Physics 4L Laboratory 2 (2026) - Time dependent signals

Let's push a bit more on resistor circuits:

2.1. Voltage divider - DC

Construct the voltage divider as shown in Figure 2.1. Apply V_{in} = 15 Volts from the power supply; confirm the voltage with the DMM.

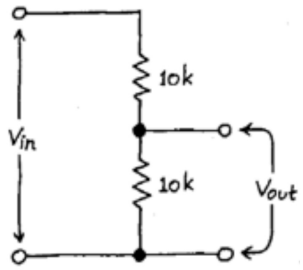

Figure 2.1: Voltage divider; **V_{in}** and **V_{out}** mark voltage levels.

Q1. Measure and report the open circuit output voltage, $V_{Open_Circuit}$ ($V_{Open_Circuit} = V_{out}$ with no load).

Now attach a 10k **Ω** load resistor to **V_{out}**, as shown in Figure 2.2.

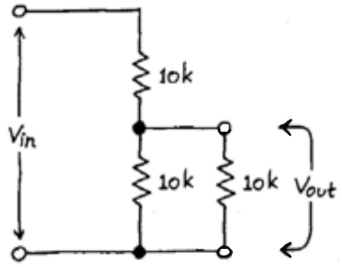

Figure 2.2: Voltage divider, as in Figure 2.1, but with a 10k Ω load resistor.

Q2. Does V_{out} go up or down? Why?

2.2 Thevenin equivalent

Let's confirm our understanding of the Thevenin equivalent circuit. Build the circuit in Figure 2.3

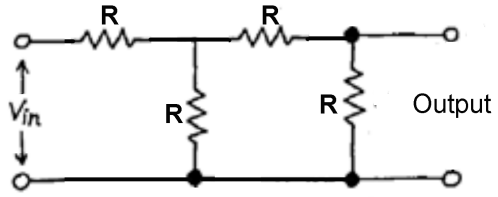

Figure 2.3: Choose Vin = 10.0 V and R = 1000 Ω.

Q3. Measure and report the short circuit current, $I_{Short_Circuit}$ (Figure 2.4).

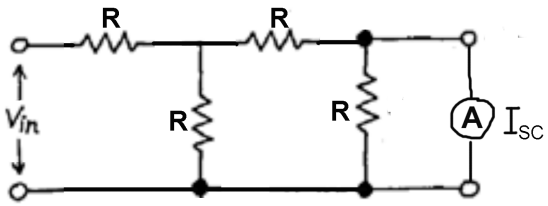

Figure 2.4. Configuration to measure short circuit current

Q4. Measure and report the open circuit voltage, $V_{Open_Circuit}$ (Figure 2.5).

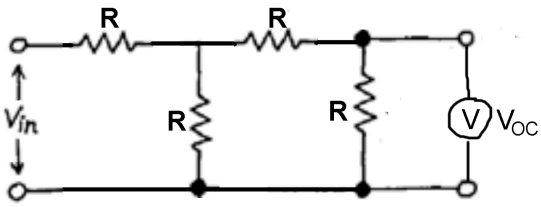

Figure 2.5. Configuration to measure open circuit voltage

Q5. From the measurements of $I_{Short_Circuit}$ and $V_{Open_Circuit}$ calculate the Thevenin equivalent voltage circuit and the Thevenin equivalent current circuit.

Q6. Calculate the expected $R_{Thevenin}$ for the circuit of Figure 2.3. Does this value match what you calculated from $I_{Short_Circuit}$ and $V_{Open_Circuit}$? Why or why not?

We now add instrumentation that allows us to analyze time-dependent signals.

2.3. Function generator

This device can generate periodic outputs of varying shape over a very broad range of frequencies - sine waves, triangular waves, square waves, and pulses from about 0.3 Hz to 20 MHz, nearly a hundred-million-fold range. The amplitude of the wave can be varied, and you can add a DC offset. There is also a **TRIGGER OUTPUT** that can be used to trigger the oscilloscope, as described next.

The function generator is an essential piece of equipment in the characterization and diagnosis of circuits. it is invariably used with an oscilloscope, described next.

