Chapter 1 About the ECEN 4/5730 labs

All the labs will be conducted in the ECEE 281 Circuits Lab

You can check out your own kit at the beginning of each lab and it should be returned to your TA at the end of the lab.

You should complete each lab on your own, but discussion with other students is encouraged.

You are responsible for all the content in your kit. Please be careful with the parts and be responsible to keep track of the items in your kit. Do not leave any parts on your lab bench, or mistakenly put them in the soldering kits.

Accidents happen, and it is ok if something breaks. If something breaks, or is missing, let you TA know and it will be replenished.

You should be able to complete all the lab assignments during class time. If you need to come in at another time, or want to stay late, you can check out your kit until you complete the lab.

If you miss a lab, check in with Prof Bogatin to receive permission to make up the lab. Life happens, but you should have a good excuse when you ask permission to make up a missed lab. Then you can arrange with your TA to make up the lab but be considerate. This is an inconvenience to your TA and is not regularly scheduled time.

Chapter 2 Kits and Tools and Accessories

Your Buff card should be set up to open the ECEE 281 lab. This will give you 24/7 access when the bld is open.

Most important lab rule is safety for your self and you fellow lab attendees comes first. Some of the labs will involve soldering or potentially blowing stuff up. Always pay attention to potential safety hazards and use precautions, such as wearing safety glasses and alerting your neighbors of possible smoke.

No food is allowed in the lab. Only sealed liquid containers are allowed. This is so that if they are accidently knocked over, the do not spill on the expensive lab instruments.

2.1 The lab equipment

All the labs will be conducted in the ECEE 281 Circuit Labs. You will use the following equipment and will become expert in their use. These instruments are on each lab bench.

- ✔ *Keysight 4024 scope*
- ✔ *Keysight function generator*
- ✔ *Keysight triple power supply*
- ✔ *Keysight bench DMM or Beckman*
- ✔ *Keysight handheld DMM or ANENG 8008 DMM*

2.2 Solder kits

Each of you will use one of the soldering kits available in the 281 lab. There are a total of 30 kits. You may have to share.

If any of these items are NOT in the solder kit you pick up, please let your TA know and it will be replenished.

The following should be in each solder kit:

- □ *Weller solder station and power cord and soldering iron*
- □ *Blue silicone rubber mat*
- □ *Tweezers*
- □ *Needle nose pliers*
- □ *Diagonal cutter pliers*
- □ *Flux pen*

- □ *Roll of lead free solder*
- □ *Copper or brass sponge*
- □ *Safety glasses*
- □ *Copper solder wick*
- □ *Tube of solder paste*
- □ *Small magnifying glass*
- □

2.3 In your lab kit, you should find:

- □ *BNC coax cable*
- □ *BNC to minigrabber cable*
- □ *200 MHz 10x scope probes*
- □ *red, banana to grabber cables*
- □ *black, banana to grabber cables*
- □ *1 USB to mini cable for your Arduino board*
- □ *Safety glasses*

2.3.1 Building solderless breadboards:

- □ *Solderless breadboard*
- □ *Box of 6 colored solid AWG 22 core wires*
- □ *Pliers*
- □ *Wire snippers*
- □ *Jumper wires connected on ribbon cable, M-M*

2.3.2 Specific chips, semiconductors, passives

- □ *Resistor kit*
- □ *2 each 1 uF and 2200 uF capacitors or equivalent*
- □ *555 timer (NE555) and (ICM7555)*
- □ *2 2N7414 hex inverters*
- □ *MCP601 op amp or equivalent op amp*
- □ *(2) TIP31c or equivalent NPN transistors*
- □ *Leaded 16 MHz crystals*
- □ *Axial lead ferrite*
- □ *Assorted LEDS*
- □ *1 ADS1115 16-bit ADC module*
- □ *2 TMP36 temperature sensors*
- □ *An Arduino Uno and USB cable*
- □ *A 5 V AC to DC supply*
- □ *A 9 V AC to DC supply*
- □ *Power jack cable with red and black bare wire ends*

- □

2.3.3 Specific boards to be handed out at the start of the lab

- □ *Digikey ruler*
- □ *Assembly practice board*
- □ *Blow traces up*
- □ *Brd 2 Chaithra' s design*

- *Switching noise shield for Arduino*
- *Cross talk with cables board*

Chapter 3 Wk 1: building a portfolio of your projects

Your next step after you leave school is to get a job. Many of you will get a job in industry, some of you will go to academia, some of you may create your own companies.

Regardless of your next step, you should have a showcase of your achievements in college to show off what you are capable of to your future employers.

The best way of doing this is by created a simple on-line portfolio. There are many ways of doing this. The absolutely simplest way is using google sites. They offer a Student Portfolio template to get started.

