

Lab 2: AC circuits and the oscilloscope (version 1.5)

WARNING: Use electrical test equipment with care! Always double-check connections before applying power. Look for short circuits, which can quickly destroy expensive equipment.

Equipment needed:

Agilent E3631A Triple DC Power Supply

Keysight digital oscilloscope

Function generator

1 set of test leads (red and black) with banana/EZ Hook ends

2 oscilloscope probes

1 BNC cable with EZ-hook test leads

Circuit breadboard or ELVIS board

2 resistors: $R_1=R_2$

The digital oscilloscope

There are a wide variety of oscilloscopes from different manufacturers on the market, but they all function in essentially the same way. The scopes available in the lab represent state-of-the-art instrumentation technology. When you have a fundamental understanding of scope operation and its various functions, you will be able to use this knowledge to operate almost any scope you encounter in your career, including decades-old analog cathode-ray machines. These instruments have long been surpassed by digital sampling scopes, but most of the controls work the same way and they can still make useful measurements.

Turn on the Keysight scope and let it go through its boot process. When completed, the Run/Stop button should be illuminated green. The first step is to test the oscilloscope probes you will be using. Most probes have selectable attenuation that reduce the measured signal levels by a factors of 10x, 100x, etc, or not at all (1x). The probe diminishes the distortion that is inherent to making a measurement, which is often important at high frequencies. Attenuation is accomplished with a divider network that also permits safe measurement of voltage levels that would otherwise overload the scope input. You must always account for signal attenuation when using a scope probe.



Modern scopes provide built-in signal sources for testing the probe. Connect the BNC barrel connector of the probe cable to the Ch 1 input. Select the Training Signals menu; if not displayed, access it with the Help button. Enable Demo 1 and select a Sine wave.

The Output box should be highlighted. Different test waveforms are accessed with the “Push to select” knob; rotate it and press on the desired signal. Clip the probe to the DEMO 1 loop on the scope face; connect the free alligator clip to GND.

Press the button marked “1” and make sure the voltage divider is consistent with the probe settings (1x, 10x). Other settings are Coupling: DC; Impedance: 1 M Ω ; Trigger Source: 1. The test signal is displayed by making three primary adjustments: Horizontal (time/division), Vertical (Volts/division), and the Trigger level. These are all accessed with buttons/knobs on the front panel of the scope. Selection of the Auto/Normal trigger modes is made by pressing the Mode/Coupling button. Set the trigger on **Auto**.

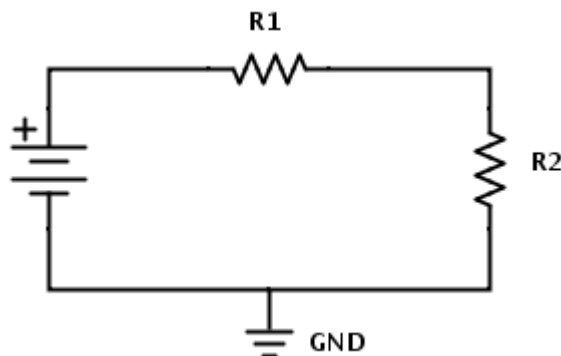
The goal is to display several periods of the Sine wave. Use the Measurement button to determine the peak-to-peak voltage and frequency. When this is accomplished, show to the instructor.

Both input channels on the scope have independent coupling controls that can be set as **DC**, **AC**, or **Ground**. Switch the coupling to **Ground** and note the position of the trace – this is the ground reference level for all voltage measurements on that channel. The user can position it anywhere on the display that is convenient. For example, when the signal voltage is negative, the Ground trace should be placed near the top of the display and vice-versa.

AC coupling removes any DC component from the displayed signal. DC coupling displays an AC signal together with its DC offset voltage. When a DC signal is measured with AC coupling the display should show the same trace as Ground. These concepts are explored next.

