

Electrical Oscillations

(subtitle: detecting faint radio waves with an LC circuit, an example of a resonant system)

Overview

Your goal today is to detect some of the **faint radio waves** traveling through the lab room using a very simple LC circuit. In building and understanding that circuit, you will observe some of the properties of a system that has a natural (or resonant) frequency, properties which an LC circuit has in common with the many resonant systems that abound in nature. Examples of such systems include electrons in atoms, the quartz crystal in your watch, sound waves in an organ pipe, electromagnetic waves in a microwave oven, and light waves reflecting from a soap bubble or within a laser. The list is endless!

Activities

- #1. Detecting (electromagnetic) radio waves!
- #2. Preparation of the oscilloscope, printer, and scope probe.
- #3. Assembly of the LC circuit and the "exciter" circuit.
- #4. Some QUALITATIVE observations of the response of an LC circuit to a short pulse ("free" oscillations)
- #5. Some QUANTITATIVE observations of the "free" oscillations of an LC circuit
- #6. Observations of the response of an LC circuit to a sinusoidal stimulus (a "forced" or "driven" oscillator)
- #7. The resonant frequency of an "RF" oscillator

Major Equipment Items

- a. A digital oscilloscope, the Tektronix model TDS-210, and laser printer.
- b. Function generator and frequency counter
- c. Variable inductor and variable capacitor mounted on a box (the "radio" box)
- d. Audio amplifier and speaker

Appendices

- I. **Basic Operations of the Tektronix model TDS210 Digital Oscilloscope**
- II. **Some specifications and information concerning the Tektronix model TDS210 Digital Oscilloscope**

Procedure**a. The format of today's lab and your report:**

- This write-up has the format of a workbook, with space for you to answer questions, do some calculations, etc.
- The write-up is organized by Activities. Attach graphs associated with a particular activity to the pages for that activity.
- If there is not enough space for your work or comments at some point in the write-up, indicate "see below" or "see attached", and **use additional paper as needed**. This may happen because

we did not leave enough space for your work, or because you need to redo some work, or because you write large, or whatever. Do not let the format of this write-up "force" you into some unprofessional habit, such as writing very small or illegibly, etc. Instead, use some additional paper; it is very cheap compared to the value of your time and the value of high quality work and habits!

- In some portions of the write-up, there are detailed instructions or explanations. Where appropriate, you should indicate that you have followed or read these by making a check mark or writing a short comment, such as "done". Write more detail if that is appropriate. If you are in doubt whether a comment is needed, then write one! Most of us tend to write too little!
- Title graphs appropriately, such as: "Frequency measurement using the 49.2 nF capacitor."
- We suggest that you number each printout within each activity, such as: Act. #3, PO #2 (that's activity #3, printout #2).
- Each time you print a display, make a notation at the appropriate point in the write-up, giving the number of the printout.
- At the end of activities #1, 4, 5, 6, and 7, the following statement appears:

Staple together the pages for this Activity and any related graphs, and place these in your folder at the end of the lab table for your instructor to review.

Your instructor will discuss this work with you at various times during the period.

- **At the end of the lab period**, or when you finish (whichever comes first), staple all your work together, in order, including the introductory pages and those for activities #1 and #2.

b. **Some Reminders:** As with all records of scientific work, you are expected to:

- **Use non-erasable pen** (except perhaps when making graphs or sketches);
- **Preserve any original data records**, and submit them with reports based on that data;
- **Show all your calculations!** Those who must rely on your work should not have to repeat your calculations to confirm or discover what you did.
- **Follow the professional practices enumerated in the Introduction to the lab manual.**
- **Review your work for each activity skeptically.** In particular,
 - I. Does your report address the problems raised and the question(s) asked in the activity?
 - II. Are the results reasonable? (For example, if a result is numerical, does it have a reasonable magnitude, or is it far too large or too small?)
 - III. Is the mathematics and/or the logic in the report correct?
 - IV. Is the work complete, with all appropriate steps shown?
 - V. Do calculations and results include all appropriate (and correct!) units?
 - VI. Is the work of professional quality? (Refer to the checklist on page 8 of the Introduction to the lab manual.)
 - VII. If some of the work appears to be incorrect or in need of redoing, draw a line through the questionable work, make a notation of the problem or concern, and then redo that work.
 - VIII. If appropriate, add any additional remarks of your choosing such as, "this work should be neater", or "I still do not know how to determine the frequency from the graph", or etc.

c. **The Activities:**

- Scan briefly the list of activities on the previous page (if you have not already done so).
- You are welcome to begin!

