Tasks & Applying Knowledge of ECE

Work Breakdown Structure

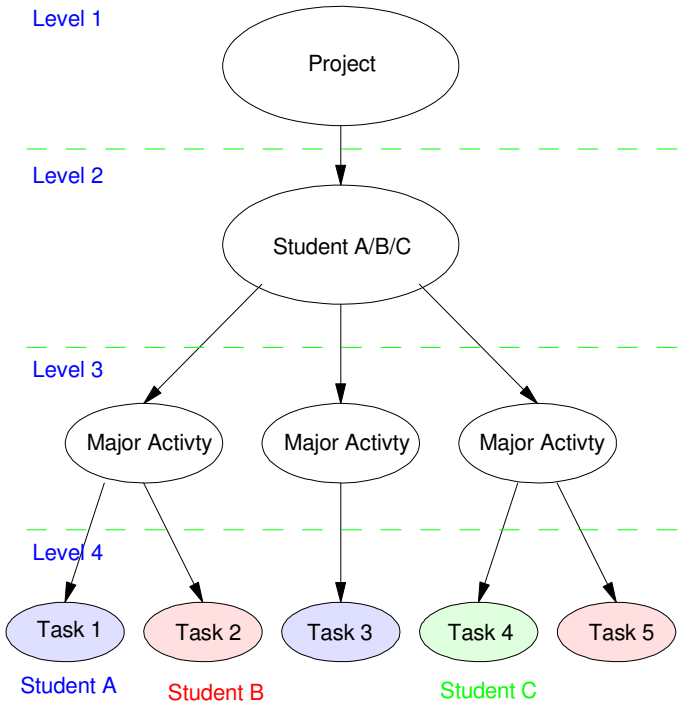
At this point, you should have

- Your Senior Design Project (level 1)
- The students in your group (level 2)
- Major Activities (level 3)
- A list of tasks to complete (level 4)

This week, the goal is to define

- What tasks are assigned to each student,
- When these tasks are to be completed, and
- Specify how each student is going to demonstrate knowledge of ECE while completing his/her tasks.

The last bullet is kind of important. Since students taking ECE Senior Design will be getting a degree in electrical, computer, or software engineering, you *do* need to demonstrate knowledge of ECE in some way. After all, half of your grade in ECE 403 depends upon this.



Goal of week #3: Identify what tasks each student is to complete

Apply Knowledge of ECE

How you split the tasks among members of your group is up to you. However, each student should have tasks which allow him/her to apply knowledge of ECE to these tasks:

- The whole point behind senior design is to demonstrate that our students are able to apply knowledge of ECE upon graduation.
- This is reflected in the course's grading scheme: you grade in Design II is depends upon your ability to apply advanced knowledge of ECE to your tasks.

Likewise, when you divide up the tasks among members of your group, make sure that each member has enough technical content so that he/she is able to get an A in Design II.

How is Design II Graded?

Essentially, your ability to apply advanced knowledge of ECE while completing your tasks determines your grade in Design II:

- A: While completing your tasks, you demonstrated an ability to apply four different advanced topics in ECE.
- B: .... three different advanced topics in ECE
- C: .... two different advanced topics in ECE
- D: .... one different advanced topics in ECE
- F: While completing your tasks, you did not demonstrated any advanced knowledge of ECE

This makes Senior Design a last check on the quality of our program: if a student somehow managed to get through all of our courses without learning anything, they won't be able to get through Senior Design.

If, on the other hand, suppose you got through our courses but are hazy on many of the topics you learned about. That's one of the reasons Bison Academy exists. Courses like circuits, electronics, embedded systems, etc. are all posted and available to anyone and everyone. If you forget what topics are covered in these courses, the syllabus for each course is spelled out with one topic for each lecture. All lectures, recorded lectures, homework sets, and solutions are available as well. Plus, there's always YouTube.

If you're a little hazy on how something works, go back and refresh your memory on how it works. You don't have to recall everything or relearn everything. All you need in this class to get an A is four.

Bison Academy: Lecture Topics				
#	**206 Circuits I**	**311 Circuits II**	**320 Electronics**	**376 Embedded**
2	Kirchoff's Laws	Phasors	Semiconductors	Comp Architecture
3	Series and Parallel	AC Impedance	pn Junction	Assembler
4	V and I Division	Complex Power	Ideal Diodes	Flow Charts
5	V Nodes	3-Phase	LEDs	Counters
6	Super Nodes	Convolution	AC to DC	Timing

If you need a refresher, Bison Academy lists topics covered in courses along with lectures & homework sets

What is *advanced knowledge of ECE?*

Exactly what constitutes *advanced knowledge* is kind of vague. Some things are not. For example, if you want to say the four advanced topics of ECE you're going to demonstrate are

- V = IR
- I = V/R
- R = V/I
- P = VI

you're not going to be happy with your grade. If I'm being generous, I might give you 2 points out of 10 for being able to apply Ohm's law. It's a pretty basic equation in ECE. The other three are just repeats - no points for demonstrating the same knowledge four times.

Surely, you learned more than that while at NDSU.

