PHYWE

High-pass and low-pass filters with Cobra3

LEP 4.4.09 -15

Related Topics
Circuit, Resistance, Capacitance, Inductance, Capacitor, Coil, Phase displacement, Filter, Kirchhoff's laws, Bode diagram

Principle
A coil, a capacitor, an ohmic resistance and combinations of these components are investigated for their filter characteristics as a function of frequency. The phase displacement of the filters is determined also as a function of frequency.

Equipment

Coil, 300 turns	06513.01	1
Resistor 1 W 5% 47 Ω	39104.62	1
Resistor 1 W 5% 1 kΩ	39104.19	2
Capacitor (case 2) 1 µF/250 V	39113.01	1
Capacitor (case 2) 2.2 µF/250 V	39113.02	1
Connecting cord, l = 500 mm, red	07361.01	4
Connecting cord, l = 500 mm, blue	07361.04	4
Connection box	06030.23	1
Cobra3 Basic Unit	12150.00	1
Power supply, 12 V-	12151.99	2
RS232 data cable	14602.00	1
PowerGraph Software	14525.61	1
Measuring module function generator	12111.00	1
PC, Windows® 95 or higher		

Tasks
Determine the ratio of output voltage to input voltage for
1. RC / CR networks
2. RL / LR networks
3. CL / LC networks
4. two CR networks connected in series

Set-up and procedure
Connect the Function Generator Module to the Cobra3 unit and set up the equipment according to Fig. 1. Connect the Cobra3 unit to your computer to port COM1, COM2 or to USB port (for USB computer port use USB to RS232 Converter 14602.10). Connect both Cobra3 and Function Generator Module to their 12 V supplies. Start the "measure" program on your computer. Select the "Gauge" "PowerGraph".

On the "Setup" chart of PowerGraph click the "Analog In 2 / S2" symbol and select the module "Burst measurement" with the following parameters to enable the "Analog In 2 / S2" to perform ac measurements. The obtained values are ac amplitude values, i.e. the positive peak voltage. To obtain the effective voltage in case of sine waves the values have to be divided by $\sqrt{2}$.

Fig. 1: Experimental set-up

High-pass and low-pass filters with Cobra3

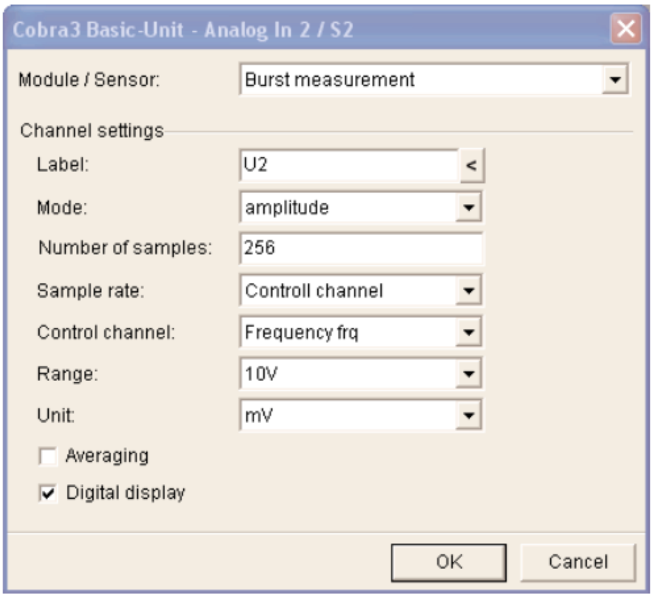


Fig. 2: “Analog In 2 / S2” settings for ac measurement

Click the “Function Generator“ module and set the parameters like this:

