

Time-Dependent Electrical Signals Name: _____

Lab Partner: _____

Section #: _____ Instructor: _____

(subtitle: learning to use oscilloscopes!)**Overview**

You will use a modern digital oscilloscope to observe the time dependence of the potential difference between two points in various situations.

Activities

- #1. Using an oscilloscope to measure a steady DC potential difference (PD).
- #2. Graphing (with an oscilloscope) slowly changing electrical signals (frequency of a few Hertz or less).
- #3. Observing the P.D. between electrodes at an "AC" electrical outlet (and using an oscilloscope probe).
- #4. Observing the very high speed (of an electrical signal!)
- #5. Triggering the acquisition of data.
- #6. The RC circuit: observing the exponential accumulation of charge on a capacitor.

Major Equipment Items

- a. A digital oscilloscope, the Tektronix model TDS-210, and laser printer.
- b. Function generator, DC power supply, analog and digital multimeters, capacitance meter
- c. Various other electronic devices

Appendices

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

Introduction

What is an oscilloscope? Answer: In effect, an oscilloscope is a voltmeter that produces a graph of voltage vs. time.

What is a digital oscilloscope? Answer: Essentially, a digital oscilloscope is an instrument that measures the input voltage at a set rate, stores these measurements as digital values in a memory, and uses those digital values to produce a visual display, most commonly a graph of voltage vs. time.

What is the fundamental difference between a digital scope and an ordinary "analog" (i.e., CRT-based) oscilloscope? Answer: An "analog" scope uses the CRT screen and the persistence of the image in your eye to "store" the waveform, while a digital scope uses ordinary integrated circuits (IC's).

What is a "CRT"? Answer: CRT stands for Cathode Ray Tube. An ordinary TV tube is an example of a CRT, a cathode ray tube. In a CRT, an electron beam is moved across the screen. The inside surface of the screen is coated with phosphors, materials that emit light when excited by bombarding electrons. Because of the presence of these phosphors, an electron beam which is deflected within the tube by magnetic and/or electric fields can produce on the screen an image (as in a TV set) or graph (as in an oscilloscope).

Procedure

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

- This write-up has the format of a workbook, with spaces 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 you may 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. You should indicate that you have followed or read these as appropriate by, for example, 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 printouts appropriately, such as: "Waveform observed at the large slot of an AC outlet."
- We suggest that you number each printout within each activity, such as: Act. #3, PO #2 (that's activity #3, print-out #2).
- Make a notation at the appropriate point within the write-up each time you print a display, giving the number of the printout. Thus your write-up should indicate the existence of each of your printouts.
- At the end of the activities, 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 together all your work **in order**, including the introductory pages of the write-up.

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 page 1 (if you have not already done so).
- You are welcome to begin!

Name: _____

Date: _____

Activity #1: Use an oscilloscope to measure a steady DC potential difference (PD).

A) Prepare the instruments for use.

A-1. For now, **turn off the outlet strip** into which your instruments are plugged (if it is on).

A-2. **Remove all wires and cables from the terminals of the instruments.**

A-3. **Suggestions for the initial settings of some controls.**

DC power supply (Lambda model #LL901-0V, provides 0-10 V and 0-1A)	Set the power switch to OFF. Set the current control about 1/3 of the way ON (about the 11 o'clock position).
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Digital Multimeter (DMM) (HP model 3476)	Set the power switch to OFF. Set the meter to measure DC volts.
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Digital oscilloscope (Tektronix model TDS210)	<ol style="list-style-type: none">1. Now turn on the outlet strip.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, and #5 of the Basic Operations (see Appendix I). For step #5, use the 1X setting for now.4. 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 (it 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) Use the **calibrated display** of the oscilloscope to measure the potential difference (PD) between the output terminals of a DC power supply; **compare these results with those of a digital voltmeter**. Document your work, including a printed copy of any pertinent scope displays. Show how you derived a value for the PD from the display.