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Date: _____

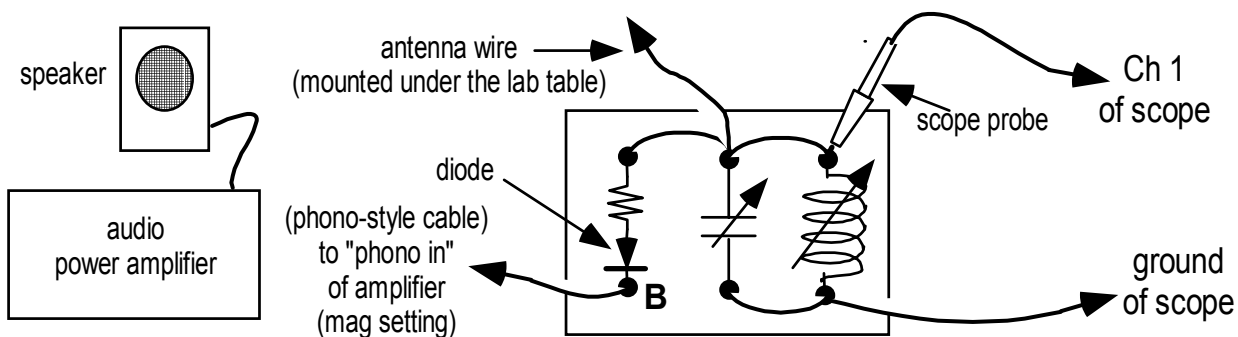
Activity #1: Detecting (electromagnetic) radio waves!!

We recommend that you can do this activity at the special table on which the apparatus is already assembled with two ANALOG oscilloscopes. We suggest that you wait until that apparatus is free, or has at most one other group of two students (four students is probably the maximum that can be accommodated at the special table). While waiting for access to the special table, please proceed with the other activities (#2, #3, etc.)!

This activity can also be done at your own lab table, but the waveforms produced by the digital scope occasionally are more difficult to interpret. WE RECOMMEND THAT YOU USE THE SPECIAL SETUP INSTEAD.

A) A simple radio based upon a resonant LC circuit

- * If the resonant frequency of an LC circuit is "tuned" to match the frequency of a passing electromagnetic (EM) wave emitted by an AM radio station, the electric and magnetic fields associated with that (nearly) sinusoidal EM wave can excite sizeable oscillations in the circuit.
- * The circuit's sensitivity to the EM wave can be enhanced by connecting one end of the circuit to an antenna (a long wire), and the other end to the earth (e.g., via the ground of the scope).
- * By adding a diode, small amplifier and speaker, we can listen to the station.



LC circuit used as a simple radio

B) Assemble the radio circuit shown above, with the connections to the amplifier, antenna and scope.

C) Prepare the instruments for this activity.

- C-1. **Set the scope to trigger on the CH 1 signal.** (On the analog scope, set the trigger source to INTernal. On the digital scope, press Trigger, then set the Source selection box to CH 1.)
- C-2. **Set the scope trigger coupling to AC.** (On the analog scope, set the trigger coupling to AC. On the digital scope, press Trigger, then set the Coupling selection box to AC.)
- C-3. **Turn OFF the function generator** (so that its signal does not compete with those of radio stations!)
- C-4. **Increase the vertical sensitivity of the scope**, since the effects due to radio waves within the lab room are not large. A setting of 20 mV/Div is a reasonable starting value; adjust this later as necessary.

D) Use the LC circuit to detect electromagnetic radio waves, and observe the effect on that circuit!

D-1. Some local AM stations are listed in the table.

D-2. "Tune" the LC circuit to detect a radio wave. That is, vary its resonant frequency until it matches that of a radio wave passing through the lab room.

Station	assigned frequency
WOI (Ames)	640 kHz
KIOA (Des Moines)	940 kHz
WHO (Des Moines)	1040 kHz
KASI (Ames)	1430 kHz
AM broadcast "band"	535-1605 kHz

- * While watching the scope display, adjust the capacitor and/or inductor to maximize the oscillation.
- * You probably need to vary both L and C in searching for various local stations.
- * At least one local station, and perhaps more, should give a significant response. Often one local station is particularly intense, occasionally masking other stations.
- * With the amplifier on, you should be able to listen to any detected station.
 - a. The "mag" setting of the "phono" input has the largest amplification and is best for weak stations.
 - b. The "cer" setting has lower amplification and may result in less distortion for strong stations.
- * Can you detect any stations on the scope? _____ Can you hear any stations? _____

D-3. For one (or more) stations, observe the oscillations of the LC circuit that are produced and note the important features.

