Lab #0

Laboratory Equipment and Measurement Techniques

Purpose

Your objective in this lab is to gain familiarity with the properties and effective use of the lab power supply, function generator and oscilloscope.

Skills to develop

After completing this lab you should be able to:

- Properly use the triple voltage supply with effective grounding
- Measure the output impedance of the function generator and interpret the amplitude reading on the front panel of the function generator and how it depends on the load resistance
- Properly connect oscilloscope probes to measure single voltages and differential voltages within the circuit
- Make effective adjustments to the oscilloscope to set voltage signal scaling and filtering, timebase, trigger setup and display options
- Be able to use the oscilloscope to measure waveform amplitude, period and frequency, rise or fall times, time delay, etc.

Materials you will need

- proto board and jumper wires
- (2) 100 ohm resistors

Equipment: You will use the bench power supply, function generator and oscilloscope.

Prelab: There is no prelab exercise for this week. Please read the lab handout before coming to lab.

Lab Work:

Triple Supply

The bench power supply has three independent voltage supplies, which are floating with respect to earth (chassis) ground. A connection to chassis ground is provided on the front panel. This chassis ground is connected to the third prong of the power cord, so it really is maintained at “earth” ground through the building wiring system. The chassis ground connection may be tied to either the positive or negative terminal of the voltage source to provide an absolute voltage reference, so that any of the voltage sources may be used to provide a potential that is positive or negative with respect to earth ground. In addition, the output of the power supplies may be connected together in series to provide a single voltage output that is the sum of the constituent independent supplies.

Two of the voltage supplies are variable, allowing the user to adjust for any desired voltage between 0 and 25 volts. In addition to setting the voltage, the user can adjust the maximum current that the supply will source. This adjustable current limit allows the user to set a maximum current as a protection for external circuit being powered by the supply. If the external circuit begins to draw more current than the set limit, the current limit light turns red and the output voltage will be reduced until the current is less than the setpoint. Inadvertently setting the current limit at its minimum value can cause the output voltage to be less than you intend when you try to power your circuit.

1. Experiment with the bench supply. Set the slide switch to INDEPENDENT. Connect the supply to create balanced voltages at +15V and -15V with respect to earth ground. Sketch the connections you make in your notebook. Connect the supplies to create a single output voltage of -40V with respect to ground. Sketch the connections or describe the setup in your notebook. Verify your voltages with the digital multimeter (DMM).
2. Adjust one supply for +7 volts. Connect this supply to a 100 ohm resistor. (How much power will the resistor dissipate – is it within the power rating for your resistor? Your resistor may get a little warm during this measurement). Look at the meter that reads current. How much current is flowing in your circuit? What happens when you adjust the current limit knob to its minimum setting? Explain your experiments and results in your notebook.

Function Generator

The function generator is a voltage source that is designed to create useful time varying voltage waveforms. You may select between sine waves, square waves and triangle waves. You may also create pulses with adjustable duration, and bursts of pulses. Your signal can be "triggered" to start when an external voltage signal is detected. More complicated waveforms are possible including amplitude and frequency modulated signals, and even "arbitrary" periodic waveforms that you can create on a computer and download to the function generator. This is a very useful tool.

Our model for the function generator is a Thevenin equivalent voltage source with 50 ohms Thevenin resistance.

