

# Damped Oscillations

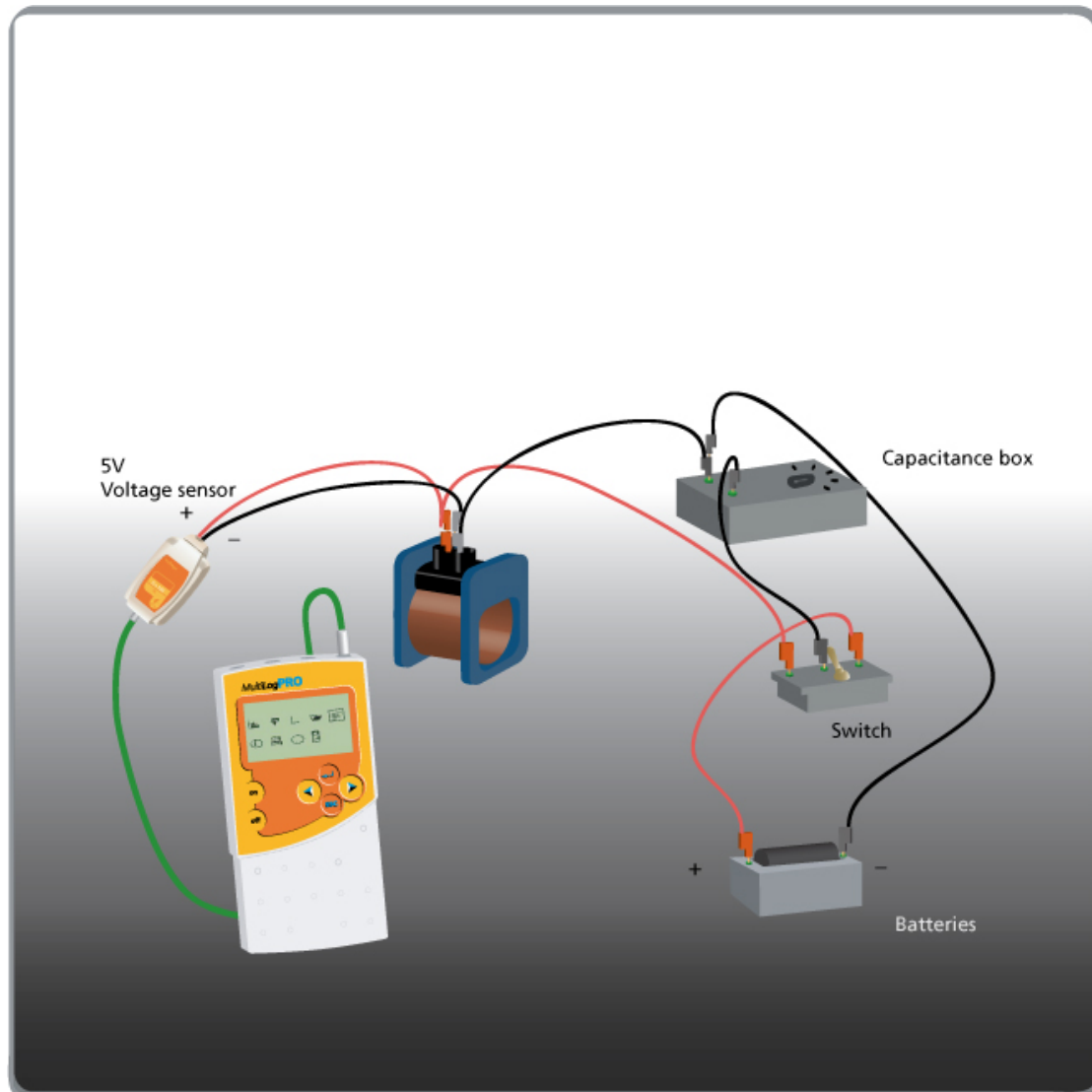


Figure 1

## Introduction

When a charged capacitor is discharged through a solenoid and a resistor the voltage and the current oscillate with gradually decreasing amplitudes. The voltage between the terminals of the capacitor is given by:

$$V = V_0 e^{-\frac{R}{2L}t} \cos\left(\sqrt{\frac{1}{LC} - \left(\frac{R}{2L}\right)^2} t\right)$$

Where  $V_0$  is the initial voltage,  $R$  is the resistance of the circuit,  $C$  is the capacity,  $L$  is the inductance and  $t$  is, of course, the time.

In this experiment this formula is explored and verified.

