

ECE 323: ELECTRONICS II

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PREFACE

SYSTEM OVERVIEW

During the course of this lab, you will be designing and constructing an USB powered audio amplifier. During this project, you will explore the principles of amplification and system design.

The USB audio amplifier project is composed of two pieces: a functional prototype, and a complete “product”. This lab structure is designed to emulate the 30-week Senior Design course in 10 weeks. Six weeks are given to complete the designing, constructing, and testing of the prototype. Three weeks are given to improve the prototype into a “product”. In order to emulate senior design more accurately, the prototype will be graded via given specification, and the improvement portion will be graded by student-determined design specifications.

HOW TO USE THIS MANUAL

During this course, various tasks will be performed from the design of electronic devices, to prototype design, as well as improvement on the prototype. These tasks are divided into individual lab documents that correspond to what is being taught in the Electronics II lecture, and emulate a real design and build engineering process.

Everything learned in lecture is relevant and useful in later (related) courses and in your future career. As various tasks are performed in these labs, try to pay attention to how the lecture material relates to these tasks. Understanding how the lecture material is used and applied will greatly improve your understanding of the topics as well.

IMPORTANT SYMBOLS

During this lab and other TekBots labs, you will encounter the following symbols. So, review or acquaint yourself with these symbols, as they are widely used in this lab manual.



This symbol indicates an **important note** that should be remembered/memorized. Paying attention to notes like these will make tasks easier and more efficient.



This symbol designates **caution**, and the information in this caution-table should be read thoroughly, and adhered to, before moving ahead.

If the caution warning is ignored, the task may appear impossible and/ or can lead to damaged TekBots and systems.



This symbol represents something that helps you make your task easier by reminding you to perform a particular task before the next step. These **reminder** symbols are not normally critical things to complete, but can make things easier.



The **innovation** symbol will give information to enrich your experience. These sections will give more insight into the what, why, and how of the task being done. Use these to learn more, or to get ideas for cool innovations.

LAB STRUCTURE

Section Overview	The section overview briefly describes what will be learned in the section, and what will be done.
Procedure	The procedure portion of each section contains all of the tasks to be completed and relates to the corresponding lecture. Keeping this in mind will help to better understand the lecture as well as the lab material.
Study Questions	The study questions are intended to give more practice and insight into what has been learned in lab and lecture. Some of the study questions will be due in lab.
Challenges	The challenge sections of labs are for extra credit. Performing the tasks in the challenge sections will improve understanding of what is being learned and will result in some outstanding TekBots and innovations.

LAB SAFETY

Safety is always important when working with electricity and electronics. This includes the safety for you, your peers, as well as safety for the circuit components you are working with. Concerns such as high voltage or currents can affect the human body, while static safety and proper component use can affect the life of your circuits.

Personal Safety

When working with high voltage and currents, it is important you remember you can be hurt if your body becomes the 'circuit', since the human body is a conductor of electricity. This issue has long been combated by using the 'one hand rule.' Whenever you are working with a potentially dangerous circuit, turn it off, but if it cannot be turned off, use only one hand when working on it. This will prevent a circuit from being made through your heart, which could be potentially fatal.

Component Safety

Many electrical components are likely to be damaged by static electricity. Static charge can build up to many thousands of volts, but with little energy. This cannot harm humans, but it can easily damage electronic components. To ensure static-safe handling, the best practice is to wear an anti-static strap and connect it to an earth ground such as a computer case or a water pipe. If you do not have an anti-static wristband, you can instead touch a ground every few minutes to discharge your static build up.

SECTION ONE
LTspice
(Week 1)

SECTION OVERVIEW

This section functions as a training/review of LTspice. Learning outcomes are:

- Able to perform design-then-simulate engineering process
- Able to perform LTspice simulation.
- Able to add models to LTspice.



Bring a printed copy of *Appendix A: A simple guide on LTspice* with you to the lab. This will enable you to work lab quickly.

PROCEDURE

A key success factor for cost effective and timely development is prototyping based on simulation and optimization. It is important to design the prototype by the given specification, followed by verification of the design via simulation before constructing the actual prototype.

Task One: Design

Design an amplifier with the following specification **on paper**:

- 5V supply voltage
- Gain = $5 \pm 5\%$
- Small signal input of $200\text{mV}_{\text{p-p}}$, 500 Hz
- Using only resistor(s), capacitor(s), and one 2N4401 OR 2N4403
- Use a reasonable value for β (refer to datasheet)

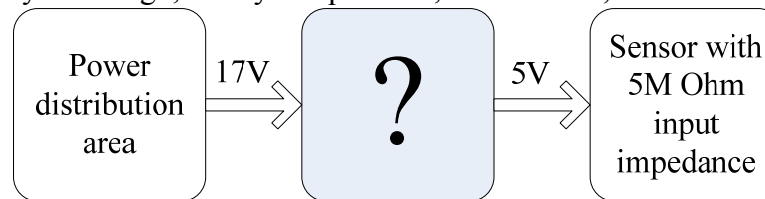
Task Two: Simulation

Simulate your design in LTspice using the correct parts that match your design. Print the following simulation results:

