Laboratory Guide

You should refer to the course Syllabus for vital course information (grading, assignments, etc.); however, the information in this handout is just as important. The general information in this handout comprises three sections:

> standard procedures in the laboratory, which are rules you must follow for safety and courtesy; and
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> useful equipment information that will help you to complete the lab work more quickly and with more accuracy; and
>
> a guide to writing reports in EE124L (this section could well be called “a guide to getting an “A” in EE124L -- read it!)

Standard Procedures:

1. Hand in reports on the date due at the **beginning** of your scheduled lab section.

2. No open food or drink is allowed in the lab.

3. Students will work in groups of two. After groups are initially formed, the instructor must approve changes in groups.

4. EE124 students may not work in the lab outside of scheduled lab periods except under the supervision of an instructor. Students should make every effort to complete their lab work on time.

6. Students should check with an instructor before using laboratory equipment for purposes not covered in the handouts. Instructors generally approve of and encourage student-designed experiments; but check with an instructor first.

7. Check with an instructor before using any equipment brought in from another location.

8. Do not move probes or leads from one lab station to another.

9. Some hook-up wire will be available in the bookshelf area. **Please clean up the scraps of wire and insulation** that are generated there and at your own workstation. Please discard the scraps in the trash.

10. At the **beginning** of the lab make sure that your lab bench is clean, that it contains all the measurement and computer equipment and leads, and that the equipment is in working order. If this is not the case, immediately inform your instructor. In this case the group who previously worked on the lab station will be held responsible. For the same reason you must make sure that you leave your lab station in a clean and operational state.

Equipment:

The Oscilloscope

Most often, measured data will be acquired with the oscilloscope. The first lab will help the student become familiar with the digital oscilloscope used in this laboratory, and the student should read the following section before starting the first lab:

Probes:

Care: The probe tip usually uses some form of a spring-loaded hook that can grab small conductors (e.g., IC package pins, component leads, and other small wires). **Avoid applying any bending moment to the probe tip hook;** if it is bent out of shape it will not retract fully and will not make good electrical contact with small wires. On many probes, the spring hook part of the probe tip can be pulled off, exposing a small-diameter, gold-plated contact. This pointed contact can be used for probing in cases where the spring hook cannot grab (i.e., a copper trace on a printed circuit board). However, in our EE124 Lab, probes are supplied where the probe sleeve cannot be pulled off. **Don't attempt to pull off the probe sleeve.**

As a general rule: If you quickly probe around the circuit to check the bias, operating points, signal flow, then use a small exposed wire hooked by the hook part of the probe tip. If you make a series of measurements, for example at different power supply voltages or at different operating frequencies, then use the spring hook part. Then putting a short piece of wire on the protoboard at the measurement point and hooking up the spring hook on the wire works best.

Probes with Attenuation: The $1\text{M}\Omega$ $\left(10^6\Omega\right)$ input resistance of the oscilloscope input is often not high enough to prevent significant loading of the circuit under test. A simple way to increase the input resistance is to add a $9\text{M}\Omega$ resistor in series with the oscilloscope input. Then the input resistance is $9\text{M}\Omega + 1\text{M}\Omega = 10\text{M}\Omega$. The resistances form a voltage divider, and the voltage at the input of the oscilloscope is $\frac{1}{10}$ of the voltage at the probe tip. This series resistor is **built in** to a probe type commonly called a "times ten" or a "10X" probe. On older oscilloscopes, the operator had to remember to multiply the volts/division scale factor by 10 when using a 10X probe. On newer oscilloscopes, the instrument can to be "told" the attenuation factor of the probe so that it can give a direct readout of the voltage at the probe tip. In our lab, this item is under the channel/probe menu. **We are normally using 10X probes. But always check this out before you do measurements.**

One way to summarize the effects of a times ten probe is that the increased input resistance is achieved by tolerating some signal loss, and then making up for the loss with gain.

