APPENDIX A

Lab Equipment Overview

HOW TO USE A LAB POWER SUPPLY

Power supplies like the one shown in Figure15 are easy to use, once the basics are understood. Use the supplies independently in this lab. Make sure both tracking buttons are in this setting.

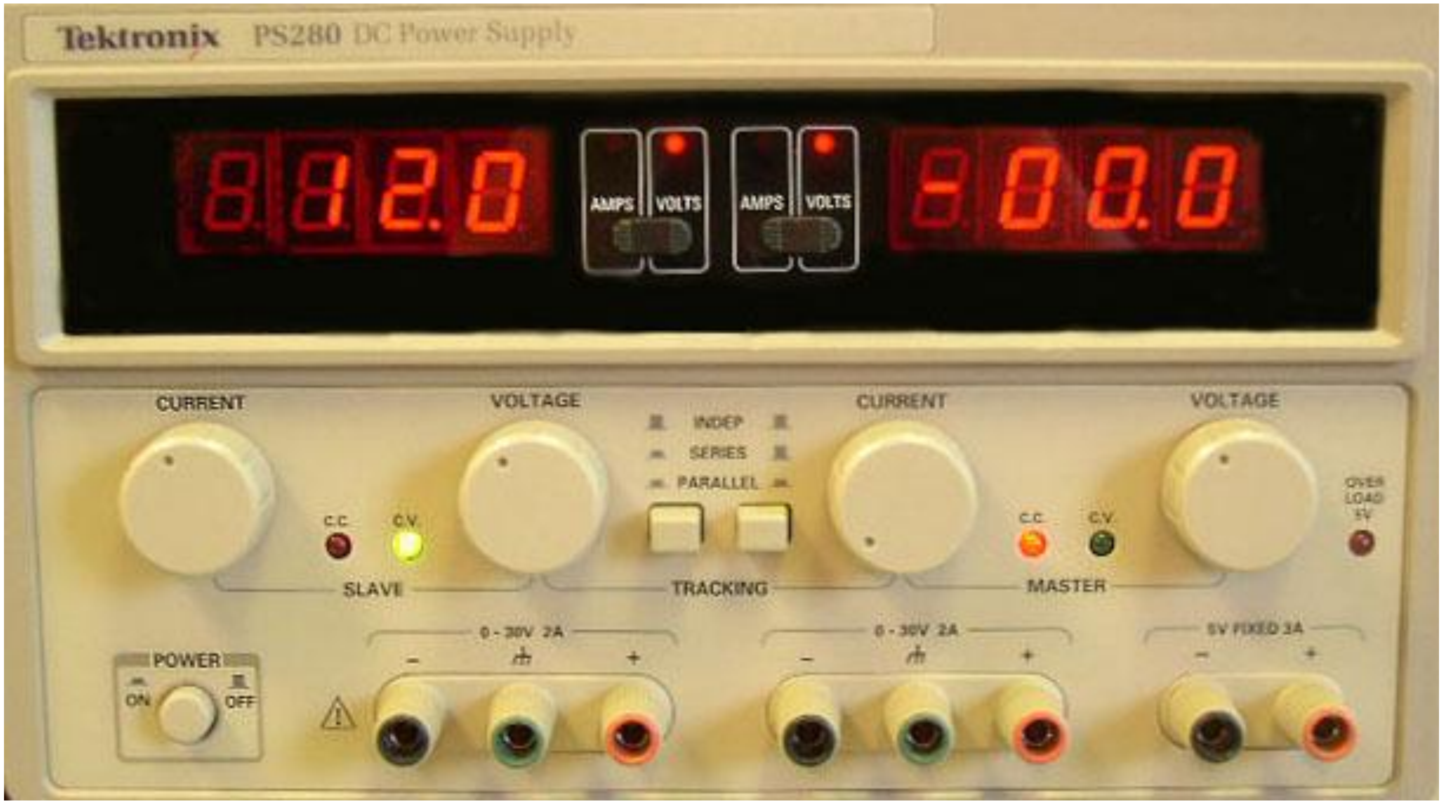

Figure 15: Tektronix PS280 DC Power Supply

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Following is an explanation of the controls/ indications on the power supply;

1. **The "CURRENT" knob:** This sets the maximum current that the channel will source. This is also useful to prevent accidentally putting too much current through your circuit.
2. **The "VOLTAGE" knob:** This is used to select the output voltage that the supply will maintain.
3. **The "AMPS" and "VOLTS":** The voltage and current being supplied can be read in the LED displays, by positioning the slider between "AMPS" and "VOLTS".

   The LED read-out may not be as accurate as you need. So, use a voltmeter to set the voltage if precision is required.

4. **The green "C.V." light:** This means that a constant voltage is being supplied, and this is also the *desired condition* for the power supply.
5. **The red "C.C." light:** This means that a constant current is being maintained, regardless of your voltage setting. This current is going to be the maximum current that you set with the "CURRENT" knob. If this light comes on, either fix your circuit, or increase the current limit to a more suitable value.
6. **Connectors:** Normally, you would use the red and black banana jacks to connect your circuit to the power supply. The green connectors are "earth grounds", and they may be used as your ground. However, this is not usually required.

   An earth ground is a connection to the planet Earth. The third prong of a power cord is also an earth ground.

Note: There are times when you need to supply a negative voltage. In this case, you would connect the red, positive connector to your circuit's ground node. Then, attach the black, negative connector to the node where negative voltage is desired.

PSPICE NET-LISTS AND SIMULATIONS

Some people prefer to write their net-lists by hand, while others prefer to use the PSPICE schematic tool to create it for them. If you use the schematic tool to generate your lists, then you will need to edit the list to give it human-readable names. Let us suppose that you wanted to create a net-list for the simple circuit shown in Figure 16.

Follow these steps to create a net-list:

1. You would first need to draw the circuit as you did in *Electrical Fundamentals (I)* (ENGR 201).

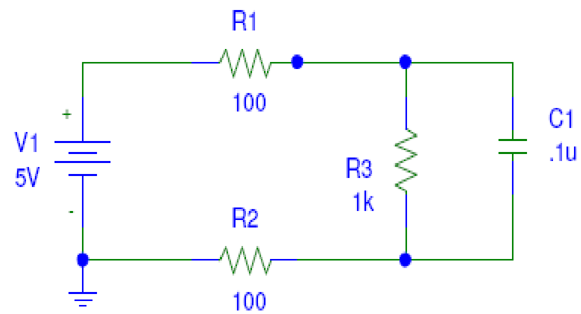

Figure 16: A very simple circuit

2. Run the net-list generator by selecting **Analysis** menu → Create Net-list. A *.net file will be created in the same directory as the schematic. The generated net-list is shown in Figure 17. This net-list contains computer-generated variables and is difficult to read and understand. However, a better (and preferred) approach would have been to manually create the net-list as shown in Figure .

```
* Schematics Netlist *
R_R3          $N_0002 $N_0001  1k
V_V1          $N_0003 0 5V
R_R2          0 $N_0002  100
C_C1          $N_0002 $N_0001  .1u
R_R1          $N_0003 $N_0001  100
```

Figure 17: Generated net-list

```
* simple_circuit.net

V1          3 0  5V
R1          3 1  100
R2          0 2  100
R3          2 1  1k
C1          2 1  .1u
```

Figure 18: Hand-created net-list

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Create a net-list (Contd.)

3. A net-list is just the beginning of the process. Instructions must be given to indicate exactly what analysis you want performed on the circuit.

   As an engineer, it is far more professional to be able to write your own net-lists that are neat and easy to read.

   If you are not familiar with net-lists, then you may choose to have PSPICE generate your net-lists until you can remember how, but do not come to rely on this crutch.

4. Add these commands to your net-list.
5. Save it as a *.cir file.
6. Open this file with the program "PSPICE AD Student". The simplest simulation of the circuit would be to run the file, as shown in **Error! Reference source not found.**9.

```
* simple_circuit.cir
* Basic analysis to find node voltages
.OP

V1          3 0  5V
R1          3 1  100
R2          0 2  100
R3          2 1  1k
C1          2 1  .1u

.probe
.END
```

Figure 19: A simple analysis

7. An output-file is generated once this circuit-file has been simulated. Create your own *.cir file.
8. Run the simulator.
9. Read the output-file and analyze/ observe the following:
   (a) What kind of information is present?
   (b) This kind of simulation is informative, but gets boring quickly.
   (c) It would, therefore, be a lot more interesting if we could run the analysis with different values for the voltage source V1.

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Create a net-list (Contd.)