## Equipment

- Coil. ( $L \sim 20$  mH,  $R$  as low as possible)
- Capacitor ( $C \sim 20$   $\mu$ F, the expected frequency should be approximately 300 Hz)
- 1.5V battery
- Switch with one pole and two Terminals (1P2T)
- MultiLogPRO or Nova or TriLink data logger
- Voltage sensor  $\pm 2.5$  V (or  $\pm 25$ V)

## Equipment Setup Procedure

1. Connect the data logger to the serial port of the computer.
2. Turn on the data logger.
3. Connect the Voltage sensor to the I/O 1 port of the data logger.
4. Assemble the electric circuit as shown by figures 1 and 2:

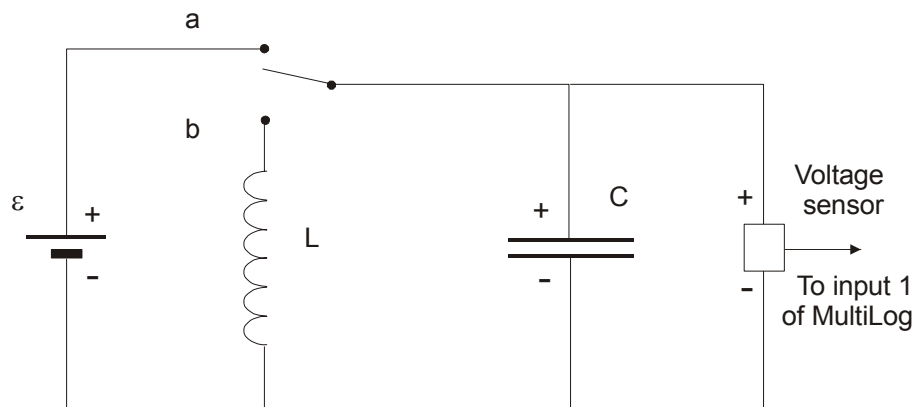



Figure 2

5. Click **Setup Wizard**  on the main toolbar and program the data logger according to the setup specified below:

In step 3 click **Triggering**, select the triggering options (see figure 3), and then click **OK**

## Data Logger Setup

### Sensors:

Input 1: Voltage  $\pm 2.5V$  (or  $\pm 25V$ )

### Rate:

20,800 samples per second

### Recording time:

240ms (5000 Samples)

### Triggering:

Based on: Input 1: Voltage  $\pm 2.5V$

Type: Above level

Level: 0.078

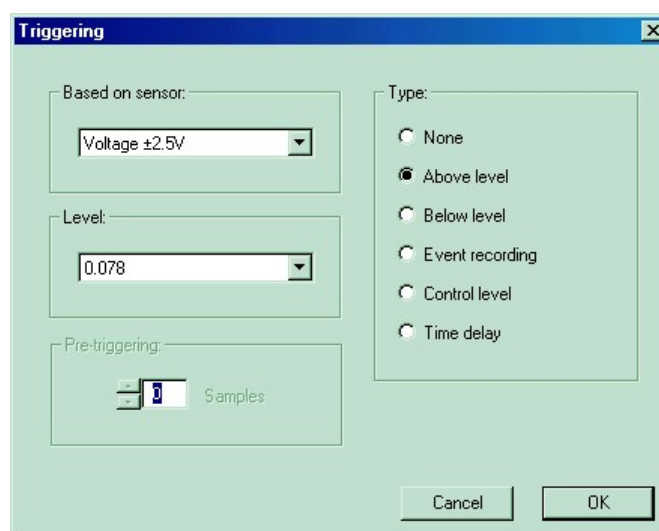



Figure 3

## Experimental Procedure

1. Move the switch to the “a” position (see figures 1 or 2) and wait a few seconds for the capacitor to be charged. The potential difference should reach a level higher than the trigger level (0.99 V).
2. Click **Run**  on the upper toolbar to begin recording data
3. Data collection will not start before the voltage exceeds the trigger level. The message **Trigger run** appears on the MultiLab display.

4. Switch to the “b” position, the capacitor will be discharged and data collection will automatically begin.
5. Wait until logging ends. Downloading to the PC will start automatically

Note: If you are using MultiLog V.6 click **Download**  on the main toolbar to download the data.