Probe compensation: The resistive voltage divider formed by a times ten probe has a Thevenin equivalent output resistance. This output resistance together with the input capacitance of the oscilloscope form a low-pass filter, which could greatly lower the bandwidth of the system. It is possible, however, to place a small capacitor across the series resistor to compensate for this effect and achieve a reasonably high bandwidth. The value of this small capacitor can be trimmed to obtain a flat frequency response within the system bandwidth.

The probes we will use have a compensation adjustment built into the probe's connector (the end attached to the oscilloscope). This adjustment should be trimmed to achieve a flat frequency response. A special tool should be used that has very little metal in it; if a metal tool is used the performance will change as the tool is withdrawn. The front panel of the oscilloscope has a probe calibration output to aid in making this adjustment. The calibration output is a $5\,V_{pp}$ square wave at approximately 1.2 kHz.

Figure 1 shows the resulting display[1] for a calibration signal input and a probe that has a high-frequency boost. This is evident from the overshoot present at each transition. This condition is called *overcompensation*. In this case, the probe compensation should be adjusted to decrease the response at high frequencies.

Figure 2 shows the display resulting from a probe with high-frequency loss. In this case, the probe is said to be *undercompensated.*

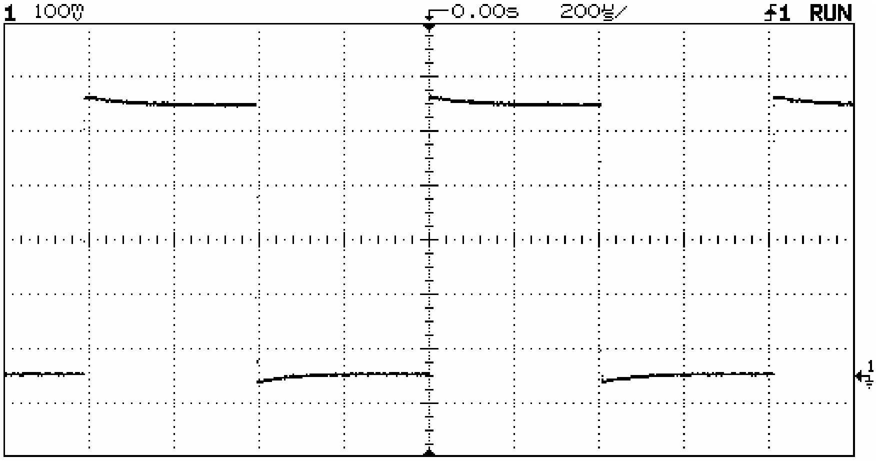

Figure 1. Display resulting from an overcompensated probe (Note: The sensitivity reading in the upper left should read 1.00 Volt/Div in our newer scopes instead of 100 mV)

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[1] The oscilloscope displays shown here are taken directly from the instruments using BenchLink Scope software, which is available at all lab stations.

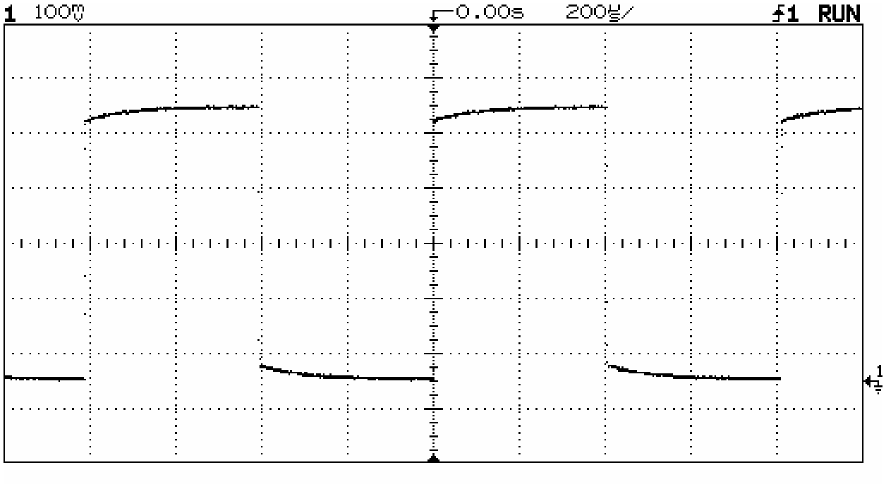

Figure 2. Display corresponding to an undercompensated probe (Note: The sensitivity reading in the upper left should read 1.00 Volt/Div in our newer scopes instead of 100 mV)

Figure 3 shows the display resulting from a probe with a flat frequency response. This is the desired condition. You should make the display look as close as possible to this when performing a probe compensation adjustment.