- * When you observe the oscillations on the scope, you likely will notice that they vary in amplitude. The radio wave itself has a changing amplitude; we say the wave is Amplitude Modulated and that the station is an **AM** station.

- * Try different time scales of the oscilloscope, as suggested in the table.

about 1 ms/DIV	best for seeing the variation of the amplitude, or the "envelope" of the oscillations
about 1 μs/DIV	best for seeing individual cycles of the RF oscillations, and for measuring the frequency

- * **Does the "envelope" of the signal appear to be synchronized with the sound?** (Hint: a time scale of about 1 ms/DIV is probably most helpful for this.) _____

A comment: An **AM radio receiver** is designed to produce a sound wave that varies just like the "envelope" of the detected radio signal. The information carried by an AM radio wave is "stored" in the variation of its the amplitude.

E) Some culture - How does this simple radio work?

The diode is the key! The diode (and some capacitance and resistance in the amplifier) forces the electrical signal (i.e., voltage) at point **B** to follow the relatively slow variations of the amplitude (i.e., the "envelope") of the high frequency oscillations. Since these slow variations represent the shape of the desired sound waves, this is all the amplifier needs to produce the appropriate sound. The diode is said to be a "peak detector" in this circuit, giving a signal that follows the peak value of the high frequency oscillations of the LC circuit. Our radio is similar to a child's "crystal" radio; in such a radio, the point of contact of a strip of metal with a quartz crystal acts like a diode. Note that if one uses energy-efficient earphones rather than an audio amplifier to listen, the energy that produces the sound comes entirely from the electromagnetic wave!

Staple together the pages for this Activity and any related graphs, and place these in your folder at the end of the lab table for your instructor to review.

Name: _____

Date: _____

Activity #2: Preparation of the oscilloscope, printer, and scope probe.

A) Prepare the oscilloscope and printer for use.

A-1. For now, **turn off each of the instruments.**

A-2. **Suggestions for some initial settings.**

Digital oscilloscope (Tektronix model TDS210)	<ol style="list-style-type: none">1. Now turn on the outlet strip into which the instruments are plugged.2. So that you can refer to it as needed today, remove Appendix I from the back of this write-up and place it on your lab table for easy reference.3. Now perform steps #1, #2, #3 of Appendix I.4. If you are unfamiliar with this scope, briefly read (without using yet!) the other Basic Operations in Appendix I.
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Laser printer (HP L4 or higher)	To print the oscilloscope display on the printer on the computer cart: <ol style="list-style-type: none">1. The outlet strip on the computer cart should be on;2. The printer will now be on (the printer does not have a power switch);3. To save power, etc., the power switch of the computer and that of the monitor should be OFF (we will not be using the computer today);4. Read this later if you have problems printing: Both the computer and the oscilloscope are connected to the printer through a two-input "auto-switch". When functioning properly, the light for each of the two input ports should light alternately. On the "True-Data" models, occasionally a reset button needs to be pressed. The auto-switch receives its power via the data cable from the printer or oscilloscope.
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B) Install an oscilloscope probe on Channel #1 of the scope, and set the scope for the (vertical) calibration appropriate for use with this probe.

B-1. Install the probe on the BNC connector for CH 1. (As usual, you should feel a gentle snap as you rotate the BNC connector of the probe CW into position.)

B-2. To display Channel 1, press CH 1 MENU. To turn off the display of Channel 1, press CH 1 MENU several times.

B-3. Set the switch on the side of the probe to the 10X position.

* The designation "10X" means that this probe attenuates the signal (makes it smaller) by a factor of 10. For example, a signal that is 20 volts at the tip of the probe will be only 2 volts at the input terminal of the scope.

* We suggest that you put a piece of transparent tape over the switch so that it retains the desired "10X" setting.

B-4. Set the vertical scale for channel #1 so that it is properly calibrated for a 10X probe. (Press CH 1 Menu, then select Probe on the screen as needed to obtain the 10X setting.)

