MASSACHUSETTS INSTITUTE OF TECHNOLOGY
6.091 Hands-On Introduction to EE Lab Skills
Laboratory No. 1 Oscilloscopes, Multimeter, Function Generator
IAP 2008

1 Objective

In this laboratory, you will become familiar with using a function generator, a digital multimeter and an oscilloscope. You will construct simple electronic circuits and develop a quantitative and qualitative understanding of the behavior of these circuits.

1.1 Digital Multimeters DMM

DMM can measure voltage, current, and resistance. Remember that voltage measurements are taken in parallel while current measurements are taken in series.

1.1.1   Exercise – Resistance Measurement

Get the following resistors from the drawers: 10K, 15K, 1M, 1.5M. Measure the resistance by attaching the resistors to the DMM with alligator clips. Set the DMM to resistance mode (Ω). Now hold the alligator clips with each hand and measure the body resistance. Now dip your fingers into a cup of water and repeat the measurement.

1.1.2   Exercise – Voltage and Current Measurements

Wire up the following circuit on your protoboard. Use +5VDC from the Proto-Board. All voltage measurements are referenced with respect to ground (zero) unless otherwise noted. Use your personal DMM for this exercise.
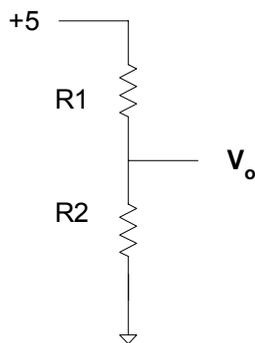
Set the DMM to voltage mode. Measure V_o for R1=10K R2=15K. Now measure the current flowing through R1 and R2.

How does voltage measurement differ from current measurement?

Repeat for R1=1M, R2=1.5M. Explain why the measurements are different.   Estimate the input resistance (order of magnitude) of the DMM? Repeat using the Agilent DMM. Explain the difference.

1.2 Oscilloscopes
   The best way to become familiar with an oscilloscope (scope) is to use it. Each oscilloscope has a calibration signal available on the front panel. (1) Turn on the oscilloscope and attach a scope probe to the calibration signal. (2) Adjust the various controls until you see a signal. If after 5 minutes, you cannot get the scope to work ask your TA or Instructor.

1.2.1   Exercise – Cursor and the calibration signal
   The scope has both vertical and horizontal bars (sliders) that allow for voltage and time measurements. To select and move the sliders, use the controls near the top of front panel marked "Cursor", "Select" and "Display". Together with the buttons at the bottom and to the right of the display, you will be able to make voltage and time measurements. When making voltage measurements be sure you know where the zero reference is.

   a) Before starting any measurement, calibrate the scope probe. There is an adjustment screw on the probe body. Turn the screw adjustment until the calibration signal is a perfect square wave. Now, using the measurement features of the oscilloscope, measure the voltage and frequency of the calibration signal. What is frequency and peak to peak value of the calibration signal? Trigger the display on the positive and negative edge.

   Frequency =

   Peak to Peak Voltage =

   RMS Voltage (DC Coupling) =

   RMS Voltage (AC Coupling) =

   Explain why the difference in RMS between DC Coupling and AC Coupling.

   b) Use the scope in single run mode. Why is single run mode useful?

   c) Set the input coupling to AC. Without going into the mathematical details, qualitatively describe when AC coupling is used and when DC coupling is used. If in doubt, notice the difference in display between AC coupling and DC coupling with the calibration signal.

1.2.2   Exercise – Scope Probes

   a) Touch your finger tip to the scope probe. What is the frequency of the signal and where is it coming from?

b) Attached a 12" length of wire between the ground of the scope and the input. What value of the voltage do you see? Where is the signal coming from?
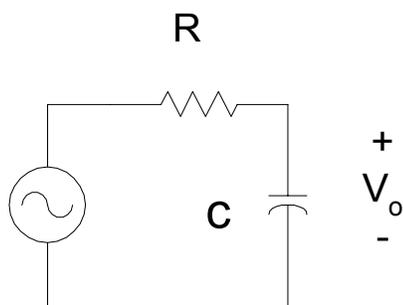
1.3 Function Generator
The function generator generates sine waves, square waves, ramps. The waveform parameters such as duty cycle, frequency, and amplitude are set via the front panel buttons. A perfectly symmetrical square wave has a 50% duty cycle. A waveform which is on for 1 ms and off for 9ms has a 10% duty cycle. Though this waveform is not "square" it is still commonly referred to as a square wave.

1.3.1   Exercise – Waveforms

a) Turn on the function generator and attach the output to the scope. Press the output button on the function generator and set the output to "high Z". The function generator will then be able to output a 10v signal. Display the following waveforms:
- 10 khz sinewave, 10 volt peak to peak
- 10 khz square wave, 10 volt peak to peak (**0 v** to **+10 v**)

b) Build the following circuit with R = 1K and C = 0.1µf and use the function generator as the input source using the 10 khz square wave. Set.   Display the input voltage source on channel 1 and display V_o on channel 2. Trigger the display on channel 1. You should be able to observe a relationship between the two waveforms. Remember that a capacitor is a component that holds a charge. As the charge increases, the voltage increases. Describe qualitatively what is happening to the voltage across the capacitor.


c) Repeat the experiment with C = 0.001µf. What is the effect of reducing the capacitance?