Note that checking the calibration output can also reveal if the oscilloscope “knows” it has a times ten probe on the channel. The calibration signal is known to be 5 Volts peak-to-peak, and the display should correctly show the amplitude. You should verify that Figures 1 to 3 do show the correct amplitude. Due to our restricted budget we use fairly cheap scope probes which replaced the much more expensive original HP probes. Unfortunately, due to student abuse of the scope probes, we could not afford to replace the original probes by the same counter part. There is an unmarked slide switch on the probe. Putting the slide in the forward position puts the probe in the 1:1 mode. Putting the slide in the back position puts the probe in the 10:1 mode. You should normally use the probe in the 10:1 mode for the EE124 Lab measurements.

In conclusion, it is a good idea to start each lab period by checking both probes on the calibration output. It should be noted, however, that each adjustment of the probe causes some wear. As long as the probes remain associated with the same oscilloscope input, they should not need to be adjusted frequently. Therefore, you should try to use the same probe on the same channel every time, and do not adjust the probes unless they need it.

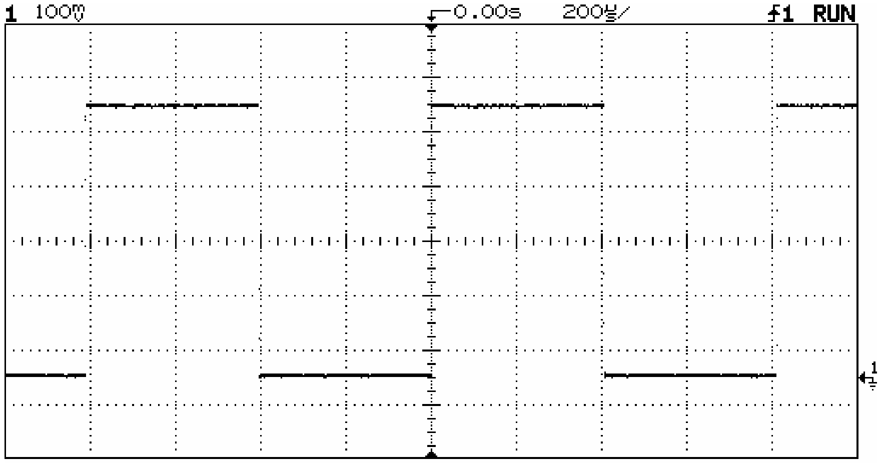

Figure 3. Display resulting from a properly compensated probe (Note: The sensitivity reading in the upper left should read 1.00 Volt/Div in our newer scopes instead of 100 mV)

Settings to Correct a Noisy or Unstable Display:

Bandwidth limit: The relatively high bandwidth of these oscilloscopes will increase the amount of noise present in the displayed signal. For low-level, low-frequency signals that are often of interest in the EE124 lab, deliberately decreasing the bandwidth of the oscilloscope can help to make a clear, stable display. To reduce the bandwidth of a particular channel, go to the channel menu and under "BW Lim" select "on". The Volts/division display on the screen will then include the symbol $^{B}_{w}$ to indicate that the bandwidth limit is on. This will make the display of a low-frequency signal appear to be clearer as the high-frequency noise is attenuated. Of course, when the full high-frequency performance of the instrument is needed, the bandwidth limit should be "off".

