DRAFT - Investigating charging and discharging of capacitors

Why do this?

Resistor Capacitor (RC) circuits are a feature of all A-Level Physics exam boards. Often an incorrect value of either resistor or capacitor might be chosen to make readings of the capacitor charge/discharge quite difficult to obtain. This guide will show how to set up and give recommended values for the Capacitor and Resistor to make reading the voltage across a charging/discharging capacitor easier. Different resistor networks in series/parallel can also be constructed allowing students to review their work on resistance from earlier in their studies.

Possible curriculum links: techniques and procedures to investigate the charge and the discharge of a capacitor using both meters and data-loggers.

This *Practical Procedure* draws on information from the following guidance. Latest versions of these resources should be consulted for additional information and/or updates.

- *Laboratory handbook: Section 9 (page 928 Cells and Batteries)*

Suitability

A-Level

Suggested apparatus and materials

- A 100uF electrolytic capacitor (a voltage rating above maximum voltage of the power supply/cell being used) (2200uF if using multi meters)
- 3-5 x 10kΩ resistor (larger values such as 47kΩ if manually taking readings with multimeters and stopwatches)
- Component holders (see GL150)
- Connecting leads
- D Cell battery with holder or low voltage power supply
- A digital storage oscilloscope/voltage logger OR digital multimeter

Notes

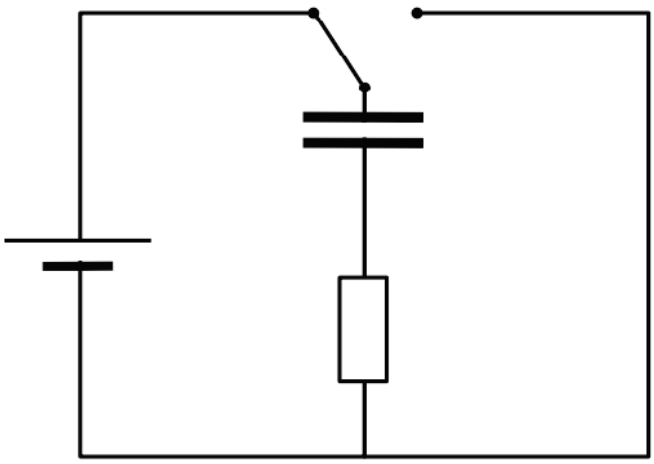
- Electrolytic capacitors may explode if non-vented and inserted into a circuit with the wrong polarity.
- The cell or power supply must not exceed the voltage rating of the capacitor, and additionally must not exceed 40 VDC.
- If manually taking voltage readings across the capacitor (e.g every 10 seconds, a larger time constant is needed (see Physics notes).
- See GLXXX for details on how to make a USB Voltage logger.

Outline method with control measures

- Ensure the polarity of the capacitor is correct with respect to the battery/power supply.

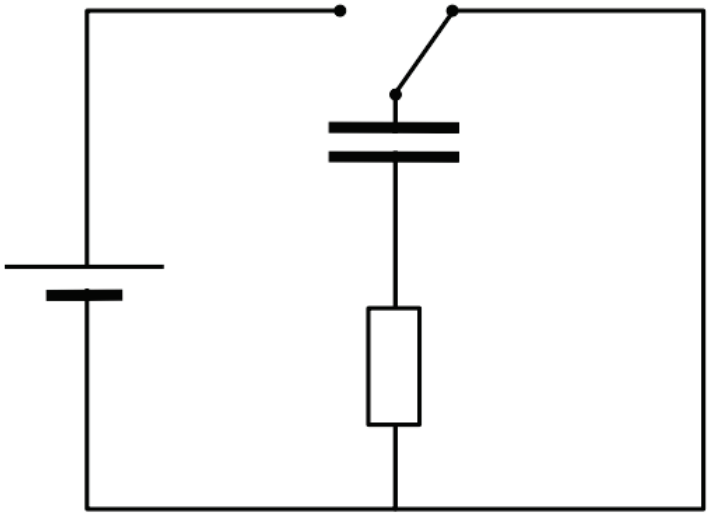
Procedure

1. Set up the circuit as per the circuit diagram leaving one terminal of the battery/power supply disconnected.
2. Insert leads from the oscilloscope/volt sensor/multimeter across the capacitor.
3. Switch your meter/oscilloscope to the suitable measuring parameters – for instance if using a 1.5V D-Cell, then voltage setting on the oscilloscope should be something of