If you forget what topics were covered in courses you took, again, go back to Bison Academy. Each class is divided up in daily lectures, with each lecture usually covering a different topic.

ECE 320: Electronics I

Digital & Analog Electronics

Date	Lecture	Videos YouTube PlayList	Handouts	Homework
Week #2	Semiconductors Slides #4	4 Semiconductors	4 Thermistor	2: Semiconductors Solution #2 (pdf) Solution #2 (YouTube)
	The pn Junction Slides #5	5 The pn Junction Diodes (EB)	5 Diode Ckt	Quiz #2 Quiz #2 Solution (pdf) Quiz #2 (YouTube)
	Quiz			
Week #3	Idea Diodes Slides #6	6 Ideal Diodes	6 Diode Ckt	3: LEDs, AC to DC Solution #3 (pdf) Solution #3 (YouTube)
	Light Emitting Diodes (LEDs) Slides #7	7 LEDs Color Wheel 1000W LED	7 LEDs	Quiz #3 Quiz #3 Solution (pdf) Quiz #3 (YouTube)
	AC to DC Converters Slides #8	8 AC to DC Full Bridge Rectifier (EB)	8 AC to DC	

Sample syllabus from Bison Academy: Topics covered in that class are under lectures.
Content by way of pdf files and YouTube videos explain the content, along with homework sets and solutions.

As a general rule of thumb, in order to be an advanced topic, there needs to be some math involved. In my opinion, if you can't describe something with mathematics, you don't really understand it. What the math shows is you understand the equations that describe what you're doing. What the math shows is that you're not using a trial-and-error design method. Trial and error does work, but it doesn't demonstrate much knowledge.

An exception to this general rule is when dealing with software. Often times, there are no computations involved when writing code. However, that doesn't mean you can't or don't use advanced knowledge of ECE when doing so. Think about the courses you took, what topics were covered, and what you learned from those courses. Then think about how you will apply this knowledge when completing your tasks.

Tasks & One-Note vs. Advanced Knowledge

In homework #3, each student is to update his/her section of OneNote to include

- A list of tasks he/she is responsible for in Design II
- A comment on how he/she will apply advanced knowledge of ECE while completing these tasks, and
- The tasks to complete (filled in later on during the semester)

One-Note Section	Pages Within This Section	Content
Student A	List of Tasks	List of tasks you're responsible for How you'll demo knowledge of ECE while doing these tasks
	Task #1	document work on task #1 (completed at a later in semester)
	Task #2	ditto
	Task #3	ditto

Each student has a section in OneNote for his/her tasks

Note that you do not have sections for advanced knowledge. Your demonstration of knowledge is within each task. Tasks and knowledge are not necessarily one-for-one

- A given task could have involve no knowledge of ECE. For example, filling in paperwork may be necessary for the completion of your project, but it doesn't show off knowledge of ECE.
- A given task could involved many different topics in ECE. For example, if your task it to measure temperature, you could incorporate into your design
  - Circuits to convert the temperature to 0-5V analog
  - A Butterworth low-pass filter to remove noise
  - Software to read the analog voltage
  - Calibration and curve fitting to compute the temperature in degrees C
  - Statistics to determine the mean, standard deviation, and 90% confidence interval for the temperature
  - WiFi or Bluetooth so that this temperature is viewable from a cell phone
  - etc.

In Design II, focus on knocking off your tasks. Just be sure that while doing so, you are demonstrating knowledge of ECE along the way.

Can I use an Arduino in my design?

Back in Design I, you were required to use a Raspberry Pi-Pico if using a microcontroller. In Design II and III, you are free to use any microcontroller you want.

The great thing about the Arduino is there is a ton of code available online for it. That makes designs using an Arduino as simple as doing a Google search for the software and hardware you need.

The probem with the Arduino is there is a ton of code availble for it. Being able to find someone else's work with a Google search does not demonstrate knowledge of ECE. You're welcome to use Arduinos in your design. Just be sure that somewhere in your design you are demonstrating knowledge of ECE.

Can I update my OneNote section?

Yes. Each student's section of OneNote will be graded every two weeks. If you got 2 points out of 10 on one section, keep working on it. During the next grading cycle, your revised content will be regarded and the new grade will be updated on blackboard.

Note that the last day to update your OneNote sections is Friday of dead week.

How to I incorporate more ECE topics?

Suppose you complete all of your tasks but were not able to demonstrate an ability to apply advanced knowledge of ECE four different ways while doing so. What do you do?

Well, for starters, that's what homework #3 is for. In homework set #3, you are to

- Split your group's tasks among members of your group,
- While making sure that each member is able to get an A.

Meaning, there's enough ECE content that each member is able to apply at least four different advanced ECE topics while completing his/her tasks.

Even then, if you just don't have enough advanced ECE topics, there's still hope. One way to get more topics is to push your design. If you're measuring temperature to one decimal place, what do you have to do to measure temperature to two decimal places? Three decimal places?

If you have a program that works, can you make it more efficient? What's your program's execution time? Can you make it 20% faster? Can you make it 50% faster? Can you make it more generic?