Display Averaging: When the displayed signal is periodic (e.g., a sine, triangle or square wave), the oscilloscope display is actually a sequence of "snapshots" of the waveform. The trigger circuitry makes sure that each snapshot shows the waveform in the same position; that is, the positive and negative peaks of the waveform appear in the same place on the screen in each snapshot. The result is a stable image of the periodic waveform. When noise that is not periodic (called *aperiodic* noise) is present, it will not be the same in each of the successive snapshots and will cause the trace to appear as a fuzzy line instead of a sharp one[2]. The digital oscilloscope can use an interesting method of eliminating aperiodic noise from the display. For each horizontal (time axis) coordinate of the display, the corresponding vertical (signal) value is averaged with other signal values (for the same time coordinate) from previous snapshots. The resulting display will converge to show the part of the signal that is the same in each snapshot

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[2] The fuzziness is not the same in each snapshot; it appears to be moving.

while “averaging out” the part of the signal that is different in each snapshot. Hence the fuzziness of the trace will be reduced.

To use display averaging, push the “Display” button. A menu should then appear at the bottom of the screen. Push the soft key labeled “average” and on the subsequent menu, choose the number of traces to be averaged (8, 64, or 256).

Trigger Noise Rejection: It is also possible to limit the bandwidth of the trigger signal. This will help stabilize the display *without reducing the bandwidth of the displayed signal*. In the trigger menu, push the button labeled “$\frac{\text{SLOPE}}{\text{COUPLING}}$” and under “reject” select “HF”. This causes the trigger circuitry to reject high frequencies. When displaying low-frequency signals, this can stabilize the display by preventing false triggering on noise.

Circuitry Problems: Sometimes the display will look fuzzy, or like the trace is much wider than it should be. This is sometimes due to the fact that the desired signal has a high-frequency oscillation added to it. Although the techniques above can reduce the effect of the high-frequency oscillation on the display, such a circuit needs to be ***fixed*** more than it needs to be ***measured***. Follow guidelines in the handouts for good layout, and always use bypass capacitors on the power supplies.

Obtaining an X-Y display

In the Horizontal section, push the “$\frac{\text{MAIN}}{\text{DELAYED}}$” button, then under “Horizontal mode” select “XY”. If any signal is connected to channel 4, it will affect the display intensity, and may hide part of the display.

The Function Generator

Operation of the HP33120A function generator is fairly straightforward and easy to figure out, at least with regard to generating standard sine, square, and triangle waveforms. However, one feature of this piece of equipment has caused some confusion. When the “Amplitude” function is enabled, the display will indicate the open-circuit (unloaded) output voltage of the generator[3]. Therefore, when the generator “sees” a high-impedance load (e.g., an oscilloscope input or some types of amplifiers) the output voltage will actually be very close to the displayed value. However, when the generator sees a load of less than about $1\text{K}\Omega$, the actual output amplitude will be significantly less than the displayed value. You must realize that the display on the function generator is not a measurement of the voltage at the output terminals; it is an indication of the voltage driving the output through a $50\,\Omega$ resistor.

The Digital Multimeter

The digital multimeter (DMM) is a useful tool for making a variety of measurements. Some common mistakes in its use are described below:

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[3] It is possible to set the display so that it indicates the output voltage that ***would be*** present ***if*** the generator were loaded by $50\,\Omega$. In this case, of course, the output voltage under unloaded conditions is twice the displayed value.

Resistors: Do not use the DMM to measure a resistance while it is in a circuit, whether the power is on or off. The DMM sends a known current through the resistor being measured and senses the resulting voltage across it, and then can calculate and display the resistance. This current can also flow through any other path present (e.g., the rest of the circuit the in which the resistor is located), reducing the voltage developed and causing the DMM to display a lower value for the resistor. For resistors above a few $\mathrm{K}\Omega$, even your body can provide a significant path for the test current, so do not measure resistors with one hand gripping each probe of the DMM! If a resistor is in circuit with the power on, additional currents may be present which will completely invalidate the measurement of the DMM.