1.3.2 Exercise – Using Diodes

a) Diodes allow current to flow in one direction. The direction is indicated by the direction of the arrow. Using the function generator as the source, wire up the following circuit using a 1N4001 and a R=10K. The strip or bar marking on the diode corresponds to the bar/strip (cathode) in the symbol.
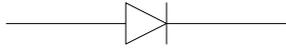
The diode is a directional device and must be installed in the correct orientation!
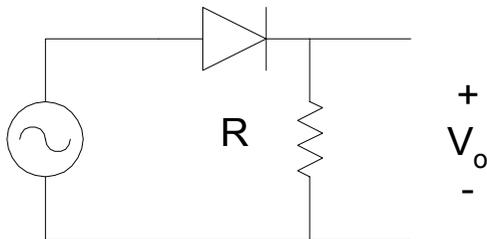
Using a sine wave, 10v peak to peak, 500 hz, display both the input source and the voltage across the resistor. What is happening? Sketch the input and output voltage below:

b) Now attach 0.1µf capacitor in parallel with the resistor. What happens now?
Note again that the diode allows current to flow in one direction only.
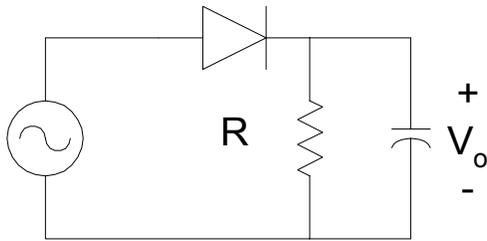
1.3.3 R2R Ladder

The R2R ladder is one of the key circuits used for digital to analog conversion. Build the following circuit using R = 1k, 2R = 2k. Be sure to use the 1% precision resistors (blue body). The resistors and switches are on bench as you enter the lab.   Use the pushbutton switches.
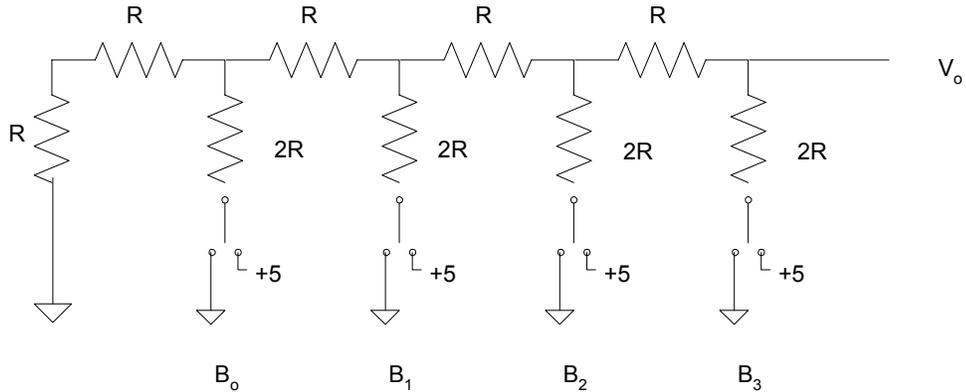
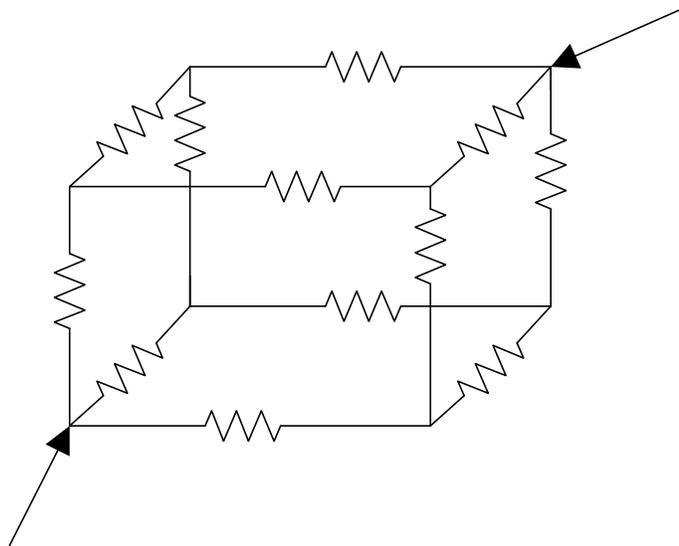In a later lecture, the formula for the output will be derived.

$$V_o = \frac{1}{2}\left[B_3 + \frac{1}{2} B_2 + \frac{1}{2^2} B_1 + \frac{1}{2^3} B_0 \right]$$

B_3	B_2	B_1	B_0	V_0
0	0	0	1	
0	0	1	0	
0	0	1	1	
0	1	0	0	
0	1	0	1	
0	1	1	0	
0	1	1	1	
1	0	0	0	
1	0	0	1	
1	0	1	0	
1	0	1	1	
1	1	0	0	
1	1	0	1	
1	1	1	0	
1	1	1	1	

Switch value of 1 = +5 V

1.3.4 Resistor Cube

Using (12) 1k resistors, create and solder a cube. Can you determine the resistance without measuring it? Record the resistance. The explanation will be provided in the next lecture.

(12) 1k resistors