10. The circuit shown in **Error! Reference source not found.**0 demonstrates several new concepts.

```
* simple_circuit.cir
* Basic analysis to find node voltages
.OP

V1          3 0  5V
R1          3 1  100
R2          0 2  100
R3          2 1  1k
C1          2 1  .1u

.DC V1 0 10 1
.print DC V(2)
.probe
.END
```

Figure 20: A more useful analysis

11. In Figure 20, notice the command ".DC V1 0 10 1". This command does a DC sweep of the voltage source V1, starting at 0V and increasing to 10V in 1V increments.

> A "DC sweep" refers to a type of analysis, where a DC voltage source has its value changed several times in one simulation. The command to do a DC sweep is ".DC". It takes a starting voltage, an ending voltage, and the voltage by which to increment each time.

12. Also, in Figure 20, the last command added, ".print DC V(2)", causes a print-out of the Node 2 voltages to the output-file. This type of the data output is useful to:

    (a) Find numerical values quickly.

    (b) Import the data into a different plotting program.

13. The output-file will now have the DC sweep values of V1 automatically included, so that you know which value of the Node 2 voltage corresponds to which V1 value. A graphical view of these values is often valuable.
14. Add a trace for "V1" and "V(2)" to the plot after the simulation is run, in order to see a graphical plot, or just input the values from the output-file into a separate graphing program.

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15. The .print commands can be used just like a trace in the graphical output. You can measure both currents and voltages simply by adding additional parameters to the "print" statement. For example, you could add V(1), I(1), and I(2), to get the voltage and current for both Nodes 1 and 2.

SIMULATING SEMI-CONDUCTORS AND INTEGRATED CIRCUITS IN PSPICE

The PSPICE program contains information regarding only the most basic components, such as voltage sources, resistors, and capacitors. If you want to use a specific diode, transistor, or op-amp in your circuit, you must use a SPICE model.

A model is a long list of parameters that describe a complex circuit element in the basic components that SPICE can understand. For example, a real diode can be modeled as a voltage source, in series with a resistor. A detailed model will also include many of the *Device Physics* features that you learned about in *Electronic Materials and Devices* (ECE 317), such as junction capacitance.

The schematic entry tool has some basic libraries that it can use, so that you do not have to use the models. However, you would be lucky to find the exact device that you need. At best, you might find a similar device that you can use, in order to get a rough idea of how your circuit might perform. For example, the libraries contain models for a 1N4002 diode and a 2N3904 transistor, but you will be using a 1N4004 diode and a 2N4401 transistor. The 1N4002 can probably be used inter-changeably, but the transistors will act slightly different.

Manufacturers often make SPICE models available for download, and this will probably be your most reliable source for SPICE models. An example of a 1N4004 diode PSPICE model is shown in
Figure 21. You may find it easier to download this model from the Fairchild Semiconductor Web-site, rather than typing it in by hand.

```
* 1N4004 - 1A 400V General Purpose Rectifier
* ---------------------------------------------
.MODEL  1N4004  D
+ IS = 3.699E-09
+ RS = 1.756E-02
+ N = 1.774
+ XTI = 3.0
+ EG = 1.110
+ CJO = 1.732E-11
+ M = 0.3353
+ VJ = 0.3905
+ FC = 0.5
+ ISR = 6.665E-10
+ NR = 2.103
+ BV = 400
+ IBV = 1.0E-03
```

Figure 21: Model of a 1N4004 diode

In Figure 21, pay particular attention to the line ".MODEL 1N4004 D". This line tells you that this is a diode "D", which you use by adding the name "1N4004" to the end of your part in the net-list.
See Figure 2222 for an example of a net-list that replaces R1 with a diode.

Notice that instead of pasting all the text of Figure 21 into the net-list, you can save it in a separate file, and then include it with the ".inc" command. Either method will work, but using "include" commands keeps your net-list-file readable, even when using monstrous models like the LM741 op-amp.

Also, notice that the net-list entry for D1 has the name "1N4004" after it, which tells PSPICE about the model to use for this device.

A diode only has two terminals, making it an easy device for which to create a net-list entry. The first net is the anode and the second is the cathode.

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```
* simple_circuit.cir
* Basic analysis to find node voltages
.OP
.inc 1N4004.mod