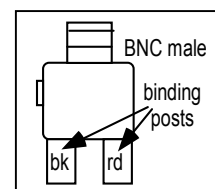
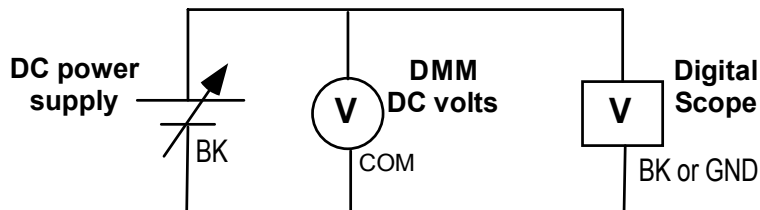
B-1. Construct the circuit shown.

* Use **Channel #1** of the scope; use an adapter which allows connection of two ordinary lab wires ("banana" wires) to the so-called "BNC" connector for channel #1.

* For any circuit today, you can connect to the **ground of the scope** via the black binding post of an adapter (double binding post to BNC) placed on a BNC connector, such as that for Ch 1 or Ch 2.

* When placing a BNC adapter or BNC cable on a BNC connector, slid the adapter or cable onto the BNC connector, **and then rotate the fitting CW until you feel a gentle "snap"**. **When properly installed, you should not be able to pull the adapter or cable from the connector.** To remove the cable, first rotate it CCW to "unsnap" it.

* On the DMM, use the terminals appropriate for voltage measurements (labeled V and COM).



B-2. Use the calibrated display of the oscilloscope to measure the steady PD produced by the DC power supply:

* Turn on the remaining instruments, including the DC power supply and the DMM.

* On the oscilloscope, press **AUTOSET**.

* Adjust the output PD of the DC power supply, and observe the response of the scope and the digital meter.

* For the oscilloscope display, if desired, adjust the vertical scale (turn the VOLTS/DIV control) and the horizontal scale (turn the SEC/DIV control).

* **The oscilloscope display is calibrated**; it can provide accurate numerical information!

1. The calibration factor for the **vertical scale is shown at the lower left of the display, in V or mV (per Div)**.

2. The calibration factor for the **horizontal scale is shown at the lower center, in nS (10^{-9} S), μ S (10^{-6} S), mS (10^{-3} S), or S (per Div)**.

3. By a **Division** is meant a major division on the screen, which is (roughly) 1 cm.

4. **"Ground"** (i.e., 0 Volts) for each channel **is indicated by the arrow along the left edge of the screen**.

* When you obtain a display from which you can determine the PD between the terminals of the power supply, you may press (RUN/STOP) once to halt data acquisition by the oscilloscope.

* Print and label appropriately any suitable scope displays.

* On an appropriate scope printout, determine the PD of the power supply; show all pertinent calculations, interval measurements, etc., on the printout. Record your result below.

PD of power supply (determined from printed scope display): _____ display #: _____

* Use the digital multimeter to measure the PD of the power supply. Record your result below.

PD of power supply (determined using the digital multimeter): _____

- * Calculate and record the percent difference between the two. Show your work.

Percent difference between these measurements: _____

- * DC voltage measurements with this multimeter are specified to be accurate to $\pm 0.5\%$, while the vertical scale of the digital scope display is specified to be accurate to $\pm 3\%$. In light of this information, comment intelligently on the difference you observed above.

C) Use the automatic **MEASURE** feature of the oscilloscope to measure the PD output of a DC power supply; **compare these results with those of a digital voltmeter**. Document your work, including a printed copy of any pertinent scope displays.

C-1. **To have various features of the waveform measured automatically** (such as the mean value), press **Measure** and use the upper selection box on the screen, and other selection boxes as needed.

- * Print and label appropriately any suitable scope displays.

- * From an appropriate scope printout, record the PD of the power supply below.

PD of power supply: _____ as determined from printed scope display #: _____

- * Use the digital multimeter to measure the PD of the power supply. Record your result below.

PD of power supply: _____ as determined using the digital multimeter.

- * Calculate and record the percent difference between the two. Show your work.

Percent difference between these measurements: _____

- * DC voltage measurements with this multimeter are specified to be accurate to $\pm 0.5\%$, while the vertical scale (and Measure feature) of the digital scope display is specified to be accurate to $\pm 3\%$. In light of this information, comment intelligently on the difference you observed above.