Pushing your design almost invariably requires you to incorporate more and more ECE knowledge.

Can several group members use the same advanced ECE Topics?

Yes. Each student's tasks should be different. There could be overlap in what techniques you used in completing your tasks. For example, if one student in your group is using structured programming with Python as one of their advanced ECE tasks, that doesn't mean that everyone else is blocked from using structured Python programs. Each program should be different, however, since they are directed at different tasks.

Can several group members work on the same task together?

No. The point behind Senior Design is that each student is to demonstrate his/her ability to apply advanced knowledge of ECE before graduation. Being a part of group where someone demonstrated that ability doesn't count.

That being said, there are many ways to skin a cat. If a task is to measure temperature, you could turn this into several distinct tasks:

- Measure temperature using thermistor
- Measure temperature using an RTD

- Measure temperature using a BMP280 sensor
- Measure temperature using a DS17B20 sensor
- Get higher resolution using an external 20-bit A/D
- etc

Each of these is a separate and distinct task. You could have divide these among different members of your group.

Examples of Tasks & ECE Knowledge

For example, suppose your Senior Design project is to build a better mouse trap. Some of the technical challenges (level 3) and associated tasks (level 4) could be:

Challenge: Detecting a mouse is in the trap

- Task: Detect a mouse using an ultrasonic range sensor (software)
  - ECE Knowledge: Timer1 Capture interrupts (ECE 376)
  - Statistics: Student-t test to find the 90% confidence interval (ECE 341)
  - Digital filtering: remove the noise to get a better reading (ECE 343)
- Task: Detect a mouse using a vibration or acoustic sensor (hardware)
  - Instrumentation Amplifier: Amplify sensor to -10..+10V (ECE 311)
  - Analog Filtering: Reduce the noise level (ECE 321)
  - Envelope Detectors: Convert AC to DC, level = amplitude (ECE 321)
- Task: Detect a mouse using motion / shadows (software or hardware)
  - SPI Communications: Read a 16-bit A/D to get better resolution (ECE 376)
  - High-Pass Filters (differentiates): ECE 321 and ECE 311
  - Amplifiers and Mixers (get 0-5V out): ECE 311 and ECE 321

Challenge: Open and Close a Door

- Task: Use a stepper motor to open/close a door
  - Stepper Motor: Drive a stepper motor (ECE 376 - software)
  - H-Bridge: Build an H-bridge to drive the stepper motor (ECE 321 - hardware)
- Task: Use a solenoid to open/close a door
  - BJT Switch (ECE 320)
  - Mosfet Switch (ECE 320)

Challenge: Communicate with a Cell Phone

- Task: Send BlueTooth data with a uP (PIC, Arduino)
  - SCI Communications (ECE 376)
  - LCD Display (watch the SCI data communications - ECE 376)
  - Custom cell phone apps (CSxxxx)
  - Software UART using Timer0 (ECE 376 - if you need a second UART)

Challenge: Coordinate the hardware using software

- Task: Write a C program to read the sensors, drive the actuators, and display on a cell phone
  - Top-Down Programming: Writing and testing a C program using top-down techniques (CSxxx)

- Bottom-Up Programming: Writing and testing a C program using bottom-up techniques (CSxxx)
- Use of Modules and Subroutines: Writing and testing a C program using CSxxx techniques
- Use of tables and data bases (CSxxx)

There's almost a limitless number of ways to tackle any given problem. For ECE 403, as long as

- You have a working solution going into ECE 405 for each of your technical challenges, and
- Each student is able to demonstrate his/her ability to apply knowledge of ECE four different ways,

you've done enough to earn an A in ECE 403. You can do more, but that is enough to get an A.

Gantt Chart

Gantt Charts help you plan out the semester

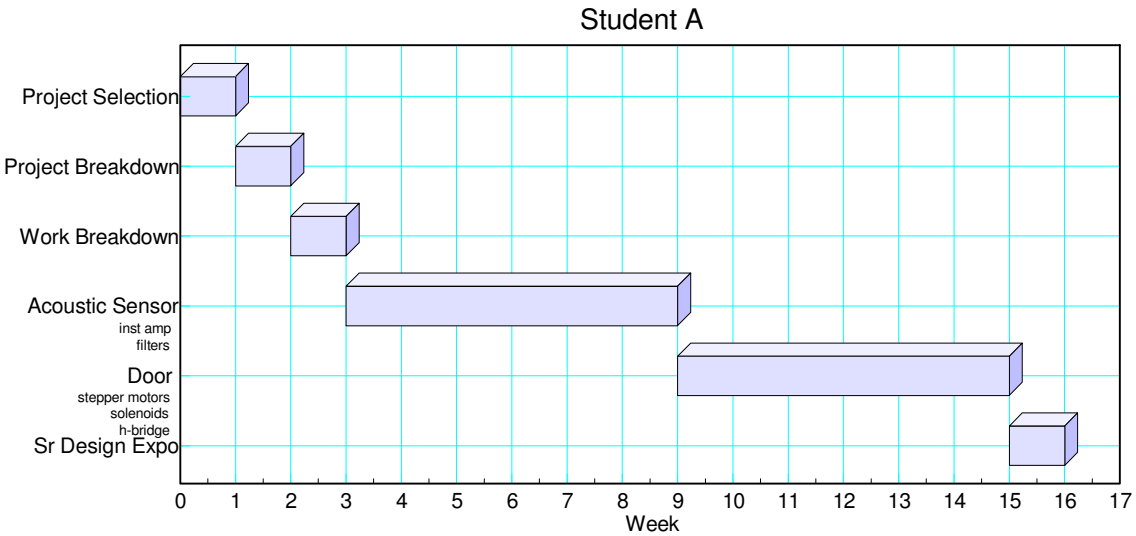
- What activities do you need to complete,
- How much time do you allocate for each activity, and
- When these activities are to take place.