C) Quickly check the probe and scope for proper functioning and calibration using the "Probe Compensation" output terminal. (This should only take a few seconds, since the probe likely was adjusted by a previous user and/or you have done this in a previous lab!)

C-1. The "Probe Compensation" port:

- * The port is located at the lower center of the scope face;
- * The port provides a **test signal** consisting of a train of positive square pulses with an amplitude of +5 Volts and a frequency of 1 kHz.
- * The signal is on the upper electrode of the port; the lower electrode is at ground potential.

C-2. **The primary purpose of the "Probe Compensation" port:** This port provides a signal useful for adjusting the electrical properties of a probe so that they match those of the particular input and scope being used. When the probe is properly adjusted, the scope display will be an undistorted representation of the signal.

The compensation port provides a signal with a square shape. To adjust the probe, one connects the probe to the port, and then turns the adjusting screw or collar of the probe until the display on the scope is also square.

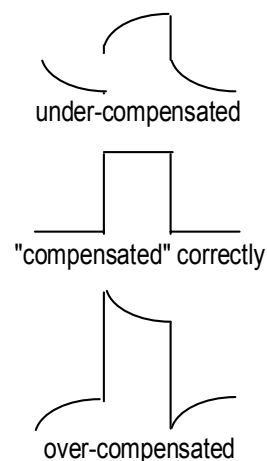
C-3. **Connect the end of the probe to the appropriate (upper) electrode of the port.**

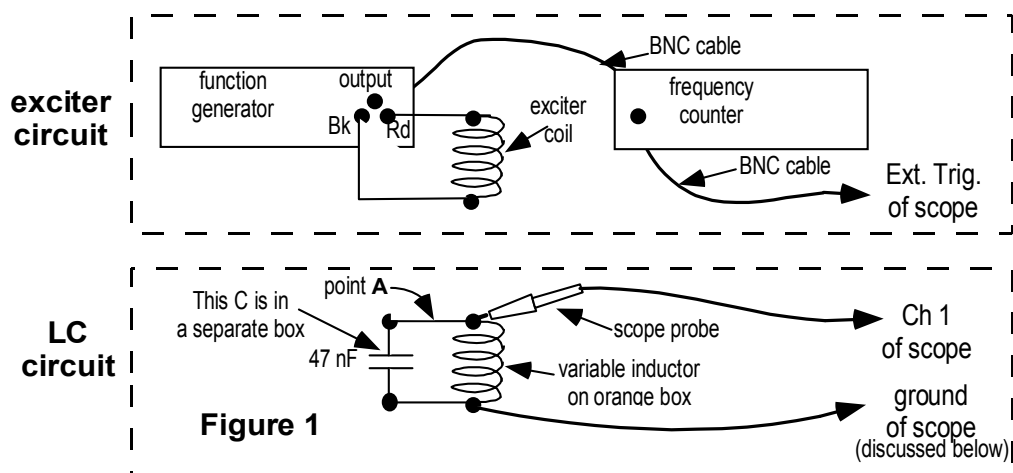
- * The probe has a metal tip (in the shape of a hook) which can be exposed by pulling back on the forward body of the probe. Test your manual dexterity by doing this with one hand.
- * The hook at the tip of the probe can be snagged on the upper electrode of the port.

C-4. **Observe the test signal with the oscilloscope, and adjust the probe if the observed signal is not square.**

- * Set the scope to display the signal. (Press Autoset, and then adjust the vertical scale (turn the VOLTS/DIV control) and the horizontal scale (turn the SEC/DIV control) to your taste.)
- * **If the pulses on the display are NOT square**, ask your instructor to help you adjust ("compensate") the probe so that they are square.

(Note to instructors: The Tektronix P2100 probe that we commonly use with this experiment has a small adjustment screw located near the BNC connector. Turn this screw until the detected pulses are square; use either the plastic tool (from Tektronix) on the supply table or a jeweler's screwdriver.)



Activity #3: Assembly of the LC circuit and the "exciter" circuit.

A) Assemble the LC circuit shown in the lower part of figure #1. (For now, ignore connections to the scope.)