D) Comment on this activity in any other way that you think appropriate; in particular, discuss any difficulties which you encountered.

Staple together the pages for this Activity (#1) and any related graphs, and place these in your folder at the end of the lab table for your instructor to review.

Activity #2: Graphing (with an oscilloscope) slowly changing electrical signals (frequency of a few Hertz or less).

A) Use the oscilloscope to observe the time dependence of the PD supplied by a DC power supply:

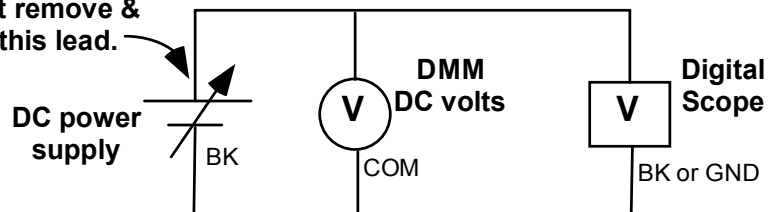
- * as you vary its (voltage) controls, and;
- * as you repeatedly "make" and "break" the contact with the power supply.

Again, document your work with appropriate notes, including a printed copy of pertinent scope displays.

A-1. Use the same circuit used in the previous activity.

A-2. **We recommend a time scale of about 500 ms/Div** for these measurements. However, use what works best for you.

You might remove & replace this lead.



A-3. **Vary the (voltage) controls of the power supply** while observing the result on the oscilloscope screen.

- * When you obtain a display that you would like to preserve, you may press (RUN/STOP) once to halt data acquisition by the oscilloscope.
- * Print and label appropriately any suitable scope displays.
- * Discuss some of the features of the printout; for example, relate features to their causes.

A-4. **"Make" and "break" contact with the power supply** while observing the result on the oscilloscope screen.

- * To "make" and "break" contact with the power supply, you can simply remove (and replace) the "lead" (banana wire) from the positive terminal of the power supply. Or you can just tap the plug of the wire against the metal inner part of the positive terminal.
- * When you obtain a display that you would like to preserve, you may press (RUN/STOP) once to halt data acquisition by the oscilloscope.
- * Print and label appropriately any suitable scope displays.
- * **Switch "Bounce":** You likely will notice that the oscilloscope display reveals that when one plugs the banana wire into the connector, electrical connection is not firmly established immediately, but rather contact typically is made and broken several times. This phenomena is quite common, and is called "switch bounce". In fact, the circuits to which each key of a computer keyboard is connected have specially designed "de-bouncing circuits", so that pressing the "A" key does not result in several "A's" appearing on the screen!

Label an appropriate portion of a printout for this activity as "switch bounce"!

- * Discuss some of the features of the printout; for example, relate features to their causes.

- B) Observe the time-dependence of the P.D. produced by a so-called function generator.
- * Use both an analog (mechanical) voltmeter and the oscilloscope to observe this PD.
 - * For this activity, use the lowest frequency range of the generator.
- Again, document your work, including a printed copy of pertinent scope displays.

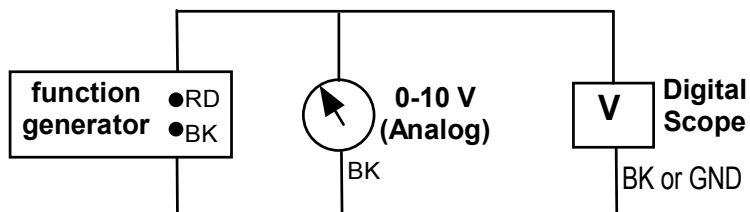
B-1. Recommended settings for the function generator and analog voltmeter:

Function Generator (B&K Precision model 4011)	<ol style="list-style-type: none"> 1. Start with function generator OFF (so that you don't inadvertently damage the analog meter). 2. Start with the OUTPUT LEVEL at its minimum, i.e., fully CCW (counter-clockwise). 3. Set all four buttons in the middle of the front panel OUT. 4. Select the lowest frequency range (5 Hz). 5. Although it will not be a problem for you, note that when using this low frequency range, the digital readout of the frequency will not be useful; only one digit will be displayed, and this will be accurate only after 20 seconds or so! 6. Select a "sine" function shape for the output (not square or triangle wave).
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Analog Multimeter (Triplett Model 60, orange)	<ol style="list-style-type: none"> 1. Set the dial for DC volts, 10 volt (full) scale. 2. We recommend that the "inverting" switch be set to the "non-inverting" position.
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B-2. We recommend the circuit shown.