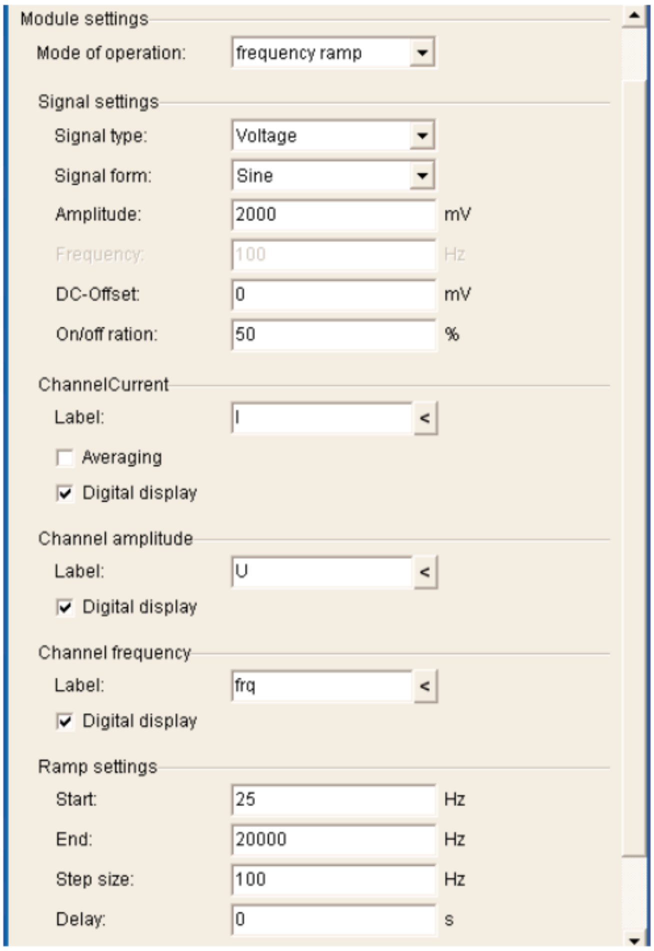


Fig. 3: Function Generator Module settings

Set the channels to be recorded like this – the “Stop condition“ “Number of values“ may also be suitable:

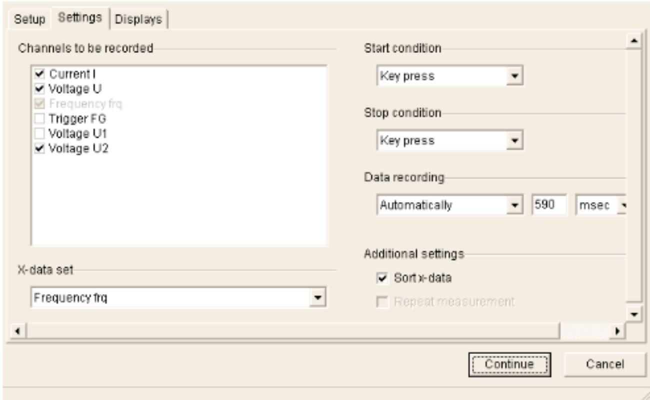


Fig. 4: PowerGraph settings

You may add a diagram to the display settings so as to see the development of the curve during recording – that makes it easier for you to decide if you have already enough values and may stop the recording.

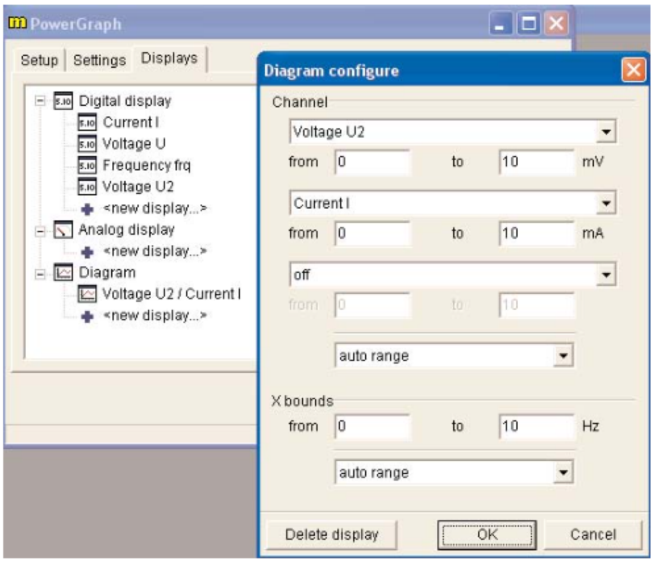
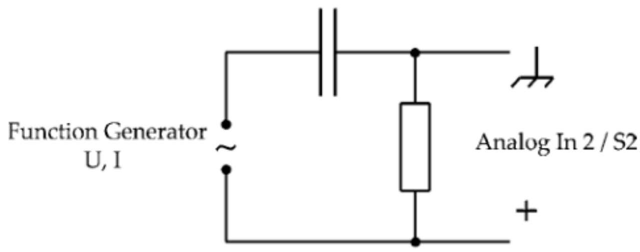


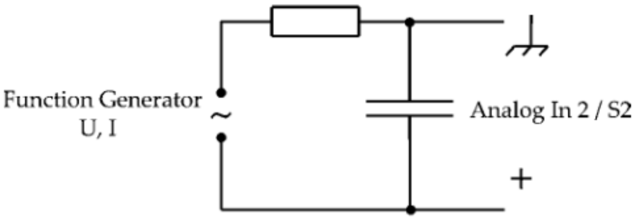
Fig. 5 PowerGraph display settings

1. RC / CR network:

Record curves for the following networks with the 47 Ohm and 1 kOhm resistors and the 1 µF and 2.2 µF capacitors.