AC voltages: When set to "AC", most DMM's are designed to display the RMS voltage of a sine wave. It usually arrives at the displayed value in one of two ways:

> 1) The DMM measures the average of the absolute value of the waveform. This is a cheap circuit to build. The relationship between this average and the RMS value for a sine wave is known, and a correction factor is applied to the measurement to get the displayed value. Hence this type of DMM will give an accurate AC measurement only for an input sine wave. The RMS voltage of a sine wave may be multiplied by $2\sqrt{2}$ to obtain its peak-to-peak voltage.
>
> 2) The DMM measures the true RMS value of any waveform. This is a more expensive circuit to build. The DMM displays this value directly without any correction factor. The RMS voltage of any other waveform is displayed correctly also. Recall that the relationship between the RMS voltage and the peak-to-peak voltage depends on the waveform, so it will not always be easy to infer the waveform's peak-to-peak voltage from the display.

DC voltages: When set to "DC", the DMM may not accurately measure the DC part of a voltage that contains both AC and DC components. For example, suppose that the user wishes to determine the output bias voltage of an amplifier (which is DC) ***while*** the amplifier is passing a signal (which is AC). The user will probably set the meter to "DC" in an effort to cause it to ignore the AC part and just measure the DC part (the offset or bias voltage). To do this, the DMM must average the signal over time. This operation requires the use of a low-pass filter (LPF). The DMM may have been designed to reject some AC noise when it is set to "DC", and it may therefore use a LPF in this mode. The LPF, however, was probably designed to remove a small (unintentional) amount of high frequency noise to stabilize the display. The meters are not usually designed to filter out large AC signals. Therefore, the AC may be passed on to the DMM's A/D converter with unpredictable results.

Another possible source of error in these circumstances is that the total instantaneous signal (AC plus DC) may contain peaks that overdrive the DMM's amplifier stages and distort the signal. If that happens, the average of the distorted signal will not be the correct value even if the LPF functions perfectly.

Here are two acceptable methods for measuring the output bias voltage of an amplifier:

> 1) Make sure that the amplifier is not passing any signal so that the output is essentially DC. Do this by setting the AC sources in the circuit to zero.

2) Use the oscilloscope to display the signal including AC and DC, then have it calculate the average voltage over one cycle (yes, it will do that!)

Writing Reports for EE124:

General

In this laboratory, students will practice their written communications skills in two main areas: 1) keeping a record of procedure and data, and 2) presenting conclusions based on an analysis of data.

The students will record their procedure and data in a laboratory notebook. At the end of each laboratory period, the student **must** hand in copies of the procedure and data taken **that** day (even if it is the first day of a two-week experiment). **The laboratory notebook must be written in ink.**

After the experiment is completed, the student will hand in a final report. There are two final report formats; an abbreviated final review report (Lab 1, 2, 3, 4) and a more detailed formal final report (Lab 5 & 7). The final review report contains an abstract and conclusions (and analysis as required). This type of report will not include the complete procedure and data as found in the lab notebook, but ***it will often be necessary to cite data in order to support conclusions***. The final review report may require a summary of collected data (e.g., a table or graph). It should be written such that a third person (familiar with Electrical Engineering concepts) understands the essence of the material covered without having to refer to additional documentation. The formal final report covers the total experiment, whereby the author must use report-writing skills (abstract, material broken down into logical sub-chapters, conclusion) to present the subject matter.

The Lab Notebook

Lab book: Your lab notebook must be a Lab Notebook by Roaring Spring Paper Products Item 77-644. In this book the pages are numbered in pairs, so that the carbonless copies will have the same page numbers as their corresponding originals. The lab book automatically copies whatever is written on a white page to the following blue page. Therefore, a thick piece of cardstock should be placed under the blue page being copied onto; otherwise, some of the writing may transfer through the following white page and onto yet another blue page.

Preparation of the lab book: Put your name, “EE124L”, your section number, the lab day and time, and “Fall 2005” on the outside of your lab notebook.

Page 1 of the lab book should have the following information recorded on it: The course number (EE124L); the section, day, and time; the lab station number; the students name; the name of the students lecture instructor; the name of the students laboratory instructor; and the semester (Fall 2005).