- * For connection to the function generator, use an adapter that allows you to connect two ordinary lab wires ("banana" wires) to the OUTPUT connector. (The OUTPUT connector is the right-most BNC-style connector.)



B-3. Now for the **FUN!!**

- * Turn on the function generator.
- * **AVOID LARGE OUTPUT LEVELS OF THE FUNCTION GENERATOR, SO THAT THE ANALOG METER IS NOT DAMAGED! THANKS.**
- * Observe the response of the analog voltmeter and the waveforms on the oscilloscope. Vary the amplitude and frequency (within the lowest frequency range) of the function generator output.
- * Adjust the vertical and horizontal scales of the oscilloscope, if necessary, so that the waveforms are displayed reasonably.
- * When you obtain a display that you would like to preserve, you may press (RUN/STOP) once to halt data acquisition by the oscilloscope.

- * Print and label appropriately any suitable scope displays.
- * Discuss some of the features of the printout; for example, relate features to their causes. In particular, discuss how the scope display is related to the frequency of the signal.

C) Comment on this activity in any other way that you think appropriate; in particular, discuss any difficulties which you encountered.

Staple together the pages for this Activity (#2) 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 #3: Observing the P.D. between electrodes of an "AC" electrical outlet (for safety, done using an oscilloscope probe).

A) Install an oscilloscope probe on Channel #2 of the scope, and set the scope for the (vertical) calibration appropriate for use with this probe.

A-1. Install the probe on the BNC connector for CH 2. (As usual, you should feel a gentle snap as you rotate the BNC connector of the probe CW into position.)

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

A-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.

A-4. Set the vertical scale for channel #2 so that it is properly calibrated for a 10X probe. (Press CH 2 Menu, then select Probe on the screen as needed to obtain the 10X setting.)

B) Check the probe and scope for proper functioning and calibration using the "Probe Compensation" output terminal. Again, document your work, including a printed copy of pertinent scope displays.

B-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.

B-2. **The primary purpose of the "Probe Compensation" port:** If the signal provided to the oscilloscope via a probe is to have an undistorted shape, a key property of the circuit within the probe must be matched to the electrical properties of the particular input and oscilloscope being used. Normally, the probe is adjusted by turning a screw or collar located on the probe.

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

B-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.

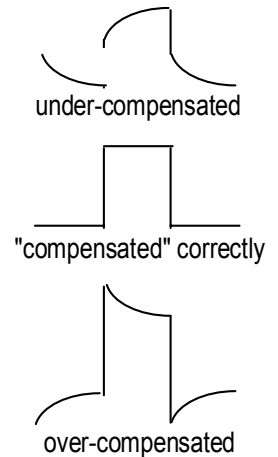
B-4. **Observe the test signal with the oscilloscope, and adjust the probe if the observed signal is not square.**

- * 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.)

- * Print and label appropriately a scope display that confirms that the probe is properly compensated.
- * Discuss whether you had any difficulties, and describe them.



C) Use the probe and Measure functions of the scope:

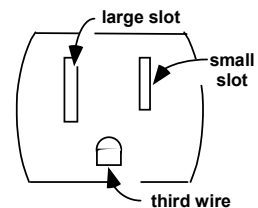
- * to identify which one of the three terminals of an AC outlet is the "hot" terminal
- * to determine the shape of its time-varying PD;
- * and to determine the frequency, amplitude, and RMS value of this PD.

