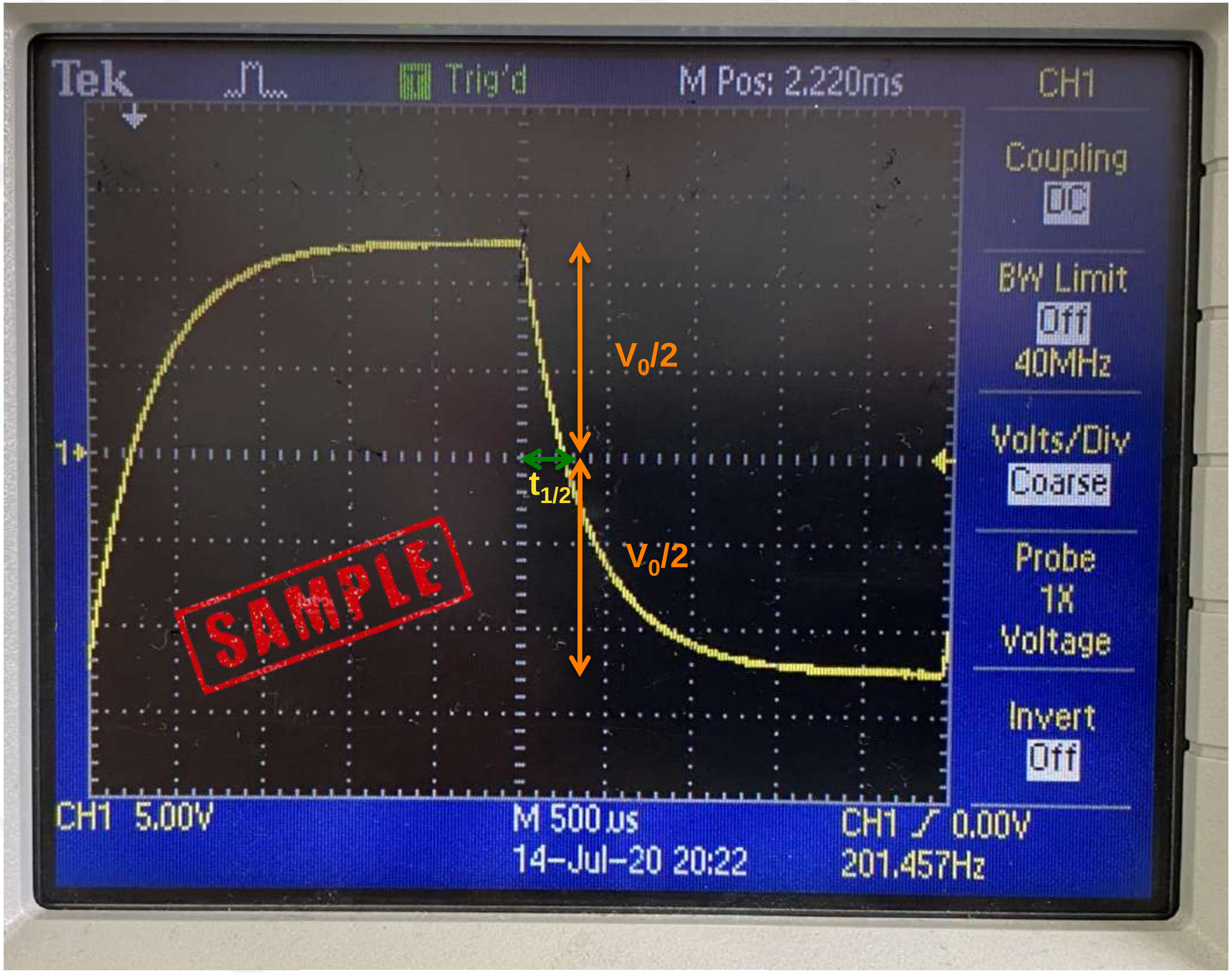
- **Calculate the square wave frequency to set to the oscillator.**

