PHY 335, Unit 1 Instruments, Signals, Resistors

Mini Lecture topics:

- **Instruments in the Lab: oscilloscope, multi-meters, signal generator**
- **Intro to error analysis**
- **Resistors; resistor connections**
- **Voltage divider**
- **Periodic signals: amplitude, period, frequency; phase**
- **RMS values, decibels, AC power**
- **Voltage divider with the load**
- **Thevenin's equivalents**

1. Start getting familiar with the main instruments on your setup: digital multimeters, DMMs (2), oscilloscope, and signal generator. Start reading instruction manuals: you will refer to them throughout this course.

2. Familiarize yourself with oscilloscope (scope, for short) and signal generator (SG) operation. Connect the SG to the scope and observe different waveforms at different amplitudes and frequencies. (Change the size, shape and frequency.) Note that the scope can be used as a voltmeter for DC and AC signals, as well as an instrument displaying signal time dependencies, however the amplitude is less precise than a DMM.

NOTE 1: An oscilloscope is an extremely useful and versatile instrument. You will be using it throughout this course. Learn about its principle of operation and various functions. In addition to the practical lab work, you may find it helpful to use some of the several oscilloscope training web sites, for example:
`https://www.tek.com/document/primer/xyzs-oscilloscopes-primer-1`
`http://www.phy.ntnu.edu.tw/java/oscilloscope/oscilloscope.html`
`https://learn.sparkfun.com/tutorials/how-to-use-an-oscilloscope/all`

NOTE 2: The web contains a wealth of material relevant to this course, including various virtual training sites, detailed manufacturer's information on the devices and components you will be using, related physics and math sites, etc. Start using the web to your advantage. You will need an access to a computer with Internet connection. Use Google or another search engine to find what you need.

3. Get familiarized with the *breadboard* (or simply board): Use an ohmmeter to see the contact arrangement, and sketch this in your lab notebook. (In the future, you'll need to understand yourself what notes and information to include in your notebook – don't expect to see specific instructions.) Use the wire stripper to prepare short wires, or use precut jumpers, to connect different contacts on the board. **Do not force thick resistor contact wires into the board – this will damage it!**

NOTE 3: When doing measurements, record what you see clearly and in enough detail for you and your instructors to understand what was done. Date your Lab book entries; give them titles. Make tables and graphs as necessary. The lab book should be kept in such as way as to allow you to understand the data you took a long time afterwards. Make special notes of anything unusual / interesting / unexpected, and always try to explain what you see.

4. Turn on the DC power supply, and, using a DC voltmeter, check voltages on the board using the DMM. Check that same voltage level using an oscilloscope and try to determine the uncertainty of this measurement (the uncertainty may originate from voltage fluctuations and/or from the reading of the voltage level on the scope screen (trace thickness, etc). Record the readings and the estimated uncertainty.

5. Learn to use resistor bar code to read resistor values. Make a copy of a bar code in your lab book. Plug into the board three resistors of different nominal value (for example, 100 ohm, 1k, 5k, or other resistors) and measure their real values in the board, first individually (note % error compared to the nominal), then in series and in parallel, and finally in series-parallel connections. Compare the measured values with the calculation [use the measured individual values for the calculation; draw the connection diagram (the circuit) and show the calculation]. Repeatedly re-insert resistors into the board to see how contact resistance affects your measurement uncertainty, if at all, and report error in your measurements.

6. Find 10 resistors with nominally the same resistance and measure their resistance. Report your result as (mean)$\pm$(standard deviation) and the number of measurements made. [N.B.: The uncertainty on the mean is actually given by the standard deviation divided by the square root of the number of samples.].

7. Find out from the multimeter instruction manual what current is passed through the resistor when you are using the multimeter as an ohmmeter. Understand the principle of a resistance measurement.

8. Recall the Ohm's Law theoretical basis. Explain the difference between the resistance and resistivity.

9. Use the signal generator to apply linearly rising and falling (triangular) voltage to a resistor. Make your scope display the triangular wave first, and record it in your lab book. Devise a circuit to measure the current through the resistor with the

oscilloscope. Think about how the grounding of the oscilloscpe interacts with your circuit! Then make your scope display the current-voltage (I-V) characteristic across the resistor, with current on the Y axis and voltage on the X axis. The linear I-V you will find is called an ohmic I-V. Find the resistance from that I-V for three different resistors. Confirm the resistance values using the ohmmeter.

10. Explain the theory of a voltage divider (using Ohm's Law): What ratio of resistors R1/R2 is required to make a 1:10 voltage divider? For a 1:5 divider? Achieve 1:10 division to better than 5% (you can either trim the ratio either by plugging in additional resistors or by using a variable resistor (potentiometer). Use a precision DMM to measure the voltages.

11. Apply to the voltage divider a signal of known amplitude from the Signal Generator (SG). Measure the amplitude with the scope, and using the scope, see that your divider indeed reduces the amplitude by about a factor of 10. Apply different waveforms and change frequency over a wide range, from Hz to the highest MHz range provided by the SG. Measure output amplitude and frequency using scope; figure out how to measure frequency using a scope.

12. Using the scope's dual-channel capability, measure the phase shift (if any) of the output compared to the input at different frequencies, going to the highest frequency available on the SG. If you find anything of interest, try to qualitatively explain what you see.

13. Root-mean-square values: Using the SG and the scope, set the output amplitude at some value by adjusting the amplitude with the SG and measuring it on the scope. Measure the same output AC voltage using a DMM (one of the digital voltmeters). Compare the two values. Do so for sin, triangle, square waves. Explore a wide frequency range; and comment on the results. In your lab report, derive the ratios you expect in these measurements for different waveforms and compare them to the measured ones.

14. Decibels: Change dB setting (amplitude ranges) on the SG (-20) and measure the amplitude changes on the scope. Calculate what they should be (from a definition of dB) and compare. Calculate the ratio of a sinusoidal wave RMS value to its amplitude in decibels.

15. Thevenin's equivalents: Make a simple 1:2 voltage divider with two 10 k resistors, and apply 15 V DC to it (measure actual resistor values and input and output voltage). Calculate V_{th} and R_{th} for this circuit. Experimentally find V_{th} and R_{th} following Thevenin's definitions. Compare calculated and measured values.

16. Attach a load resistor R_L to the output of this divider; first, $R_L \gg R_{th}$ (at least 10 times larger), then $R_L \approx R_{th}$ (comparable), then $R_L \approx 0.1R_{th}$. Measure the amplitudes of a signal on those loads. Comment, with calculations, on what you see and what you expect theoretically.

17. Take 5 different resistors, connect them all in a random series-parallel arrangement of your choice, taking one output at some point. Apply 15 V DC from the power supply, experimentally find V_{th} and R_{th} (follow the definition of Thevenin's equivalents to find them experimentally). In your report, draw the original circuit and its Thevenin's equivalent circuit. Comment on the value of the load that can be attached to your circuit's output without "bending" the output voltage by more than 10%.