C-1. **To have various features of the waveform on channel 2 measured automatically** (such as the frequency, period, peak-to-peak value, and RMS value for one cycle),

- * press **Measure** and use the upper selection box on the screen, and then other selection boxes as needed.
- * **The meaning of RMS:** RMS is a widely used abbreviation of Root Mean Square. The RMS value of a function is the Root (i.e., the square root) of the Mean (or average) value of the Square of the function. It is a common and useful way of specifying the size, if you like, of electrical quantities. You will gain more experience with this term in a later experiment (#6) this semester.

C-2. **An ordinary three-wire AC wall socket:**

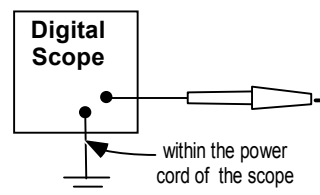
- * One of the electrodes is connected to ground (the so-called "third" wire).
- * Another typically is close to ground (the so-called "neutral" wire).
- * And the third is "hot", that is, has a large PD with respect to ground.



C-3. **Observe the potential available at each electrode:**

- * **You can use the oscilloscope probe** to search the openings of an AC socket on the wall or on an outlet strip to find the electrode "which is hot", i.e., at which a large electrical potential is present.
- * **For safety, put nothing but the probe tip into the socket!!**
- * Since the oscilloscope probe was not made for sticking in wall sockets, you will have to struggle to obtain a good electrical contact; try thrusting the probe tip toward the metallic electrode located at the side within each opening.
- * Press the **RUN/STOP** button to temporarily stop data acquisition and retain a desired waveform in the oscilloscope; press **RUN/STOP** again to restart normal operation of the scope.
- * How can you measure the difference in potential between two points if you are only using one "wire", i.e., the tip of the probe? What are you really measuring when you use the probe, or a single wire, connected to a scope input?

The answer: The scope "ground" is connected to the "ground" of the electrical system of the building via a wire in the scope's power cord. When you use the probe, you are measuring the PD between the point you touch with the probe and the ground of the building electrical system, which is close to the potential of the (local) earth in most cases.



C-4. Some questions!

Document your responses below with a copy of appropriate printed scope displays. Of course, a single printout may document several responses; you do not necessarily need a separate printout for each question.

- a. **Which of the openings is electrically "hot"?** _____
- b. **What is the (approximate) shape of the waveform at the "hot" electrode?** _____
- c. **What is the amplitude of this waveform?** _____ (Hint: you can carefully examine the waveform, or you can use and interpret the peak to peak (Pk - Pk) option of the Measure function.)
Describe how you determined this value.

- d. **What is the frequency of this waveform?** _____
Describe how you determined this value.

- e. **What is the period of this waveform?** _____
Describe how you determined this value.

- f. **What is the RMS value of this waveform?** _____
Describe how you determined this value.

- g. Did you expect any of the results you obtained above? Or are any of the values familiar, in some sense?

D) Comment on this activity in any other way that you think appropriate; in particular, discuss any difficulties which you encountered.

Staple together the pages for this Activity (#3) 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 #4: Determining the (very high!) speed of an electrical signal within a coaxial cable!

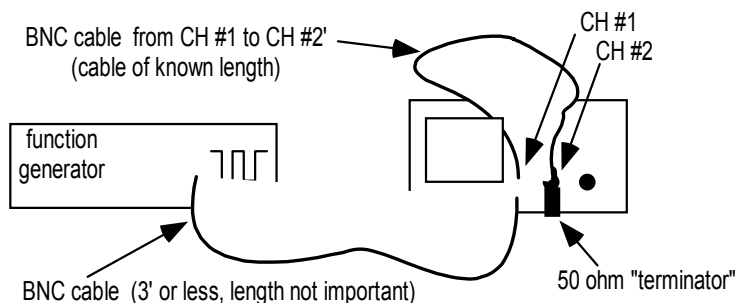
A) Assemble an appropriate circuit.

A-1. Prepare the oscilloscope for accurate time measurements.

- * remove all cables and connectors from the front of the scope; then press the UTILITY button and select DO SELF CAL. **Allow 1 min., 40 s for the process to be completed; spend your time usefully while waiting.**

A-2. Then assemble the circuit shown.

- * Place a BNC "Tee" adapter on both CHannel 1 and CHannel 2 of the scope.
- * To begin, connect CH #1 to CH #2 with a cable that is at least 2 m in length.