Essentially, a Gantt Chart is a tabular form of each person's Work Breakdown Structure. The list of tasks kind of depends upon which project management structure you're using.

Waterfall: If you are going to do your tasks one at a time, your Gantt chart might look something like this:

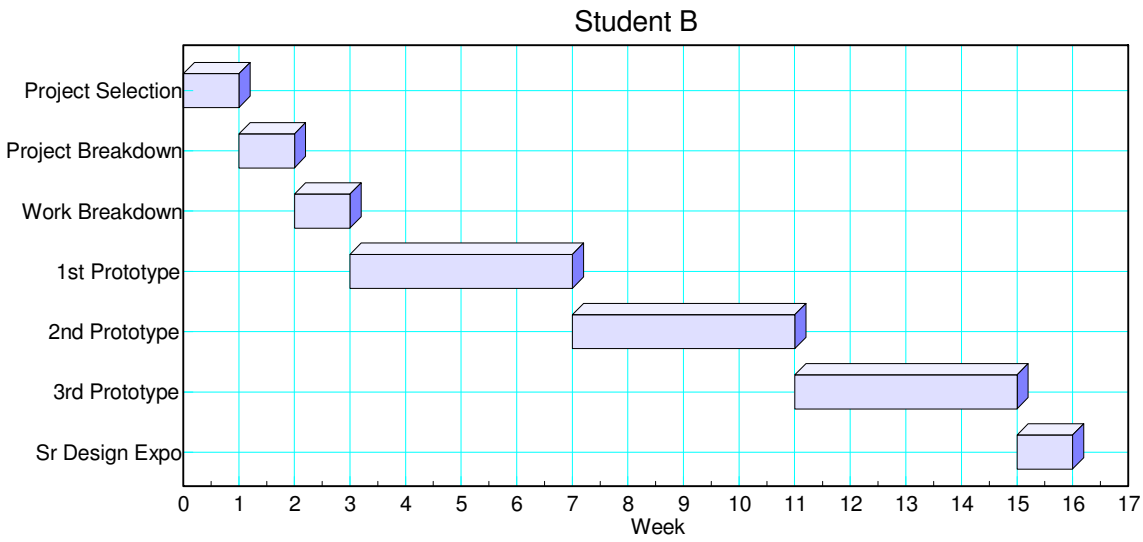
- Each task corresponds to one of the technical challenges you need to solve in ECE 403, and
- It also specifies which ECE topic you'll demonstrate on that task.

The latter serves as a reminder that when you're doing Task 2, you should include information showing your understanding of and ability to apply your knowledge of filters when designing an acoustic sensor.



Gantt Chart for a Waterfall-Type Project

Agile: If you are going to start with a rough prototype then keep improving it, your Gantt chart might look like this:



Gantt Chart for an Agile-Type Project

It's more or less up to you - just specify

- What activities you're planning on doing in ECE 403 (tasks), and
- When you plan on doing these tasks

with the end date being the end of the semester.

OneNote Sections

Documenting this in OneNote is a little tricky since you're trying to do two things at once:

- Document your work on each of your tasks, and
- Demonstrate your ability to apply knowledge of ECE four different ways.

How you organize your OneNote section is up to you. As long as you meet both objectives and the grader can find this information, any organization works.

Some suggestions based upon how your project is organized follows:

WaterFall: With a waterfall-type of project, you work on the tasks one at a time. This works well in OneNote: each page can contain:

- A different task, and while working on that task,
- Demonstration of your ability to apply knowledge of ECE

Note: You only need to demonstrate your ability to apply knowledge of ECE four different ways. If you have more than four tasks, it's perfectly OK to complete the latter tasks without dwelling on how you're applying knowledge of ECE in these latter sections.

If you're using a WaterFall approach for your project, your OneNote document might look something like this:

OneNote Section	Pages Within Section	Content
Student A	HW3: Work Breakdown	Major Activities (technical challenges) Tasks to complete in ECE 403 Gantt Chart for ECE 403
	Task #1	Task and/or Technical Challenge you're solving. Include: - Task Description - Advanced ECE Topic(s) this demonstrates - Analysis & schematics - Simulation results (analysis is good) - Breadboard results (analysis is good) - Photos and videos
	Task #2	ditto but for - A different task / challenge, and - A different area of knowledge of ECE
	Task #3	ditto
	HW8: ECE Tools	Note which two ECE tools you used to validate your design was working

Possible OneNote organization for a waterfall-type of project

Agile: With an Agile-type of project, you focus on getting a prototype out quickly. Then, with feedback on that prototype, you improve your design several times.