Here is the step by step to create a google site: https://support.google.com/sites/answer/6372878?hl=en

This link will get you to your google sites pages: https://sites.google.com/new?tgif=d

By the end of week 1, you will create a google site which will be your portfolio. What you put up there is up to you. However, I strongly recommend you consider using selective labs you do in our class as examples to add to your portfolio.

For example, in wk 1, you are building a 555 timer and characterizing it. Your lab report is a 1 page description. Why not consider writing up to put on your portfolio page. What new thing did you learn? What skill would you want to show off to a potential employer?

Maybe:

- *Your ability to translate a datasheet into a working circuit*
- *Your observation of the difference in performance between two different 555 timers*
- *How you designed for a specific freq and duty cycle and your ability to measure it and achieve it.*
- *Special skills at best scope measurement processes.*

The details are up to you. The better organized your portfolio is, the better the message you project to anyone viewing it.

As you complete other projects in other classes, you should consider adding the description with pictures, in your portfolio page.

Chapter 4 Wk 1 Mon: build 555 timer as SBB

The first board project you will build is brd 1, the practice board. Before you commit the time (can be as long as 2 weeks) or the money (typically about $10 per board for our class), you want to have high confidence the components connected together, as described in the schematic, will work.

One way we increase confidence is by going through design reviews. The PDR happens early in the design cycle to review the plan of action. The CDR happens before we commit major resource. In addition, if it is practical, you can build a solderless breadboard version of the circuit to test it out, or, if you have the tools available and are skilled in the art, you can build a virtual prototype using simulation.

Often, you can build a solderless breadboard version of your project in hours and test out circuit alternatives before you finish the schematic capture and send the layout files to fab.

Before you start the design of brd 1, you will build most of the circuit in a solderless breadboard to get familiar with the circuit design and performance. Use this solderless breadboard circuit to gain confidence in your design.

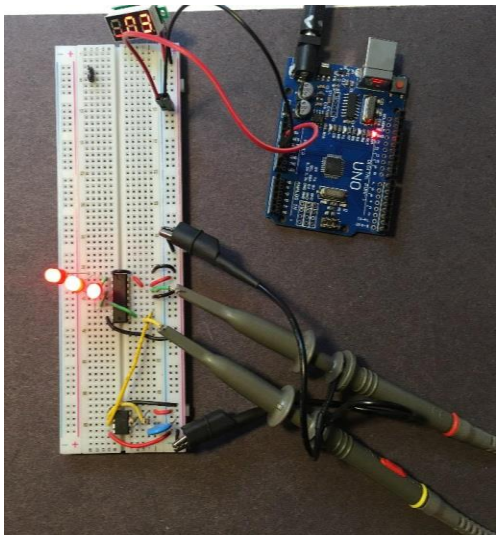
4.1 Before you start this lab

You should have viewed the skill building workshop videos on using the Keysight 4024 scope and 10x probe.

4.2 Purpose of this lab:

1. *Build a prototype version in a solderless breadboard of the brd 1 project you will design and build as a circuit board.*
2. *Try your hand at building a functional circuit in a solderless breadboard.*
3. *Get some hands-on experience with scope measurements.*
4. *Practice finding datasheets of components and reading them.*
5. *Find useful circuits online but make them your own. If you use a specific component in your schematic, know why!*
6. *Make some design decisions, balancing tradeoffs of parts and performance.*
7. *Practice rule #9*

An example of the simple solderless breadboard circuit you will build is shown below.



An example of the circuit you will build, debug and characterize. The top part of the circuit with the LEDs is with a hex inverter- not necessary for this lab.

4.3 What you will do in this lab

Goal: design a 555 astable vibrator circuit operating at about 500 Hz and about 50% duty cycle. Use the 555 timer chips and the capacitors in your kit. Pay attention to the circuit design in the SBB and how you will replicate it in your circuit board.

Use a 5 v rail from an Arduino to power the circuit. Plug the Arduino into a 9 V AC to DC converter. Use jumper wires from the 5 V pins of the Arduino to your board. Did you also connect the return path?

You will build one circuit with the fast 555, and then replace it with the slow 555 and compare the rise and fall time of the outputs. How well are each of them able to drive the 50 ohm resistor and LED?

Once you have your circuit working, drive an LED with alternately, a 50 ohm series resistor, a 1k, and a 10k series resistor. Notice any differences? Why?

With the scope and 10x probe, measure the:

- ✓ *Rise and fall time of the 555 output for each device, with and without the 50 ohm resistor and LED.*
- ✓ *The frequency and duty cycle- how does this compare with your predicted values.*
- ✓ *Only use cursors or measurement functions AFTER you have estimated the figures of merit with your mark I eyeball.*

4.4 Some hints

In this first lab, it is not necessary to use Best Measurement Practices. This lab is just a first step at building and debugging a circuit and performing simple measurements with a scope.

