

Experiment 1

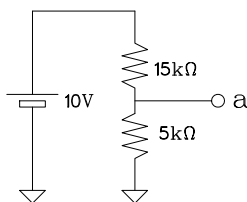
Breadboard techniques and simple circuits.

1.1 Introduction to the workbench.

Spend some time getting acquainted with the tools available at your workstation. Make sure you understand their markings, controls, and limitations. A few minutes spent now on learning your way through the oscilloscope's knobs and dials will quickly pay off.

- ❗ Become familiar with the breadboard socket connections
- ❗ Investigate the power-supply controls and the output voltages provided
- ❗ Practice the techniques of connecting between devices on the breadboard, and to devices not on it.
- ❗ Measure variable voltages on the “job board” over their full range, $\pm 1\text{ V}$ and $\pm 10\text{ V}$. Use both the scope and the DMM.

1.2 Errors introduced by the instruments



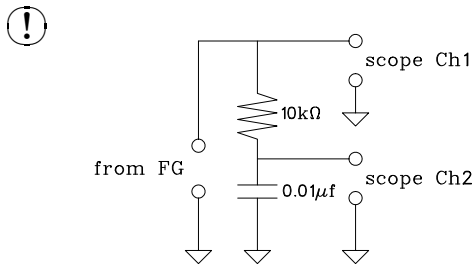
For the circuit diagram shown, what is the voltage between the point a and the ground?

What will be measured at point a with a voltmeter set to the 5 V range if the meter has a sensitivity of $10,000\ \Omega/\text{V}$? It may help to re-draw the circuit diagram including the Thévenin equivalent representation of this voltmeter.

- ❗ Using one or two resistors and the $+5\text{ V}$ power supply of the breadboard system, estimate the internal resistance of the DMM when used as a DC voltmeter. Compare your result with the posted specs of the DMM.

1.3 Low-pass filter

In this part of the experiment we compare the relative importance of various sources of error: systematic errors due to differences between nominal and actual component values, instrumental errors, random scatter, etc.



Wire the circuit shown. The FG and scope should be connected to the circuit using BNC or banana plug connectors on the frame. Be sure all common connections are made, especially if using the banana connectors (with BNC connectors, the connection to common is automatically made).

- ⓘ Measure the input and output amplitudes as a function of frequency, [at least] for the frequencies shown in the table below. An easy way to do this is to set the scope time base so that dozens of cycles appear on the screen. The signals then appear as horizontal bands whose height is a measure of the signal amplitude. The FG output can be adjusted if necessary, to keep the Ch1 amplitude constant. Use an FG amplitude of 5 to 10 V. Express the gain $G = V_{\text{out}}/V_{\text{in}}$ in decibels (dB).¹

Frequency, ν	$\log_{10}(\nu)$	V_{in} , V	V_{out} , V	$ V_{\text{out}}/V_{\text{in}} $, dB
10 Hz				
30 Hz				
100 Hz				
300 Hz				
1000 Hz				
3000 Hz				
10 kHz				
30 kHz				
100 kHz				

If you are using a computer program to do your calculations, fill only the two middle columns of the above data table.

- ❓ Plot the absolute value of the gain, $|G|$, in dB *vs.* log frequency. Determine the cutoff frequency and the attenuation slope (in dB/decade) at high frequencies.
- ❓ Review Simpson, Sec. 2.10. Using the nominal (marked on the component) values of C and R , calculate and add to your plot the line representing the expected frequency response of this low-pass filter.

Treat $\tau = RC$ as a parameter and, starting with the initial value given by the nominal component values, fit a theoretical curve to your data. Add this curve to the same plot. Explain any differences observed.