A-3. Place a so-called 50 ohm terminator on one side of the Tee adapter on CH 2 (to prevent reflections of the electrical signal by the end of the cable.)

A-4. Set the function generator to produce a square "wave" (i.e., square-shaped function) with a frequency of about 500 Hz.

B) Using the oscilloscope, observe **simultaneously the PD at CH 1 and CH 2. For a cable of known length, measure the **time** required for the signal to travel from CH 1 to CH 2! From this measurement, determine the speed of the electrical pulse in the cable. Again, document your work, including a printed copy of pertinent scope displays.**

B-1. Observe simultaneously the PD at CH 1 and CH 2.

- * Press the CH 1 Menu and the CH 2 Menu as necessary, so that both CH 1 and CH 2 are displayed.

B-2. From the scope display, determine the time delay of the signal at CH 2 with respect to that at CH 1.

Use two "time" cursors to automatically measure the time between the 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 corresponding points on the two waveforms.
- * Document this work. Include a printout of the display showing the cursors!
- * Measured time delay: _____

C) From your measurements, determine the speed of the electrical pulse within the cable.

- * Result for the speed of the electrical pulse within the cable: _____ ; _____
(Express your result both in S.I. units and as a percentage of the speed of light.)

Staple together the pages for this Activity (#4) 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: "Triggering"!!

A) Triggering - A definition and some explanations and requirements!

- A-1. To "trigger" the acquisition of data, we mean the electronic process that causes an instrument (such as an oscilloscope or computer) to acquire and store a set of data.
- A-2. Data for a finite period of time is stored, and it is critical that the event of interest occur during this period. If the trigger occurs too early or too late, the event of interest may be missed!
- A-3. If the event of interest is repetitive, typically the trigger should occur at the same time in each cycle, so that a display of the stored data is stable in time.
- A-4. Most instruments that store data require triggering. Only by storing data at a slow rate, or by having very large storage capacity, can an instrument simply store data continuously and avoid having a trigger.

B) The trigger time, i.e., the time at which the trigger occurs.

- B-1. The **downward-pointing arrow along the top edge of the display marks the time** at which the trigger occurred, that is, the time at which trigger circuits "told" the oscilloscope to collect data. AUTOSET places this arrow at the center of the display.
- B-2. **Why is there data to the left of the trigger time, that is, before the trigger occurred???**
Answer: On a typical analog oscilloscope, there is no waveform to the left of the trigger! But most digital oscilloscopes continuously store data, and keep writing over the oldest data until a trigger is detected. Thus, the oscilloscope already has some data stored when the trigger occurs! Thus you can see what happened before the trigger! Pretty clever, heh?

C) The trigger level, i.e., the value or "level" of signal voltage required for a trigger to occur.

- C-1. **The current trigger level** is indicated by the **leftward-pointing arrow along the right edge** of the display.
- C-2. **To adjust the trigger level**, turn the trigger level knob (on the right side of the front panel).

D) The trigger slope.

- D-1. The triggering signal can reach the trigger level either by increasing or decreasing in value.
- D-2. If an increasing signal is required by the trigger circuits, we say the trigger slope is set to be **rising** or **positive**.
If a decreasing signal is required, the trigger slope is said to be set to **falling** or **negative**.

E) The trigger "source", i.e., the signal used to trigger the acquisition of data.

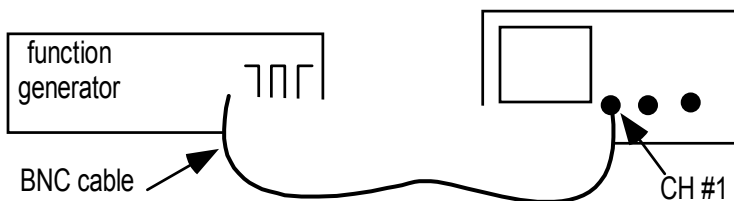
- E-1. One can select as the trigger source (the signal at) **input #1**, **input #2**, the special **external trigger input** (or that signal attenuated by 5), or the **AC power line**.
- E-2. We commonly will use the displayed signal itself as the trigger signal.
- E-3. AUTOSET sets the trigger "source" to the input that is displayed (#1 or #2), or to input #1 if both are displayed.