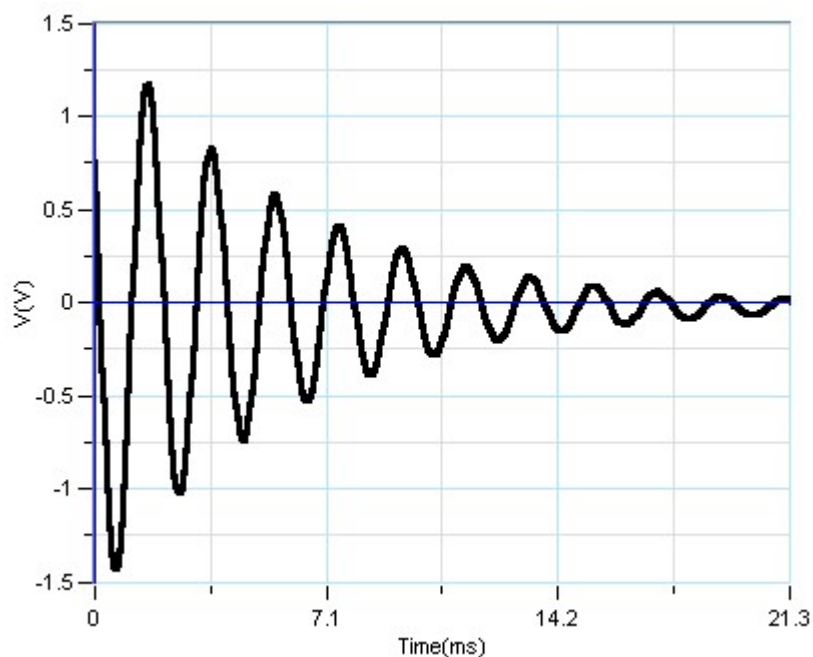


Figure 4

## Data Analysis

1. Using the cursors measure the frequency of the damped oscillations and compare to the expected value:

$$f = \frac{1}{2\pi} \sqrt{\frac{1}{LC} - \left(\frac{R}{2L}\right)^2}$$


2. Explore the exponentially damping amplitude:

$$V(t) = V_0 e^{-\frac{R}{2L}t}$$

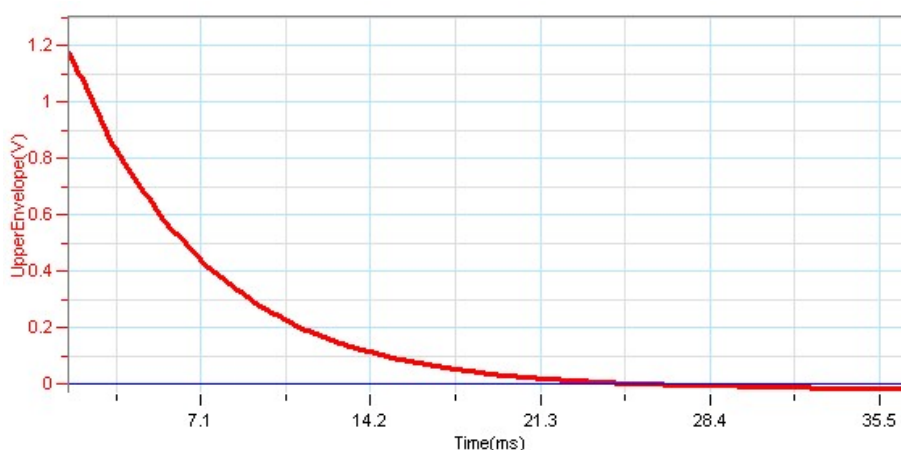
- 2.a. Use the cursor to select the graph: click **Toggle first cursor**




on the graph toolbar

- 2.b. Click **Analysis Wizard**  on the main toolbar, then click the **Functions** tab

- 2.c. In the **Functions** drop list select **Envelope (upper)**, then click **OK**



**Figure 5**

- 2.d. Use the cursors to select the part of the envelope where the values are above zero
- 2.e. Click **Analysis Wizard**  on the main toolbar, select **Exponential** and then click **OK**
- 2.f. Verify that your results fit the theory by comparing the exponent to its predicted value:

$$exponent = -\frac{R}{2L} \cdot x$$

## Further Suggestions

1. You can repeat the experiment with different solenoids and capacitors.
2. You may want to add a resistor to the circuit and see what resistance will cause the complete damping of the oscillations.



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3. You can repeat the experiment during the charging of the capacitor. You then have to connect the solenoid in series with the capacitor.
  4. You may use a Current sensor simultaneously with the Voltage sensor. You then have many options:
    - Compare the time constants of the two sensors.
    - Compare the derivative of the voltage to the current. The potential difference between the terminals of the capacitor is proportional to the charge on it, and since the current is the derivative of the charge it is expected that the voltage derivative will be proportional to the current.