The Voltage Divider

Construct the two-resistor voltage divider circuit as shown in the figure. Choose R1 and R2 with about the same values (in the range of a few k Ω is good). Check the resistor values with the multimeter before inserting them into the breadboard. Calculate the voltage division expected between input (power supply voltage) and output (voltage across R2).



Set the Agilent power supply to 5V DC. If you forgot how to do this, consult the instructions for Lab 1. Use the EZ-hook test leads to connect the power supply output to the circuit. Be sure both red and black leads are connected.

The oscilloscope can perform many of the functions of the digital multimeter that was introduced in Lab 1. Here it will function as a DC voltmeter. Connect the BNC (barrel shaped) plug of one scope probe to CH 1 of the oscilloscope. Clip the CH 1 probe to the output node between R1 and R2 and connect its ground clip to circuit ground (the black test lead on the power supply should also be connected to this node). Ensure that the scope channel is set for DC coupling.

Enable the power supply output, measure the DC output voltage on the scope, and verify the expected signal level. Change the coupling to AC and then to Ground and explain what is observed for all 3 cases. Turn off the power supply and disconnect it from the circuit.

The Function Generator

The function generator can produce a wide variety of periodic voltage waveforms that can be displayed and analyzed on the oscilloscope.

It's best to start in the Default mode. For the Agilent 33120A this is RECALL 1. Use the "Set to Defaults" soft-key for the Agilent 33220A. These function generators are powerful and flexible. The frequency can be set in several different ways. Direct entry is made with the keypad (enter a number and then select appropriate units). One can also highlight the desired display digit and then rotate the dial and/or use the scroll up/down arrows. The voltage amplitude is set in the same way.

Set the function generator to produce a sine wave having a frequency (**Freq** button) of 455 kHz and an amplitude (**Ampl** button) of 1.2Vpp (peak-to-peak). Verify the output by observing the waveform on the scope, i.e. do not connect the function generator to your circuit at this time. Set the time base to display several periods of the waveform.

Note: The oscilloscope amplitude may differ from the function generator setting by a factor of 2. This is because the output impedance of the function generator is set to 50 Ω . Change it to high impedance (High Z) using the Utility menu.

Now add a 500 mV (0.5 V) positive DC offset voltage to the sinusoidal waveform. This is done by pressing the **Offset** button on the function generator and setting the desired value. Display the waveform on the oscilloscope with and without the voltage offset. To do this, enable DC or AC coupling on the scope, respectively. The ability to view and isolate components of a time-varying waveform is one of the advantages of an oscilloscope compared to a multimeter. Demonstrate scope operation for the instructor.

AC signal measurement with a simple circuit

Connect the BNC end (barrel shaped plug) of the BNC/EZ Hook test lead to the function generator and the red and black EZ Hook clips to the circuit input (one side of R1) and ground connections, respectively.

Note: The red clip corresponds to the inner conductor of the coaxial cable; the black clip is the outer braid. The black clip provides a return path for the signal. It also defines the ground potential node of the circuit board, which would otherwise float with respect to the other instruments. Poorly defined or floating grounds are often the cause of ground loops in electronic equipment ranging from research experiments to home entertainment systems. Ground loops can be cause a lot of undesired background noise including hum at the 60 Hz AC power line frequency. A circuit may still work with a ground loop present, but it will work poorly.

Connect the BNC plugs of the two scope probe test leads to CH 1 and CH 2 of the oscilloscope. Clip the CH 1 probe to the input node on R1 and connect its ground clip to circuit ground. In a similar manner, connect the CH 2 probe to the output at the junction (node) between R1 and R2.

Now compare the signals on both channels. This is most easily accomplished with the Auto-Scale button, but it is good to practice acquiring the signals manually using the Normal trigger. Use the measure functions on both channels to verify proper voltage division. The key observation here is that voltage division can be accomplished with constant (DC) signals and also with time-varying (AC) signals. Show your results to the instructor and demonstrate the Normal trigger function of the scope.