F) Observe the effect of varying the trigger level and slope on the displayed waveform.

F-1. Assemble the circuit shown.

F-2. Set the function generator to produce a sine "wave" (i.e., function) with a frequency of about 500 Hz.

Adjust the oscilloscope so that several cycles of the waveform are displayed. Use the AUTO trigger mode (press the **Trigger Menu** to check this).



F-3. Vary the trigger level and the trigger slope, and note the change in the display.

Do this long enough so that you understand the function of both these controls.

Print and label **appropriately** scope displays for each of the following conditions:

- * Positive trigger level and positive slope.
- * Negative trigger level and negative slope.

G) The three trigger "modes".

trigger mode	Description of this trigger mode
Auto mode	<ul style="list-style-type: none"> * This mode allows the oscilloscope to acquire a waveform even when the trigger condition is not satisfied. * If no trigger occurs within a set time (determined by the time scale used), the scope will trigger automatically. Since this trigger time likely has no relation to the displayed waveform, an unstable waveform may result. * AUTOSET selects this mode.
"Normal" mode	<ul style="list-style-type: none"> * In this mode, if no trigger occurs, no data will be acquired. On a digital scope, the previous waveform will remain displayed. On an analog scope, no waveform will be displayed.
Single shot mode	<ul style="list-style-type: none"> * In this mode, the oscilloscope will to trigger only once. To reset the trigger and repeat the process, one must press the RUN button.

G-1. Set the trigger level above the largest value of the waveform. Discuss what happens and why. (Hint: the scope is in the AUTO trigger mode.)

H) **Trigger "coupling"** determines the part of the signal used by the trigger circuits. Often one simply chooses the "coupling" that works best, e.g., gives a stable display.

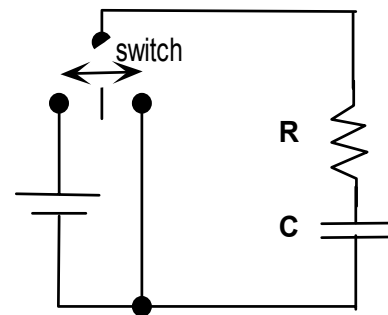
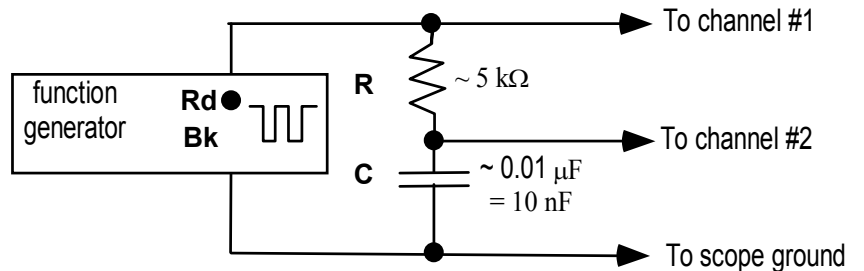
"coupling"	Effect on the trigger signal or circuits
DC	The entire signal is used. For us, this is a common choice.
AC	Only the time-varying part (the "AC" part) of the signal goes to the trigger circuits.
Noise Rejection	Reduces the sensitivity of the trigger circuits.
High Frequency Rejection	Attenuates the high-frequency components of the trigger signal.
Low Frequency Rejection	Attenuates the low-frequency components of the trigger signal.

Activity #6: The series RC circuit: Observing the exponential accumulation of charge on a capacitor
A) Assemble an appropriate RC circuit

A-1. Assemble the circuit shown. For now, do NOT make the connections to the oscilloscope; assemble only the circuit itself!

A-2. Set the function generator to produce a square "wave" (i.e., square-shaped function) with a frequency of 500 Hz.

A-3. **Some explanation:** In this circuit, we replace the switch and battery shown in the circuit in the pre-lab with a function generator set to produce a square wave output. The generator acts like an electronic switch, switching from one potential difference to another, much like a mechanical switch can switch between the potentials of two different batteries or points. Note that our generator can out-perform any mechanical switch; for example, it can switch back and forth very rapidly, up to several million times per second!