V1  3 0  5V
D1  3 1  1N4004
R2 0 2  100
R3  2 1  1k
C1  2 1  .1u

.DC V1 0 10 1
.print DC V(2) V(1)
.probe
.END
```

Figure 22: Net-list using a model

Notice that the diode's name is "D1". This is because the 1N4004 model specifies the name "D" to be used with it. If you use a sub-circuit, then you must use an "X" name instead.

HOW TO USE THE TEKTRONIX CFG250 FUNCTION GENERATOR

In this section, you will be using a function generator as your small signal AC source. Figure 23 shows a Tektronix CFG250 Function Generator.

> Be careful not to load the function generator by more than 10mA, as it is not designed to support large current loads.

To attach your function generator to the circuit, follow these steps:

1. Attach your BNC to alligator clips cable to the "Main" output connector of the function generator.
2. Set the "Volts Out" push button for the 0-2V or 0-20V range, depending on your voltage requirements.
3. Press the "Function" button corresponding to the waveform you need.
4. Press the "Range" button for the desired range.
5. Adjust the "Frequency" dial to the desired frequency.
6. Turn the power on to the function generator.
7. If your signal needs a DC component, pull out the "DC Offset" knob, and adjust it to the desired DC bias point. (Use your oscilloscope to measure the DC offset).
8. Adjust the "Amplitude" and the "Frequency" dials to the desired settings, while using an oscilloscope to precisely measure the output signal.
9. Attach the signal generator to your circuit.

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Figure 23: Tektronix CFG250 Function Generator

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Appendix B
Project Design Specification Document

DOCUMENT OVERVIEW

Modern engineering requires groups of engineers to work together, possibly across large distances, to develop sophisticated systems. In order for all of the parts of a project to work together, a project specification document is vital. Development of a project specification document is ***always*** the first step in any project. Unless all engineers working on the project have the same understanding of the project pieces, the final result will not function.

Project specification documents come in many a varied format/ outlook. Sometimes they will be formal written documents like those submitted for patent approval. Other times they may be 'back of the napkin' sort of documents that give only the briefest explanation, but help an engineer to stay focused. For this course, you will be writing a project specification that is somewhere between the two. You will have a formalized structure to follow, including typographical layout and document length.

It is important to realize that in many of the courses you will be taking up in later terms, you will be asked to produce design specifications. The sections and content may vary slightly for each course: so, pay attention to what is asked for, in the requirements. For example, in your *Senior Design* course, you will be asked to write a very in-depth design specification for your final project. Remembering what you have done in these early courses will dramatically improve your success during the senior design implementation.

DEVELOP THE PROJECT SPECIFICATIONS

When developing any project specification, a few general steps should be taken. In order to make a complete design, use these basic guidelines:

- Conduct a technology review.
- Come up with a top-level design.
- Outline the testing process.

Conduct a technology review

The first step in developing the project specifications is to review the 'state of the art', which is more commonly called a **technology review**. This can be achieved thus:

- Find projects similar to yours.
- Review other similar projects.
- Tabulate the results with a comparative analysis.

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- Make final analytical conclusions from the review.

Find projects similar to yours

This first step involves finding similar projects and digging into them to **see how they were accomplished**. Often times, this could be combined with a market analysis as well, if the project will result in a product to be sold.

When working on a new project, you may find that there is nothing on the lines of what you want to design, in existence yet. (This is a good thing, since it means you have something no one else has, and can set your own standard for it.) But, it also means that you cannot make a direct comparison. However, you are most likely to find at least one other project that has some of the same aspects for your comparison. For example, you might not be able to find many examples of three-phase power generators; but, DC generators have a lot of similarities.

Review other similar projects

Ideally, you should review an infinite number of projects that help you to understand what others have done, but infinity is an awful big number. As a rule of thumb, the more the better, and the more complex the problem, the more projects to compare that are necessary. For the simple project in this course, **five to six projects** should be sufficient. If you are having trouble finding projects to review, be sure to search projects under the topics of commercial products, student projects, large scale generators, and the like.

Tabulate the results with a comparative analysis

Once a full technology review has been conducted, you should be able to generate a table that has your project as well as the other reviewed projects together. The table should have **key information that allows you to compare them**, in the method "apples to apples *and* oranges to oranges." For example, if there is a power generator project that has information on cost, size, output watts, and method of generating power, you can compare your project with that, using the same parameters.

Make final analytical conclusions from the review

Using all of this information you should be able to decide on the **features and design trade-offs** required, so that you can explain your project specification. It is important that all of your design choices are backed by solid facts and reasoning, and that you understand the basis of the analysis that you are using to make each decision.

This is a powerful tool, because if any of your base assumptions are changed by new information, you can quickly revise any decisions that were made, to conform to the new information.

Come up with a top-level design

Any design can be broken down into three components: **inputs, outputs, and function**. To come up with the final design, follow these steps:

- Start with a generic design.
- Remove any ambiguity.
- Split the generic design into more well-defined components.

Start with a generic design

This simple idea can be easily (and often is), represented as a block diagram like the one in Figure 1.

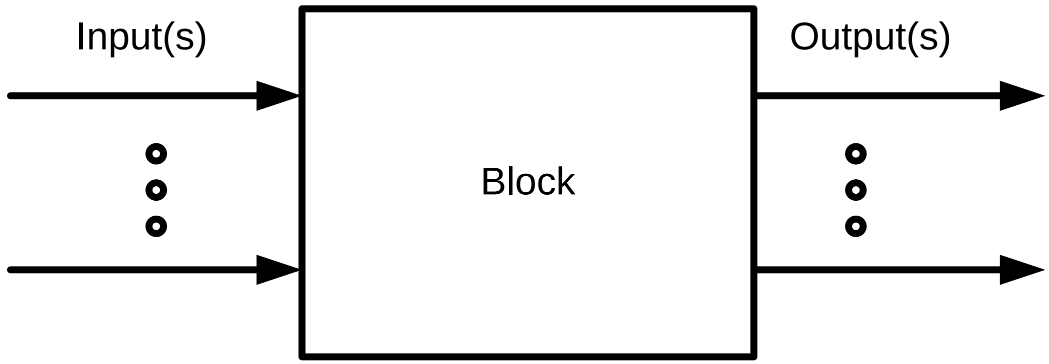

Figure 1: Generic design represented in a block diagram

This simple design could have any number of inputs and any number of outputs. Its function could be defined as simply as, "**Definition I:** Input 1 is added to Input 2, and is sent to Output 1." However, its function could also be as complex as, "**Definition II:** Input 1 will be used to power the system."

Remove ambiguity

In the above definitions, even though the number of words in the description is about the same, the amount of ambiguity in Definition II is much larger. This ambiguity is what leads to mistakes and differences between what two engineers design. For example, if one engineer assumes that the system will be supplied with 1000W of energy, and another engineer assumes they only need to supply 10W of energy, nothing will work well or as expected.

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Split the generic design into more well-defined components