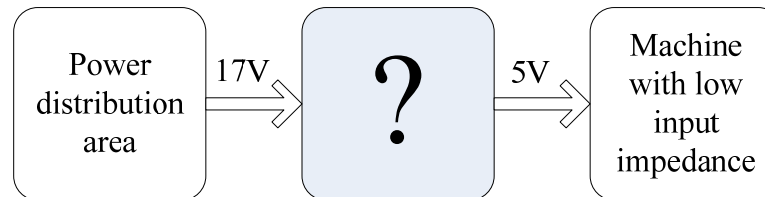
- A plot that contains both input and output waveform. (.TRAN)
- A plot that contains both magnitude (bode) plot and phase plot. (.AC)
- Simulation results on input and output impedance.
 - Hint: Research the transfer function simulation (.tf)

STUDY QUESTIONS

1. Were there any inconsistencies between your calculated and simulated results? What might be some of the causes? You had the option to choose either a 2N4401 or 2N4403 transistor. Which one did you choose and why did you choose it? Provide pros and cons for both transistors. Please give detailed answers for all of the above questions.
2. A sensor with 5M Ohm input impedance needs 5V to operate correctly. Assume that you get exactly 17V from the power distribution area. Design a functional block, (represented by the gray block), which will be able to change 17V to 5V. Use **ONLY** discrete parts (resistor, capacitor, diode, and transistor). Please provide detailed solution including reasoning of your design, theory of operation, calculations, detailed schematic, and simulation result.



3. A machine with low input impedance needs 5V and current ranges from 0.5 – 1 Amp to operate correctly. Assume that you get exactly 17V from the power distribution area. Design a functional block, (represented by the gray block), which will be able to change 17V to 5V. Use **ONLY** discrete parts (resistor, capacitor, diode, and BJT). Please provide detailed solution including reasoning of your design, theory of operation, calculations, detailed schematic, and simulation result.



4. Construct a parts list for the circuits designed in #3 and #4. Minimal requirement: location of purchase, vendor parts number, unit cost, total cost.

TURN-IN

- A copy of your design process, include equation used and calculation results with units.
 - a. Equations used to initially calculate all resistors in your design.
 - b. Calculations showing that the circuit still functions for maximum and minimum values of Beta from the datasheet.
- A copy of your simulation result including:

Section One: LTspice

- a. Input and Output Waveforms (on one graph)
 - b. Magnitude and Phase Plots (on one graph)
 - c. Input and Output Impedance
- Answers to study questions (typed, with SPICE schematic, equation editor for equations).

SECTION TWO
Design the prototype
(Week 2 – 3)

SECTION OVERVIEW

In this section, you will design the schematic for your prototype USB powered audio amplifier. You will simulate and breadboard your design to check for functionality and consistency.

PRE-LAB (PART 1)

1. Review the three types of BJT amplifier configurations and complete the following table.
2. Comment on the advantage and disadvantages of each type of amplifier.
3. Design a single transistor amplifier with adjustable gain of 1 – 10 on paper.
4. Print out your simulation result showing outputs with gain of 1 – 10, with gain increment of 1.

Type	Gain equation	Input impedance	Output impedance	Advantage	Disadvantage
	$A_v =$	$R_{in} =$	$R_{out} =$		
	$A_v =$	$R_{in} =$	$R_{out} =$		
	$A_v =$	$R_{in} =$	$R_{out} =$		

PROCEDURE (PART 1)

Design specification

The project requirements are listed below. Your prototype must meet ALL of the “Absolute Minimum Requirements” now, and at least one requirement in the “Desired Features” after the ‘Project Improvement’ section.

Absolute Minimum Requirements:

- USB powered
- Outputs at least 92dB
- Use only discrete components (resistor, capacitor, diode, transistor)
- Stereo output
- Adjustable gain
- System draws at least 90mA
- Total harmonic distortion less than 30%
- Receives audio signal from a computer
- Soldered

Desired Features

- Printed circuit board finish
- Louder output (more than 0.75 W)
- FM transmission
- Audio transmitted via USB
- Other student authored innovative improvements

Design Considerations

1. Are the components used in simulation reasonable?
 - a. Can they be purchased?
 - b. Will they handle the power dissipation needed?
2. How much current does your amplifier need? Can your amplifier supply enough current?
 - a. Is your Beta affected?
3. What is the desired R_{in} and R_{out} for your amplifier(s)?
 - a. Is a range allowable?

Design Process

1. First determine the audio signal you will need to amplify by measuring the signal output from your computer using the audio cable (provided in the lab kit) and oscilloscope.



A signal generator computer application will be helpful on determining the output signal amplitude. You may find an online audio frequency generator.

Section Two: Design the Prototype

2. Determine the gain you will need to amplify the audio signal to the maximum
3. Design your gain amplifier
4. Simulate your design to verify functionality

PRE-LAB (PART 2)

1. Research the following basic output stage designs. The internet and Chapter 14 in Sedra/Smith should be helpful.
 - a. Class A amplifier. What are the advantages and disadvantages to a Class A design?
 - b. Class B amplifier. What are the advantages and disadvantages to a Class B design?
 - c. Class AB amplifier. What are the advantages and disadvantages to a Class AB design?
 - d. Class C amplifier. What are the advantages and disadvantages to a Class C design?(Hint: Two transistors, 2N4401 and 2N4403, as well as the audio transformer were included with your selection of parts for this section. A common design for this type of application is a Class-AB push-pull amplifier.)
2. Choose a topology from the list above or from your research (there are many more designs than those above and many of them could provide better characteristics than the simpler designs). Calculate the component values for your chosen topology based on the requirements of your system. You may want to check your textbook, look on-line, or ask professors for topology ideas. Also, there are a large number of schematic “cookbooks” with example circuits.

