Circuit Analyses. Laboration 4 Measurements and simulations on AC-circuits.

This booklet, signed by the teacher, serves as a receipt for passing the lab. Each student must have a booklet of his own with solid preparation and completed readings.

Name:
Confirmed (Teacher):

Objective in this lab, you will learn how to implement ac voltage measurements of phase, amplitude and impedance. You should also use PSpice for AC-analyses.

Equipment

- Oscilloskope DSO2014A
- Funktionsgenerator PM *5139* or the internal Wave-generator of the oscilloscope.
- Digital multimeter (DMM) Fluke45
- RCL-meter PM6303
- Breadboard and components

Litterature Presentations on the course web.

Report Write down your measured values, and figures, in this booklet and report to the teacher during the laboration.

Preparation tasks, quick summary

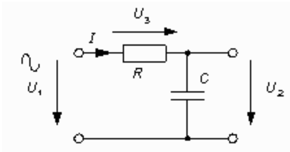
F1: Parameters of an AC-voltage

Assume that a sinusoidal ac voltage is mathematically described by the following relationship:

$$u(t) = 3\sin(6280t)$$

Enter the peak-peak value ($U_{t\text{-}t}$) RMS-value (U) mean-value ($\overline{U}$) frequency (f), in the table.

F2: Set up expressions for absolute value and phase for the RC-circuit.



Set up an jω expression for the transfer function of the RC link in the figure. Also, set up expressions for the absolute value and the the phase function.

Calculate U_2 if the input volyage is the signal specified in F1 and R = 10 kΩ and C = 10 nF. $u(t) = 3\sin(6280t)$

F3: cutoff frequency

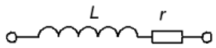
- How is the cutoff frequency defined?
- What is the absolute value and the phase value of the transfer function at the cutoff frequency?
- Calculate the cutoff frequency of the RC link in the figure (with R = 10 kΩ and C = 10 nF). f_g = ?

F4: Prepare the Lin-Log-graph

In this booklet is a sheet with two charts. Both should have a linear y-scale (0...1 for the absolute value and 0°...-90° for phase). The frequency scale should be logarithmic and have the appropriate numbering. Also, provide values for the tick marks within the decades. Give the axles appropriate headings.

F5: Measuring impedance *L+r* with the oscilloscope

$$Z = \frac{U}{I} \quad Z = \sqrt{r^2 + (2\pi f \cdot L)^2} \quad \varphi = \arctan\frac{2\pi f \cdot L}{r}$$



During the lab you will measure an unknown coil with a series resistance. Derive an expression that can be for calculating *L* and *r* given *Z* and *f*.
Calculations are simplified if you let the measurements take place at the phase angle |φ| = 45°.

$L = f(Z,f)$ $r = f(Z)$ at $|\varphi| = 45°$

F6: Measuring an impedance *L+C+r* at resonance. The Q-value.

Check what the Q value of a resonance circuit is about, and how it is calculated. How could the Q-value be calculated from the measured oscilloscope voltages?

F7: Measuring impedance *L* with the DMM

Higher accuracy in the measurement of *L* can be obtained with the DMM. Derive an expression of how *L* can be calculated if one measures the impedance of Z_1 and Z_2 at two different frequencies f_1 and f_2.
$L = f(Z_1, Z_2, f_1, f_2)$

Measurements, report of preparation tasks

F1, M1 Parameters of an AC-voltage

Assume that a sinusoidal ac voltage is mathematically described by the following relationship:

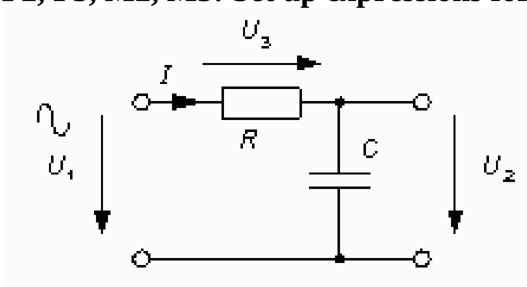
$$u(t) = 3\sin(6280t)$$

Enter the peak-peak value ($U_{t\text{-}t}$) RMS-value (U) mean-value ($\overline{U}$) frequency (f), in the table.

	peak-peak ($U_{t\text{-}t}$)	RMS-value (U)	meanvalue ($\overline{U}$)	frequency (f)
Preparation				
Measurement				

Set the function generator (or the oscilloscope's built-in-Wave Generator) so that the voltage is according to the preparatory task **F1.** Measure the voltage peak-peak value($U_{t\text{-}t}$) mean ($\overline{U}$), rms (U), frequency (f) with the oscilloscope. Fill in the answers in the table and check with preparation values from **F1**.