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

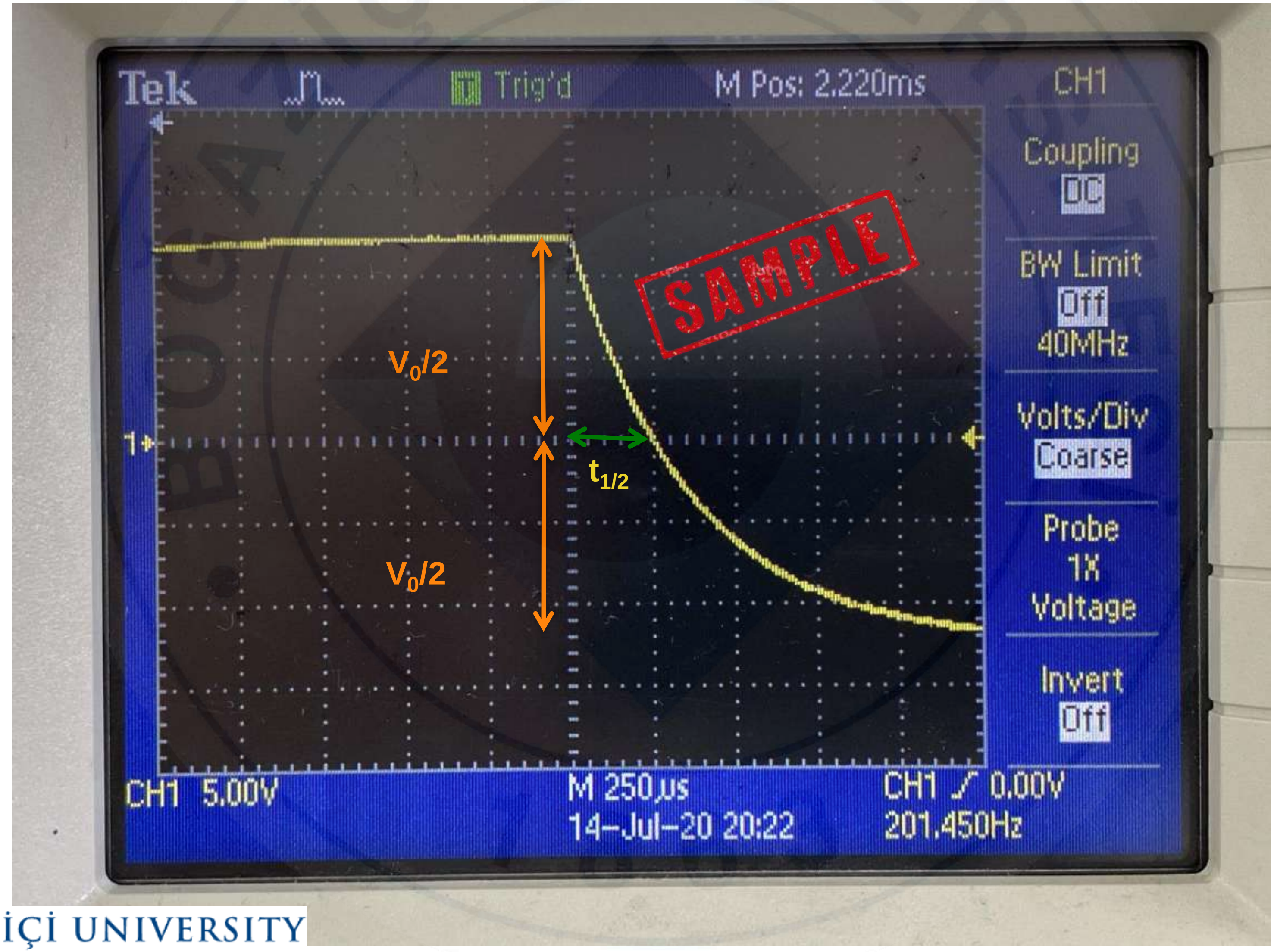
- **TIME/DIV and VOLT/DIV knobs are set to display one charging and one discharging phase on the oscilloscope screen.**



- 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).