PROCEDURE (PART 2)

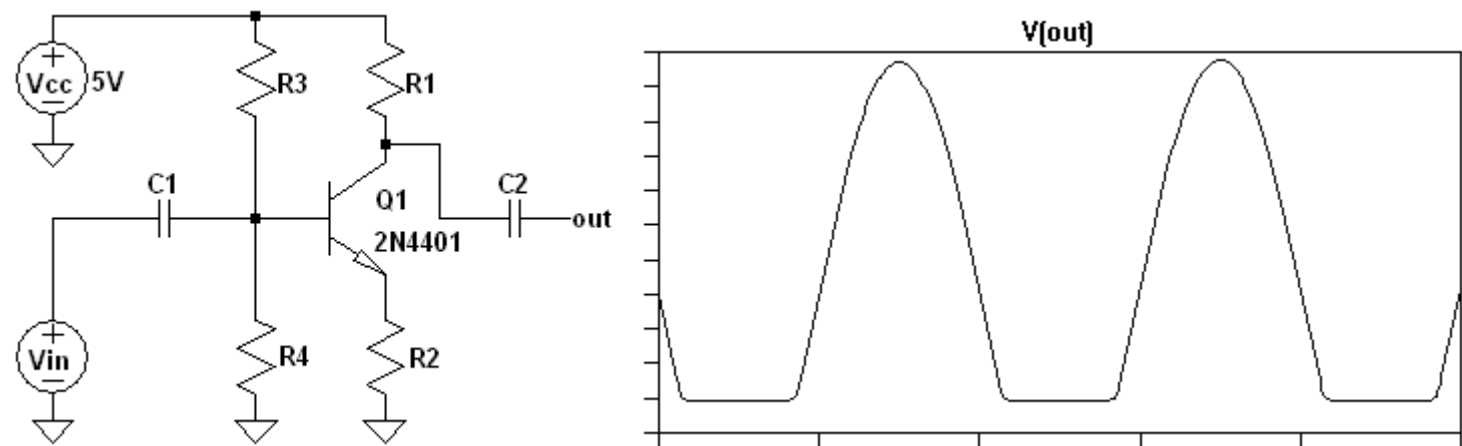
Design Process

Now you have your gain stage amplifier(s) simulated, does it supply enough current so that the audio output is audible? If not, find a solution to this problem using your knowledge from Pre-lab (part 2). Simulate your design result and fill out the table below.

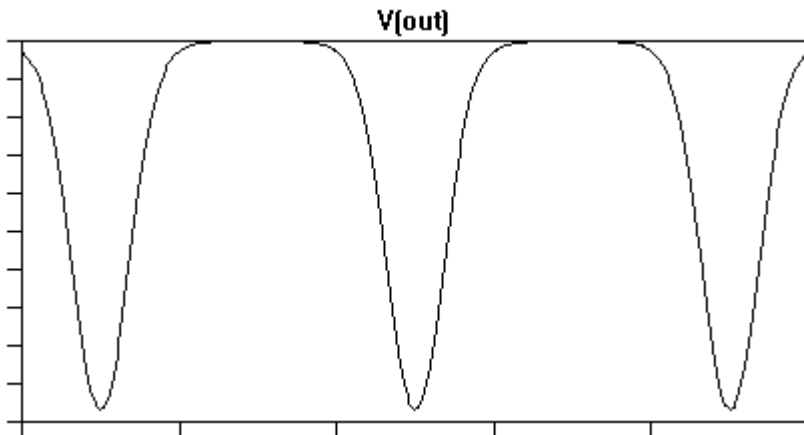
Frequency	Vin (Peak-to-Peak)	Vout (Peak-to-Peak)	Phase Shift (Degrees)	THD
100Hz				
1kHz				
10kHz				
20KHz				

STUDY QUESTIONS

- The following circuit has an input signal of 0.1V_{p-p} at 500 Hz . The output waveform is shown below. What could be the cause of the signal clipping? What can you do to make the circuit output a full waveform with a gain of at least 10? You may not adjust the supply and signal voltage. Please give calculation, equation, and reasoning.



- Referring to the circuit in question #1, your output waveform is shown below. What could be the cause of this waveform? What can you do to make the circuit output a full waveform with a gain of at least 10? You may not adjust the supply and signal voltage. Please give calculation, equation, and reasoning.



TURN-IN

- A copy of your design process, include equation used and calculation results with units.
 - a. Equations used to initially calculate all resistors in your design.
 - b. Calculations showing that the circuit still functions for maximum and minimum values of Beta from the datasheet.
- A copy of your simulation result including:
 - a. Input and Output Waveforms (on one graph)
 - b. Magnitude and Phase Plots (on one graph)
 - c. Input and Output Impedance
 - d. The table of values based on frequency
- Answers to study questions (typed, with SPICE schematic, equation editor for equations).

SECTION THREE
Prototype & Construction
(Week 4 – 5)

SECTION OVERVIEW

In this section, you will first breadboard your USB powered audio amplifier. After verifying the functionality, you will construct the prototype.

PRE-LAB

1. Find a way to measure/calculate **total harmonic distortion** (THD). Give detailed procedure.
2. Construct a parts list for the circuits designed in Section 2. Minimal requirement: location of purchase, vendor parts number, unit cost, total cost.
3. Acquire all parts needed to construct your prototype.

