Lab exercise III – Circuits

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Objective: Measure time-varying voltage signals. Plot and fit the data to extract experimental parameters.

Report: Hand in a report with the answer to questions (Q marked in red).

Equipment:

Oscilloscope GW Instek GDS-1022 (Fig. 1): The oscilloscope is primarily suitable for measuring dynamic voltage signals that are generally periodic. In this exercise a sinusoidal voltage from a signal generator and a damped oscillatory voltage in an RLC circuit are studied. Values are read off the oscilloscope by placing marker lines on the screen. The sought numeric information will appear on the screen of the oscillator.

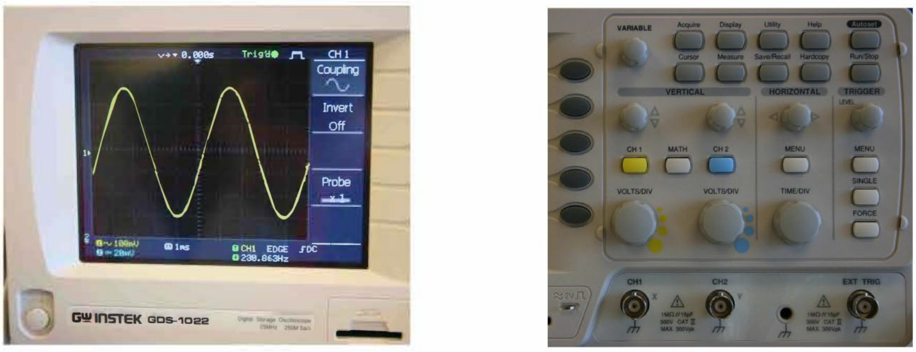
The oscilloscope is controlled via a panel. Submenus appear on screen when using designated function keys (instructions for measurements below). The user manual specifies the following instrument accuracy:

Vertically ± (3 % x [read value] + 0.1 x [read scale factor VOLTS/DIV] + 1 m V)

Horizontally ± (0.1 % x [read scale factor TIME/DIV])

555 RC Oscillator (Fig. 2): Sine and Square Wave Generator (signal generator) with various frequencies and amplitudes.

Multimeter: Measuring instrument that can measure voltage, resistance, and current. When measuring AC voltage signals the multimeter returns the so-called RMS value (root mean square), V_m. Connection between this value and the amplitude value, V_0, is given by: $V_m = \frac{V_0}{\sqrt{2}}$



(a) Sinusoidal voltage signal shown on the display of the oscillator. Settings here are, as shown: VOLTS/DIV = 100 mV and TIME/DIV = 1 ms.

(b) Buttons and control knobs on the oscillator panel.

Fig. 1 screen and panel of the oscilloscope

Fig. 2 Signal generator - 555 RC Oscillator

Basic concepts:

Sinusoidal voltage signal:

Q1. Write an equation that best describe the signal in Fig. 3, in terms of the maximum amplitude V_0 and the period *T*.

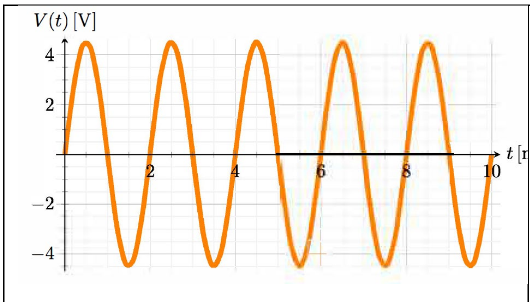


Fig. 3 A sinusoidal voltage signal as seen on an oscillator. The signal shown has an amplitude V_0 = 4.5 Vand a period T = 2.0 ms.

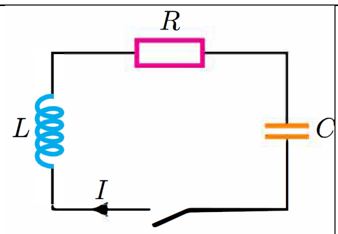


Fig. 4 *RLC* circuit in serial connection

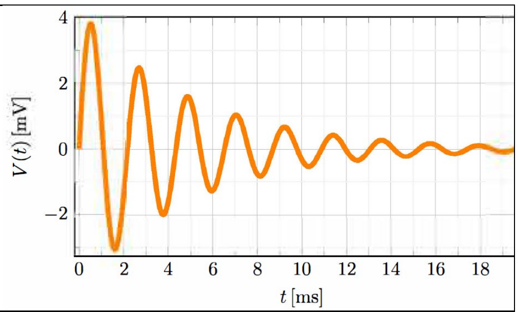


Fig. 5 Voltage across the resistor as a function of time when the capacitor is discharged. The signal represents a damped oscillation. The time constant There is 5.0 ms.