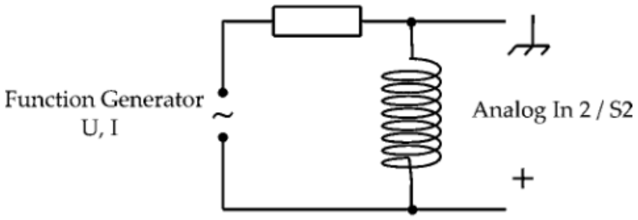


The CR network

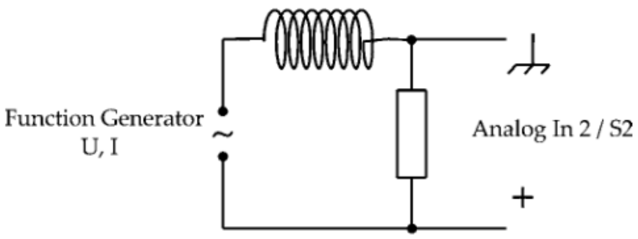


The RC network

2. RL / LR network:
Record curves for the following networks with the 300 turn coil and the 47 Ohm resistor:

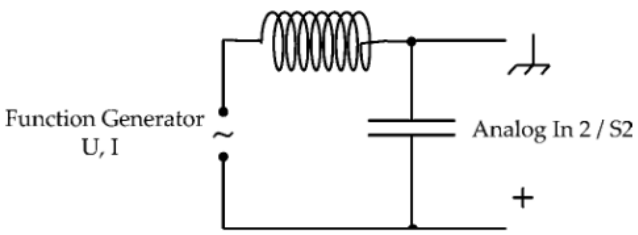


The RL network

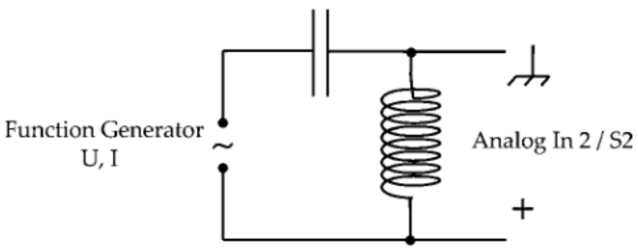


The LR network

3. LC / CL network:
Record curves for the following networks with the 300 turn coil and the 1 µF and 2.2 µF capacitors:

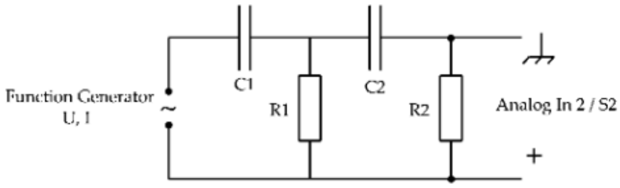


The LC network



The CL network

4. Two CR networks connected in series:
Record curves for this network, e.g. C_1 = 1 µF, R_1 = 47 Ohm, C_2 = 2.2 µF, R_2 =1 kOhm:



Two CR networks in series

Plot the ratio output to input voltage for the recorded curves using the "Channel modification" function. The results may look like this:

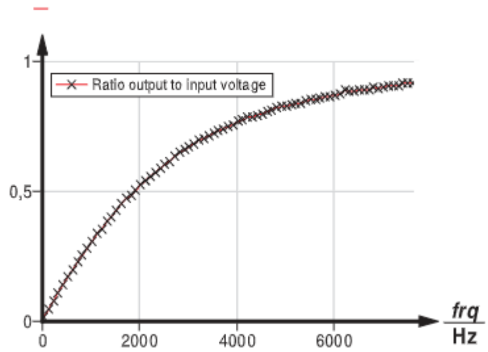


Fig. 6 : Two CR networks in series

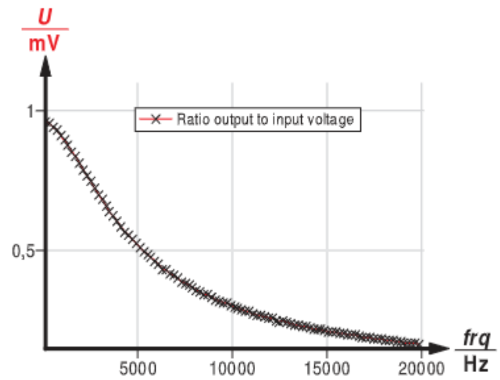


Fig. 7 : LR networks

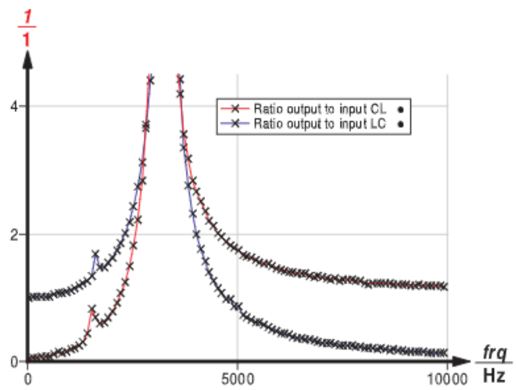


Fig. 8: LC and CL network

Theory and evaluation

The voltage U_C on a capacitance C with charge

$$Q(t) = \int_0^t I(t)\,\mathrm{d}t$$

is

$$U_C(t) = \frac{Q(t)}{C}.$$

The voltage on the resistance R is with current $I(t) = \frac{\mathrm{d}Q}{\mathrm{d}t}$