PROCEDURE

Construct

1. Breadboard your designed and simulated circuit by blocks (assume each amplifying stage is a block).
 - Once your circuit is breadboarded, fill in the following table with measurements. Once filled in, have your TA sign off they have seen the measurements.

Frequency	Vin (Peak-to-Peak)	Vout (Peak-to-Peak)	Phase Shift (Degrees)	THD
100Hz				
1kHz				
10kHz				
20KHz				

2. After verifying the functionality of your breadboard circuit, construct the prototype.
 - Once your circuit is constructed, fill in the following table with measurements. Once filled in, have your TA sign off they have seen the measurements.

Frequency	Vin (Peak-to-Peak)	Vout (Peak-to-Peak)	Phase Shift (Degrees)	THD
100Hz				
1kHz				
10kHz				

20KHz				
-------	--	--	--	--

A few recommendations on your prototype:

- Construct the system by sections/blocks, and verify that each block functions correctly before proceeding to the next block.
- Avoid having long and/or exposed wires on the prototype.
- Double check places for components before you permanently solder them.

Matching Simulation Results

You need to ensure your prototype matches your simulation as close as possible. For this project, you will be required to match your simulation results within $\pm 10\%$. For example, if your peak to peak voltage is 4 volts, the inconsistency can be ± 0.4 volts.

STUDY QUESTIONS

1. Comparing the output of your breadboard circuit and your simulation, describe the inconsistencies. Please note there WILL be inconsistencies. What might be some of the causes for the inconsistencies? What modifications did you do to match the two outputs? Please give details such as reasoning, calculations, etc.
2. Comparing the output of your breadboard circuit and your prototyped (soldered) circuit, describe the inconsistencies. Please note there WILL be inconsistencies. What might be some of the causes for the inconsistencies? What modifications did you do to match the two outputs? Please give details such as reasoning, calculations, etc.

TURN-IN

- A copy of your design process, include equation used and calculation results with units.
 - a. Equations used to initially calculate all resistors in your design.
 - b. Calculations showing that the circuit still functions for maximum and minimum values of Beta from the datasheet.
- A copy of your simulation result including:
 - a. Input and Output Waveforms (on one graph)
 - b. Magnitude and Phase Plots (on one graph)
 - c. Input and Output Impedance
 - d. The two tables of values based on frequency
- Answers to study questions (typed, with SPICE schematic, equation editor for equations).

- This check off sheet.

PROTOTYPE CHECK-OFF SHEET

<u>Test (from Project Specification)</u>	<u>Measurements</u>	<u>TA signature</u>
7.1.1 – USB Powered		_____
7.1.2 – Components Used		_____
7.1.3 – Signal Source		_____
7.1.4 – Volume Control		_____
7.1.5 – Stereo Output		_____
7.1.6 – Current Consumption		_____
7.1.7 – System THD		_____
7.1.8 – Solid Construction		_____

SECTION FOUR
Project Improvement
(Week 6 – 9)

SECTION OVERVIEW

In this section, you will make your designed USB powered audio amplifier prototype into a “product”.

PRE-LAB

Complete your project improvement proposal document (located on lab page). The proposal shall contain at minimum the following parts:

- A short paragraph describing how and why your improvement choice is important.
- A check-off list for your improvement. Be as specific as possible, including testing procedure.

PROCEDURE

Several options are listed below on improving your prototype USB powered audio amplifier.

- Printed circuit board
- Case
- More power
- Other innovative ideas (must be approved by course instructor or TA)

TURN-IN

Printed circuit board

- A printed copy of your schematic drawn with your PCB design tool
- A printed copy of your layout drawn with your PCB design tool
- A printed copy of your FreeDFM
- A written summary of your designed PCB
- A copy of your project improvement proposal with TA’s approval signature
- Check-off sheet

Case

- A printed copy of your case drawn with a 3D CAD tool
- A written summary of your designed case, include dimensions/sizes.
- A copy of your project improvement proposal with TA’s approval signature
- Check-off sheet

More power

- A printed copy of your schematic drawn with a CAD tool
- A written summary of your design. Include any reasoning, equations, calculations, references, etc.
- A copy of your project improvement proposal with TA's approval signature
- Check-off sheet

Other innovative ideas

- A written summary of your design
- A copy of your project improvement proposal with TA's approval signature
- Check-off sheet
- Other material that is required to receive credit. These requirements should be approved BEFORE the beginning of week 7.

FINAL CHECK-OFF SHEET

Please be sure to include your improvement check-off criteria

<u>Test (from Project Specification)</u>	<u>Measurements</u>	<u>TA signature</u>
7.1.1 – USB Powered		_____
7.1.2 – Components Used		_____
7.1.3 – Signal Source		_____
7.1.4 – Volume Control		_____
7.1.5 – Stereo Output		_____
7.1.6 – Current Consumption		_____
7.1.7 – System THD		_____
7.1.8 – Solid Construction		_____

APPENDIX A

LTSPICE

Useful Links & References

<http://www.ece101.com/2010/01/an-introduction-to-LTspice/>

- Has video tutorial for LTspice dealing with an inverting amplifier

<http://denethor.wlu.ca/LTspice/>

- Very thorough tutorial of basic operations in LTspice (with screenshots)

http://highered.mcgraw-hill.com/sites/0073106941/student_view0/lt_spice_instructions_and_support_files.html

- Download contains a long powerpoint that is useful at first; gets more complicated at end

<http://claymore.engineer.gvsu.edu/~steriana/Videos/>

- Contains 2 video tutorials for LTspice; one basic, one dealing with models

<http://ece.sdsmt.edu/ee221/Intro%20to%20LTspice.pdf>

- Shorter tutorial, has lots of screenshots though (very simple, easy to follow)

<http://home.zcu.cz/~panek50/TE1/Introduction%20to%20SwitcherCAD.pdf>

- Quick PDF with basic operations

<http://www.linear.com/designtools/software/LTspiceGettingStartedGuide.pdf>

- Guide distributed by company which has good information

I. DOWNLOADING LTSPICE

1. Go to this website: <http://www.linear.com/designtools/software/>
2. Click the link titled "Download LTspice IV."
3. It isn't necessary to register for an account with the site.
4. Save the file to your computer and finish the download.