F2, F3, M2, M3: Set up expressions for absolute value and phase for the RC-circuit.



$\dfrac{\underline{U}_2}{\underline{U}_1} =$ $\left|\dfrac{\underline{U}_2}{\underline{U}_1}\right| =$ $\arg\left(\dfrac{\underline{U}_2}{\underline{U}_1}\right) =$

If $u(t) = 3\sin(2000\pi t)$ $U_2 = ?$

F3: Cutoff frequency

- How is the cutoff frequency defined? What is the absolute value and the phase value of the transfer function at the cutoff frequency?

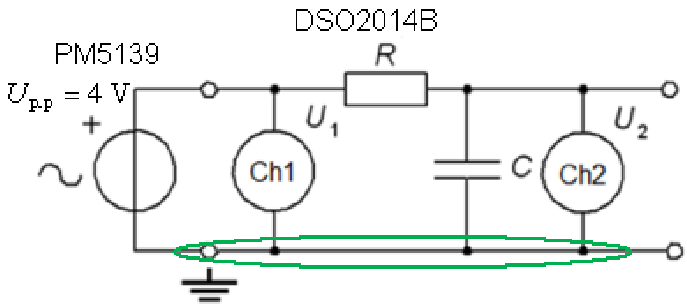
- Calculate the cutoff frequency of the RC link in the figure (with R = 10 kΩ and C = 10 nF). $f_g = ?$

- Is the RC-link an HP LP BP or BS filter? Motivate your answer.

M2: Measuring absolute value and phase at one frequency

Connect the RC-circuit on the breadboard with R = 10 kΩ and C = 10 nF. Use input voltage $u(t) = 3\sin(2000\pi t)$ as in **M1**. Connect the RC-link input and output to a respective channel of the oscilloscope.

It's the setting Phase(2→1) that gives you the correct sign for the phase.



Measure U_1 and U_2 with the oscilloscope, och calculate $\left|\frac{\underline{U}_2}{\underline{U}_1}\right|$. Measure the phase, $\arg\left(\frac{\underline{U}_2}{\underline{U}_1}\right)$.

	$\left\|\frac{\underline{U}_2}{\underline{U}_1}\right\|$	$\arg\left(\frac{\underline{U}_2}{\underline{U}_1}\right)$
Preparation		
Measurement		

Does your measured values complies with your calculated values? If not, what can be the reason?