RLC circuit: Electrical circuit consisting of a resistor (R), an inductor (L), and a capacitor (C). It forms a harmonic oscillator for current, and resonates. Introducing the resistor increases the decay of these oscillations, which is also known as damping. The resistor also reduces the peak resonant frequency. The capacitor in Fig. 4 is charged when the switch is open. When this is closed, the capacitor will discharge by a current flowing in the circuit.

From LAB EXERCISE B "Voltage signal measurements" FYS210

For a small resistance, the voltage across the resistor is expressed by:

$$V(t) = V_0 \exp\left(-\frac{t}{\tau}\right)\sin\left(\frac{2\pi t}{T}\right) \quad (1)$$

The time constant, τ, and the period, *T*, are given by:

$$\tau = \frac{2L}{R} \quad (2) \quad \text{and } T = 2\pi\sqrt{LC} \quad (3)$$

In this exercise charging and discharging of the capacitor is realized by ex-changing the switch with a periodic square wave signal from an oscillator. The voltage signal expressed by equation (1) is visualized in Fig.5.

Q2. How can you get rid of the damping effect?

Q3. What happens to the signal if L is replaced by another R?

Q4. For which values of t do you get a maximum voltage?

Experimental tasks:

Part A: Amplitude and frequency from a signal generator

In this part, we will set a sine wave with a signal generator. We will use a multimeter to check its amplitude, then an oscillator to find the amplitude and period of the same signal. The two amplitudes can be compared, and from the period we can determine the frequency (with uncertainty) as well.

- Connect the output OUT of the signal generator (555 RC Oscillator) to the first channel CH1 of the oscilloscope. Connect the multimeter to OUT on the signal generator as well.
- Q5: which variables can you control with the signal generator?
- M1: measure V_m with the multimeter after setting your variables
- Visualize the signal in the oscilloscope
- M3: measure in the oscilloscope the period and amplitude of the signal*.
- Q6: Compare the multimeter and oscilloscope V_m values. Can you estimate the error of these?
- Q7: calculate the signal frequency.

Part B: Damped oscillations in an *RLC* circuit

In this part, we shall record pairs of time- and amplitude values when using the RLC circuit as shown in Figure 5.

- Connect the output OUT of the signal generator (555 RC Oscillators) to the *RLC* circuit at the «+» and «-» sockets.
- Connect the CH1 channel of the oscillator across the resistor («R»).
- Set the frequency of the signal generator to 750 Hz.
- Use maximal voltage amplitude.
- Set the signal form to be square.
- Visualize the signal on the oscilloscope.
- M4: measure the time and the amplitude of the signal maxima using the oscilloscope.
- Q8: Find the average signal period with error bar.
- Q9: Plot the data you took by hand, make sure axis are well labelled. Add error bars. Which kind of function is this?
- Q10: Find a strategy to fit (manually) these data. Find inspiration on the signal function.
- Q11: Fit your data to find the time constant and V_0.
- Q12: what would you do to estimate the errors of these values?
- Q13: Find V_m, this time using the oscilloscope data. How does it compare to the multimeter value?
- Q14: Determine the inductance when C=1nF. Which units are appropriate?
- Q15: Determine the resistance with appropriate units.

How to measure with an oscilloscope:

- Press Autoset and check that the signal looks all right on the screen.
- Press [CH1 ⟩⟩ Coupling] so that the grounding symbol is shown, and centre the signal vertically in the screen (yellow, horizontal line) by using the «⇳» button. (Any blue CH2 line may be switched off with the blue button.) Now press Coupling until the sine symbol is shown.

☞ Adjust the VOLTS/DIV button to gain a curve as large as possible fitting the screen. Mark down the set voltage value per grid tile (displayed on the bottom of the screen).

☞ Adjust TIME/DIV similarly. One to two periods shown on the display should be fine. Also write down this selected number.

- Press Cursor. Make sure that CH1 is selected as Source. Use the «X ⟷ Y» function button to set marker lines. Y is a horizontal line for measuring voltage. X is a vertical line for time measurement. Positioning is done with the Variable control knob.

☞ Choose horizontal marker lines. Adjust the position of these liens (Y1 and Y2) by using the Variable knob and read off the peak-to-peak voltage. The «Δ» in the Y1Y2 pane corresponds to $2\,V_0$. Estimate your accuracy (random error) in reading these values.

☞ Change the mode to X representation. Use the two marker lines (X1 and X2) once more to determine the period T of the signal. The «Δ» in the X1X2 pane corresponds to T. Remember to estimate a random error here as well.