II. TYPES OF SOURCES

1. Voltage sources can be configured in many different ways in LTspice. In order to change one, right clicking on the source will bring up a window titled "Independent Voltage Source". (You might need to click "Advanced" to see these options)
 - a. (none) – This is the basic DC voltage source, simulating a simple battery. On the side of the window you can adjust the DC value to whatever voltage necessary.

- b. PULSE – This source defines a voltage with pulse characteristics. This is generally used for a transient circuit simulation in order to make a voltage source act like a square wave source. (*Note: Never use it for a frequency response study, because the probe plot will give inaccurate results.) The adjustable values are as follows:
 - Vinitial is the value when the pulse is not “on.” So for a square wave, the value when the wave is “low” and this can be zero or negative depending on what is needed.
 - Von is the value when the pulse is turned “on,” and can also be zero or negative.
 - Tdelay is the time delay (default units are seconds), and may be zero but not a negative value.
 - Trise is the rise time of the pulse (default units are seconds). It may be zero, but using zero can cause convergence issues in some transient analysis.
 - Tfall is the fall time of the pulse (in seconds).
 - Ton is the pulse width (the time in seconds that the pulse is fully on).
 - Tperiod is the period (the total time in seconds of the pulse).
 - Ncycles is the number of cycles of the pulse that should happen (use zero if you want ongoing pulses).

- c. SINE – This is the AC voltage source, and defines a sinusoidal voltage. There are two possible ways to analyze the source (AC analysis and transient analysis), which two sets of parameters that can be changed.
 - AC Amplitude is the RMS value of the voltage.
 - AC Phase is the phase angle of the voltage.
 - DC offset is the DC offset voltage (should be zero if you need a pure sinusoid).
 - Amplitude is the undamped amplitude of the sinusoid.
 - Freq is the sinusoid frequency in Hz.
 - Tdelay is the time delay (in seconds, set to zero for normal sinusoid).
 - Theta is the damping factor, should be set to zero for a normal sinusoid (this is not the phase angle). Used to apply an exponential decay to the sinusoid.
 - Phi is the phase advance in degrees (set to 90 if you need a cosine wave form).
 - Ncycles is the number of cycles of the pulse that should happen (again, use zero if you want ongoing pulses).

- d. EXP – This is an exponential independent source that defines a voltage with exponential rise time and exponential fall time.
 - Vinitial is the initial voltage
 - Vpulsed is the pulsed value.
 - Rise Delay is the time delay before the rise of the exponential function.
 - Rise Tau is the rise time constant.
 - Fall Delay is the time delay before the fall of the exponential function.
 - Fall Tau is the fall time constant.

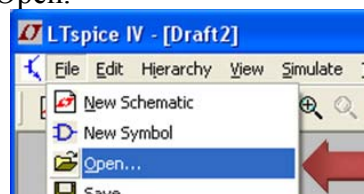
- e. SFFM – This stands for “Single Frequency FM.” It represents a single-frequency voltage source whose frequency modulated output voltage value is independent of the current through the source.
 - DC offset is the magnitude of the time-independent part of the output voltage.
 - Amplitude is the magnitude of the sinusoidal part of the output voltage.
 - Carrier Freq is the frequency of the carrier wave. It may be zero, but cannot be negative.
 - Modulation Index is the amount by which the modulated signal varies around its unmodulated level. It may be zero, but cannot be negative.
 - Signal Freq is the frequency of the modulated signal. Value must be greater than or equal to zero.
- f. PWL – This is a piece wise linear function that can be used to create a waveform consisting of straight line segments drawn by linear interpolation between points that you define (as many points as you want can be used). The structure for this source is flexible and has a variety of parameters to choose from. However, there are some requirements:
 - Two-dimensional points consisting of a time value and a voltage.
 - Time values must be in ascending order (however, intervals between the values don’t need to be regular).

2. Current Sources

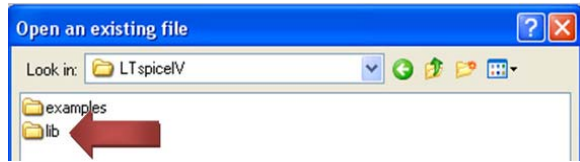
There exist current sources for all of the aforementioned voltage sources. The difference is that they produce current instead of voltage, and that you have to be aware and careful of the direction of the current arrow and the resulting polarities.

III. ADDING NEW MODELS TO LTSPICE

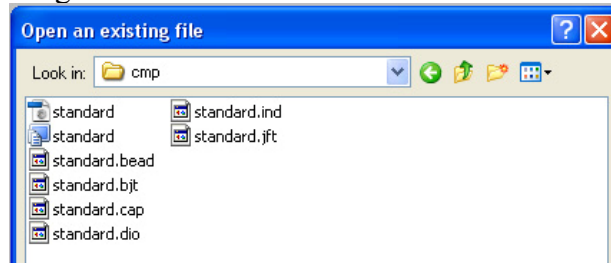
1. Here is an example to add a diode. Other components are added the same way.
2. First start by clicking the “File” menu, and “Open.”



