DATE	COURSE/YEAR/GROUP	STUDENTS NAME

UNIVERSITY OF PLYMOUTH

Department of Communication and Electronic Engineering

EXPERIMENT FY2

RESPONSE OF A SERIES CONNECTED R-C CIRCUIT

OBJECTIVES

(a) To investigate the response of a series connected R-C circuit to a d.c. input.

(b) To investigate the concept of the TIME CONSTANT.

APPARATUS

Standard "Work Station" equipment available in Laboratory Room 304. Locktronics connection board and selection of resistors and capacitors.

INTRODUCTION

When a capacitor is charged from a d.c. supply through a resistor, the charging current is large at first, but gradually falls to zero as the capacitor voltage increases towards the supply voltage. The variation of the capacitor voltage with time has a characteristic EXPONENTIAL shape.

When a capacitor is discharged through a resistor, the capacitor voltage again varies exponentially, but in this case decreases with time.

These exponential variations have associated with them a "Time Constant", which is a measure of how quickly the capacitor charges and discharges. This time constant is numerically equal to the product of the resistance and capacitance, i.e. time constant $\tau = RC$.

SECTION 1 CAPACITOR CHARGING

Connect the circuit as shown in Fig. 1. Using the d.c. power supply to produce the 12 V input voltage. NB Check the voltage with the Voltmeter. To permit visual reading of the capacitor voltage variation, the values of resistance and capacitance must be relatively large. **NOTE: the polarity of the capacitor.** With the SWITCH OPEN, discharge the capacitor by shorting it with a 1kΩ resistor. Close the switch and take readings of time as the capacitor voltage increases.

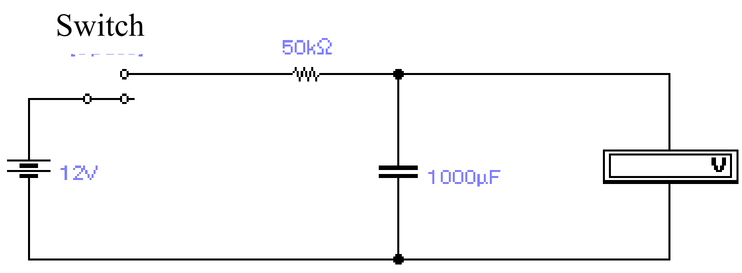
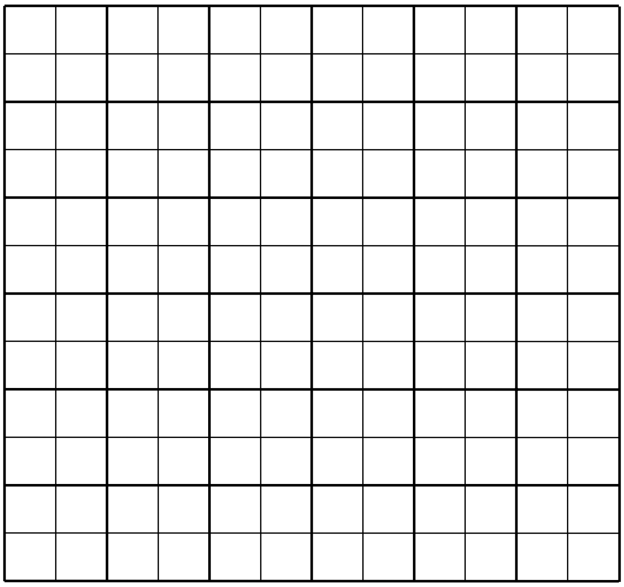


Fig. 1

Capacitor Voltage V	Time s
1	
2	
3	
4	
6	
8	
10	
11.5	

Plot the capacitor voltage against time of the graph below.



Determine the TIME CONSTANT using the following methods:

(i) Calculate the time constant using $\tau = RC$ τ = ... s

(ii) Estimate the time constant by determining the time taken for the capacitor voltage to reach 0.632 times the supply voltage, i.e. 0.632 x 12V = 7.58V in this case.
Note: this is approximately 2/3 of the supply voltage.

τ = ….................. s

(iii) Estimate the time constant by drawing a tangent to the capacitor voltage curve at time $\tau = 0$, i.e. a line denoting the initial slope of the curve, and find the time at which this line passes through the supply voltage level.

τ = ... s

Compare the values obtained for the time constant using the three methods.

Using the graph of capacitor voltage against time, has the capacitor voltage settled to within 5% of steady-state after 5 to 6 time constants?

YES/NO

SECTION 2:VARIATION OF RESISTOR VOLTAGE.

Move the voltmeter to measure the voltage across the resistor.

Repeat the measurement of voltage against time, again ensuring that the capacitor is initially uncharged.

Plot a graph of resistor voltage against time on the graph below.

Resistor Voltage V	Time s

Superimpose on the graph the variation of the capacitor voltage against time previously measured. Now ADD the capacitor voltage to the resistor voltage at a number of times and plot the result.