To illustrate how you could make a generic design more well-defined, consider the design for a generator. For a generator, you might start with a block diagram like the one in Figure 1. This diagram is the simplest one that could be produced. From this simple diagram, you should use ‘top down design’ to split it into smaller and smaller more well defined components. These smaller components allow you to specify every piece of your design clearly and concisely.

Description: The generator block accepts motion input, and through magnetic coupling, generates a voltage and current capable of charging a portable device identified by the designer.

Signal Name	Direction	Description
Motion	Input	This is the energy input to the system. Motion: Rotational Min. Speed: 100 RPM Max. Speed: 2000 RPM Nomin

Figure 2: Example of a design with well-defined components and their descriptions

The question that rises is: **How do you know when to split a component-block into further components?**
You should split any component-block that you cannot fully understand how to implement, into further components. For example, you may not know how a digital wrist watch performs. However, once broken into its individual parts, such as: display, crystal, buttons, state machine, casing, battery, etc, you might find it easier to understand. If one of those pieces is ambiguous, you would again further split it down in more sub-components, to get a more complete picture.

Outline the testing process

The final yet very important section of the design specification is explaining **how the project will be tested**, to ensure that it meets the requirements and goals defined in the project specification.

This could involve outlining the following qualitative/ quantitative testing procedures/ requirements:

- Measurements.
- Long-term usage.
- Destructive testing
- Others.

The tests that are chosen will be depend on and determined by the project. By and large, these tests are very simple.

For example, if a requirement for a design is that the device be portable, the test for this might be: "The team will ensure device portability by having one member of the team pick the device up and move it across the room." Or, you could instead specify it as: "The device will not weigh more than 20 pounds, and will not be larger than 12"x12"x12"."

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APPENDIX C
Presentation Pointers

OVERVIEW

The purpose of any form of *technical communication* is to inform, not impress. Classes that need students to give a *technical* presentation, actually require one that falls in the genre of *formal* presentation. This document falls in the same genre too. In addition, there is sometimes the requirement for the student to submit the written matter of that presentation in hard or soft copy. This document is therefore intended to help you with some basic tips to refine the outlook of a technical presentation, both for the presenter as well as for the presenter's document. Use them as guidelines and the result will be a well-prepared, well-presented, professional presentation.

OBJECTIVES

Any formal presentation has the following key features that presenters need to focus on:

- Writing the document to be submitted for the presentation.
- Outline of the presentation content/ slides.
- Communicating effectively through presentation media.
- Dressing right and using the right body language for the presentation.

Writing the document to be submitted for the presentation

Assuming that you have researched the presentation subject very well, and have sufficient and relevant presentation matter, write/ type a rough draft and then refine it as you progress.

The tips for the written material (that you would submit at the end of the lab) include:

- Outline of the document content.
- Content of the document.
- Language of the written document.

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Outline of the document content

The outline of the document (i.e. introduction/ body of the document/ conclusion), are explained later in this document under the section: ***Outline of the presentation content/ slides.***

Content of the document

The content of the document would be similar to what you present in class as well. Following are some quick tips to start you on the content of the document, as well as on the slides:

1. **Make a rough draft:** Write down a synopsis of your goals, which would essentially be the purpose of the document.
2. **Research the goals:** Use reliable Internet resources/ the Library/ conduct surveys or interviews and get valid information to support your goals.
3. **List five important facts:** Depending on the length of the document, select any five goals/ concepts on which to focus the basis of your document, and arrange them in order of chronology/ priority.
4. **Add appropriate visuals:** A picture is worth a thousand words. Any part of the document text that can be replaced/ enriched with a visual will create more impact than just plain-text.
5. **Cite all your resources:** Check all author-date citations and all entries in the reference list for both accuracy and conformance to the format being imposed for your document.
6. **Proofread:** Use the spell-checker and/ or have a friend peer-edit the document before submission.

Language of the written document

Each document has a voice. Here are a few tips to observe, in order to ensure the language is not offensive or ambiguous:

1. Use a clear and informal style, avoiding unnecessary jargon and acronyms. Acronyms can be used when it is understood by both the audience and the writer.
2. Preferably, use the first person and active voice.
3. Avoid language that might be construed as sexist/ racist/ politically incorrect.
4. Analyze the audience (international/ multi-cultural/ academic diversity). For an in-class, technical presentation/ submission, the presenter typically does not need to worry about the nature of the audience, but this is a handy tip that most presenters tend to overlook.

Outline of the presentation content/ slides

These tips are of paramount importance to forming a powerful outline for any technical document and/ or presentation slides:

1. **Start with a welcome-slide.**
   The first slide welcomes the audience, (and it is worthwhile to make a mention of notable attendees), and then introduce yourself. (This would conform to the cover-page of your written document).

2. **Spell out your conclusion or summary first.**
   Most people attending a presentation will "remember" no more than five concepts. Ideally, the presenter should have a list of the five most important points/ concepts/ facts that should be remembered. This introduction with the concepts should **spell out the agenda** for your presentation. Giving your audience a framework of understanding at the beginning allows them to easily integrate information into their knowledge, because they already have a 'place to put that information.'

3. **Highlight the main concepts, using visuals and minimum text.**
   a) Use an 18-point (or higher) font size for your slides. Also, use an appealing but light-and-bright solid background color for the slides.
   b) From the above-mentioned five primary concepts, allocate an average of two slides of text to each main concept.
   c) Have about four to five key points for each concept.
   d) Write these key points briefly in short one-liners, and elaborate on the points in the speech instead.
   e) **About three visuals** for the entire presentation should be sufficient, as long as they give appropriate and complete backing to the associated content.
   f) Too much information, small-size text, and unclear visuals renders the presentation less effective in terms of message-delivery.