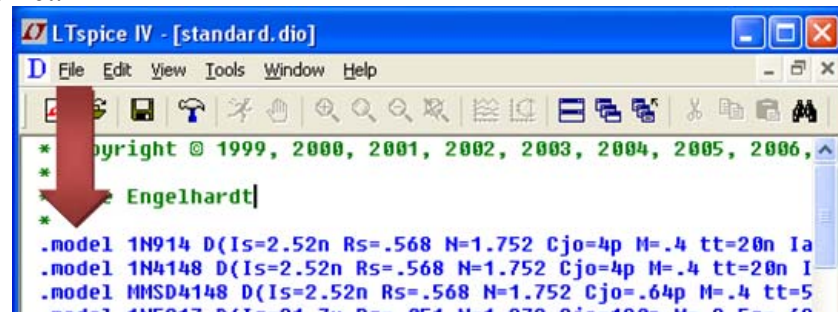
3. Look in the LTspice folder, and click the folder called “lib.” It contains the symbol libraries.



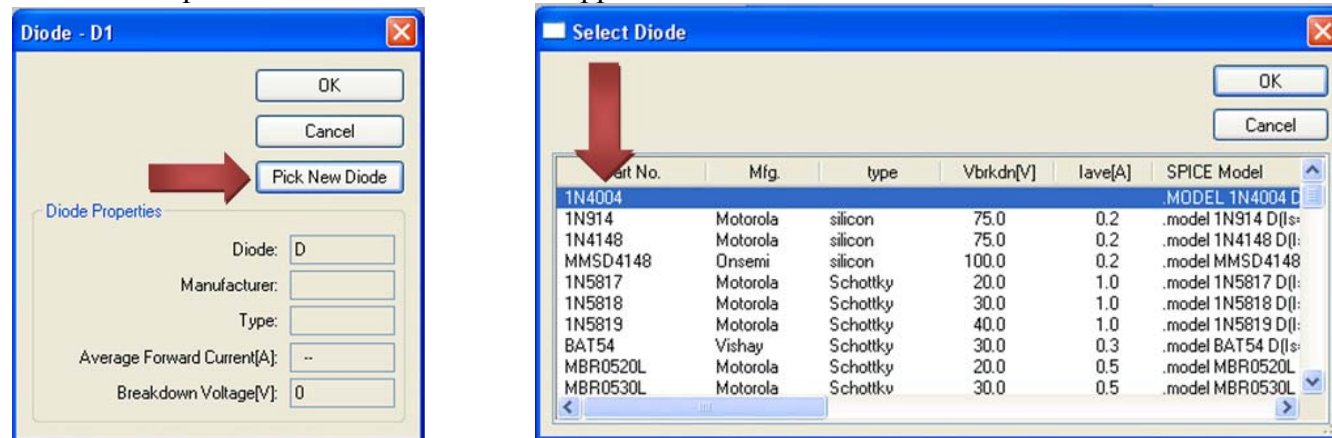
4. Select the folder titled “cmp” and change the “Files of type:” option at the bottom of the window to “All Files (*.*)”. You will then see a few files that begin with “standard.”



5. Choose and open what kind you need from these standard devices:
 - Standard.bjt – contains the bipolar junction transistors (BJTs)
 - Standard.dio – contains the diodes
 - Standard.cap – contains the capacitors
 - Standard.ind – contains the inductors
 - Standard.jft – contains the junction gate field-effect transistors (JFETs)
 - Standard.bead – contains the ferrite beads
6. Add a line with the “.model” line for the device you are adding to the end of the file. Now it should show up in the LTspice lists, and you should be able to pick it as though it was one of the pre-existing models. You can find the model spice netlist on the internet.



- In order to find your newly added model for use in your LTspice circuit, place the basic symbol for the component you want. Then, right click the part, and a window will pop up that contains the option to “Pick New Diode,” and then select the correct part number from the list that appears.



IV. SIMULATION

- Go to Simulate Menu in the tool bar and click on the “Edit Simulation CMD”.
- Select the type of simulation desired and make sure to place the spice directives on the schematic (See below for description of types of simulation)
- Then click on “Run”. (If errors appear then correct and rerun.)

V. SIMULATION COMMANDS

- DC Operating Point
 - This is the most basic and commonly used analysis.
 - It does not give any plots but it is still very powerful.
- Transient
 - It is used to observe various values of your circuit over time.
 - The ratio of Stop Time: Maximum Timestep determines how many calculations LTspice must make to plot a wave form. LTspice always defaults the start time to zero seconds and goes until it reaches the user defined

final time. Determine what timestep you should use before running the simulation. If you make the timestep too small the probe screen will be cluttered with unnecessary points making it hard to read, and all calculation performed by LTspice will take much longer to complete if you set the timestep too high, you might miss important phenomenon that are occurring over very short periods of time in the circuit. Therefore, play with step time to see what works best for your circuit.