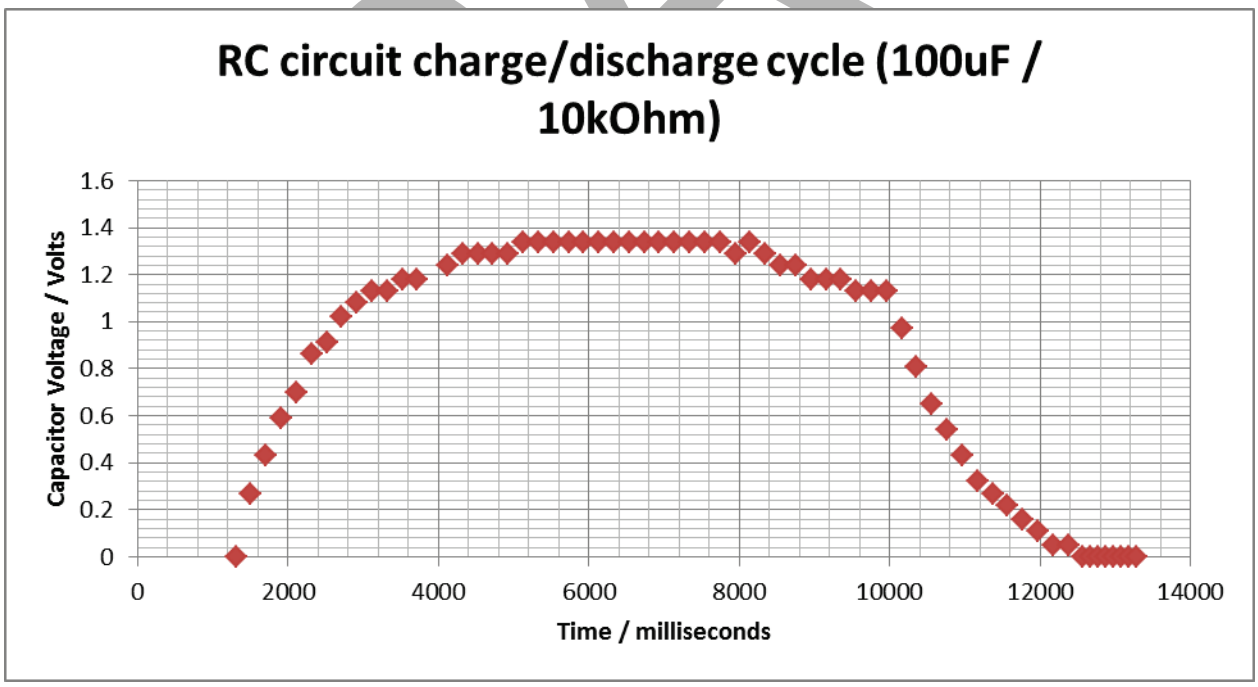
the order 500mV per division. If using a digital storage oscilloscope using the roll function of the time base will be most useful here (see associated video).

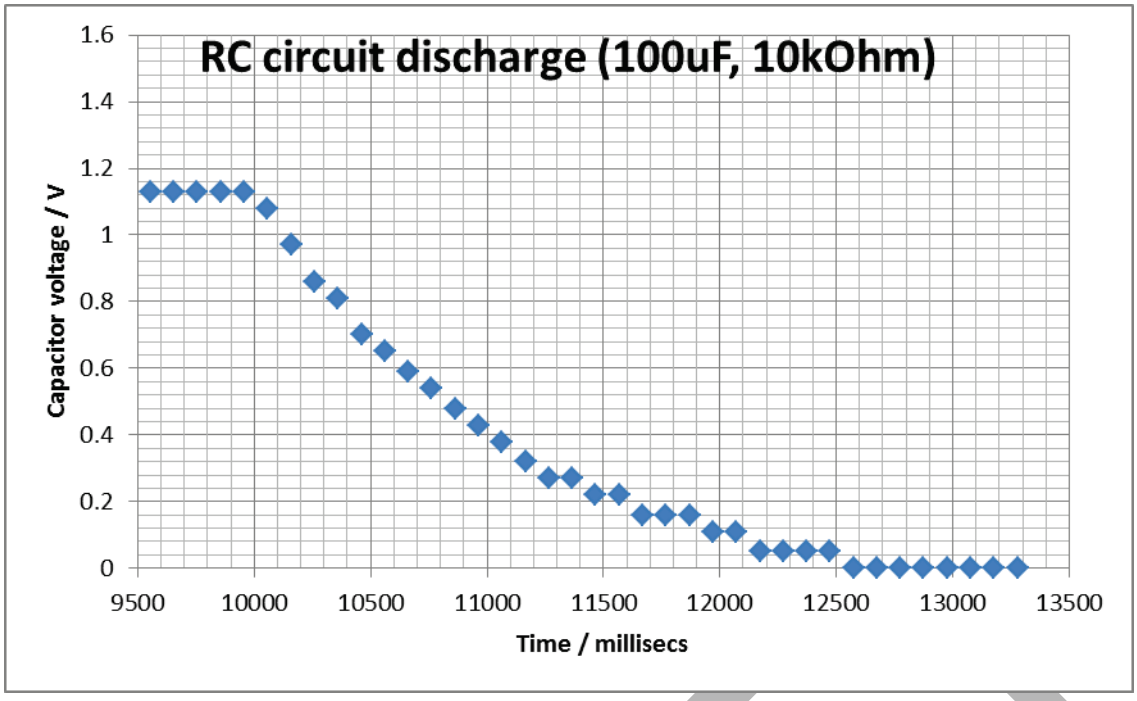
4. Complete the circuit by connecting the lead to the battery/power supply and observe the charging of the capacitor via the oscilloscope or meter. Take readings at suitable intervals if manually obtaining data with a meter/stopwatch.
5. To discharge the capacitor. Use the flying lead to connect the circuit diagram as below.



Expected observations/results

Plotting a graph of Voltage against Time should yield an exponential growth/decay curve as follows:





Physics notes

Resistor-Capacitors circuits (RC circuits) have a property called the 'time-constant' which is defined as:

Time Constant (seconds) = Resistance (Ohms) x Capacitance (Farads)

$$T = R \times C$$

It is the time it takes for voltage across the capacitor to charge to approximately 67% of the supply voltage (or conversely for the voltage across a capacitor to decay to approximately 37% of the supply voltage value).

It is thus important to choose Resistance and Capacitance values accordingly. The below table shows recommended components depending if you want a 'fast' charge/discharge, and a 'slow' charge discharge (if using the multimeter/stopwatch method). Choose components close to these values.

Method	Fast (RC < 1second)	Slow (RC ~100 seconds)
Resistor / Ω	10k	47-100k
Capacitor / µF	100	2200