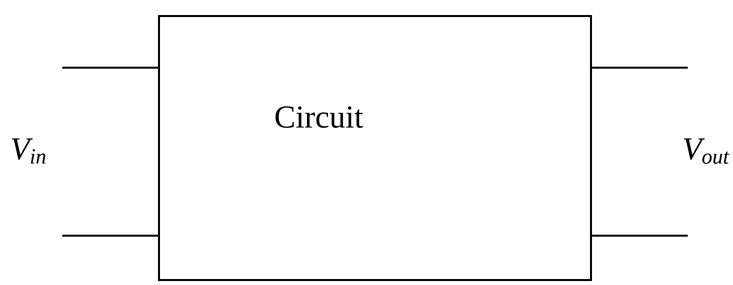
Introduction to Fields and Waves

Welcome to Fields and Waves I. This semester, classes begin on Tuesday so our first class session takes place in the studio classroom JEC 4107. The first lecture will be on Thursday. The purpose of this first class is to give you all a practical sense of what electromagnetics is about. This very fundamental area has been an essential part of electrical engineering and electric power engineering since we became a separate discipline in the late 1800s. It is also important to computer engineers with an interest in hardware. You will hear more about this in the first lecture. For now, your job is to complete two experiments. Once you have finished the two experiments, your work for today is done. If you wish to stay and work on some of the other experiments, that is up to you.

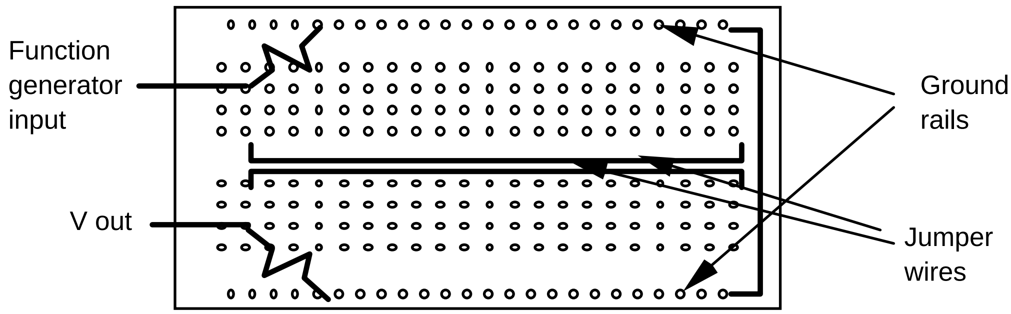
In this and other experimental activities in this course, you are to work in groups of four or fewer. Only one report is necessary for each group. However, you should all be sure that you understand what you have done since you will be asked questions about your experiences in class and on quizzes.

There are some questions at the end of this write up. These are to be handed in at the end of class. Usually, you will receive assignments like this up to a week in advance so you will be able to work on them ahead of time. You should generally try to get those parts of each assignment that do not require experiments done before class so you have time to complete in class tasks.

For nearly all of these experiments, you will be connecting a function generator to the input of some circuit and observing both the input and output voltages. Be sure that you always observe both V_{in} and V_{out} on the oscilloscope.



Experiment 1 - capacitive coupling
Connect the circuit together as shown in the diagram below. The jumper wires may need to be cut from the reels of wire near the studio door. Cut them to be about the length of the protoboard. Note that the spatial layout of the jumper wires is important in this experiment. Use resistors that are approximately 10 kΩ. Set the function generator to 30 kHz with a 10 V P-P output. Monitor the function generator output on one scope channel and the output voltage on the other scope channel.



How large a voltage do you measure at V_{out}? Is it what you expected? The two wires form a capacitor. Draw a circuit diagram with the capacitance of the wires unspecified. Be sure you include the internal impedance of the function generator. Vary the spacing between the wires and the frequency. What changes occur?

Experiment 2 – Transformers
Connect the output of the function generator across a 1 μH inductor using a coaxial cable and a coax to clip-leads adapter. Set the function generator frequency to 1 MHz and the amplitude to 10 V P-P. Monitor the function generator voltage on one channel of the scope. Take another piece of wire (cut if necessary) about 20-30 cm long and wrap it around the inductor. Monitor the voltage observed between the ends of this piece of wire with the second channel on the oscilloscope. What do you observe? Vary the frequency and the wire positions. What circuit device have you just made by wrapping the wire around the inductor?

Experiment 3 – EMI radiation and wave propagation
Create a receiving antenna using a simple wire connected to the oscilloscope through a coaxial cable with coax to clip-lead adapter. You can probably use one of the unshielded wires in the cable box. Try both a closed loop and an open loop configuration. The various electrical devices in the room (and elsewhere in the building) produce electromagnetic signals. Identify at least two different signals with whichever antenna works best. *Hints: look for frequencies under 100 Hz and above 20 kHz. Some noise signals observed will be sinusoidal and some will be a series of pulses.*

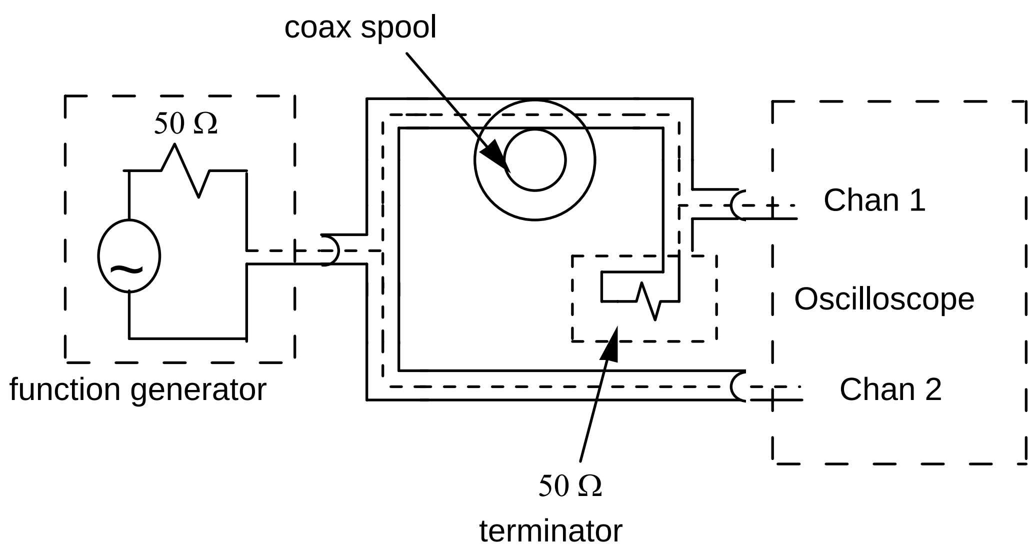
Experiment 4 – Motion sensor
Connect the coil on a cantilever beam apparatus to the oscilloscope. Monitor the voltage across the coil as the lever arm vibrates. Note that there are two sets of wires on the beam. Do not use the wires from the strain gauge. You will probably have to manually scale the scope voltage and time scales since the frequency will be low (as is the case with most mechanical systems).

Experiment 5 – Transmission lines
Connect a simple circuit with a long spool (80 $\pm$ 20 meters) of coaxial cable as shown below. Be sure you include the 50 Ω terminating resistor at the scope channel 1.

a. Obtain a sine wave from the function generator. Set the frequency to 10 kHz. What do you observe on each channel?

b. Do the same experiment, but at higher frequencies. Try several between 100 kHz and 1 MHz. What additional effect appears? Can you qualitatively explain what you observe?

c. Remove the 50 Ω termination at the oscilloscope and repeat the experiment.



d. Measure the resistance of the center and outer conductors of the long coaxial cable. Do the same for the short cable. *Hint: remember to first measure the resistance of the cable you are using to connect to the multi-meter by short circuiting the two mini-grabber connectors together and then subtract this resistance from the resistance of the cables. Because you have to eliminate the effect of the measuring cable, your answer for the short cable may not be very accurate.*

Be sure to clean up, neatly returning everything to its proper location, before leaving.

Grade Sheet

Experiment 1

a) Draw the circuit diagram and show where the scope is connected.
b) Describe two qualitative differences between the input and output voltages
c) Does the output voltage increase or decrease when the wire separation is increased?

Experiment 2

a) When you set the function generator at 10V P-P, what voltage do you observe across the inductor at *1 MHz*?
b) What qualitative differences do you observe between the input and output voltages at *1 MHz*?
c) What kind of a circuit device did you construct by winding the wire around the inductor?

Experiment 3

a) Describe the antenna you have built.
b) Qualitatively describe (sketch if you wish) two signals you observe. Give their characteristic frequencies.
c) Identify the sources of the two signals you observed. (Guess, but try to make a reasonable guess)

Experiment 4

a) Approximately, what frequency do you observe?
b) Qualitatively describe the observed voltage (sketch if you wish)

Experiment 5

a) What qualitative differences do you observe between the input and output voltages at *10 kHz*?
b) What qualitative differences do you observe between the input and output voltages at some significantly higher frequency? The frequency should be high enough to observe something different.
c) What qualitative differences do you observe (at both frequencies) when the 50 Ω termination is removed?
d) What are the resistances of the inner and outer conductors for both the short and long cables?

Did You Clean Up?

Name: ______________________

Name: ______________________

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Grade: ______________________.