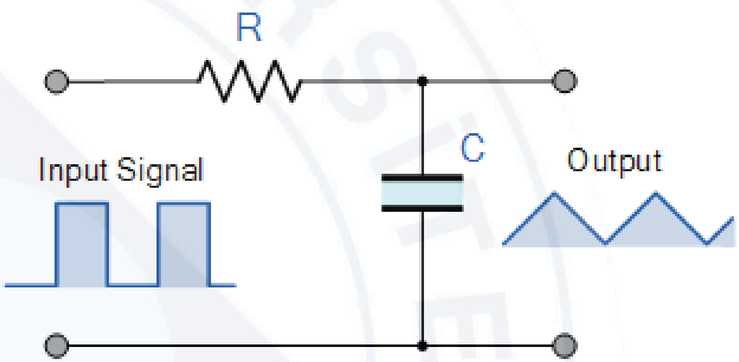
Half Life of Capacitor measurement with different TIME/DIV setting.



PART 2:
AN INTEGRATING CIRCUIT

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.

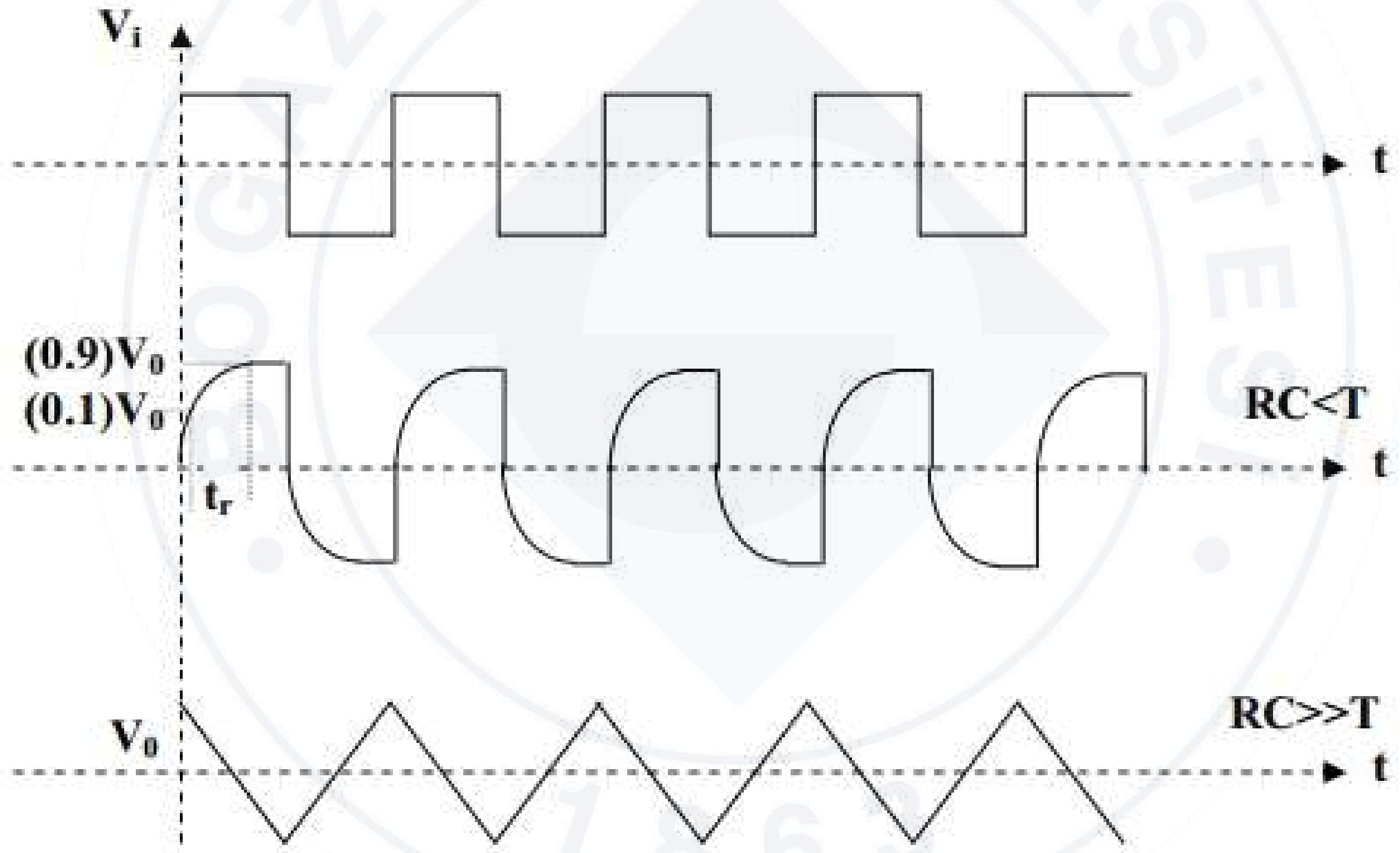
T << RC