3. Set the function generator to produce a 1 kHz sine wave. Set the DC Offset to 0V. Set the AC Amplitude to 1 Vpp (meaning 1 volt peak – to – peak, or 0.5 V amplitude).
4. Connect the function generator directly to your oscilloscope, using a BNC cable (carefully remove the oscilloscope probe from one of the channels to do this by gently pushing and turning counterclockwise until the probe slides free). Set the input impedance on the oscilloscope to 1 Mohm. Use the MEASURE feature of the oscilloscope to measure the peak-to-peak voltage amplitude of your 1 kHz sine wave. Record your connections in your lab notebook, using a sketch. Note the settings for both function generator and oscilloscope. Does the voltage measured with the oscilloscope agree with the voltage setting on the function generator?
5. Change the input impedance of the input channel of the oscilloscope to 50 ohms. Now read the peak-to-peak voltage amplitude that the oscilloscope measures. How has it changed, and why? Sketch a circuit in your lab notebook using a Thevenin source for the function generator, with a 50 ohm source resistance, and a 50 ohm load resistor (the input to the oscilloscope). Comment on the meaning of the number the function generator displays for its voltage amplitude reading. Return the oscilloscope input impedance to 1 Mohm.
6. Answer the following question: In order to generate an open circuit output voltage (meaning $R_{LOAD} = \infty$) of 1 Vpp, how will you set the function generator amplitude?
7. Measure the "output resistance" (the Thevenin equivalent resistance) of the function generator using a 1 kHz sine wave. Describe your method and your results in your lab notebook. You will want to refer to these results in later labs, when knowing the actual output resistance to an accuracy of 1-2 ohms will be helpful. Ask the instructor or the TA for assistance in devising a way to make this measurement.

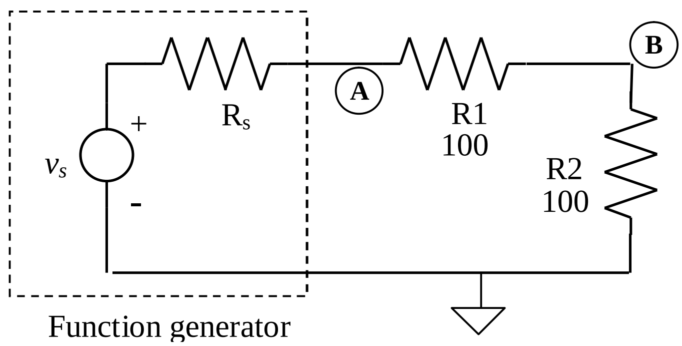
Oscilloscope

You have already used the oscilloscope in previous labs and you are already familiar with its use to plot voltage as a function of time. Making *effective* use of the oscilloscope takes practice and education about the operation of the instrument. It also takes a healthy dose of curiosity about how the instrument is working, and what it might be capable of to make your measurement more accurate, fast and easy. This lab only introduces a few basic techniques.

Here are a couple of pointers:

- Don't use the AUTOSET button! (it seems so convenient, but after spending several minutes adjusting the scope to do what **you** want it to do, hitting AUTOSET resets everything, and you have to start all over again) If you accidently hit AUTOSET, there is an UNDO AUTOSET feature under the ACQUIRE menu.
- **The ground clips on the scope probes are not floating!** Remember chassis ground from the power supply? Through the third prong on the power plug, it is at the same potential as the chassis ground of the oscilloscope, which is connected directly to the ground clip on the oscilloscope lead. Anyplace you clip your ground lead will be connected to earth ground.

8. Build the simple circuit below so that you can explore the scope a little bit. Set the function generator for 1 kHz, 1 Vpp amplitude sinewave (what is the "open circuit" voltage of the function generator when you select 1 Vpp on the front panel?). Sketch the circuit in your notebook, using a Thevenin model for the function generator.



9. Connect the oscilloscope ground clip to the grounded node in the circuit. Measure the voltage amplitude using the MEASURE feature at nodes **A** and **B**. Set the timebase to display at least two periods of the waveform for these measurements. Experiment with the timebase setting until less than one period is displayed. Does the measured Vpp change? Return the timebase setting to have multiple periods displayed.
10. Try to measure the voltage drop across resistor R1 directly by placing the ground clip on node **B** and the probe tip on node **A.** What is the value you measure for Vpp? Is this the same as the difference between the values you measured in the last step? Describe how you have altered your circuit by placing the ground lead at node **B**, and explain using circuit analysis the value of the voltage you measured across R1.
11. Now use two oscilloscope probes in channels 1 and 2. Clip both ground leads to the ground point in your circuit. Place the probe for channel 1 at node **A** and the probe for channel 2 at node **B**. Use the MATH feature to display Channel 1 – Channel 2 to correctly measure the voltage drop across resistor R1. You may use the MEASURE feature to make this measurement.