3. AC Analysis
 - a. Allows plotting magnitude and/or phase versus frequency for different inputs of signals.
4. DC Sweep
 - a. Allows different types of sweeps of voltage, current and temperature to see how the circuit reacts.
 - b. For all sweeps make sure to specify a start, stop and the number of points you wish to plot.
5. Noise
 - a. This simulation allows for the creation of noise either as an input or output
6. DC Transfer
 - a. Finds small DC signal transfer function of a node voltage or branch currents due to small variations of independent sources.

VI. GENERAL TIPS AND HINTS

A. Changing Part Values: "M" and "m" are interpreted the same by SPICE, because it is case insensitive. Putting 10m and 10M for a resistor value will have the same effect, giving it a value of 10 milliohms. Also, don't enter "1F" for a capacitor, because this will read as a femto-farad. To avoid this, reference the following information:

- | | | |
|-------------------------|-------------------------|--------------------------|
| - T = terra = 10^{12} | - K = kilo = 10^3 | - N = nano = 10^{-9} |
| - G = giga = 10^9 | - M = milli = 10^{-3} | - P = pico = 10^{-12} |
| - MEG = mega = 10^6 | - U = micro = 10^{-6} | - F = femto = 10^{-15} |

B. LTspice Leading characters

“A” - Special functions device

“B” - Arbitrary behavioral source

“C” - Capacitor

“D” - Diode

“E” - Voltage dependent voltage source

“F” - Current dependent current source

“G” - Voltage dependent current source

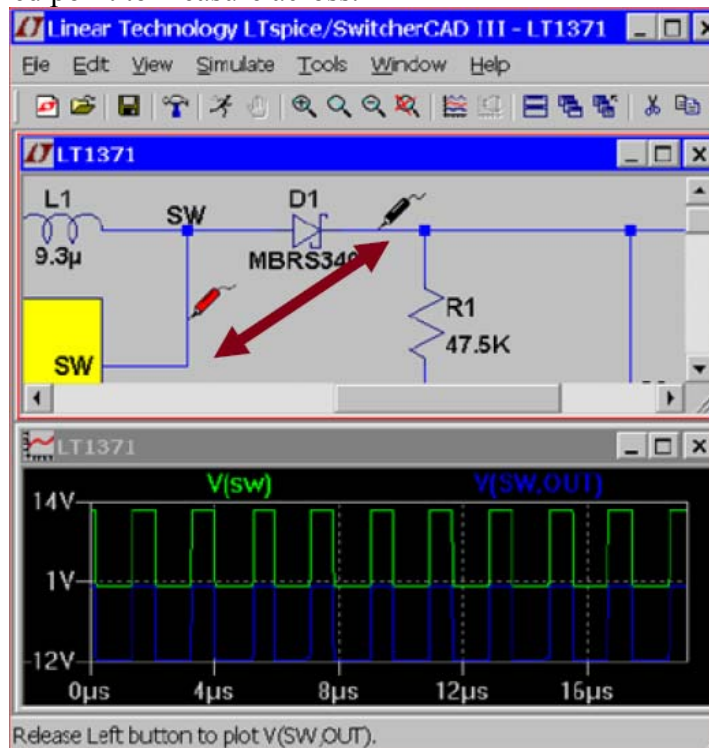
“H” - Current dependent voltage source

“I” - Independent current source

“J” - JFET transistor

“ K ” - Mutual inductance	“ U ” - Uniform RC-line
“ L ” - Inductor	“ V ” - Independent voltage source
“ M ” - MOSFET transistor	“ W ” - Current controlled switch
“ O ” - Lossy transmission line	“ X ” - subcircuit invocation
“ Q ” - Bipolar transistor	“ Z ” - MESFET transistor
“ R ” - Resistor	“ * ” - Comment
“ S ” - Voltage controlled switch	“ + ” - Continuation of prior line
“ T ” - Lossless transmission line	“ . ” - Simulation directive

- The auto-generated SPICE netlist is located in the View menu.
- To set a component to a specific manufacturer right click on the component and then click “Select Component Type”.
- Finding a voltage difference across two points can be achieved by simulating the design. Then using the red probe, left click, hold, and drag to desired point to measure across.



APPENDIX B

Total Harmonic Distortion

SIMULATE TOTAL HARMONIC DISTORTION USING LTSPICE

1. Setup a transient analysis with the analysis time a multiple of your signal generator's period
2. Add **.four** command using the "SPICE directive" button. `.op`

Syntax: `.four <frequency> [Nharmonics] [Nperiods] <datatrace1> [<data trace2> ...]`

Note: The frequency in **.four** command is the same as the frequency of an input source. For example, if your signal generator is set to 1kHz and you want to watch the node named "out." The command would be:

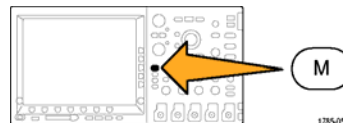
Example: `.four 1kHz V(out)`

3. After running the simulation, you can see the results of THD using *View >> SPICE error log*

MEASURE TOTAL HARMONIC DISTORTION WITH DPO4034 OSCILLOSCOPE

After acquiring the output signal from your circuit, follow the procedure below in order to calculate the Total Harmonic Distortion;

1. Push **Math**



2. Push **FFT**



3. Push the side-bezel menu **FFT Source** repeatedly for the channel with reference waveform to be analyzed (your output waveform).
4. Push the side-bezel **Vertical Units** button repeatedly to select **dBV RMS**.
5. Push the side-bezel **Window** button repeatedly to select **Hanning** window choice.
6. Push the side-bezel **Horizontal** button. Use knob **a** and **b** to pan or zoom the FFT display on screen. Below is the example screen after step 1-5.