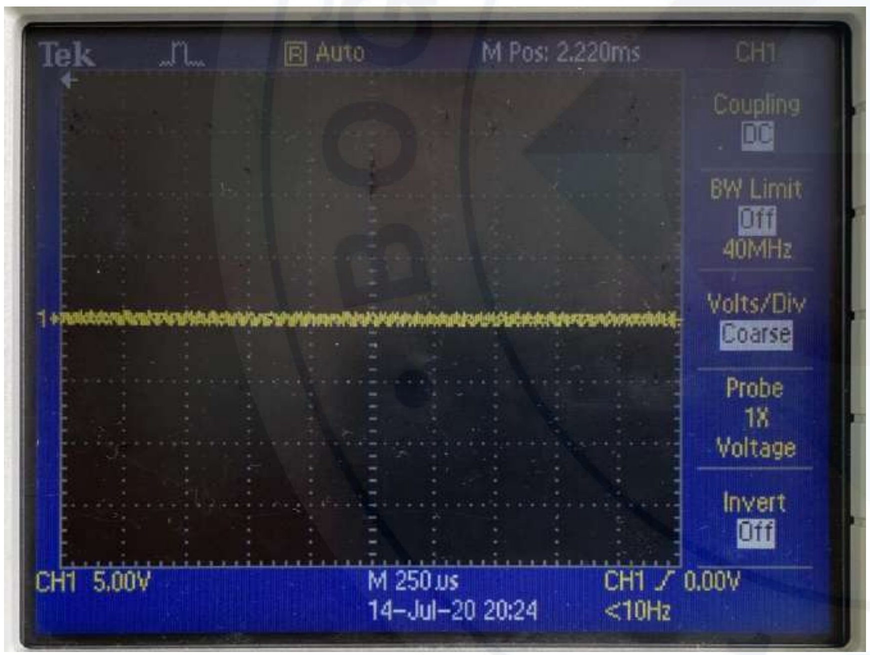
since $V_C \ll V_R$

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

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.



Use the same circuit, but set much higher frequency on the Square Wave Generator ($20x10^3$ Hz).