The circuit in the pre-lab

B) Using the oscilloscope, observe the PD across the RC combination, and also across the capacitor. Do this for various values of capacitance. Again, document your work, including a printed copy of pertinent scope displays.

B-1. **Make the connections to the oscilloscope illustrated in the circuit above**, so that you are prepared to observe the PD between various points in the circuit.

- * You can use the probe on channel #2 if you like. Or you can remove the probe and use an adapter and ordinary lab wire, much as you have done previously for Ch #1.
- * If you use an ordinary lab wire on CH 1, set the vertical scale for channel #2 so that it is properly calibrated for direct wire connection (1X setting). (Press CH 2 Menu, then select Probe on the screen as needed to obtain the 1X setting.)

B-2. **Use the oscilloscope to display simultaneously graphs of:**

- a) **the PD applied by the function generator across the series RC circuit;**
- b) **the resulting PD across the capacitor.**

Print and label appropriately any suitable scope displays.

B-3. **Is the finite time required to charge the capacitor in such a circuit evident** in any of your recorded waveforms? Discuss this matter.

B-4. Observe the effect on the waveforms of using capacitors of larger and smaller value than 10 nF.

- * As the capacitance gets larger, does the capacitor require more or less time to acquire charge? _____

Print and label appropriately any suitable scope displays that illustrate the effect of capacitors of different value.

C) Determine the "time constant" of the waveform of the PD across a "mystery" capacitor (i.e., a capacitor of unknown value) when used in the circuit above.

From this information, **determine a value for the capacitance of the capacitor, and compare this with a value determined independently using an accurate capacitance meter.**

Again, document your work fully, including a printed copy of pertinent scope displays.

C-1. Replace the capacitor in the circuit with a "mystery" capacitor of unknown value.

C-2. Use the oscilloscope to determine the time constant for this series RC circuit.

For this method to be accurate:

- Manually adjust the horizontal scale so that "decay portion of a waveform extends over a significant portion of the display (do you understand why?).
- Note that you can measure either the time constant or the "half-life", whichever you prefer, and then calculate one from the other. However, describe clearly the feature you measure, and label the interval on your printout; an acceptable description might read "the interval during which the potential fell from 4 DIV to 2 DIV above its asymptotic value". Adjust the time base as necessary so that you obtain a result of reasonable precision.
- Note that you must observe (or know) the asymptotic value toward which the curve is decaying in order to determine the time constant.
- Use two "time" cursors to automatically measure the time between the 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. Include a printout of the display showing the cursors!

e. Summarize your measurements below.

time interval measured: _____

description of feature contained within that time interval: _____

capacitor #: _____ time constant: _____

C-3. Use your results above to calculate the capacitance of the capacitor. Show your work below.

capacitance (determined from the RC time constant): _____

C-4. Use now the capacitance meter available in the lab to measure the capacitance of this component. Ignore the "zero" adjustment of the cap. meter; this is important only when measuring very small values, say, below 1 nF.

capacitance (using capacitance meter): _____

C-5. Calculate and record the percent difference between your two values of the capacitance. Show your work.

Percent difference between these measurements: _____

C-6. Most students are lucky if their result for the time constant is accurate to 20%, while the capacitance meter is specified to be accurate (for $C < 20 \mu\text{F}$) to $\pm 0.2\% \pm 1$ digit. In light of this information, comment intelligently on the difference between your values of capacitance.

D) Comment on this activity in any other way that you think appropriate; in particular, discuss any difficulties which you encountered.

Staple together the pages for this Activity (#4) 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. 2
Time-Dependent Electrical Signals

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version 22#2V4d3: reformatted a bit (using print driver HP Laserjet 2100 PCL 6)

FCP's personal miscellaneous junk that may be useful sometime:

Please discuss any difficulties which you encountered in this activity, or comment in any other way you think appropriate on this activity.

Comment on this activity in any other way that you think appropriate; in particular, discuss any difficulties which you encountered.