M3: Measuring absolute value and phase as a function of frequency

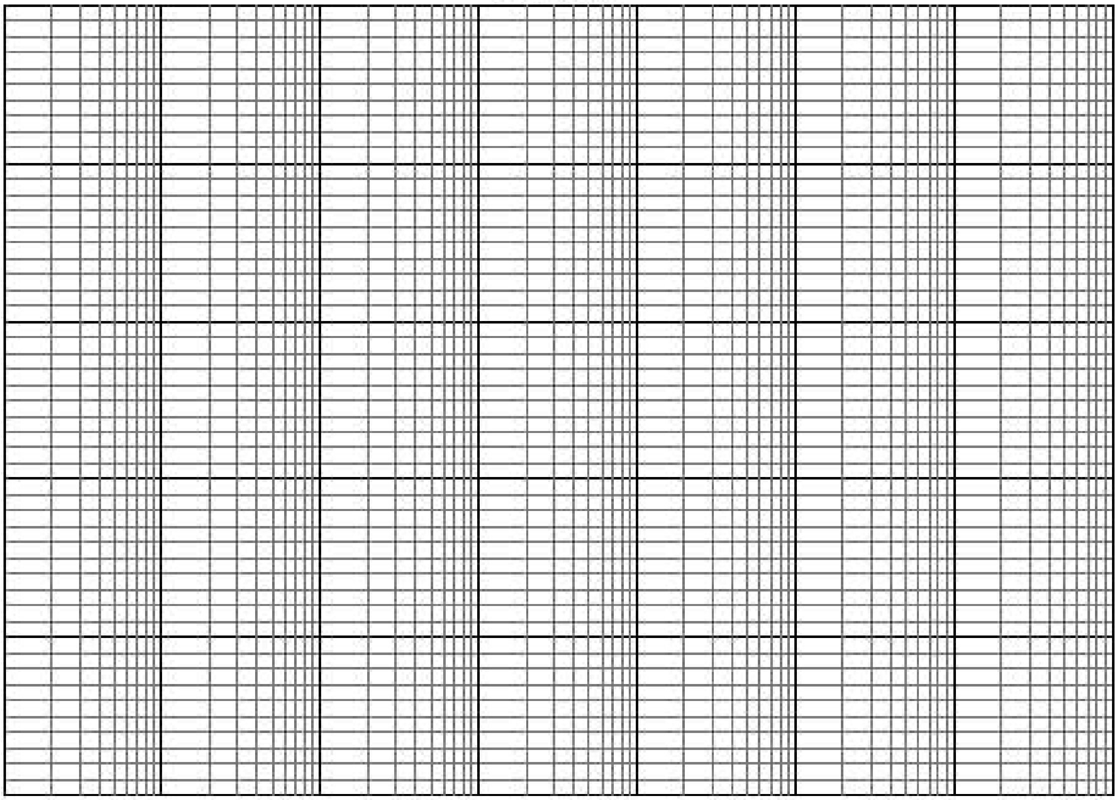
Use same connections as in **M2**. Varying only the frequency of U_1. Measure the transfer function, absolute value an phase for frequencies 10 Hz … 100 kHz with ”logaritmic steps” between points (1 2 5 … will bee enough cover). Tip! Set U_1 to 1,00 V on the oscilloscope – then U_2 will directly display the attenuation without any calculations!)