Documenting your work with this format as well as how you've applied knowledge of ECE is a little tricky. One way to do that is to have

- Separate pages for each iteration. This is where most of your documentation and results would go. Then have
- Additional sections where you point out how you applied knowledge of ECE in your design.

The additional sections are important since this amounts to half of your grade in ECE 403. For these sections, you don't need to copy or duplicate information in previous sections - just refer to it. The grader will be able to see your previous pages in OneNote.

OneNote Section	Pages Within Section	Content
Student B	HW3: Work Breakdown	Major Activities (technical challenges) Tasks to complete in ECE 403 Gantt Chart for ECE 403
	1st Prototype most of the content is here	Description open/close mousetrap door prototype #1 Analysis & Schematics Simulation Results Breadboard Results Photos of breadboard, oscope, etc Links to videos showing it worked (YouTube?)
	2nd Prototype	ditto
	HW8: ECE Tools	Note which two ECE tools you used to validate your design was working - you don't need to duplicate content - just refer to where you demonstrated use of two different tools

Possible OneNote organization for an agile-type of project

Examples of OneNote Pages:

Assume you're using a waterfall-type of project organization with

- N tasks specified for ECE 403, and
- Each task highlights your ability to apply a different set of knowledge of ECE.

Task 1: Trap Empty / Full Indicator

Description: Turn on an LED when the mousetrap is full, off when empty.

ECE Knowledge: Using a BJT transistor as a switch (ECE 320)

Requirement:

- Input:
  - 12V power supply, capable of 1A
  - A: TTL input: 0V/5V capable of 10mA
- Output: 5W white LED. Vf = 5V @ 1A
- Relationship:
  - When A is 0V, the LED is off
  - When A is 5V the LED is on, drawing 500mA, +/- 10mA

Analysis:

Pick a 6144 NPN transistor

- Capable of 3A continuous, 10A peak
- 200 < gain < 500
- Vbe = 0.7V
- Vce(sat) = 0.36V

Calculations:

$$R_c = \left(\frac{12V - 5V - 0.36V}{500mA}\right) = 13.28\Omega$$

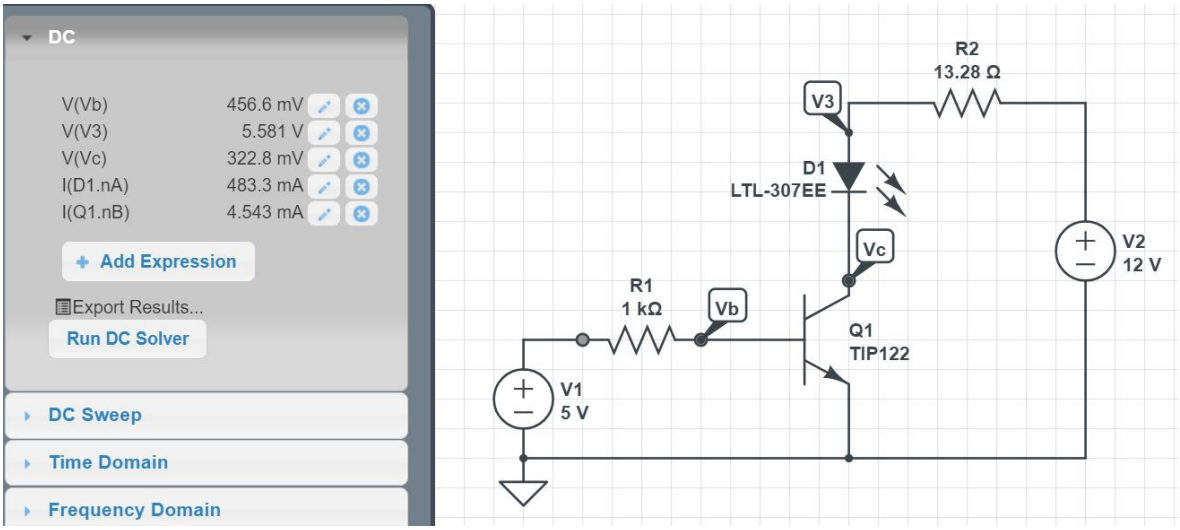
$$\beta I_b > I_c$$

$$I_b > \frac{I_c}{\beta} = \frac{500mA}{200} = 2.5mA$$

Let Ib = 4.3mA

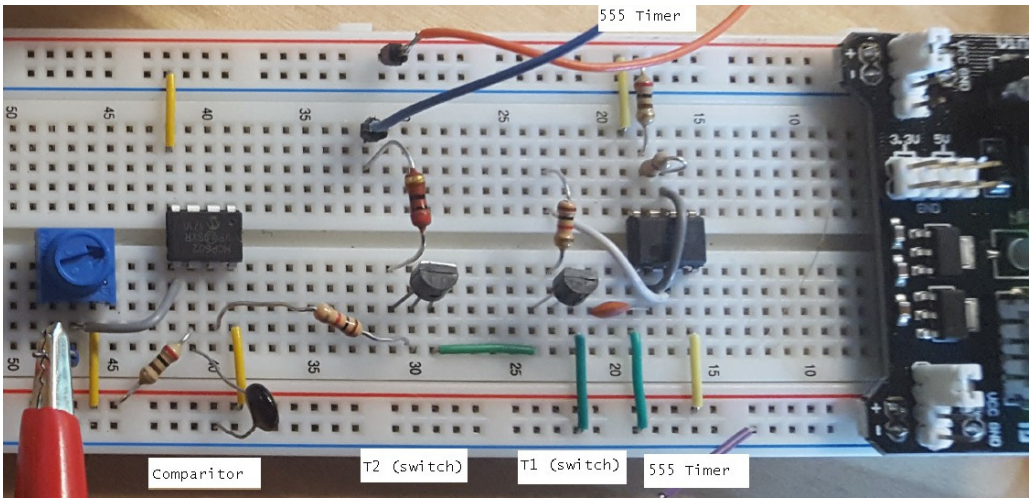
$$R_c = \left(\frac{5V - 0.7V}{4.3mA}\right) = 1k\Omega$$

Simulation:



Breadboard:

(include a photo similar to this - this is actually a different circuit but same idea...)



Summary:

	Calculation	Simulation	Breadboard
12V source	12V	12V	12.13V
5V source	5V	5V	4.89V
Rc	13.28	13.28	12.04
Rb	1k	1k	986
Vb(on)	700mV	456mV	723mV
Vce(on)	360mV	322mV	68mV
Vd	5.0V	5.258V	5.25V
Ib	4.3mA	4.543mA	4.27mA
Ic	500mA	483.3mA	479mA

Comments:

- Task #1 is completed: an LED indicator light can be turned on and off electronically.
- My ability to use a BJT transistor as a switch was demonstrated. The results were similar to what was expected. The slight differences in the voltages and resistances (actual vs. ideal) caused most of the differences.

Task #2: Noise Reduction

Description: Reduce the noise level on a temperature reading. This reduces the size of the 90% confidence interval for the actual temperature.

ECE Knowledge: Active Low-Pass Filters (ECE 321)

Requirements:

- Input: +/- 5V analog signal, capable of 10mA, 20-20kHz
- Output: +/- 5V analog signal, capable of 10mA, 20-20kHz
- Relationship:
  - $0.9 < \text{gain} < 1.1$ 0-100Hz
  - $\text{gain} < 0.2$ f > 200Hz

Analysis:

Number of poles needed in the filter

$$\left(\frac{250Hz}{500Hz}\right)^n < 0.2$$

$$n > 2.32$$

Let n = 3.

Pick a 3rd-order Chebychev filter with a corner at 238Hz

With a corner at 1 rad/sec

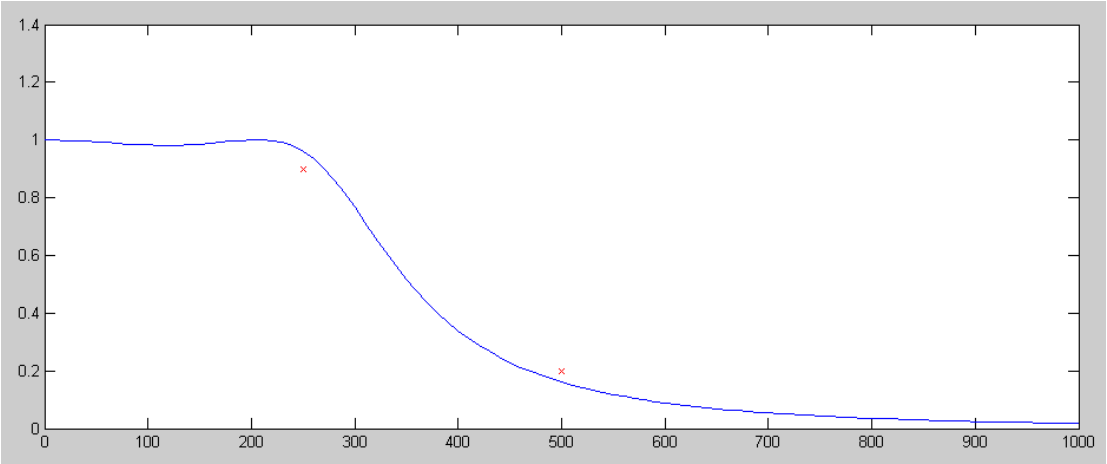
$$G(s) = \left(\frac{1}{(s+0.85)\left(s+1.21\angle\pm 69.5^0\right)}\right)$$

With a corner at 238Hz:

$$G(s) = \left(\frac{k}{(s+1275)\left(s+1815\angle\pm 69.5^0\right)}\right)$$

Checking in Matlab if this meets the requirements

```
>> f = [0:10:1000]';
>> w = 2*pi*f;
>> s = j*w;
>> p1 = 1500 * 0.85;
>> p2 = 1500 * 1.21 * exp(j*69.5*pi/180);
>> p3 = conj(p2);
>> G = p1*p2*p3 ./ ( (s+p1).*(s+p2).*(s+p3) );
>> plot(f,abs(G),[250,500],[0.9,0.2],'rx');
```



That works. To build this filter, do it in three stages

$$\left(\frac{1}{RC}\right) = 1275$$

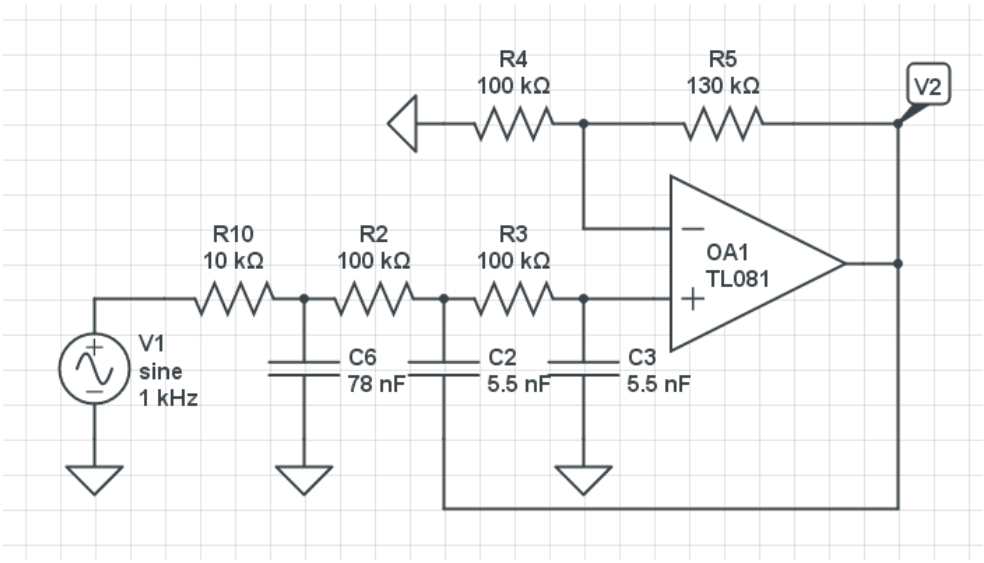
R = 10k, C = 78nF

$$\left(\frac{1}{RC}\right) = 1815$$

R = 100k, C = 5.5nF

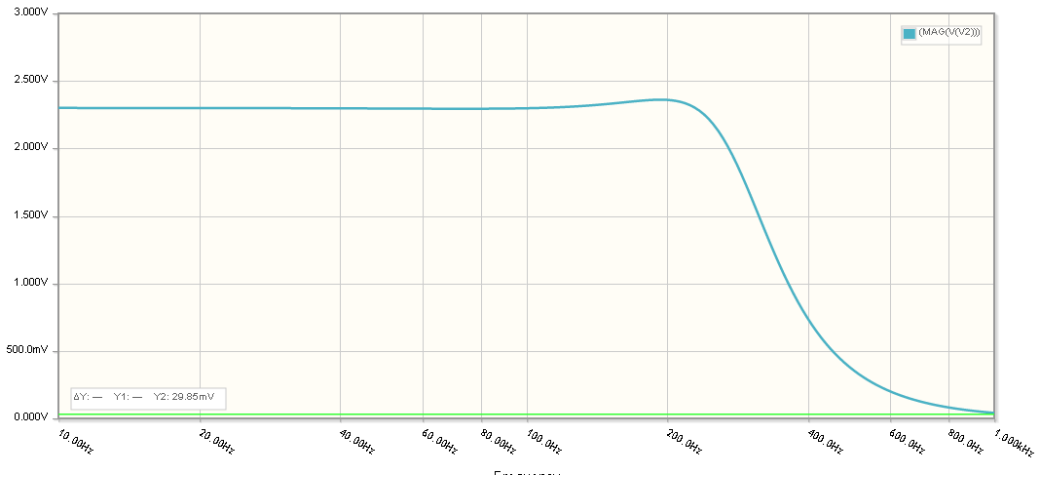
$$3 - k = 2\cos(69.5^0)$$

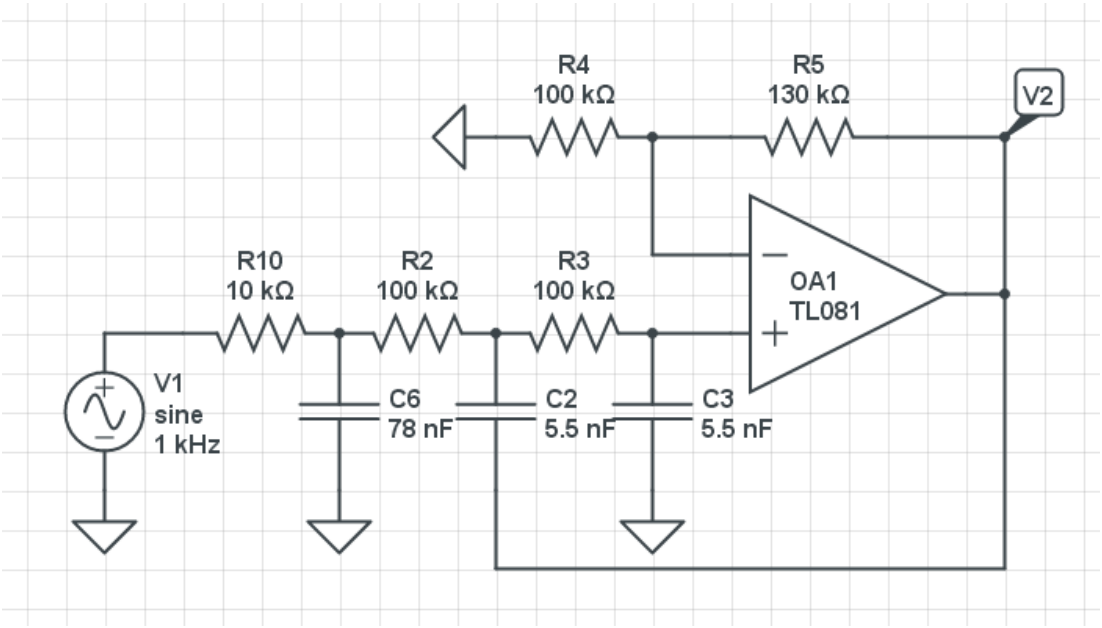
$$k = 2.30$$



Simulation: Simulate your filter in CircuitLab to verify that it meets your requirements

- 0.9 < gain < 1.1 in the pass-band region, and
- gain < 0.2 in the band-reject region

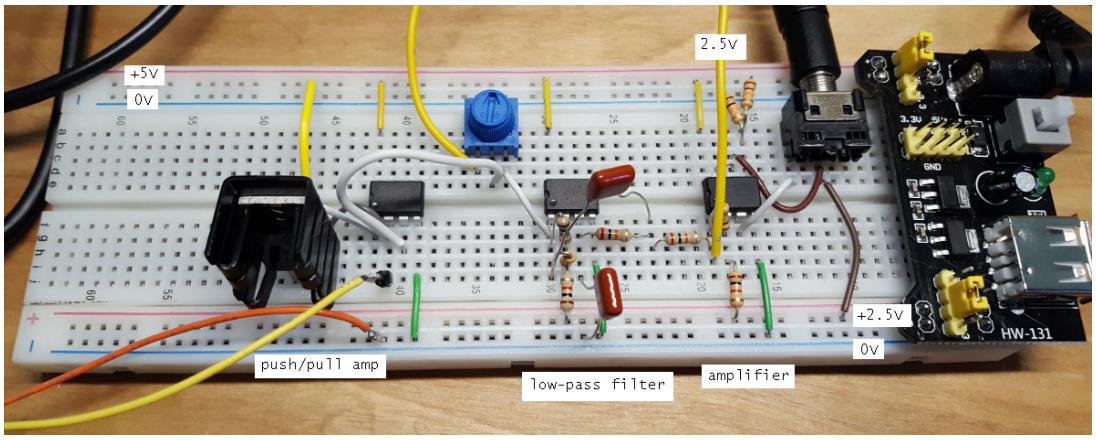




Hardware: Build your filter and verity it meets your requirements.

- 0.9 < gain < 1.1 in the pass-band region, and

gain < 0.2 in the band-reject region



Hz	100Hz	250Hz	500Hz	1000Hz
Requirement	1.1 < gain < 0.9	1.1 < gain < 0.9	gain < 0.2	gain < 0.2
Gain (calculated)	0.9825	0.9606	0.1610	0.0177
Gain (CircuitLab)	0.9878	0.8693	0.1533	0.01813
Gain (measured)	xxxx	xxxx	xxxx	xxxx

Homework #3: Work Breakdown Structure

For each student in your group, add pages to your section for HW3 to HW8

Add content to the page for Homework #3 including

- Technical challenges you need to solve in ECE 403 (Level 3 of work breakdown structure)
- Tasks you need to complete in ECE 403 (Level 4 of work breakdown structure).
- A Gantt chart for ECE 403
  - The order in which you'll do your tasks
  - When your plan on working on each task

Also list out

- Four advanced ECE concepts you'll apply to your part of the design
- Two ECE tools you'll use
  - Oscilloscope,
  - Multimeter
  - Emulator,
  - etc.

OneNote Section	Pages Within Section	Content
Student A	HW3: Work Breakdown	Major Activities (technical challenges) Tasks to complete in ECE 403 Gantt Chart for ECE 403 4x ECE concepts you will use 2x ECE tools you will use
	Task #1	*fill in later in the semester*
	Task #2	*fill in later in the semester*
	Task #3	*fill in later in the semester*
	HW8: ECE Tools	*fill in later in the semester*