4. **Cite any sources** for visuals/ text, by mentioning it verbally or including it on the slide, in a smaller footer area..

5. **Have a strong conclusion.** Make the closing short and sweet. Re-iterate the three dimensions of your message (what, why and how) in a powerful one-slide finale to the presentation. A good rule of thumb is to use 10-15% of your time for the ***opening*** and 5-10% for the ***closing***.

6. **Question-time.** Make the discussion open to questions from the audience after your closing. Answer the questions as briefly and concisely as you can. It is best to paraphrase the question before answering it, to clarify it in your mind and to make sure you understand the question. If you do not know the answer, say so. Do not try to make one up.

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Communicating effectively through presentation media

To make your presentation more than just a stand-up speech with the whiteboard and markers as your tools, add pizzazz to your presentation by taking advantage of the multimedia tools. **Confirm with your professor/ TA as to what multimedia will be available for that day/ classroom.** Any of the following will make your presentation more effective:

If a computer will be available for your presentation, digital slides maybe a good choice for your presentation. However, make an intelligent decision because if slides are not needed or are an ‘overkill’ for your presentation, do not endanger your presentation by using them.

If you do decide to make digital slides, bear these guidelines in mind:

- **Use Microsoft PowerPoint or even Adobe PageMaker:** These **are** ideal for adding color, background theme, convenience and dynamic appeal to your presentation.
- Read and use the tips mentioned in the previous section, “*Outline of the presentation content/ slides*”, to create your PowerPoint slides.
- **Confirm with your professor/ TA regarding what storage media (**i.e. **USB mass storage removable disk, CD, etc) you can use, and/ or if you can bring your own PC-notebook, or if there is wireless network access, with which to launch your PowerPoint presentation.**
- Allow the audience at least half to one minute to read a slide with important, concise, bulleted points and stress or elaborate on them verbally.
- Do not read your slides for your audience, because they can usually do that themselves. Instead, use your time to maximize impact by elaboration or descriptions and examples.

Dressing right and using the right body language for the presentation

The document and slides are not the only aspects for the presentation. In order to be effective in delivering the message, the presenter needs to bear in mind a few key-points as well. This has to do with dressing appropriately and using the right body language.

The ideal way to present yourself successfully is to use the three main components of person-presentation, commonly called **the three Vs: Visual, Vocal,** and **Verbal**.

Visual

The first thing your audience members see is your appearance. Your body language will also send the audience a message. Before you get a chance to say a word, some of them will already have judged you based solely on how you look. Your visual outlook therefore comprises of your ***attire*** and ***body language*.**

Tips for presentable ***attire***:

- You can never be faulted for looking "too professional," even if the audience is dressed down.
- Formal clothing makes the audience accord you respect.
- Comfortable clothing helps the presenter to move around easily.
- Be certain that your outfit and accessories do not detract the audience from your presentation.
- Avoid anything that makes noise or looks flashy, like jangling bracelets or earrings.
- Avoid having money and keys in the pockets, especially if you have a tendency to put your hands in the pockets.

Tips for using the right ***body language***:

- Do not cross your arms or fidget.
- Use gestures to emphasize points, but be careful not to flail your arms around.
- The most effective stance is a forward lean, *not* swaying back and forth or bouncing on your feet.
- Make regular eye contact with audience members, holding the connection to complete an idea. Look around with a panoramic view while you speak. Effective eye-contact helps draw listeners into your speech.
- Nodding to emphasize a point also helps make a connection with the audience. If you nod occasionally, audience members will too -- creating a bond.

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Vocal

If you have ever listened to people speaking in a monotone, or too softly, you know how difficult it is to pay attention. There are six ***vocal cues*** to remember: pitch, volume, rate, punch, pause, and diction.

- **Pitch and volume**: It is very important to speak loud, clearly and enunciate. When you look down, your voice drops.
- **Rate:** If you rush your delivery, the audience will have to work too hard to pay attention. Vary your tone and speed and tailor your delivery rate to accommodate any regional differences. Keep your chin up while speaking, and do not bury it in note-cards.
- **Punch and pause:** Emphasize or "punch" certain words for effect, but do not forget to incorporate pauses to give the audience time to let important points be understood.
- **Diction:** Proper diction is also essential; if you are not sure how to pronounce a word, look it up or do not use it.

Verbal

There are three ***verbal communication rules*** to remember:

- Use descriptive and simple language.
- Use short sentences.
- Avoid buzz-words and jargon.

Video-tape your presentation or practice in front of a friend. Watch your expressions, body language, vocal and verbal delivery, and your confidence level. See if you have smiled enough and in appropriate places.

CONCLUSION

As with most documents, this document re-caps the main points to remember for the final presentation:

1. **Know the purpose, audience, and logistics** (such as time-limit for presentation, whether each member talks or just a team representative talks, and the visual equipment available for the presentation).
2. **Prepare and research adequately** (with an opening that creates impact, and a closing that ends with strength).
3. **Create a user-friendly draft** (that makes use of the available multimedia, such as PowerPoint presentation).
4. **Most important of all: PRACTICE WELL prior to giving your presentation.** (Video-tape yourself or envision a set-up similar to the presentation while practicing the speech delivery).
5. **Arrive early** (to meet up your team, check that the visual equipment works, go over the slides).
6. **Apply the delivery techniques** as a presenter (visually, verbally and vocally).
7. **Handle questions and answers with tact.** (Stick to the time-limit, so that there is time for the Q&A session).

8. **Be confident** (especially after you have read and applied the above techniques for an excellent presentation)!

REFERENCES

Following is a list of sources that were referred to extensively, in the making of this document. You are encouraged to refer to these sites, for more presentation pointers, apart from those outlined in this document.

1. Society for Technical Communication
   http://www.stc.org/

2. The Art of Communicating Effectively
   http://www.presentation-pointers.com/

3. National AV supply
   http://www.nationalavsupply.com/

4. Chicago Manual of Style
   http://www.libs.uga.edu/ref/chicago.html

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APPENDIX D
Tektronix TDS 210 Oscilloscope

SECTION OVERVIEW

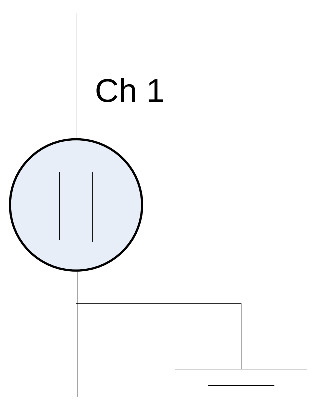