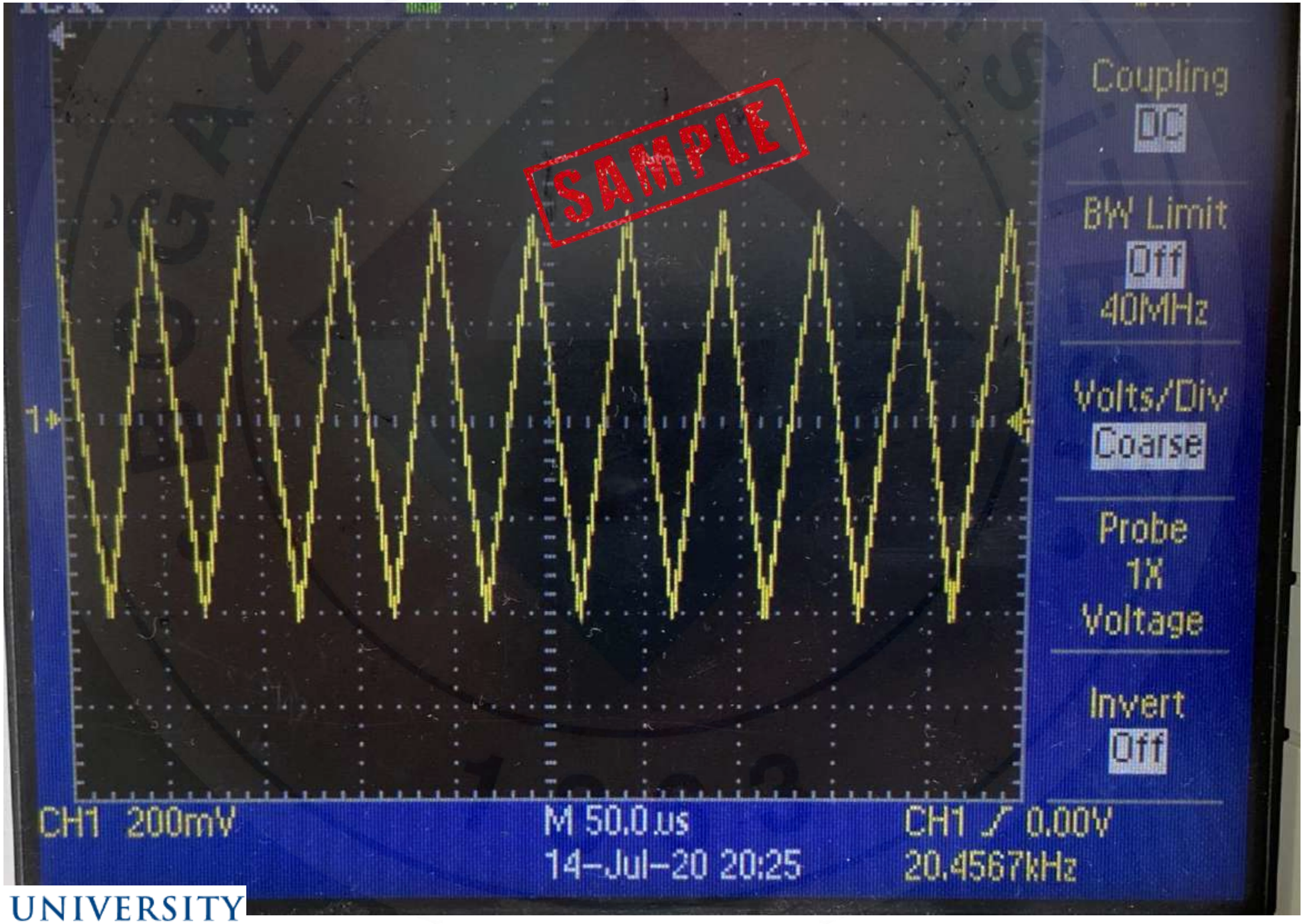
Oscillator (SWG)