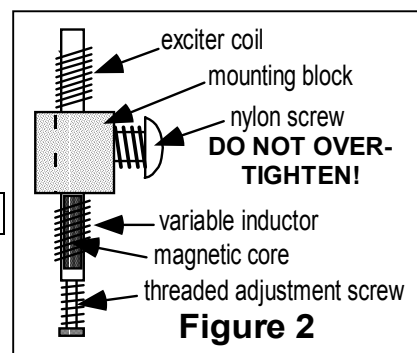
A-1. Use short banana wires to connect the inductor on the orange box with a capacitor whose nominal value is 47 nF (i.e., 0.047 μ F). This capacitor is one of many mounted in the "capacitor box".

* For possible reference, record the following: "radio" box #: _____ capacitor box #: _____
The "actual" value of the capacitor as recorded on the capacitor box. _____

B) Set the variable inductor (on the orange box) of the LC circuit for maximum inductance:

B-1. To change the inductance, one can turn the screw to move the ceramic core (containing iron) with respect to the windings of the inductor.

B-2 **Start today's measurements with the screw turned all the way in (fully CW)**; this puts the ceramic core approximately at the center of the coil, corresponding to the largest inductance.



C) Assemble the "Exciter" Circuit, as shown in figure #1.

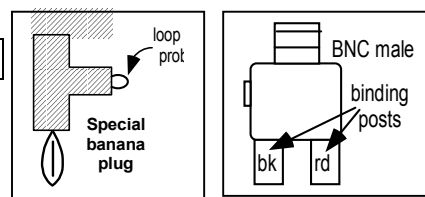
C-1. A change in the magnetic field produced by current in the exciter coil can induce an EMF in the inductor of the LC circuit. This EMF is enhanced by locating the exciter coil close to the inductor.

C-2. As shown in figure 2, slide the exciter coil into the small mounting block at the far end of the variable inductor; then **gently** tighten the nylon thumb screw to hold the exciter coil in place. **Do not crush** the form of the exciter coil.

D) To observe oscillations in the LC circuit, connect the scope:

D-1. See figure 1 above for the three suggested connections to the scope.

D-2. To connect the probe to the circuit, snag its hook on the loop of a special banana plug (see figure) and insert the plug as needed.



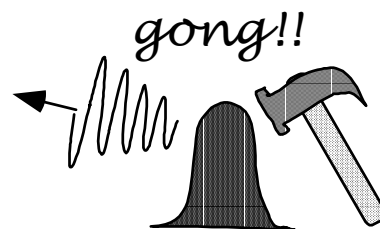
D-3. You can connect to the **ground of the scope** at the black binding post of an adapter (double binding post to BNC) placed on a BNC connector, such as that for Ch 2.

D-4. A BNC cable should run from the generator output to the Frequency Counter, and then on to the **EXTERNAL TRIGGER** input of the oscilloscope.

Activity #4: Some QUALITATIVE observations of the response of an LC circuit to a short pulse (i.e., "free" oscillations)

A) Some Background.

When a brief pulse of electrical energy is injected into an LC circuit, the circuit responds much like a bell which is struck sharply; it oscillates briefly at a rate determined by its own physical properties. Very brief pulses of energy can be delivered to your LC circuit by driving the exciter coil with a square wave; with each abrupt change in the generator voltage, an induced EMF will result in the inductor of the LC circuit. This circuit subsequently oscillates electrically, with the oscillations gradually decreasing in magnitude as the electrical energy within the circuit is dissipated, principally by the resistance of the circuit.



B) Set the instruments appropriately.

B-1. **Turn on the function generator and frequency meter.**

B-2. **Suggestions for some initial settings.**

<p>Frequency Counter (LG Precision FC-7015)</p>	<ol style="list-style-type: none"> 1. Set the three button switches for Input A to their recommended settings, namely, OUT IN IN. 2. Since this instrument automatically sets itself for frequency measurements when it is first turned on, you likely do not need further instructions (refer to those on top of the instrument if necessary).
<p>Function Generator (B&K Precision model 4011)</p>	<ol style="list-style-type: none"> 1. Set all four buttons in the middle of the front panel OUT. 2. Select a "square wave" function shape for the output. 3. Set the frequency to a nominal value of 500 Hz (the exact value is not critical). 4. Set the OUTPUT LEVEL at its maximum, i.e., fully CW.
<p>Digital oscilloscope (Tektronix model TDS210)</p>	<p>In addition to what you did previously in Activity #2,</p> <ol style="list-style-type: none"> 1. You may press Autoset as needed today, and then adjust as needed: <ul style="list-style-type: none"> * the horizontal position & the horizontal scale (SEC/DIV); * the vertical scale (VOLTS/DIV). 2. We strongly recommend that you use the signal at the external trigger input, attenuated by a factor of 5, to "trigger" the acquisition and display of data. To do this, press TRIGGER and set the Source selection box to EXT/5. 3. AN INCONVENIENCE! EACH TIME YOU USE AUTOSET, RESET THE TRIGGER TO EXT/5 AS DESCRIBED ABOVE!!!! (Since AUTOSET sets the trigger source to CH 1!) 4. For a more stable display, we recommend that you press TRIGGER and set the MODE selection box to HF Reject. 5. Before printing a display, you can stop data acquisition (press RUN/STOP), so that you know exactly what you are printing!