This document gives you an overview of the functions of the **Tektronix TDS 210 Oscilloscope** used in the ENGR 201 - 203 labs. It also shows you how to properly connect the oscilloscope with your circuit to measure different quantities. You will notice that the oscilloscope is often referred to in lab as well as in lab manuals as **'scope' or sometimes 'oscope'**.

Read the lab handout *The Oscilloscope* first, to understand the meanings of the terms used in this guide, specific to the **Tektronix TDS 210 oscilloscope.** Most of the information presented in this handout is taken from the manual *Tektronix Oscilloscope TDS 210.*

Read the section on *Safety* carefully, and make sure you understand every detail. Overlooking or not bearing in mind the safety precautions explained in the *Safety* section could cause severe property damage and can also be hazardous to you.

SYMBOLIC REPRESENTATION

Similar to all other devices in electrical engineering, there also exists a standard symbol (including alternative symbols) for the oscilloscope in schematics. Unfortunately, this symbol is not widely used, nor is it easy to recognize. The symbol used for the oscilloscope in the documents and handouts for ENGR 201 and 202 is shown in Figure 1. The symbol shows a circle (as with all other measuring devices), and two vertical lines representing the two vertical plates in a tube of an analog scope. Figure 2 shows the BNC-connector for one channel and the corresponding terminals.



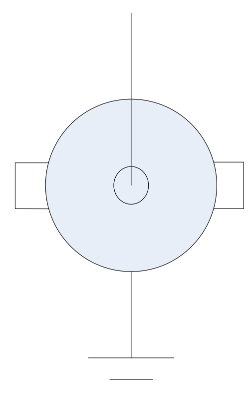


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Figure 1: Symbol for an oscilloscope

Figure 2: BNC-connector on an oscilloscope

SAFE USAGE OF THE OSCILLOSCOPE

Although the oscilloscope measures the voltage between two terminals as any multimeter does, there are important differences between oscilloscopes that are: (i) attached to the power grid, and (ii) stand-alone, battery-powered multimeters. The ground wires of the inputs (channel, trigger, etc.) are internally connected together. The ground wires are connected (hard or soft) to the earth ground of the power source.

You should always assume that the grounds of the BNC-connectors (outer metal part) on the scope are connected together and most likely connected to the earth ground of the power source. This also applies to the BNC-connectors of the function generator.

A **hard connection** to the earth ground of the power source means that the ground is connected directly to the earth. A **soft connection** means that an internal circuit makes sure that the ground and the earth are on the same voltage level, but has no direct connection. This internal connection of the grounds restricts what voltages you can measure in a circuit.

Before making connections to the input or output terminals of the oscilloscope, ensure that the oscilloscope is properly grounded.

Following are the **connections** that you can or cannot make, using the oscilloscope:

1. You can only measure voltage levels with reference to a common ground in the circuit, (as shown in Figure 3), i.e. you **can** only measure the voltages on the nodes as defined for the node voltage method referenced to ground, but you **cannot** directly measure the voltage between any two nodes, (as shown in Figure 4).

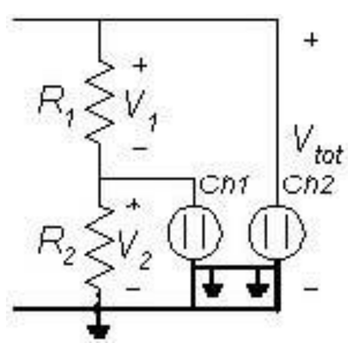

Figure 3: Correct connection, since the ground node in the oscilloscope is the same as in the circuit

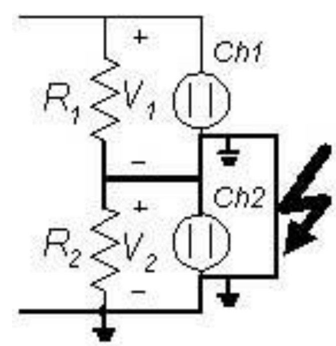

Figure 4: Faulty connection, since the ground node in the oscilloscope short circuits the resistor R2 with the Ch 2 ground connection to V2

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Oscilloscope connections (Contd.)

2. If you connect a function generator or a second oscilloscope to your circuit, you have to use the same common ground for all instruments, (as shown in Figure 5). You cannot connect the oscilloscope to a different ground as the ground of the function generator, (as shown in Figure 6).
3. The connection shown in Figure 6 is the most dangerous one, because you will be involving the power supply in the fault connection that causes a large fault current. The least danger that can be caused as a consequence of this fault current is that it will trip the circuit breaker or blow a fuse, but it can also cause a greater damage such as melting the ground connection and causing damage to the scope or even to you.

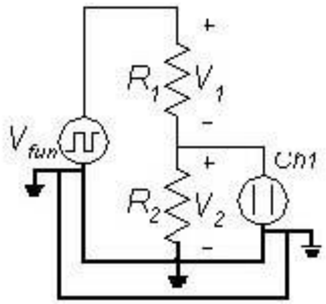


Figure 5: Correct connection, since the ground node of the oscilloscope and function generator (solid line) is the same as in the circuit (dashed-line)

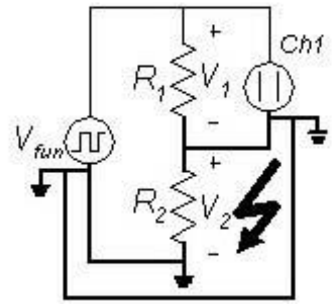


Figure 6: Faulty connection, since the ground node of the oscilloscope and the function generator is connected to V2 by the Ch 1 ground connection

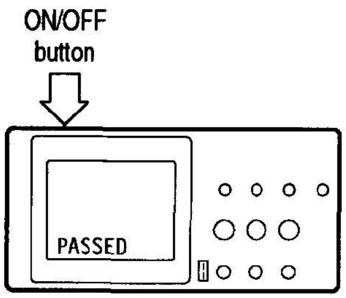
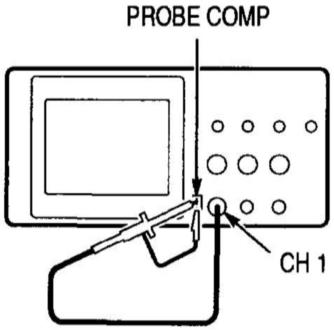
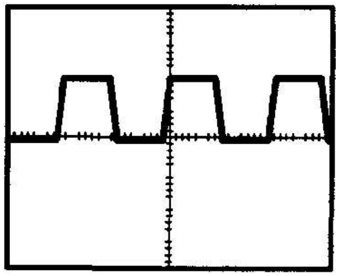
If it is necessary to measure the voltage across R1 in Figure 2 to Figure 6, you have to make a 'differential measurement' and use the math functions that are provided by the oscilloscope. In order to do so, connect the oscilloscope as shown in Figure 3 and subtract the two measured voltages, i.e. $V1 = V_{Ch2} - V_{Ch1}$.

Because of the connection between the circuit ground and the earth ground of the power supply, there are other related issues that you have to consider, such as the floating ground.

If you are working with power circuits, transformers or systems with several different ground nodes, you have to be especially careful. Refer to a manual of your equipment for further explanation. .

FUNCTIONAL CHECK

Perform this quick functional check to verify that your instrument is operating correctly.

Step I	Step II	Step III
		
Turn on the instrument. Wait for the confirmation that any and all self-tests have passed.	Connect the oscilloscope probe to Channel 1. Attach the probe tip and reference lead to the PROBE COMP connector.	Push the AUTOSET button. Within a few seconds, you should see a square wave in the display, (which is approx. 5V at 1 kHz). Repeat Steps II and III for Channel 2.

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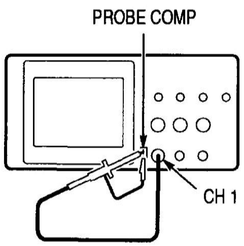
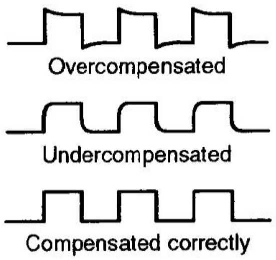
PROBE COMPENSATION

Perform this adjustment to match your probe to the input channel. This should be done whenever you attach a probe for the first time to any input channel.

Step I	Step II
	
Perform a functional check for the channel to which the probe is attached. Make sure that the probe is properly connected to the PROBE COMP connector.	Check the shape of the displayed waveform. If necessary, adjust your probe by turning the small screw on the probe. (This adjusts the RC time constant of the probe by varying C).

OPERATING BASICS

The front panel, as illustrated in Figure 7, is divided into a number of functional areas. This section provides you with a quick overview of the controls and the information displayed on the screen.

The operating basics are divided into the following sub-sections: **display area, vertical controls, horizontal controls, trigger controls, connectors, and control buttons.**

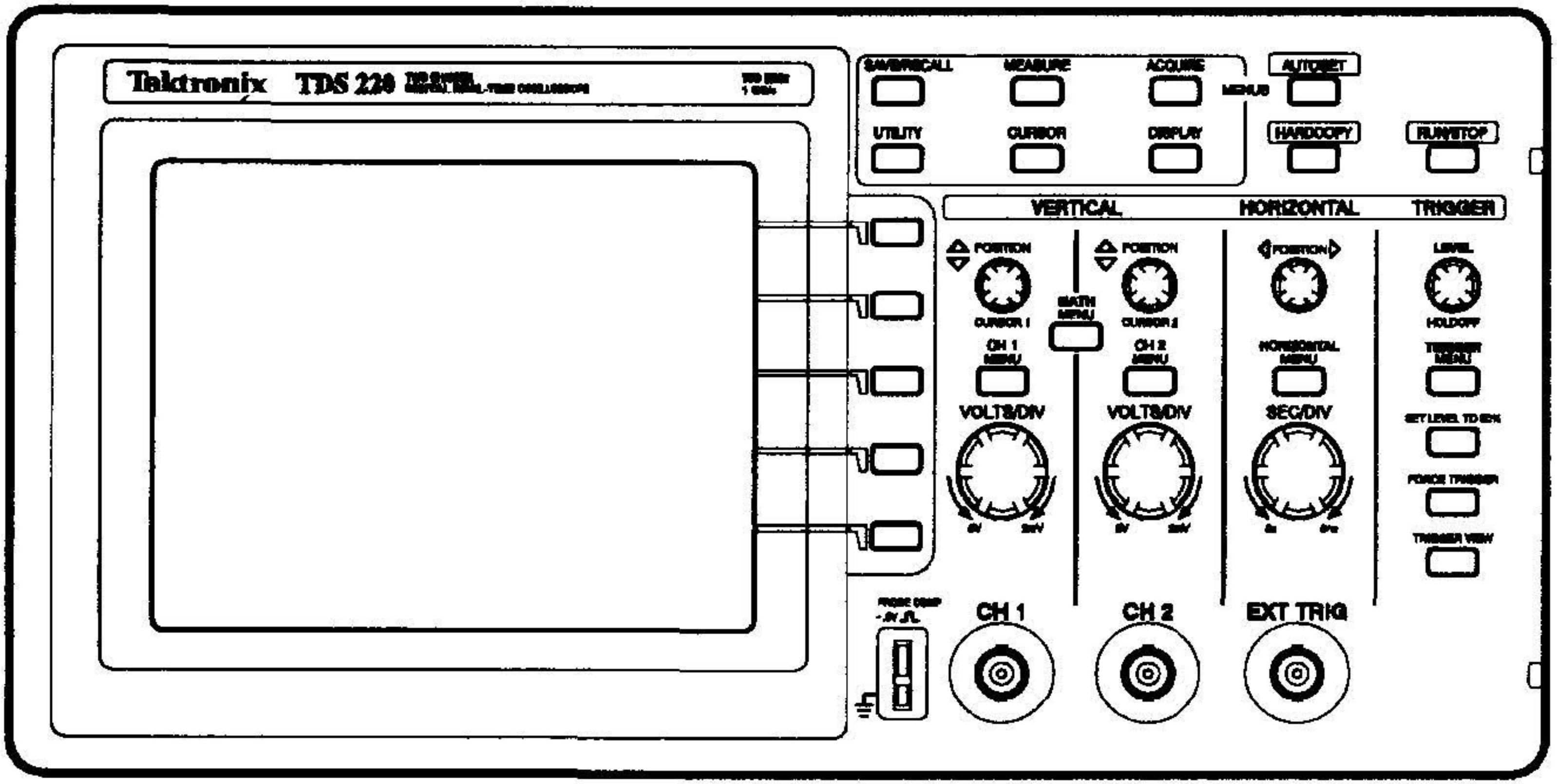


Figure 7: Front panel of Tektronix oscilloscope TDS 210 and TDS 220

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Display Area

In addition to displaying waveforms, the display area provides detailed information about waveforms as well as instrument control settings. The display area is detailed in the following sub-sections: **waveform display** and **display modes**.

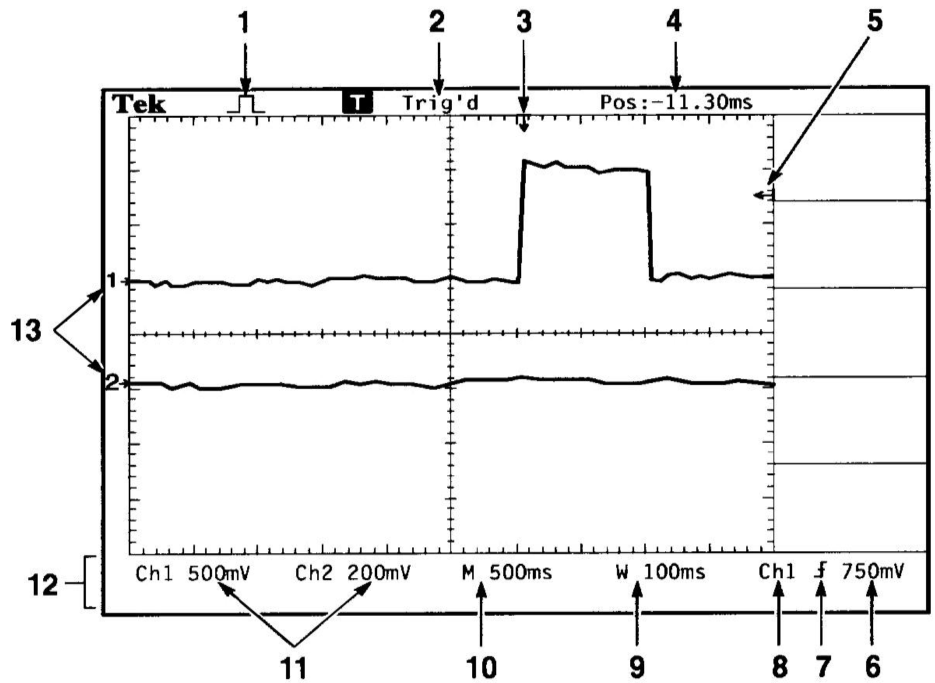

Fig. 8: Display area

Waveform display

Depending on the type, waveforms will be displayed in three different styles: black, gray, and broken.

Black indicates a live waveform display.
Gray indicates reference waveforms and waveforms with persistence applied.
Broken indicates the waveform display accuracy is uncertain.

Display modes