Internal resistance, R_{SWG} = 600 Ω

Resistor Box

R= 3000 Ω is set

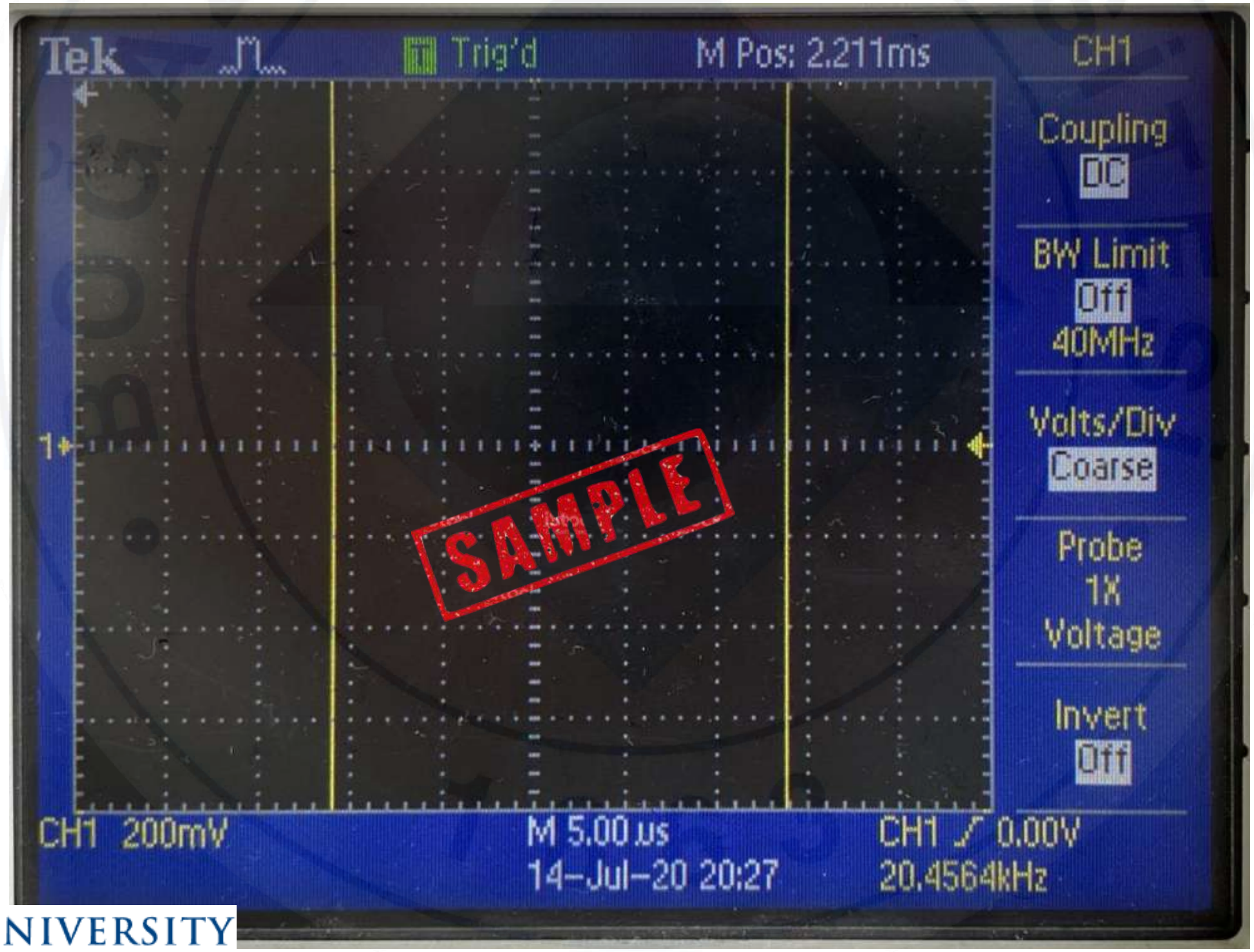
The controls (TIME/DIV and VOLT/DIV) are adjusted to for optimum focus.



Draw one period of the voltage across the capacitor (the Capacitor Voltage Waveform) in your report.