C) Check that the elements of your LC circuit have the recommended value or setting.

- C-1. The capacitor should have a nominal value is 47 nF.
- C-2. The variable inductor should be set at its maximum value (screw turned fully CW).

D) Some Preliminary Qualitative Observations

D-1. Adjust your oscilloscope so that you can observe clearly a burst of oscillations that results when energy is injected into the LC circuit by one of the sharp transitions in the square wave.

* In some parts of this lab, it is best to adjust the display so that a single burst fills the screen, while at other times it is best to have several bursts visible. Adjust the scope accordingly today.

D-2. Does each burst appear to have the form of a damped sinusoid? That is, do you think that the oscillation can be described qualitatively by the equation below?

$$v(t) = A e^{-t/\tau} \sin(2\pi f t)$$

E) Observe and note the effect of changing the AMPLITUDE OF THE EXTERNAL STIMULUS.

- E-1. The amount of energy injected into the LC circuit can be altered by moving the exciter coil with respect to the LC circuit, and, of course, by varying the output level of the function generator.
- E-2. While observing the oscillations, change the size of the external stimulus of the LC circuit by moving the exciter coil about.

Describe the principal effect(s); in particular, which parameter(s) of the oscillations are noticeably affected, namely the **amplitude, A, the frequency, f, and/or the decay constant, τ .**

(Before continuing, return your circuit to its original configuration with the exciter coil mounted as described in Activity #3, and the function generator set for maximum output.)

F) Observe and note the effect of changing the CAPACITANCE IN THE LC CIRCUIT.

F-1. Try capacitors of various values while observing the oscillations.

Describe the principal effect(s); in particular, which parameter(s) of the oscillations are noticeably affected, namely the **amplitude, A, the frequency, f, and/or the decay constant, τ .**

(Before continuing, return your circuit to its original configuration with the 47 nF capacitor.)

G) Observe and note the effect of changing the RESISTANCE IN THE LC CIRCUIT.

Since the resistance of the LC circuit is due principally to the resistance of the wire of the inductor, it is difficult to reduce this quantity. However, we can easily increase the total resistance and note the effect.

G-1. Locate the variable resistor (0 to 100 ohm) on your lab table. Then use the ohm-meter function of a digital multimeter to observe the range of its resistance values. (There should be a multimeter or two available on a supply table in the room.) Record your findings below.

G-2. Alter your LC circuit so that the variable resistor is in series with the inductor and capacitor. We suggest that you insert the resistance into the circuit at point A shown in figure 1.

G-3. We suggest that you adjust the scope so that the beginning of a burst is visible on the screen.

G-4. Then vary the value of the resistance over its entire range while observing the oscillations.

Describe the principal effect(s); in particular, which parameter(s) of the oscillations are noticeably affected, namely the **amplitude, A, the frequency, f, and/or the decay constant, τ .**

(Before continuing, return your circuit to its original configuration with no added resistance in the circuit.)

H) Observe and note the effect of changing the FREQUENCY OF THE EXTERNAL PULSES.

Just as we can tap a bell more or less rapidly, similarly we can vary the rate at which our LC circuit gets "tapped".

H-1. Vary the frequency of the square wave applied to the external coil over the range from 50 Hz to 500 Hz while observing the oscillations.

Describe the principal effect(s); in particular, is the "burst" frequency (i.e., number of bursts per second) affected?

(Before continuing, return your circuit to its original configuration with the function generator set to about 500 Hz.)

Staple together the pages for this Activity and any related graphs, and place these in your folder at the end of the lab table for your instructor to review.

Name: _____

Date: _____

Activity #5: Some QUANTITATIVE observations of the "free oscillations" of our LC circuit

A) Before continuing, return your circuit to the recommended configuration.

