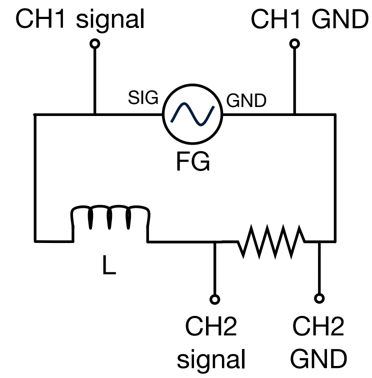
F. Inductive reactance X_L and RL phase shift

We will use the following components in series with the function generator: a resistor R = 1 kΩ to 5 kΩ , and the L = 33 mH inductor (the inductor with "323" written on it).



The multimeter does not measure inductance (it requires AC voltage). The specifications of the inductor from the supplier[1] is: Type = Drum Core, Wirewound, Material of Core = Ferrite, Inductance = 33 mH, Tolerance = ± 10%, Max DC Current Rating = 90 mA, DC Resistance = 91.50 Ohm Max. Use the supplier's tolerance as your uncertainty in L.

Because an inductor has long wiring, we cannot exclude its DC resistance. We will call the DC resistance of the inductor's wiring R_L.

Use the multimeter to measure the resistance of the resistor, the capacitance of the capacitor, and the DC resistance of the inductor

Connect the circuit as shown to the right, ensuring the grounds of the function generator and the two scope channels are shorted together. Apply a signal of $V_{p\text{-}p}$ 5 V and set the frequency to 100 Hz.

For analyzing this circuit, we have to use the total resistance value given by $R_{tot} = R + R_L$ (where R is the resistance of the resistor)

Draw a phasor diagram for the current in the circuit, resistor voltage V_R , inductor voltage V_L, and the emf. Which quantities are you measuring with the scope in this experiment?

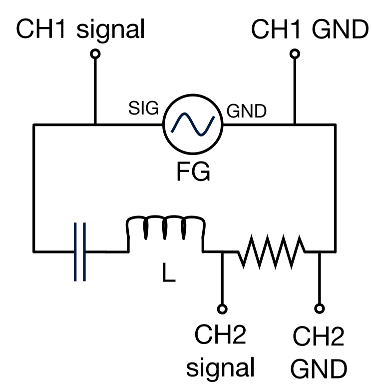
For the frequencies in the table below:

a) calculate the inductive reactance $X_L = 2\pi fL$
b) calculate the expected phase between the two signals, using the $\phi = \text{atan}(X_L/R_{tot})$.
a) Measure the phase directly using the scope by measuring the time shift between the two traces.
b) Compare the expected and measured phases

Frequency f (Hz)	calculated X_L (Ohms)	Expected phase using X_L and R_{tot} (deg)	Measured Time shift Δt	Period of Signal T_0	Measured phase using Δt	%-discrepancy between expected and measured phases
100	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
500	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
1,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
2,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
4,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
10,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*

E. RLC Circuits: Resonance, Phase, and Quality Factor

Use the following components:
R = 1 kΩ or 2 kΩ, L = 33 mH, C = 0.1 uF.
Use measured resistance, capacitance, and DC resistance of the inductor values where possible. Connect the three components in series and measure the two voltages, one across the whole circuit and another across the resistor, using two channels of scope as shown on the diagram to the right.
Apply V_{pp} ~5 V and a frequency of 100 Hz.



Calculate the following and put in a table like that below in your:

a) Calculate X_C, and X_L
b) Calculate the phase as $Ø = \text{atan}(|X_L - X_C|/R_{tot})$, where $R_{tot} = R + R_L$, which includes the measured DC resistance of the inductor R_L
c) To calculate the current in the circuit from the measurement of $V_{pp,R}$, you use R (and not R_{tot})
d) At this stage, you may use the "automatic" measurement features built into the scope to measure V_{pp} and phase difference between two channels quickly. You still need to estimate the uncertainties, though!

[1] https://www.digikey.com/en/products/detail/bourns-inc/RLB9012-323KL/2561406 (Search Digikey for RLB9012-323KL)

Frequency f (Hz)	X_C (Ω)	X_L (Ω)	Expected phase using X_C and X_L (deg)	Measured voltage across resistor $V_{pp,R}$	*Current in circuit I_{pp}, using* $V_{pp,R}$ and R	Measured Phase shift using scope	% discprepancy between expected and measured phase
100	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
500	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
1,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
1,500	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
2,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
2,500	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
3,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
3,500	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
4,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
5,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
6,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
7,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
10,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*

Repeat the above replacing the resistor with R = 220 Ω

Frequency f (Hz)	X_C (Ω)	X_L (Ω)	Expected phase using X_C and X_L (deg)	Measured voltage across resistor $V_{pp,R}$	*Current in circuit I_{pp}, using* $V_{pp,R}$ and R	Measured Phase shift using scope	% discprepancy between expected and measured phase
100	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
500	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
1,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
1,500	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
2,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
2,500	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
3,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
3,500	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
4,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
5,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
6,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
7,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*
10,000	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*	*(labbook)*

For your data analysis:

a) plot the current vs frequency for the R = 1 kΩ or 2 kΩ circuit and the R = 220 Ω circuit on the same set of axes.
b) Estimate, with uncertainty, the resonant frequency of the circuit from the plot above.
c) On separate axes, plot the phase shift vs frequency for the R = 1 kΩ or 2 kΩ circuit. Use this plot to estimate the resonant frequency with uncertainty.
d) On separate axes, plot the phase shift vs frequency for the R = 220 Ω circuit. Use this plot to estimate the resonant frequency with uncertainty.
e) Compare the above estimated resonant frequencies with the expected $f_0 = \frac{1}{2\pi\sqrt{LC}}$