Page 2 of the lab book should have a list of the equipment at the student’s lab station. Include the make, model, and serial number of each piece of equipment at the station. For the purpose of inventory control please also record the ID of the PC, monitor, keyboard and mouse. When you use your lab notebook for data entry it is assumed that the equipment on page 2 was used. If equipment has to be replaced due to malfunction or calibration, make a dated note on page 2 to this effect, and record the ID of the new equipment.

Page 3-4 of the lab book should be a table of contents giving the starting page of each experiment. Make new entries in this table as each experiment is started.

Page 5 of the lab book will be the first page of Experiment 1.

Reason for using the lab book: During the process of research and development, it is vitally important that experimental procedures and their resulting data be recorded with precision. A good indicator for the amount of detail required is that another engineer (who is reasonably familiar with the particular subject) should be able to reproduce the experiment from the laboratory notes and get the same results. A detailed record of the procedure gives meaning to the data that is recorded. For example, data already recorded can sometimes be used for a purpose other than originally intended, as long as the procedure is well documented.

Students should therefore learn to record procedures accurately ***while the experiment is in progress***. This system will ensure that after the lab, when the student is analyzing data and writing conclusions, the correct data for each step can easily be found. It is also hoped that the student will save some time by not having to re-write the entire procedure for inclusion in the final report.

Although it is possible to download an image from the oscilloscope to the computer, and then print it, ***it is still necessary to sketch waveforms in the lab book by hand***. See the section on "waveforms" below. In other words, do not become too dependent on the computer aids. Having only one networked printer in the lab, it generally takes longer to generate computer printouts. In special cases, when instructed by the experiment description, you will need computer printouts for your final report.

Procedure: Each experiment in the lab manual describes the procedure in a series of numbered steps. The student will execute the steps in numerical order, following the instructions and recording the procedure in the lab book. Some steps will completely describe the procedure to follow***, but the student still must record the procedure in the lab book in his/her own words***. Do not copy the handout.

You must write a complete record. Don't assume that the reader of the report is also reading the handout. Suppose a report says:

> "It was 1.1 Volts."

How does the reader know ***what*** was 1.1 Volts? The statement above is not even worth partial credit because it is meaningless. The above example should have been written as a complete thought:

> "A peak voltage of 1.1 volts was measured at v_2."

Some steps will only state an objective, leaving the procedure for the student to describe. For each measurement, be sure to describe the conditions (the input signal, load, power supply voltage, etc.) present during the measurement if they are needed to interpret the data. For example, if the gain of a circuit depends on the load, be sure to record the load present when the gain is measured. Another example: if the performance of the circuit does not depend much on the power supply voltage (e.g., the AC performance of an op-amp) then only record the power supply voltages at the start of the experiment. Your procedure only needs to be reasonably complete and accurate. You may eliminate extra words to save space and time; completely correct grammar is not required.

Each time you start a new experiment in your lab notebook, write the experiment title centered on the top of a **new** page. Write a few general remarks about the experiment, such as the type of circuit under investigation and the measurements to be made. Then write "Step 1" and the procedure and the data resulting from Step 1. Next write "Step 2" followed by all the procedure and data resulting from Step 2. Do not combine the steps. Do not put the steps out of sequence. ***When the reports are graded, points will be awarded for each step based <u>only</u> on what is written following the corresponding step number.***

It should be noted that the lab book is not only for raw data. It is common for a researcher to make an observation while recording data. Therefore, the instructions for each step will sometimes ask the student to make a comment about a relevant principle or relationship. Simply write the answers to these questions in your lab book, as part of the step in which they appear.

<u>Schematics:</u> Draw schematics for every circuit tested. If Steps 1 to 3 use the same circuit, only draw the schematic for Step 1 and refer to that schematic when writing Steps 2 and 3. You can also refer to a schematic and describe a change with words. For example: "The circuit of Step 1 was tested except that R_5 was changed to $33\mathrm{k}\Omega$."