Comment on the variation of the resistor voltage variation and the voltage summation. (Are the results as expected?)

SECTION 3: CAPACITOR DISCHARING

Replace the voltmeter to monitor the capacitor voltage. This time start with the capacitor charged and take readings of capacitor voltage against time as the capacitor discharges through the resistor.

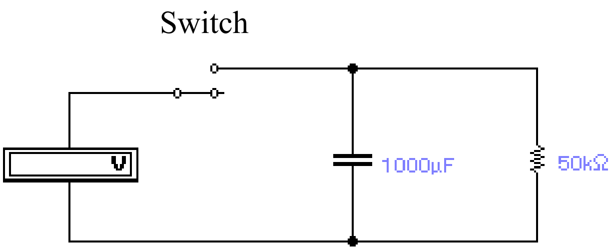
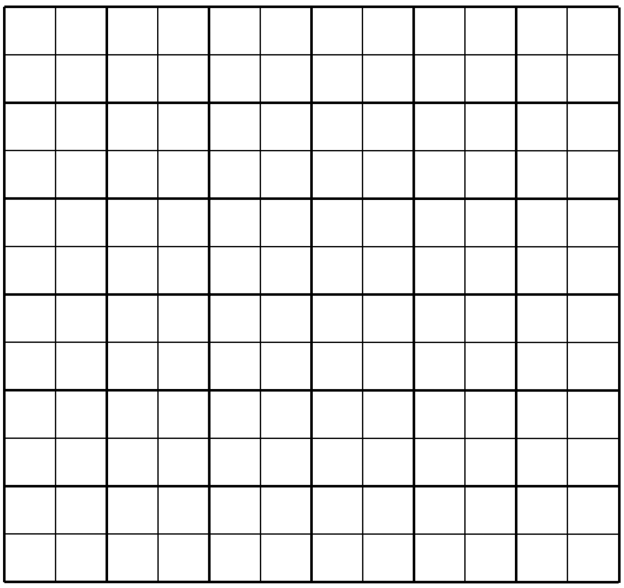


Fig. 2

Capacitor Voltage V	Time s

Plot the variation of the capacitor voltage against time on the graph below.



Using the above graph, determine time constant by:

(i) estimating the time taken for the voltage to reach 0.368 times the supply voltage (i.e. approximately 1/3 of the supply voltage).

Time Constant τ = …………….. s

(ii) drawing a tangent to the curve at $\tau = 0$ and projecting down to find the time at which the tangent passes through the zero voltage position.

Time Constant τ = …………….. s

Using the plotted variation of capacitor voltage, after how many time constants may the capacitor voltage be assumed to have reached steady-state (i.e. within 5%)?

Number of time constants = …………….

SECTION 4: RESPONSE OF R-C SERIES CIRCUIT TO SQUARE WAVE INPUT

Connect the circuit as in Fig. 1 but using C = 0.1 μF and R= 1kΩ . Replace the P.S.U. with the Function Generator and set the output to give a 5 V peak-to-peak SQUARE WAVE at 1 kHz.

Display the capacitor voltage on the oscilloscope and record the waveform using the graph on the next page.

Repeat the procedure for values of the resistance R = 2.5 kΩ and R = 5 kΩ

Calculations:

Square wave input is at 1 kHz, therefore period of waveform = ……………… s.

Hence, time for one half period of the waveform is …………….s.

Calculate the Time Constant for the circuit using $\tau = RC$.

When R = 1kΩ Time Constant τ = …………….. s

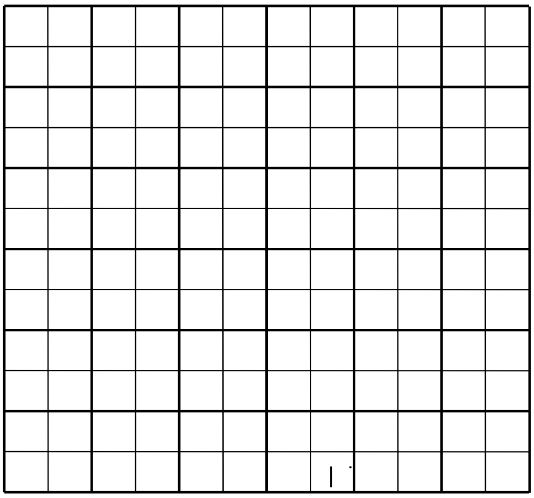
R = 2.5kΩ Time Constant τ = …………….. s

R = 5kΩ Time Constant τ = …………….. s

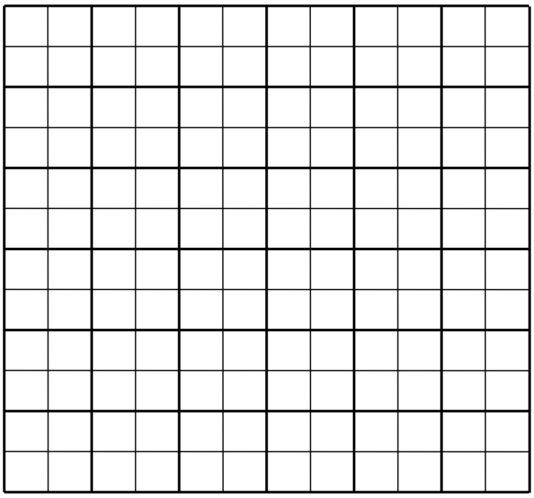
Discussions:

Use the values calculated above to explain the capacitor voltage waveforms recorded.