Now reduce the amplitude of the function generator to 50 mVpp.

12. Measure the voltage at node **B** (on Channel 2), using the MEASURE feature to measure Vpp. You will want to set the TRIGGER input to CHAN 2. Record this value. Then, set the input bandwidth for Channel 2 to be 20 MHz. Does your measurement value change for the peak-peak voltage?

When you use the scope to measure Vpp, it is truly calculating the maximum peak voltage minus the minimum peak voltage. When you have an appreciable amount of noise in your signal (the "fuzz" that makes the trace fat), it will increase the apparent Vpp. This is a measurement error, since we'd really like to estimate the signal amplitude we'd get in the absence of noise.

Many types of noise are "broadband", meaning the noise has energy at low frequencies as well as at high frequencies. By setting the input bandwidth at 20 MHz, you are "filtering out" signals with frequencies greater than 20 MHz (noise and useful signals alike). Since the scope has an unfiltered input bandwidth of 100 MHz (some of the oscilloscopes in the labs have 500 MHz input bandwidth), filtering the input to 20 MHz can remove an appreciable amount of unwanted high frequency noise. We will not need more than 20 MHz bandwidth for our measurements in this course, so the 20 MHz input bandwidth should be your standard setting when using the oscilloscope in this class.

Now connect the BNC cable from the SYNC output on the back of the function generator to the EXT TRIG input on the oscilloscope. Adjust the TRIGGER input to select EXT/10 as the trigger source, and adjust the trigger level (the small rotary knob in the TRIGGER group) to about 2 V. You can see the trigger level setting on the screen. The SYNC signal is a 5V square wave signal that is synchronous with the sinewave output. You should see the sinewave on channel 2 as a stable waveform (not moving about).

13. Select the ACQUIRE menu, and choose AVERAGING for the acquisition mode. You can adjust the number of traces to average using the "soft knob" at the left of the upper row of buttons on the oscilloscope. What happens to the noise in the displayed waveform as you average many traces together?
14. Finally, compare the measurement precision using the MEASURE feature to determine Vpp when you adjust the voltage scale so that the sinewave fits in less than a single small vertical division, to the precision when you increase the scale so that the waveform nearly fills the screen. (You may need to increase the amplitude of your signal to be able to fill the screen, but once you increase it, keep the amplitude constant for the comparison of the two cases). This effect is more evident when you turn AVERAGING off (select SAMPLE under the ACQUIRE menu). Look at the fluctuating digits in the pk-pk measurement value.

Measurement advice: *For the highest precision when using the scope for voltage measurements, limit the bandwidth of the input to no more than you require for your measurement, adjust the voltage scale to fill the screen as completely as possible, and establish a clean trigger in order to use signal averaging to minimize the effect of electronic noise.*

Lab Report (The report is due one week after completion of Lab 0.)

For Lab 0, you will only report a subset of your measurements. Please describe the measurement activities including a detailed connection or circuit description as well as instrument setup parameters, along with your results and analysis, for parts **1, 4, 5, 6, 7, 8, 9, and 10.**

Refer to the lab report guidelines found on the course website:
http://www.coe.montana.edu/ee/davidd/ee207/ee207.html

Your lab report should include the following:

1) a title
2) a brief description of the purpose of the lab
3) reference to an appended pre-lab, if there was one (there wasn't for Lab 0)
4) for each experiment/measurement include:
   - brief description of the experiment/measurement
   - sketch of circuit/description of measurement, identifying measurement nodes and any other pertinent details
   - measured data, organized in tables if appropriate
   - plots of data that are appropriate
   - analysis or calculations requested in the lab handout
   - comments about special circumstances, quality of data, confidence in results etc. as appropriate
5) Conclusions you drew from the activity, the most significant points, take-home message etc.
6) Appendix with pre-lab and any lengthy data that would distract from the flow of the report. You might also want to append data sheets for parts, for your future reference, or to support your analyses.