<u>Corrections and Formatting:</u> Since you will write the lab books in ink, you cannot erase any entries (you cannot erase the carbonless copies anyway). Simply draw a line through errors and then write the correct words or numbers. There is no penalty for corrections. If you take a whole page of bad data, simply draw a box around it, put a big "X" in the box, write "error" in the box, and then start taking new data. Of course, you should describe the error made and how you corrected it. Never tear out pages; the lab notebook must be treated as a single document. Also do not insert loose pages in your lab notebook. If you need to insert a SPICE figure or a computer printout, you must paste this information on the "original" page **and** on the carbonless copy. A classical example of a bad choice for notebook entry is Robert Peary's diary of his polar expedition in 1909. On April 6, 1909 he claimed to have reached the Northpole. However, "later explorers questioned this evidence, wondering why the entry was on a loose sheet inserted among other blank pages. The debate continued into the 1980's, when an investigation suggested that he may have been 30-60 miles short of the Pole."

When you finish writing a page in your lab notebook, and there is significant blank space remaining on the page (e.g., you want to start a new page so that a data table will fit on one page), you should cross out the blank area with an "X". Above the blank area, write "to next page" to clarify that the remainder of the page is intentionally blank**.** ***At the end of each lab period, place an "X" in any remaining blank space on the last page*** so that you can start a new page at the next lab period. This is essential so that you can hand in the copies of your work on that day.

Data: Whenever reasonable, make a data table. This is true even if the table has only two rows. The tabular form makes visual comparisons of the results easier.

Waveforms: The instructions will frequently call for you to make a sketch of a waveform in your data book. The word "sketch" implies a **rough** drawing that conveys only basic information about a waveform. A sketch should show the basic shape of the waveform (sine, square, triangle, etc.) and the maximum positive and negative peak amplitudes should be labeled. Also the frequency or period of the waveform should be made clear, either by labeling the time of one period on the sketch or by stating the frequency in writing. Put these sketches in your lab notebook; do not draw them on separate paper. Put the sketches along with the rest of the procedure and data for the given step.

The Final Report

General: The final report will have a title page, followed by an abstract page, and then the conclusions. The record of procedure and data is in the lab notebook; **there is no procedure and data section in the final report.** Instructions for the title page, the abstract, and the analysis and conclusions are found below.

- **The Title Page:** The first page of each final report shall be a title page. Please follow closely the format of the sample title page at the end of this section. In the upper right-hand corner of the page, on four lines, write:
-

  1) the words "Final report" followed by the **experiment** number
  2) the **course** number, laboratory **section** number, and **day/starting time** of the lab

  3) the **Lab Station** and
  4) the actual **date** of the lab handed in.

  Centered on the page, write:
  5) the experiment title, and beneath it
  6) the names of the authors of the report.

- **The Abstract Page:** The second page will also contain an abstract for the experiment. Do not put the abstract on the Title Page. The abstract should be on a separate page because ***it should be written after the rest of the report is finished*** and then placed at the beginning. This way, the student can reflect on the entire experiment before writing the abstract. See the section "How to write an abstract" below.

- **The Analysis and Conclusions Section in the Final Review Report:** The lab manual contains numbered questions for the student to answer. The student should write answers to the questions by the numbers and in order. Instead of restating the question, they should create a title for each question to be answered, so implicitly the reader will know the contents covered in each part. Be sure to write your answers as complete thoughts. **You will lose points if your answers do not make sense when read by themselves.**

For each question, you should cite relevant data from your lab notebook to support your conclusion. You must also show figures for the circuits under discussion, properly labeled so that items within the text can be easily traced on the circuit.

The questions in the final report may sometimes call for a graph to be made. If the graphs exceed half a page then put these graphs on a separate, full-sized sheet of appropriate graph paper and mark them with the number of the question to which they apply. Please be careful to distinguish between simulated and measured data. If you are asked to make a graph from your measured data, do not submit a graph taken from SPICE output. One good way to avoid misrepresenting data is to include either the word "simulated" or the word "measured" in the title of every graph.

- **The Final Formal Report:** This also contains a title page as specified and an abstract. However, instead of addressing stated conclusion questions, the total experiment must be described in a logical fashion paying attention to good report writing skills, like subdividing the Experiment into logical sub-sections. It must also contain a summary.