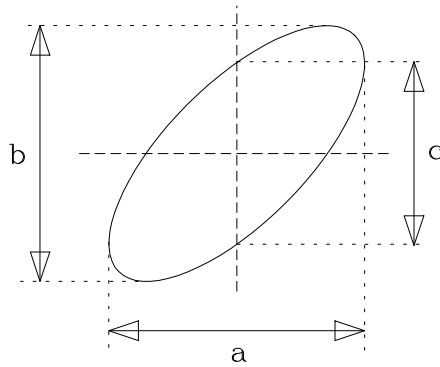
1.4 Observing phase shift with Lissajous patterns

- ⓘ With the FG at 100 kHz, set the scope time base to observe 1–5 cycles. Note that signal across the capacitor lags the signal across the function generator. This phase shift can be measured as the fraction of a cycle delayed times 360° . What is the phase shift at 100 kHz?
- ⓘ Now measure the phase shift by means of Lissajous figures. Switch the scope display to xy -mode to observe the Lissajous pattern as shown in figure below. Consult the manual for your

¹see Simpson, p. 81, for the definition of decibel.

scope to find how to select the xy -mode. Be sure to note the sensitivity setting of each input in your measurement. The amplitude values should be recorded in volts rather than divisions. Set the sensitivities so that the major axis of the ellipse is at an angle of about 45° and several divisions in length. The pattern should be centered on the screen so that the central chord of the ellipse c , can be measured with the vertical centerline of the scope graticule.

An easy way to perform the measurement is as follows:



1. Ground the vertical amplifier input (with the input switch) and align the trace with the horizontal center line.
2. Switch the vertical amplifier to DC and ground the horizontal amplifier input. Center the trace horizontally. Measure the length of that trace which is the quantity b .
3. Switch the horizontal amplifier to DC and measure c . Repeat for the same frequencies as before (you may simply add columns to the table from the previous Section.).

Frequency, ν	$\log_{10}(\nu)$	b , V	c , V	$\phi = \arcsin(c/b)$
10 Hz				
\vdots	\vdots	\vdots	\vdots	\vdots
100 kHz				

- ?** Plot the phase angle, ϕ , vs. log frequency. Again, if you are using a computer program to plot the data, you only need to fill out the columns for b and c .

On your plot, add the line $\phi = -\arctan(\omega\tau)$, where again $\tau = RC$, using the nominal component values. Does it agree with the data?

- ?** As before, treat τ as a parameter and fit the theoretical curve to your data. Compare the two curves, and the data. Are the results of this fit in agreement with the ones from Section 1.3? Explain the differences, if any.

1.5 Shielding and induced signals

- !** Disconnect all signal inputs and outputs from the breadboard frame. Connect a shielded cable to the scope input, but leave the other end of the cable unconnected. Observe the display and record the amplitude of any open circuit signal present. Connect the cable to the breadboard frame and again measure the signal amplitude. Now insert a job board and again measure the signal amplitude. Also determine the signal frequency. The signal can be further increased by connecting a wire to a job board contact to the scope connector and touching the other end of the wire. The amplitude of the signal is also affected by whether you are touching the frame (or other ground) or not.

- ?** What is the source of the signal observed and why is it affected by the amount of unshielded conductor exposed?

- ⓘ Connect the FG signal output to a frame connector. Connect the FG output to the Ch1 scope input through the contacts on a job board. Set the FG for a 1 kHz, 10 V sine wave. Connect the Ch2 scope input to another frame connector, but do not make any connections to the corresponding job board contact. Record the magnitude of the signal observed on Ch2 at the frequencies in the table below. Keep the Ch1 amplitude constant at 10 V. Now connect a 10 k Ω resistor between the Ch2 input contact on the job board and common. Repeat for a resistor of 1 k Ω .

Frequency	Ch2 amplitude, V		
	no load	10 k Ω	1 k Ω
10 Hz			
100 Hz			
1000 Hz			
10 kHz			
100 kHz			
1 MHz			

NB: What you have observed is called *cross-talk*. It occurs when a signal in one conductor can induce a signal by capacitive, inductive or electromagnetic coupling in another conductor. The small currents induced in the “receiving” conductor produce voltages across the impedance between the conductor and common. The larger the impedance, the larger the voltage as your data shows. When high impedance signal lines must be used, they should be shielded. Examples of shielded lines used in high-impedance voltage measurements are BNC cables and oscilloscope probes.²

²See Faissler, p. 137, or the scope manual for a discussion of scope probes.