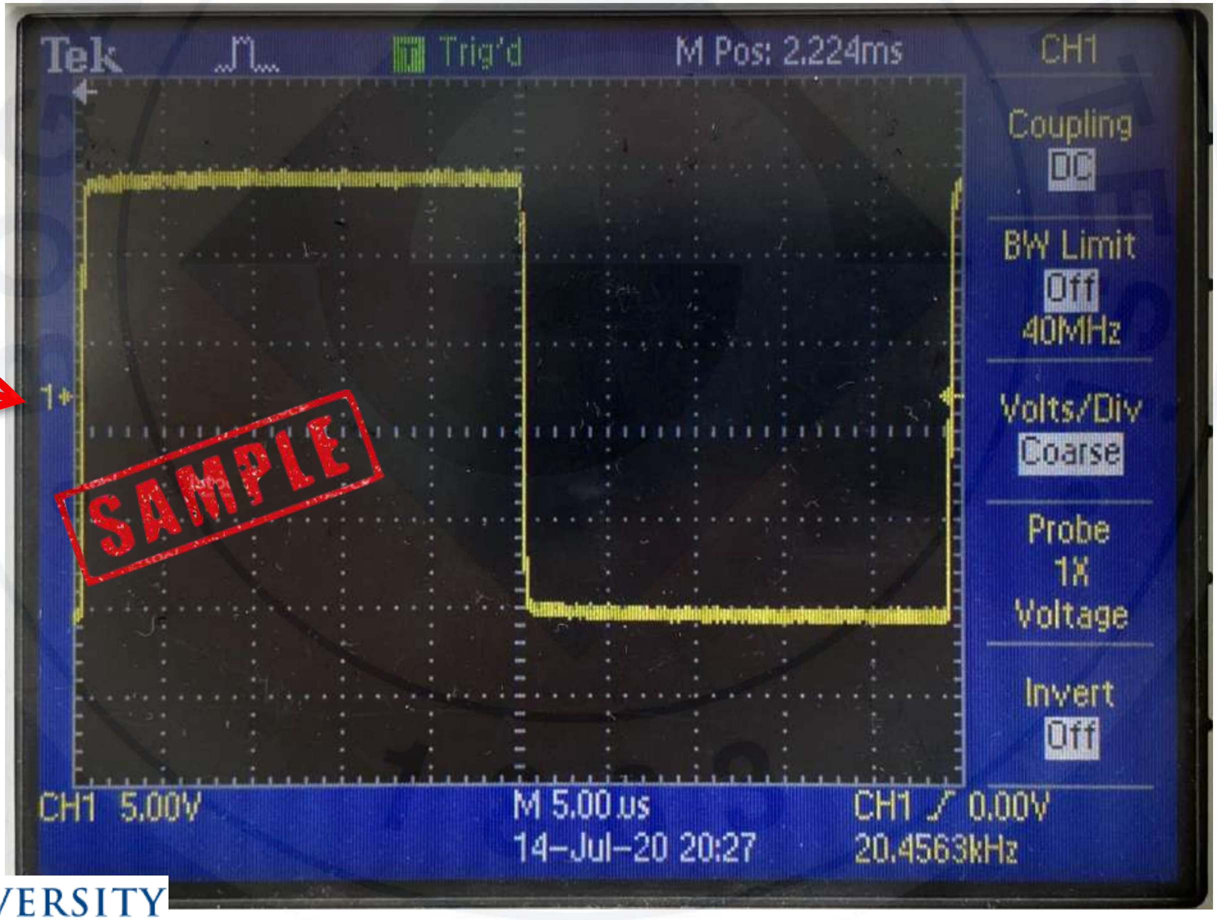
Indicates the horizontal axis where the signal is zero.

Now, connect the oscilloscope directly to the square wave generator in order to observe the applied voltage. Since $V_{app} >> V_c$ we need to adjust the VOLT/DIV setting.



Draw one period of the applied square wave voltage by using the same scale you drew the corresponding pattern for the voltage across the capacitor (V_c). Show that the capacitor voltage is proportional to the integral of the applied square wave voltage

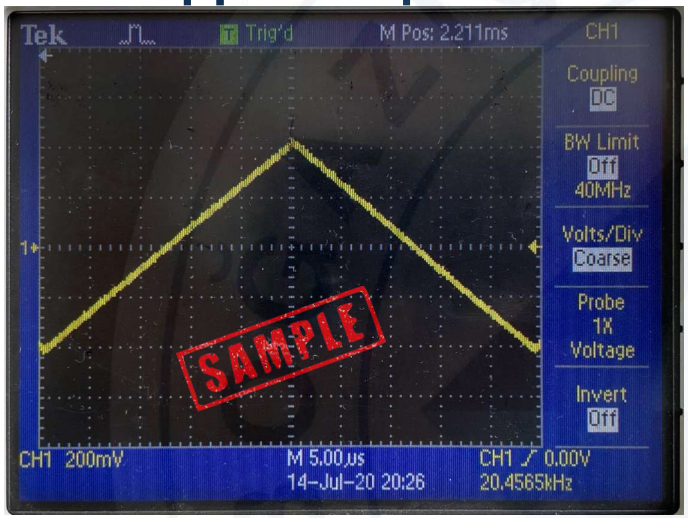
Indicates the horizontal axis where the signal is zero.



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

V_{c2}

V_{c1}



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

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

t_1 t_2

V_{app}

$-V_{app}$

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