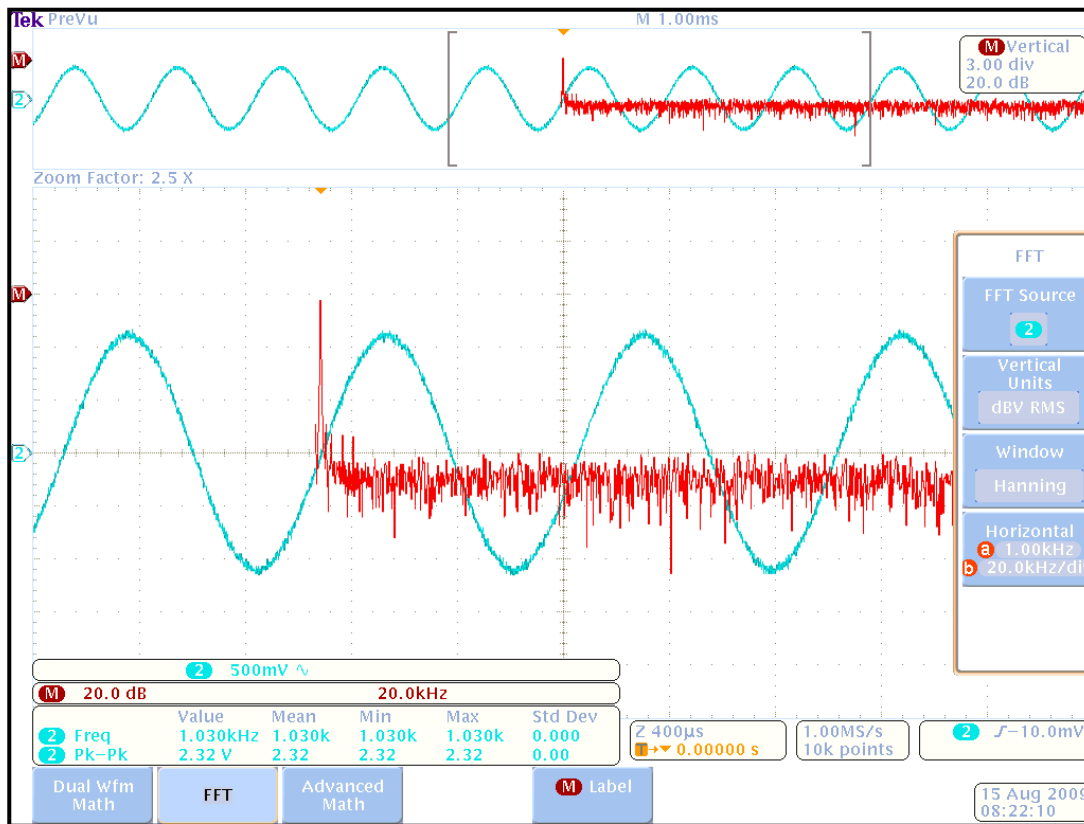
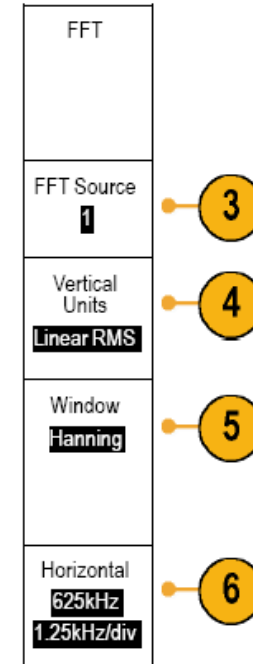


Figure Display Output Waveform and the Result of *Math/FFT* Function

7. Save your waveform in **.csv** format.
8. Import the data to your computer.
9. Choose the harmonic frequency and convert the data in dB to power using the equation below;

$$Power = 10^{\left(\frac{dB}{20}\right)}$$

Example: $P_1 = 10^{\left(\frac{-17.9156}{20}\right)} = 0.1271$

4.20E+02	-45.0688
4.50E+02	-24.15
4.80E+02	-21.0344
5.00E+02	-17.9156
5.20E+02	-20.8281

10. Use equation below to determine THD;

$$\% THD = \left(\sqrt{\frac{(P_2 + P_3 + P_4 + \dots + P_n)}{P_1}} \right)$$

Note: P_n = the n^{th} power harmonic, where the fundamental harmonic is at $n=1$.

APPENDIX C

Presentation Pointers

SECTION 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 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 appropriate and using the correct body language for the presentation.

Writing the document to be submitted for the presentation

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.

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*.

Content of the document

The content of the document would be similar to what you present in class. The 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 reader.
2. Preferably, use first person and active voice.
3. Avoid language which 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 great 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. **Citation** – Cite any sources for visuals/ text, by mentioning it verbally or including it on the slide,, in a smaller footer area..
 5. **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 don't know the answer, say so. Do not try to make up an answer.

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.

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:

- **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).
- **Prepare and research adequately** (with an opening that creates impact, and a closing that ends with strength).
- **Create a user-friendly draft** (that makes use of the available multimedia, such as PowerPoint presentation).
- **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).
- **Arrive early** (to meet up your team, check that the visual equipment works, go over the slides).
- **Apply the delivery techniques** as a presenter (visually, verbally and vocally).
- **Handle questions and answers with tact.** (Stick to the time-limit, so that there is time for the Q&A session).
- **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>

APPENDIX D

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