2.4. Oscilloscope

We'll use the oscilloscope ("scope") to visualize signals. Get familiar with the oscilloscope using the waveform generator as input. Start with a simple waveform, say a 1 kHz sine wave.

Play with the scope's sweep and trigger menus and controls. Specifically, try the following:

- The vertical scale switch. This controls "*volts/div*"; note that "*div*" for division refers to the centimeter marks, not to the tiny 0.2 cm marks.
- The horizontal scale selector: *time* per division.
- The trigger controls. Triggering is the subtlest part of scope operation. "**Auto**" is a way to observe a slowly evolving signal on "Untriggered Roll". Nonetheless, always use "**Normal**" with a stable waveform, like the **TRIGGER OUTPUT** of the waveform generator, with a judicious choice of "**Level**".
- The use of **10-X OSCILLOSCOPE PROBES** to measure from test-points in a circuit. These act as a high impedance input to the oscilloscope and should unfailingly be used for all test-point measurements. Use a BNC cable directly between test instrument outputs and inputs.

  Remember to select the vertical scale through the oscilloscope menu when you use - or don't use - an oscilloscope probe, i.e., set the input selector to 10-X with a probe.

- **A warning on the AC/DC selector on the oscilloscope.** Common sense may seem to invite you to use the ***AC*** setting;

after all, you are addressing time-varying signals. *Eschew* this plausible error. The ***AC*** setting puts a capacitor in series with the oscilloscope input and will produce startling distortions of waveforms.

Display a 5 Hz sinusoid in Channel 1 with DC coupling on and the same signal (use a Tee) in channel 2 with AC coupling on.

Q7. Include a SCREENSHOT of the comparative traces of AC versus DC coupling.

Now change to a 5 Hz triangle wave in Channel 1 with DC coupling on and the same signal in channel 2 with AC coupling on.

Q8. Include a SCREENSHOT of the comparative traces of AC versus DC coupling.

A note on SCREENSHOTS

You will use **SCREENSHOTs** throughout the class to log and document your results. SCREENSHOTs are bit-mapped images that are downloaded from the oscilloscope onto a USB drive and are readily inserted into a report as a PNG file.

Make sure that:

1. The data fills the oscilloscope screen.
2. Input, output, and possibly auxiliary signals are present in the same plot so that relative timing can be ascertained.
3. Unused channels are turned off for clarity.
4. Label the axes with names and units, and label the different channels, after you insert the SCREENSHOT in a report.

On occasion, you *will* want to look at a small sinusoidal component with its DC level stripped; but always you will want to know that this DC information has been made invisible. Keep in mind the utility of putting the same signal into two separate channels, one DC coupled, and the other AC coupled, to observe the small sine.

2.5 Different waveforms

Switch the function generator to square waves and use the scope to measure the “rise-time” of the square wave (defined as time to pass from 10% to 90% of its full amplitude).

Q9. Include SCREENSHOTS of the rise for 1 kHz, 10 kHz, and 100 kHz square waves. Are the rise times the same or different for the three cases? Why?

What comes out of the function generator’s **TRIGGER OUTPUT** connector? Look at this on one channel while you watch a triangle or square wave on the other scope channel. To see how this can be useful as a synchronization signal, try to trigger the oscilloscope on the peak of a sine wave, rather than an intermediate value, using the level adjustment on the oscilloscope in the "normal" trigger mode. Notice how entirely reliable it is to trigger when you do use **TRIGGER OUTPUT** as the “external” trigger.

For a sine wave, the external trigger has a $\pi/2$ phase shift. Use the phase-shift control on the generator to remove this relative shift.

Triggering on a well-defined point in a waveform, such as peak or trough, is especially useful when you become interested in measuring a difference in *phase* between two waveforms.

Q10. Include a SCREENSHOT of the TRIGGER OUTPUT and a sinusoidal waveform, triggering on the TRIGGER OUTPUT.

Set the function generator to some frequency in the middle of its range, then try to make an accurate frequency measurement with the scope; you are obliged to measure *period*, of course, not frequency. In general, trust the scope period readings and not the function generator.

Q11. Comment on the relative accuracy of the stated frequency from the function generator versus what you measured with the oscilloscope.