- * Again, use the capacitor with a nominal value of 47 nF;
- * The variable resistor should no longer be in the LC circuit;
- * The inductor should still be set at its maximum value (screw turned fully CW);
- * The function generator should be set at its maximum output level, and at a frequency of about 500 Hz.
- * **An important point:** For many of the measurements today, you will want the same value of inductance; hence, you should not change the position of the core until necessary (in parts of Activities #6 and #7).

B) Measure the FREQUENCY of the "free oscillations" of the LC circuit.

Use **both** methods described below.

B-1. Method #1: Use the Measure feature to directly measure the frequency of the decaying oscillations!

For this method to be accurate, manually adjust the **horizontal scale and horizontal position** so that:

- a. a single burst of decaying oscillations fills the screen, and;
- b. there are many cycles of the decaying oscillation.

Under these conditions, the frequency determined by the Measure function typically is quite accurate. Print a suitable scope display and record below your result.

B-2. Method #2: From a print-out of the display, determine the time for a number of cycles, and from that the period and frequency.

For this method to be accurate:

- a. manually adjust the horizontal scale so that a single burst of decaying oscillations fills the display;
- b. use points separated by a significant part of the width of the display (do you understand why?);
- c. Use two "time" cursors to automatically measure the time between two points of interest on the waveform.

- * **Use of these cursors likely will save you time, even if you have never used them before!**
- * To turn these cursors ON, press Cursor, then under Type select Time, and then use the Cursor 1 and Cursor 2 control knobs to mark two points of interest.
- * Document this work below. Include also a printout of the display showing the cursors!

Staple together the page for this Activity and any related graphs, and place these in your folder at the end of the lab table for your instructor to review.

Name: _____

Date: _____

Activity #6: Observations of the response of an LC circuit to a sinusoidal stimulus

Rather than sharply "rapping" your LC circuit with the abrupt transitions of a square wave, energy can be transferred into the circuit with a gentle, continuous sinusoidal excitation. An oscillator that is excited by a sinusoidal stimulus is commonly referred to as a **"forced" or "driven" oscillator**.

A) Your predictions: Before using a sine function to drive the exciter coil, predict the time-dependence of the voltage across the capacitor or inductor that will result.

* Do you expect to see "bursts" of damped oscillations as before, or something else?

* Will the response depend on the frequency of the excitation? If so, at approximately what frequency might something special happen? Discuss this point, and include at least one interesting **numerical prediction**.

B) Set up the circuit and instruments appropriately.

* The function generator should be set for a sine function output of maximum size.

C) Resonance! ! Find that frequency of excitation that results in the largest oscillations in the LC circuit (the so-called "resonant" frequency).

C-1. Adjust the frequency of the function generator to obtain the largest oscillations possible in the LC circuit. Then use the frequency counter to measure the resonant frequency.

* The frequency counter: Each time the (faint) **Gate Time (GT)** light turns on, a new measurement is displayed. Only the digits that do not change, or change by only ± 1 or 2, typically are reliable.

Record any comments and your result below.

C-2. **Compare this resonant frequency with the frequency of the "free oscillations"** that you observed in Activity #5. Calculate the difference between these two as a percent. (Agreement within a few percent is typical.) Show your work.

A comment: For a circuit without large "damping", these two frequencies should be similar but not exactly equal. The small difference depends upon the parameters of the circuit and the exciter circuit.

C-3. Determine the inductance of the inductor in your LC circuit. (We recommend that you use your measurement from part C-1 above, unless you have good reason to do otherwise.)

inductance of the variable inductor (screw fully CW): _____

C-4. **What is the frequency of the "forced" oscillations within the LC circuit?** In part C-1 above, whether at resonance or not, the frequency counter indicated the frequency of the output of the function generator, and thus the frequency of the external excitation of the LC circuit.

Your prediction: But what is the frequency of the oscillation of the LC circuit? Is it always the same as the generator frequency, both at and off resonance? Or is it determined by the values of L and C, and thus the same regardless of the frequency setting of the function generator? _____

C-5. Use the oscilloscope to determine the frequency of the oscillation in the LC circuit.

Then use the frequency counter to determine the frequency of the output of the function generator.

Calculate the difference between these two as a percent.

A comment: These two are exactly equal. Any difference that you observe is due to inaccuracies of the measurements! And this relationship holds at any frequency, not just the resonant frequency!