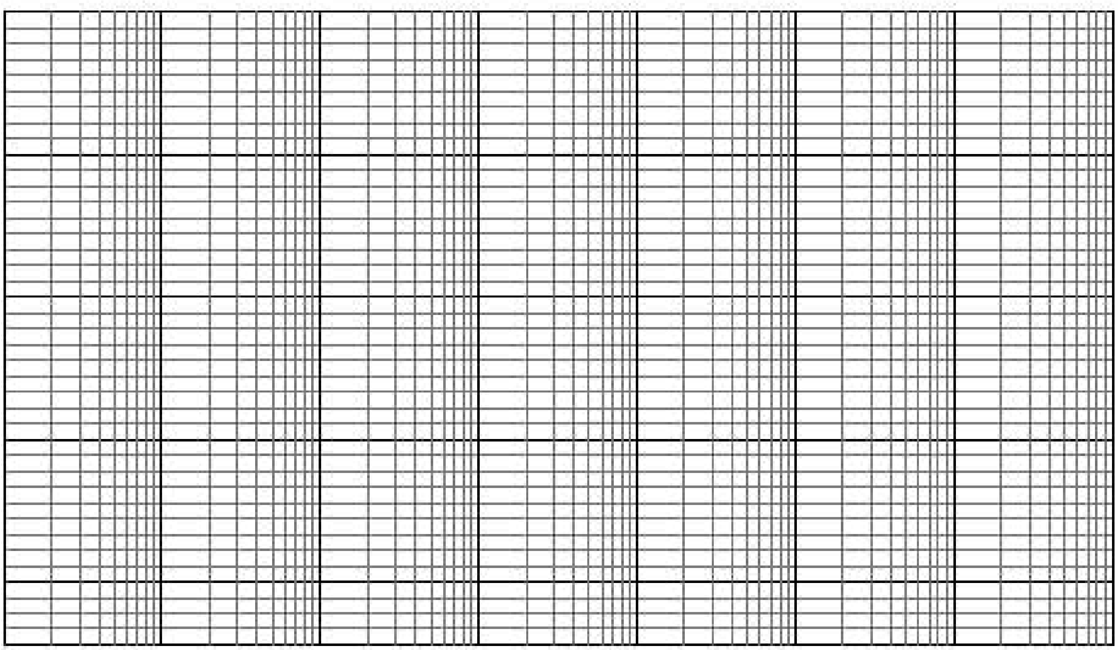
Frekvensgång, Gränsfrekvens

frekvens	10 Hz	20 Hz	50 hz	100 Hz	200 Hz	500Hz	1kHz	2kHz
$\left\|\frac{\underline{U}_2}{\underline{U}_1}\right\|$								
$\arg\left(\frac{\underline{U}_2}{\underline{U}_1}\right)$								
frekvens	5khz	10kHz	20kHz	50kHz	100kHz	f_g		
$\left\|\frac{\underline{U}_2}{\underline{U}_1}\right\|$								
$\arg\left(\frac{\underline{U}_2}{\underline{U}_1}\right)$								

Then vary the frequency free to determine the cutoff frequency as closely as you can. The cutoff frequency is best determined by **phase** measurement.

M3, F4: Plot the results of your measurements in the chart that you have prepared.





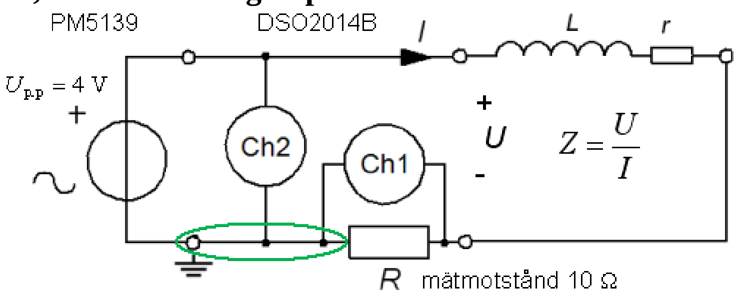
M4: Simulation of a time sweep (time domain, transient)

Perform a time sweep corresponding to the measurement of **M2**, ie shows input and output voltage as a function of time (as on the oscilloscopescreen). Draw the curves in Probe and print the result / show the labassistant.

M5: Simulation of a frequency sweep (AC Sweep)
Perform an AC analysis, AC Sweep, which corresponds to the measurement of **M3**, which gives the am attenuation and phase angle as a function of frequency. Draw curves in Probe and print the result / show the labassistant.

(If you wish, you can alternatively express the amplitude in decibel DB. Curves then form a so-called Bode diagram.)

F5, M6: Measuring impedance *L*+*r* with the oscilloscope



$$Z = \frac{U}{I} \quad Z \approx \frac{U_{CH2}}{U_{CH1}} R$$

φ = Phase(2→1)

At the lab you will measure an unknown coil with a series resistance. Oscilloscopes can only measure voltages. A measuring resistor R = 10 Ω will have a voltagedrop proportional to the current. Another limitation is that both oscilloscope channels and the signal generators share the same common ground. This forces us to use external voltmeter connection.

As the signal generator you can use the PM5139 or oscilloscope's in-built-Wave generator.

Swipe the frequency starting with 50 Hz to about 5 kHz and write down the approximate frequencies when the phase angle is 30°, 45°, 60°. **Measure the frequency of 45° carefully**.

Measurement of frequency for three phase angles

φ = 30° $\approx f_{30}$ [Hz]	φ = 45° f_{45} [Hz]	φ = 60° $\approx f_{60}$ [Hz]

Preparation task **F5**, write down your expressions for L and r at 45° :

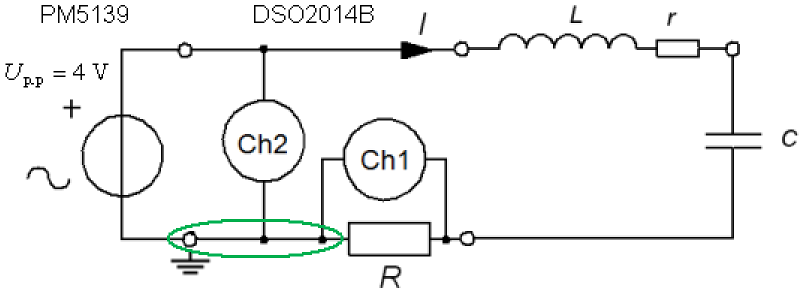
r (φ = 45°) = $f(Z_{45})$ =

L(φ = 45°) = $f(Z_{45}, f_{45})$ =

Measurment with oscilloscope at 45° calculated values. Note! You can ”draw” the value of the known measuring resistor R 10 Ω from your calculated value of r !