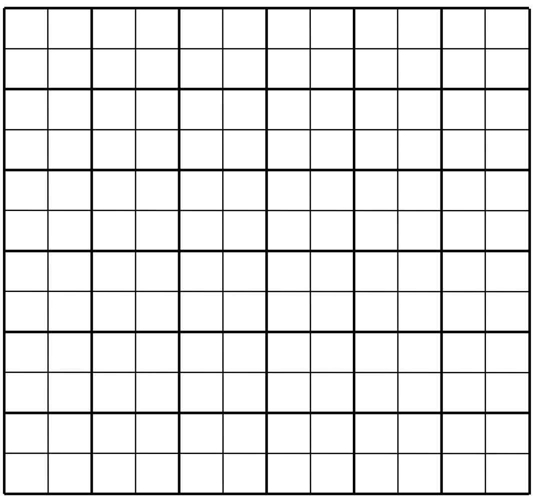
R = 1kΩ



R = 2.5kΩ

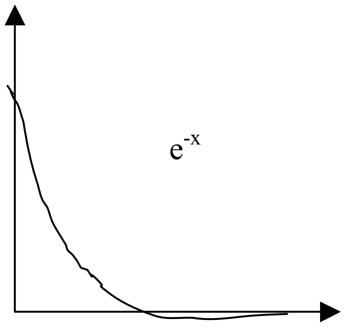


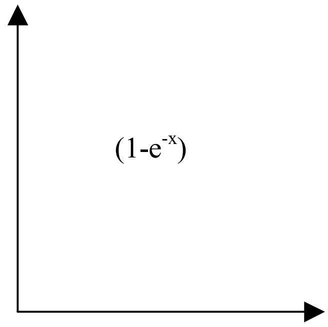
R = 5kΩ



Response of a Series Connected R-C Circuit (supplement)

Graphs of the following forms have the following equations:-





E.g. for charging $V_R = V_S\ e^{\frac{-t}{RC}}$ $V_C = V_S\,(1 - e^{\frac{-t}{RC}})$

$I_C = I_{max}\ e^{\frac{-t}{RC}}$

where $V_S = 12$ V, $I_{max} = \frac{V_S}{R}$

Prove these equations are correct by calculating values and then comparing with your graph.

(N.B. Check your V_S =12 V, or use the actual voltage in the calculations).

t/seconds =	**60**	**100**	**180**
V_C Calc			
V_C Graph			
% difference			

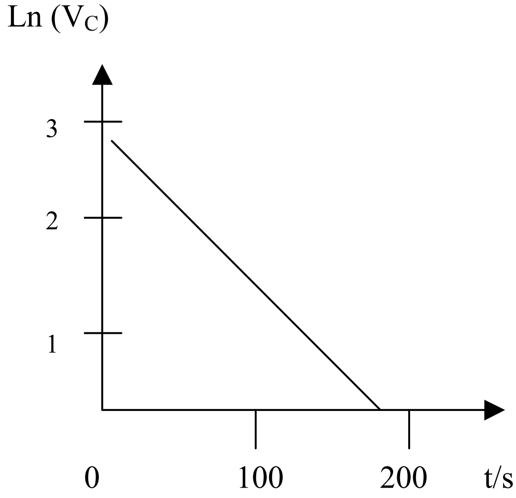
General Technique

If we have a series of results and want to find the equation, we take logs (1n) to get a straight line graph (i.e. of the form y = mx + c) and then calculate m (gradient) and C (the y axis intercept).

Example for **Discharge** results:

Add another column and then plot 1n (V_C) against τ .

T	V_C	1n (V_C)



Slope of graph = ___________________________________

Theory

$$V_C = V_S\ e^{\frac{-t}{RC}}$$

$$1n\,(V_C) = 1n\,(V_S\ \ e^{\frac{-t}{RC}})$$

$$1n\,(V_C) = 1n\,(V_S)\ \frac{-t}{RC} \qquad \text{(as } 1n\,(e^Z) = Z\text{)}$$

Compare with y = c + mx (general form of a straight line equation) i.e. m $= -\dfrac{1}{RC}$

(as y = 1n (V_S) and x = τ)

$$\therefore \text{ slope of graph} = -\frac{1}{RC}\ ;\ RC = -\frac{1}{Slope} \quad = \_\_\_\_\_\_\_\_$$

How well does this compare with the component RC? _________________