Paper and Writing: The final reports must be written on standard 8.5 by 11 inch paper. Do not write your final reports on pages from your lab notebook. There should be writing on only one side of each sheet of paper. The reports should be computer-generated. Only time-consuming parts, for example the writing of equations, sketches and circuits and annotation of graphs may be written in ***ink***. Words for Windows has need tools for equation writing. Attempt to use these tools as much as feasible in order to give your report a professional appearance. Corrections by lining out are acceptable. In computer-generated reports, ***use double spacing or at least*** $1\frac{1}{2}$ ***spacing*** to make room for comments. Pencil is not acceptable. The color red is reserved for grading; ***do not use red***. Do not put reports in plastic covers or other kinds of folders. Simply staple the pages together with one staple in the upper left-hand corner.

A Word about Academic Honesty: Each lab-group is expected to write a final report for each experiment. Groups may confer with other groups about items in the final report[4]. **However, students may not copy another student's answer.**

Do not use graded lab experiments from the last term as a guide to writing reports. The experiments do change slightly, and copying is easy to detect and prove. Copying answers from an old report shall be considered cheating as defined in the university policy on academic dishonesty[5] and severe penalties will be sought.

How to write an abstract[6]: The purpose of the abstract is to briefly acquaint the reader with the content of the report that follows. Abstracts are often no longer than about six sentences (the writer must choose words wisely). Abstracts for experiment reports

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[4] Actually, instructors are also quite willing to help!

[5] Document F88-10, Sections 1.1.1 and 1.1.2

[6] See also American National Standards Institute (ANSI) Z39.14-1979

should summarize the major accomplishments of the lab rather than detail every step. For example, if the purpose of a lab were to show that the gain-bandwidth product (GBP) of an op-amp was the same when calculated at different gains, the abstract would ***not*** explain the procedure for measuring the GBP. Instead, it would just say, "The GBP was calculated for different gains and found to be constant . . ."

In general, do not put numerical results in the abstract. Raw data belongs in the "Procedure and Data" section. Sometimes, if the purpose of the experiment is to establish some measurable level of performance, one might put that number in the abstract. Example: ". . . Operation in vacuum lowers the Brownian noise of a polysilicon accelerometer to below $1\frac{\mu g}{\sqrt{Hz}}$ " [7].

A word of advice: When writing an abstract, do not think about the sequence of events (what you did first, second, etc.). Think instead about what was accomplished (i.e., what overall goals were reached). That is why it is better to write the abstract ***after*** you have written the report.

It is a common mistake for students to refer to components such as R_1 or Q_3 in an abstract. The abstract must be written so that it stands alone from any diagram. For example, in an abstract you **should not write:**

> "The circuit of Figure 1 was constructed . . ."
>
> "The value of C_4 was reduced . . "

Instead, you **should write:**

> "A common emitter amplifier circuit was constructed . . ."
>
> "The value of the emitter bypass capacitor was reduced. . . "

> Hint: Make yourself a template in the beginning of the semester as shown on the last page in this chapter. Only 3 lines (Type of report and report number, date and title) have to be changed from report to report.

The Preliminary Preparation

No written preliminary report is due. However, part of the preliminary preparation is to study the experiment prior to coming to the lab. You have to be able to understand and answer the questions posed in the preliminary report part. Some preliminary items, for example your design approach and the resulting circuit must be entered into your lab notebook. Come well prepared to the lab. A periodic quiz will ask you questions on the previous experiment and on your preliminary preparation. In some cases you will be asked to bring the results of your computer simulations.

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[7] Bernhard E. Boser and Roger T. Howe, "Surface Machined Accelerometers" *IEEE Journal of Solid State Circuits*, vol. 30, no. 12, p. 366, March 1996.

Example of Title Sheet for Final Report

Final Review Report 3
EE124L, Section 7, T8:30
Lab Station 3
Oct. 18, 2005

Destruction of an Op-Amp
by
Jane Doe and Ethel Mertz