L = [mH]	r = [Ω]

M7: Serieal resonance circuit *L*+C+*r* with oscilloscope



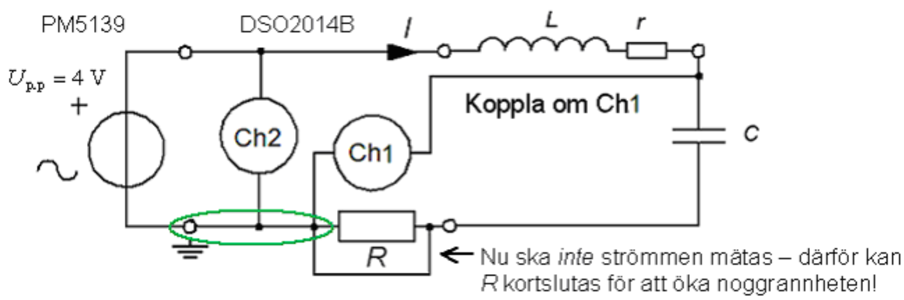
Add a series capacitor C = 330 nF, so that impedance now is a series resonant circuit. Search for the resonance frequency f_0. It is characterized in that the current I has it’s maximum (Ch1 max).

• Vilken Which phase angle φ between current and voltage has the impedance then?

f_0(measured) =   [Hz]

Calculate the resonance frequency with the value of L from **M6**: $f_0 = \dfrac{1}{2\pi\sqrt{L \cdot C}} =$

F6, M8: Measuring an impedance *L*+*C*+*r* at resonance. The Q-value.



At the resonance frequency. Switch the oscilloscope's Channel 1 so that you measure the voltage across the capacitor. (Now R can be shorted because we no longer need to measure the current.)

- What is the voltage over C? U_{Ch1} =   [V]

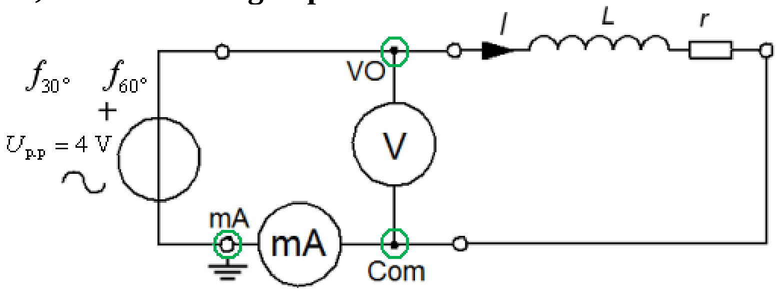
  What is the feeding voltage on the circuit? U_{Ch2} =   [V]

- How do you explain this "mystery" ?

F6 How can the Q-value be calculated directly from the measured values?)

• The inductor’s Q-value at our resonance frequency. Q =

F7, M9: Measuring impedance *L* with the DMM



A more accurate measurement of the coil impedance can be done with DMM. It has no common ground with the signal generator (or oscilloscope wave generator) so you can then select “inner voltmeter connection”. Connect the inductor on the breadboard for measuring current and voltage with the DMM. Measure the impedance at two frequencies, the frequency when φ according to **M6** vas 30°, and the frequency when φ was about 60° (we take measurements of both sides of the impedance cutoff frequency). Measure frequency thoroughly with DMM.

F7. Your expression for calculation of *L* based on the two measurements:

$L = f(Z_{60}, Z_{30}, f_{60}, f_{30}) =$

Fill in your measured values

Beräkna $Z = \frac{U}{I}$		f [Hz]	
Z_{30} $(\varphi \approx 30°)$	Z_{60} $(\varphi \approx 60°)$	f_{30} $(\varphi \approx 30°)$	f_{60} $(\varphi \approx 60°)$

Calculated impedance

L = [mH]

M10: Checking with the RCL-meter

L = [mH]	*r* = [Ω]

- How good was the oscilloscopemesurement?
- How good was the DMM-measurement?

Your comments: