

## Studio Session 1

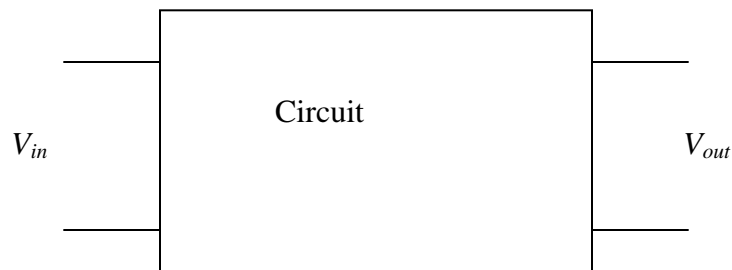
**Introduction to Fields and Waves**

Welcome to Fields and Waves I. The purpose of this first studio 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. Today, your job is to complete two experiments. Once you have finished the two experiments, your work is done. However, you should try to complete at least three and, if possible, all five experiments since this experience will help prepare you to understand the theoretical concepts of the course. You should definitely do experiment five on transmission lines. Of the other four experiments, the first one is the most important, but you are free to choose any of the others.

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. If you display only what is happening at the output end of the circuit, you will generally have learned nothing about how the circuit works.

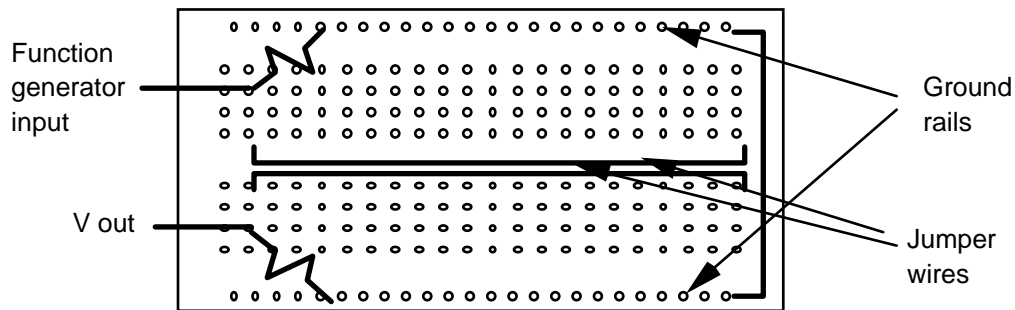


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*Note that there is additional information on what to expect from these experiments in the Lecture 1 slides found on the LMS site for this course.*

### 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 or, better yet, taken from the box of random wires you will find on the front table. 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  $10\text{ k}\Omega$  (again, you should expect to find the parts for the experiments on the front table). Set the function generator to  $30\text{ kHz}$  with a  $10\text{ V P-P}$  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  $V_{\text{out}}$ ? 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? Is the peak-to-peak amplitude of the input voltage you observe on the scope equal to  $10\text{V}$ ?

### Experiment 2 – Transformers

Connect the output of the function generator across a  $1\text{ }\mu\text{H}$  inductor using a coaxial cable and a coax to clip-leads adapter. Set the function generator frequency to  $1\text{ MHz}$  and the amplitude to  $10\text{ V P-P}$ . Monitor the function generator voltage on one channel of the scope. Take another piece of wire (cut if necessary) about  $20\text{-}30\text{ cm}$  long and wrap it around the inductor. (You can re-use one of the wires from the first experiment.) 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 or you can cut a new one from the reels of wire. 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  $100\text{ Hz}$  and above  $20\text{ kHz}$ . Some noise signals observed will be sinusoidal and some will be a series of pulses. Since you will be looking at*

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noise, it may be difficult to trigger on the signals. To observe them clearly, you may want to stop the scope from scanning.

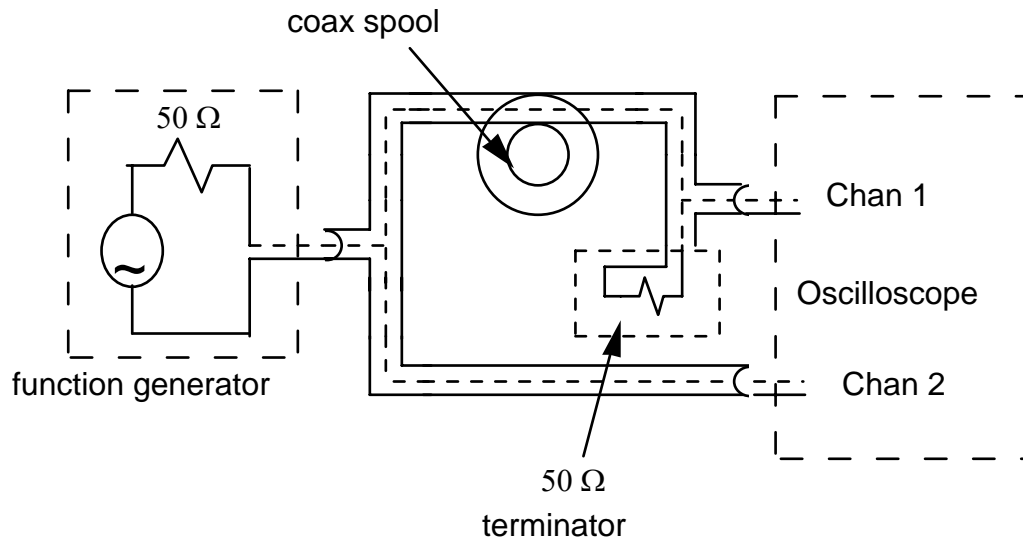
**Experiment 4 – Motion sensor**

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). Describe the signal that you see.

**Experiment 5 – Transmission lines**

Connect a simple circuit with a long spool (80 ± 20 meters) of coaxial cable as shown below. Be sure you include the 50 Ω terminating resistor at the scope channel 1.

- Obtain a sine wave from the function generator. Set the frequency to 10 kHz. What do you observe on each channel?
- 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?
- Remove the 50 Ω termination at the oscilloscope and repeat the experiment.



- 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.**

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## Grade Sheet

## Experiment 1

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

## Experiment 2

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

## Experiment 3

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

## Experiment 4

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

## Experiment 5

- What qualitative differences do you observe between the input and output voltages at 10 kHz?
- 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.
- What qualitative differences do you observe (at both frequencies) when the 50  $\Omega$  termination is removed?
- What are the resistances of the inner and outer conductors for both the short and long cables?

Did You  
Clean Up?

Name: \_\_\_\_\_

Name: \_\_\_\_\_

Name: \_\_\_\_\_

Name: \_\_\_\_\_

Grade: \_\_\_\_\_.