$$U_R(t) = R \cdot I(t) = R\frac{\mathrm{d}Q}{\mathrm{d}t}.$$

$$U(t) = U_C(t) + U_R(t) = \frac{Q(t)}{C} + R\frac{\mathrm{d}Q}{\mathrm{d}t} = U_0 \cos(\omega \cdot t).$$

for a resistor and a capacitance in series connected to an ac voltage source. Differentiating this equation yields

$$\frac{I}{C} + R\frac{\mathrm{d}I}{\mathrm{d}t} = -\omega \cdot U_0 \sin(\omega \cdot t).$$

This differential equation has the solution

$$I(t) = I_0 \cos(\omega \cdot t + \varphi)$$

with

$$\tan(\varphi) = \frac{1}{\omega \cdot CR} > 0$$

i.e. the current is ahead of the voltage and

$$I_0 = \frac{U_0}{\sqrt{R^2 + \left(\frac{1}{\omega \cdot C}\right)^2}}.$$

The voltage on the resistor is $U_R = R \cdot I(t)$ and for the amplitudes is the ratio output to input in the case of a CR filter then

$$\frac{R \cdot I_0}{U_0} = \frac{R}{\sqrt{R^2 + \frac{1}{\omega^2 C^2}}} = \frac{1}{\sqrt{1 + \frac{1}{\omega^2 C^2 R^2}}}$$

which is low for low frequencies and reaches one for high frequencies, i.e. the CR filter is a high pass filter.

The voltage amplitude on the capacitor is with the impedance of the capacitor

$$\hat{R}_C = \frac{1}{\omega \cdot C} = \frac{U_{C_0}}{I_0}$$

$$U_{C_0} = \frac{U_0}{\omega \cdot C\sqrt{R^2 + \frac{1}{\omega^2 \cdot C^2}}}$$

so the ratio output to input is then

$$\frac{U_{C_0}}{U_0} = \frac{1}{\sqrt{\omega^2 C^2 R^2 + 1}}$$

wich starts for low frequencies at one and drops to zero for high frequencies like $\frac{1}{\omega}$, i.e. the RC filter is a low pass filter.

2. RL / LR filter:

Inductance L and resistance R are connected in series to an ac source

$$U(t) = U_0 \cos(\omega \cdot t) = R \cdot I(t) + L\frac{\mathrm{d}I}{\mathrm{d}t}.$$

This differential equation has the solution

$$I(t) = I_0 \cos(\omega \cdot t + \varphi)$$

with

$$I_0 = \frac{U_0}{\sqrt{R^2 + \omega^2 L^2}}$$

and

$$\tan(\varphi) = -\frac{\omega \cdot L}{R} < 0,$$

i.e. the voltage is ahead of the current.

The voltage on the resistor is $U_R = R \cdot I(t)$
and for the amplitudes is the ratio output to input in the case of a LR filter then

$$\frac{R \cdot I_0}{U_0} = \frac{R}{\sqrt{R^2 + \omega^2 L^2}} = \frac{1}{\sqrt{1 + \frac{\omega^2 L^2}{R^2}}}$$

which is one for low frequencies and reaches zero for high frequencies, i.e. the LR filter is a low pass filter.

The voltage amplitude on the inductance is with the impedance of the coil

$$\hat{R}_L = \omega \cdot L = \frac{U_{L_0}}{I_0}$$

$$U_{L_0} = \frac{U_0 \cdot \omega \cdot L}{\sqrt{R^2 + \omega^2 \cdot L^2}}$$

so the ratio output to input is then

$$\frac{U_{L_0}}{U_0} = \frac{1}{\sqrt{\frac{R^2}{\omega^2 \cdot L^2} + 1}}$$

wich starts for low frequencies at zero and rises to one for high frequencies, i.e. the RL filter is a high pass filter.

3. LC / CL filter

Inductance L and capacitance R are connected in series to an ac source

$$U(t) = U_0 \cos(\omega \cdot t) = \frac{Q(t)}{C} + L\frac{\mathrm{d}I}{\mathrm{d}t}.$$