Following are some of the features of the display modes:

- **Icon** display indicates:
  Acquisition mode, (which could be sample, peak detection or average mode).
  Selected trigger slope for edge triggering.

- **Trigger** status indicates:
  If there is an adequate trigger source, or if the acquisition is stopped.
  Indicates the difference (in time) between the center graticule and the trigger position.

- **Center** screen:
  Equals zero.

- **Marker** status indicates:
  Horizontal position, since the Horizontal Position control actually moves the trigger position horizontally.
  Trigger level.

- **Readout** status indicates:
  Numeric value of the trigger level.
  Trigger source used for triggering.
  Window zone timebase setting.
  Main timebase setting.
  Channels 1 and 2 vertical scale factors.

- **On-line messages**:
  Displayed in the display area momentarily.

- **On-screen markers:**
  Show the ground reference points of the displayed waveforms. (If there are no markers, it means that the channel is not displayed).

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Vertical Controls

The following table details the usage for the vertical controls of the oscilloscope:

Control	Usage
CH1 (CH2) and CURSOR 1 (2)	Vertically adjusts the channel 1 (2) display, or positions cursor 1 (2).
MATH MENU	Displays the waveform math operations menu.
CH1 (CH2) MENU	Displays the channel input menu selections and toggles the channel display on and off.
VOLTS/DIV (CH1 and CH2)	Selects calibrated scale factors.

Figure 9 illustrates the vertical controls of the oscilloscope.

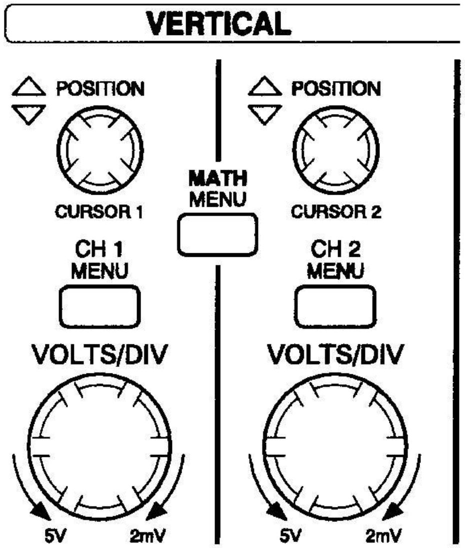

Figure 9: Vertical controls

Horizontal Controls

The following table details the usage for the horizontal controls of the oscilloscope:

Control	Usage
POSITION	Adjusts the horizontal position of all channels.
HORIZONTAL MENU	Displays the horizontal menu.
SEC/DIV	Selects the horizontal time/div (scale factor) for the main time-base and the Window Zone.
VOLTS/DIV (CH1 and CH2)	Selects calibrated scale factors.

Figure 10 illustrates the vertical controls of the oscilloscope.

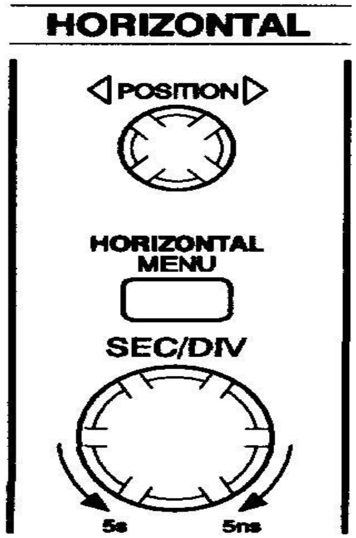

Figure 10: Horizontal controls

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Trigger Controls

The following table details the usage for the trigger controls of the oscilloscope:

Control	Usage
LEVEL AND HOLDOFF	This control has a dual purpose which is defined in the Horizontal Menu system. As a trigger control, it sets the amplitude level that the signal must cross to cause an acquisition. As a holdoff control, it sets the amount of time before another trigger event can be accepted.
TRIGGER MENU	Displays the trigger menu.
SET LEVEL TO 50%	The trigger level is set to 50% of the signal level.
TRIGGER VIEW	Displays the trigger waveform in place of the channel waveform, while the TRIGGER VIEW button is held down.

Figure 11 illustrates the vertical controls of the oscilloscope.

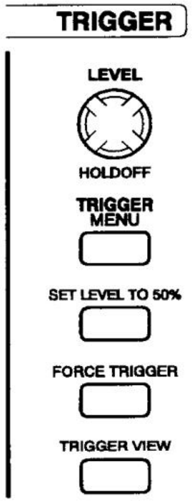

Figure 11: Trigger controls

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Connectors

The following table details the usage for the connectors of the oscilloscope:

Control	Usage
PROBE COMP	Voltage probe compensation output and ground. Use this to electrically match the probe to the input circuit. Refer to second section. **The probe compensation ground and BNC shields are connected to earth ground.** **Do not connect a voltage source to these ground terminals.**
CH1 and CH2	Input connectors for waveform display.
EXT TRIG	Input connector for an external trigger source. Use the Trigger menu to select the trigger source.

Figure 12 illustrates the vertical controls of the oscilloscope.

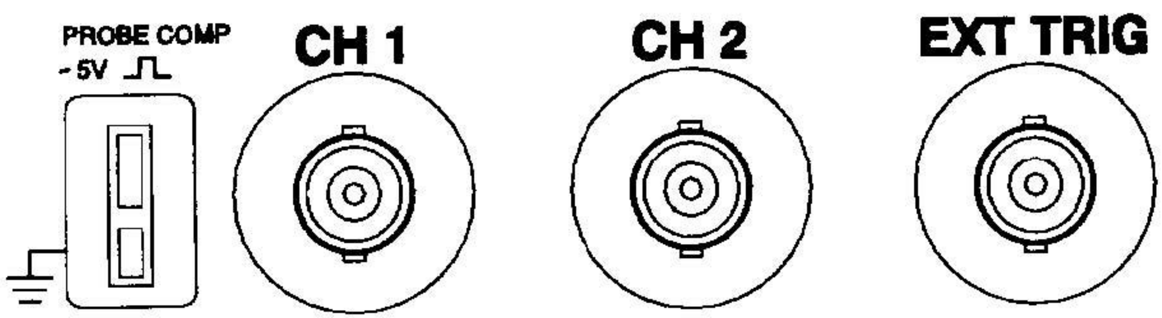

Figure 12: Connectors

Control Buttons

The following table details the usage for the connectors of the oscilloscope:

Control Button	Usage
MENUS	Some of the control buttons under "Menus" are explained in this table.
AUTOSET	Automatically sets the instrument controls to produce a usable display of the input signal.
HARDCOPY	Starts printing operation if a printer is attached to the oscilloscope.
RUN/STOP	Starts and stops waveform acquisition.

Figure 13 illustrates the control buttons of the oscilloscope.

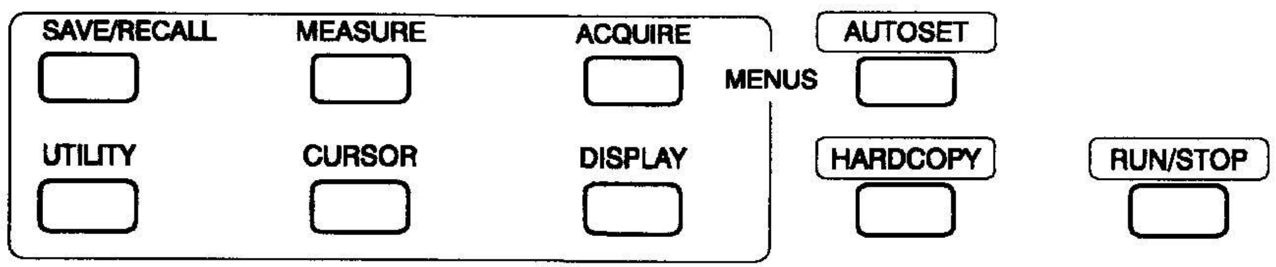

Figure 13: Control buttons

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REFERENCE

Use this section to as a detailed reference for the following controls / settings: A**utoset, Vertical, Display, Trigger, Math, Measure, Cursors** and **Acquire.**

Autoset

The Autoset feature automatically adjusts controls to produce a usable display of the input signal. Pushing AUTOSET adjusts or sets each of the items listed in the following table:

Function	Setting
Acquire mode	Sample
Vertical coupling	DC (if GND was selected)
Vertical VOLTS/DIV	Adjusted
Bandwidth	Full
Horizontal position	Centered
Horizontal SEC/DIV	Adjusted
Trigger type	Edge
Trigger source	Lowest numbered channel displayed
Trigger coupling	Adjusted to DC, Noise Reject, or HF Reject
Trigger slope	Rising
Trigger holdoff	Minimum
Trigger level	Set to 50%
Display format	YT
Trigger mode	Auto

Note: If your oscilloscope does not have an AUTOSET function, you have to set these items by hand.

Vertical

You can use the vertical controls to display waveforms, adjust vertical scale and position, and set input parameters. The vertical menu contains the items listed in the following table, for both Channel 1 and Channel 2. Each item is set individually for each channel.

Menu	Settings	Comments
Coupling	DC AC GND	**DC:** Passes both AC and DC components of the input signal. **AC:** Blocks the DC component of the input signal. **GND:** Disconnects the input signal.
BW Limit	20 MHz Off	Limits the bandwidth to reduce display noise.
Volts/Div	Coarse Fine	Selects the resolution of the Volts/Div knob.
Probe	1x 10x 100x 1000x	Selects the appropriate setting to match your probe attenuation factor, which in turn makes the vertical scale readout correct.

Waveform off: To remove a waveform from the display, push the CH1 MENU or CH2 MENU button to display its vertical menu. Push the menu button again to turn the waveform off.

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Display

Push the DISPLAY button to choose how waveforms are presented as well as to change the appearance of the entire display.

Menu	Settings	Comments
Type	Vectors Dots	**Vectors:** Fills the space between adjacent sample points in the display. **Dots:** Displays only the sample points.
Persists	OFF 1 sec 2 sec 5 sec Infinite	Sets the length of time for which each displayed sample point remains displayed.
Format	YT XY	**YT**: Displays the vertical voltage in relation to time (horizontal scale). **XY:** Displays Channel 1 in the horizontal axis and Channel 2 in the vertical axis.
Contrast Increase		Changes contrast (increasingly).
Contrast Decrease		Changes contrast (decreasingly).

Trigger

Two types of triggers are available: edge and video. For the lab, only edge triggering is used and therefore it is the only one explained in this manual as well.

Video triggering is used to trigger on lines of fields of a NTSC, PAL, or SECAM standard video signal. **Edge triggering** is used to trigger on the edge of the input signal at the trigger threshold.

Menu	Settings	Comments
Edge		With Edge highlighted, the rising or falling edge of the input signal is used for the trigger.
Slope	Rising Falling	Select either option to trigger on either the rising or the falling edge of the signal
Source	CH1 CH2 EXT EXT/5 AC Line	Select the appropriate input source as the trigger signal.
Mode	Normal Auto Single	Select the type of trigger signal **Normal Mode:** To trigger only on a valid trigger. **Auto Mode:** To let the acquisition free-run in the absence of a valid trigger. **Single Mode:** To capture a single acquisition of an event. The content of a single acquisition sequence depends on the **acquisition mode** (i.e. **sample, peak detect** or **average** mode).