Staple together the page for this Activity and any related graphs, and place these in your folder at the end of the lab table for your instructor to review.

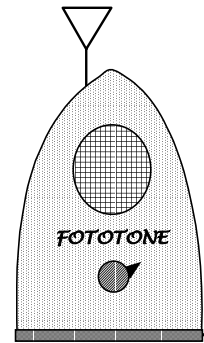
Name: _____

Date: _____

Activity #7: The resonant frequency of an "RF" oscillator

A) What is an "RF" oscillator?

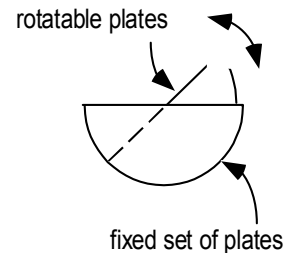
The abbreviation "**RF**" comes from the words "**R**adio **F**requency" and is used colloquially to refer to frequencies of the order of 1000 kHz, i.e., 1 megahertz (1 MHz). The term has its roots in the fact that the commercial AM radio "band" extends from 535 kHz to 1605 kHz. In a moment you will construct an LC circuit which has its resonant frequency in this region, and hence which is an "RF" oscillator. For many decades, such oscillators were the key components of radio receivers.



B) An adjustable capacitor (useful for making a "tunable" RF oscillator)

B-1. By using a capacitor of appropriate value in parallel with the inductor on the orange box, you can create an RF oscillator. **The adjustable capacitor mounted near the center of the orange box is such a capacitor.**

B-2. The **adjustable capacitor** on the orange box consists of a movable set of metal plates which are intermeshed with a fixed set of plates.



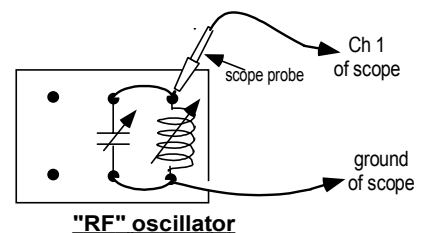
- * Turn the knob to vary the degree to which the plates are intermeshed.
- * **A warning:** Occasionally an adjustable capacitor will "short out" because some of the plates are bent and touch when the knob is turned; if this happens, typically you can hear or feel the plates rubbing against one another as you turn the knob. Notify your instructor if your capacitor has this problem.
- * Try rotating the moveable set of plates back and forth. Predict which configuration gives the largest capacitance, namely, when the plates are fully meshed, or when the two sets of plates are maximally separated? Explain your reasoning.

- * Using a capacitance meter (likely available on a supply table), measure the extreme values of capacitance for this capacitor. Describe the position of the rotatable plates in each case.

C) Assemble an RF oscillator; predict and measure its resonant frequency.

C-1. **Assemble an LC circuit with a resonant frequency in the RF range.**

- * Remove the 47 nF capacitor from your circuit, and use instead the adjustable capacitor on the orange box. Connect this capacitor to the inductor with very short (~ 10 cm long) wires.



- * Set the variable capacitor for maximum capacitance.
- * The inductor should still be set at its maximum value (screw turned fully CW);

C-2. **Now predict the resonant frequency of this circuit, based upon you measurements of the previous activities.**

C-3. **Now excite the large resonant frequency response of this circuit, and measure that frequency.** As appropriate, use the sine function output of the function generator, and the frequency counter.

How well does your result agree with your prediction?

D) Now turn the process around!! Use the LC circuit and oscilloscope to "detect" or receive the electromagnetic fields (of arbitrary frequency) produced by the function generator!!

D-1. Set the frequency of the function generator to approximately 500 kHz.

D-2. Can you "detect" the fields produced by the function generator and its "antenna", the exciter coil?

Adjust the variable capacitor to maximize the oscillation in the LC circuit! Do you find a large "narrow" resonance? (By "narrow", we mean the range of settings of the capacitor that gives a large response is small.)

D-3. Can the LC circuit "detect" signals at other frequencies as well, say at 600 or 700 kHz? Try another frequency or two, and describe your findings.

Staple together the pages for this Activity and any related graphs, and place these in your folder at the end of the lab table for your instructor to review.

Physics 222 - Lab No. 7

Electrical Oscillations

Page Layout

Sheet	Front (page #)	Back (page #)
1	1	2
2	3	4
3	5	6
4	7	
5	8	9
6	10	
7	11	
8	12	13
9	14	15
10	16	17