Coupling	AC DC Noise Reject HF Reject LF Reject	Select the components of the trigger signal applied to the trigger circuitry.

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AC Line Source: The AC Line trigger source uses the power signal as the trigger source. Trigger coupling is set to DC and the trigger level to 0V.

Math

Push the MATH MENU button to display the waveform math operations. Push the MATH MENU button again to turn off the math waveform display.

Menu	Comments
CH1-CH2	Channels are subtracted from each other.
CH2-CH1	Channels are subtracted from each other.
CH1+CH2	Channels are added together.
CH1 invert	Channel 1 is inverted. (However, it cannot be inverted if Channel 2 is inverted as well).
CH2 invert	Channel 2 is inverted. (However, it cannot be inverted if Channel 1 is inverted as well).

Channel Display: Displaying a math waveform automatically removes the display of channels used to create the math waveform.

Math Operations: Only one math operation is allowed.

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Measure

Push the MEASURE button to access the automated measurement capabilities. There are five measurements available along with the ability to display up to four at a time. Following are the settings under the **Measure** menu, with either **Source** or **Type** highlighted.

Source

With the **Measure** menu displayed and **Source** highlighted, define the channel you want the measurement to be performed on.

Menu	Settings	Comments
Source		With Source highlighted, choose the channel to measure.
	CH1 CH2	Select a channel for the measurement. If the selected source (channel) is not displayed, CHx Off is displayed.

Type

With the **Measure** menu displayed and **Type** highlighted, define the menu structure by selecting the type of measurement to display in each of the available menu locations.

Menu	Settings	Comments
Type		With Type highlighted, choose the type of measurement to display next to the on-screen-menu button.
		Select the measurement type to display in each menu location.
	Cyc RMS	**Cyc RMS:** True RMS measurement of one complete cycle of the waveform.
	Mean	**Mean:** Arithmetic mean voltage over the entire record.
	Period	**Period:** Time for one cycle.
	Pk-Pk	**Pk-Pk:** Absolute difference between the maximum and minimum peaks of the entire waveform.
	Freq	**Freq:** Frequency of the waveform.
	None	**None:** To stop and remove measurements from the menu location.

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Cursors

Push the CURSOR button to display the measurement cursors and cursor menu.

Function	Settings	Comments
Type	Voltage Time Off	Select and display the measurement cursors. Voltage: Measures amplitude. Time: Measures time and frequency.
Source	CH1 CH2 MATH REFA REFB	Choose the waveform of the channel or source that the cursors are attached.
Delta		The difference (delta) between the cursors is displayed here.
Cursor 1		Displays Cursor 1 location, (where time is a reference to the trigger position, and voltage is referenced to ground).
Cursor 2		Displays Cursor 2 location, (where time is a reference to the trigger position, and voltage is referenced to ground).

Acquire

Push the ACQUIRE button to set acquisition parameters.

Function	Settings	Comments
Sample		This is the default mode and provides the fastest acquisition.
Peak Detect		Use this to detect glitches and reduce the possibility of aliasing.
Average		Use this to reduce random or uncorrelated noise in the signal display. The number of averages is selectable.
Averages	4 16 64 128	Select the number of averages.

Note: If you probe a noisy square wave signal that contains intermittent, narrow glitches, the waveform displayed will vary depending on the acquisition mode you choose, as shown in Figure 14.

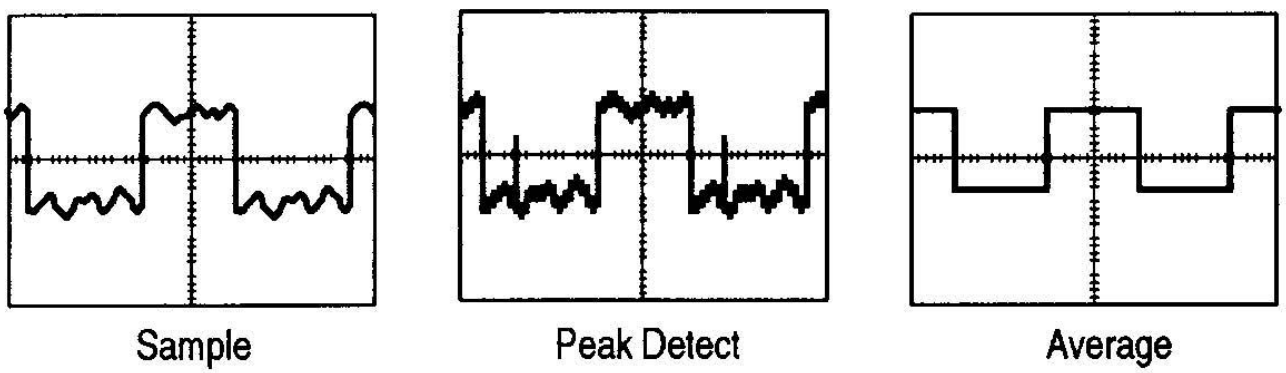

Figure 14: Display of a noisy signal depending on the acquisition mode

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APPENDIX E
Parts

This table has a list of parts:

Qty.	Description	Fig.	Supplier	Supplier #
1	Metal enclosure	A	Jameco	208928
1	Transformer	B	Jameco	102111
1	Power cord	C	Jameco	339733
1	Fuse holder	D	Jameco	102867
1	1A Fuse	E	Jameco	10372
8	1N4004 Diode	F	Jameco	35991
2	Capacitor	G	Jameco	331715
1	HLMP1700 LED	H	Jameco	253690
1	T1 LED mount	I	Jameco	95513
1	4.7 kΩ 1/4W Resistor	J	Jameco	31026
1	Heat shrink, 0.12” diameter	K	Jameco	184721
1	Heat shrink, 0.16” diameter	K	Jameco	182730
2	Machine screw, 10-24, 3/8”	L	McMaster-Carr	90272A240

Fig. A

Fig. B

Fig. C

Fig. D

Fig. E

Fig. F

Fig. G

Fig. H

Fig. I

Fig. J

Fig. K

Fig. L

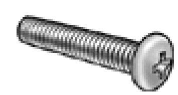

Fig. M

Fig. N

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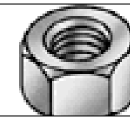
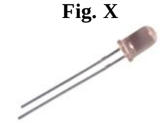
2	Nut, hex, 10-24	M	McMaster-Carr	90480A011		
Qty.	**Description**	**Fig.**	**Supplier**	**Supplier #**	**Fig. O**	**Fig. P**
1	TIP29 NPN Transistor	N	Jameco	297781		
10	2N4401 NPN Transistor	O	Jameco	38421		
2	1N5819 Schottkey Diode	F	Jameco	177965	**Fig. Q**	**Fig. R**
4	0.1µF ceramic	P	Mouser	581-SR205E104M		
3	100uF electric capacitor	Q	Jameco	93761	**Fig. S** 	**Fig. T** 
5	1KΩ 1/4W Resistor	J	Jameco	29663		
2	2KΩ 1/4W Resistor	J	Jameco	30277	**Fig. U** 	**Fig. V** 
2	0.68Ω 1W Resistor	J	Jameco	P0.68W-1BK-ND		
2	50K pot	R	Jameco	264428	**Fig. W** 	**Fig. X** 
2	Heat sink	S	Mouser	532-507302B00		
2	3/8" 4-40 machine screw	L	McMaster-Carr	90272A108	**Fig. Y** 	**Fig. Z** 
12	4-40 machine nut	M	McMaster-Carr	90480A005		
1	TIP30 PNP Transistor	N	Jameco	179346	**Fig. AA**	**Fig. AB**

5	2N4403 PNP Transistor	O	Jameco	38447		

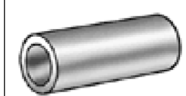
Qty.	Description	Fig.	Supplier	Supplier #
3	10K Ω 1/4W Resistor	J	Jameco	29911
2	100K Ω 1/4W Resistor	J	Jameco	29997
1	12VDC 2"x2" fan	T	Jameco	206965
1	3 pin piece of male header	U	Jameco	103341
2	LM741 Op Amp	V	Jameco	24539
1	10K Ω Thermistor	W	Jameco	207036
2	Machine screw, 1", 4-40	L	McMaster-Carr	90272A115
10	100Ω 1/4W Resistor	J	Jameco	29946
2	2N7000 N-Channel MOSFET	O	Jameco	119423
1	10μF electric capacitor	Q	Jameco	94369
2.5	Circuit board, 3.75"x2"	Z	TekBots	protoboard.1

Fig. AC

Fig. AD

Fig. AE

Fig. AF



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1	On-Off Toggle switch	AA	Jameco	76523		

Qty.	Description	Fig.	Supplier	Supplier #		
2	Binding Posts	AB	Jameco	71239		
1	Power Cord strain relief	AC	Jameco	182369		
1	CAT5 cable, 1 foot	AD	Jameco	201603		
1	22AWG stranded wire (5 ft), black	AE	Jameco	126084		
1	22AWG stranded wire (5 ft), red	AE	Jameco	126033		
8	Machine screw, 4-40, 1/2”	L	McMaster-Carr	90272A110		
8	Mounting spacer, 3/16” long	AF	McMaster-Carr	94639A704		
2	10Ω 1/4W Resistor	J	Jameco	93761		

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APPENDIX F
Suppliers

This section has a list of our suppliers:

DigiKey	701 Brooks Ave. South Thief River Falls, MN 56701-0677 (800) 344-4539 **http://www.digikey.com**
Mouser Electronics	1000 N. Main Street, Mansfield, TX 76063 (800) 346-6873 **http://www.mouser.com**
Allied Electronics	6700 SW 105th St, Suite 106 Beaverton, OR 97008 (800) 433-5700 **http://www.alliedelec.com**
TekBots	220 Owen Hall Oregon State University Corvallis, OR 97331 tekbots_support@eecs.oregonstate.edu **http://eecs.oregonstate.edu/tekbots**
Solarbotics	179 Harvest Glen Way N.E. Calgary, Alberta, Canada T3K 4J4 (866) B-ROBOTS **http://www.solarbotics.com**
McMaster-Carr	P.O. Box 7690, Chicago, IL 60680-7684 (562) 692-5911 **http://www.mcmaster.com**
Jameco Electronics	1355 Shoreway Rd, Belmont, CA 94002 (800) 831-4242 **http://www.jameco.com**

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