In following labs, the right way to engineer the interconnects and perform quality measurements will be the focus. It is more important to complete the circuit, get it working and end up with some measurements which seem reasonable.

You should at least practice Rule #9 in this lab. (Rule #9, of course, is never do a measurement or simulation without first anticipating what you expect to see.)

4.5 What you should pay attention to:

1. *How the holes in the solderless breadboard are connected.*
2. *How to read a datasheet to understand the electrical properties of the devices*
3. *How to read a schematic and translate it into a physical layout*
4. *How to wire up the connections to build a circuit*
5. *How to probe a circuit with a scope*
6. *How to use a scope to see a clear voltage signal*
7. *How to use measurements on a scope to debug a circuit*
8. *How to use Rule #9 to help you debug a circuit and get quality measurements.*
9. *How to use an Arduino Uno as a power source for 9 V, 5 V and 3.3 V voltages.*
10. *How to build a circuit in stages, debugging each part of the circuit as you go.*
11. *How to trigger a scope on a switching signal on one channel*
12. *How to adjust the time base of the scope to zoom in the features of interest.*
13. *How to extract an important figure of merit from the front screen of the scope using your Mark I eyeball. DO NOT USE cursors or the measurement function.*

If you are unfamiliar with some of these principles, check the skill building workshops on my YouTube Channel.

4.6 Check off with your TA

In order to get credit for this lab, you must go through a check out with your TA. If you do not get checked off during the lab, you will get a 0 for this lab.

At some point when you are ready, call your TA over for them to review what you have done. You should be prepared to answer the following questions:

1. *What is the connectivity of your solderless breadboard?*
2. *How are you routing power and signals on your solderless breadboard?*

3. *What did you predict for the frequency and duty cycle and what did you measure for each of the two 555 timers? Was there a difference?*
4. *How did you verify your 10x probe was compensated?*
5. *What is the rise and fall time of the two different 555 timer chips and how did you measure them?*
6. *What is the difference in brightness of the LEDs with 1k and 50 ohm resistors for each of the two 555 timers?*
7. *Why is there a difference?*
8. *What was the output voltage of the different 555 timers with and without the LED and resistor?*
9. *Did you learn anything new from this lab?*
10. *Did your circuit work the first time or did you have to debug any of it?*

4.7 Your lab report

In your 1-page lab report summary, include a screen shot showing the scope trace of the output of your 555 timer showing at least 2 cycles on easily readable scales.

Include a screen shot showing the rise or fall time on a scale allowing you to measure it from the front screen.

You select which 555 timer to use in your screen shots.

Include a description of what these scope traces mean and your analysis of them. How well do they match what you expect based on the circuit you designed and the data sheets?

When you are done with your report, create a pdf and post it on the canvas page under assignments for wk 1.

4.8 Grading rubric:

2 points if you have screen shots that are easy to read the information about the waveforms and you have an accurate analysis of the measurements.

1 point if the scope is not set up properly or if you are using the technical terms incorrectly.

0 points if you turn in nothing or clearly have no clue what you did.

Chapter 5 Wk 1 Wed, wk 2 Mon: Brd 1 design PCB

This lab will be on Wk 1, Wed and carry over to wk 2, Monday

5.1 Purpose of this lab

Complete your first PCB design and submit the board design files.

Your circuit board will contain:

1. *A power plug to use an external 5 V AC to DC charger to power your board*
2. *A 555 timer chip and circuitry designed for about 500 Hz and 60% duty cycle.*
3. *Using parts in the JLC integrated library. If you wish to assemble the board, you should select parts you can assemble. Otherwise use BASIC parts.*
4. *Add 4 LEDs of all the same color and series resistors: 10k, 1k, 300, and 50 Ohms.*
5. *Use indicator lights, test points and isolation switches as appropriate*
6. *Measure the 5 V input rail, the 555 output voltage and the current through the 50 Ohm LED.*

5.2 What you will need

Altium Designer and the integrated libraries provided online.

5.3 Prep before you start this lab

All the details are in the skill building workshop SBW-1 on my YouTube channel. Review each of these videos BEFORE YOU COME TO THE LAB. They will walk you through, from beginning to end, how to design this board.

5.4 What you will do

Before you come to the lab, you should review the videos in SBW-1.

Before you come to the lab, you should make a start at sketching the block diagram, the schematic, the schematic capture and the layout.

Wk 1, Wed: During the lab time, you will finish the schematic capture and the layout under the guidance of the TAs

Wk 2: Mon: come to class with your schematic and layout completed. We will do a CDR in the lab.

1. *Selected students will present their schematic for group review.*
2. *Students will pair off and do a peer design review with each other's design.*
3. *Students will revise their designs.*
4. *Selected students will present their layout for group review.*
5. *Students will pair off and do a peer design review with each other's layout.*
6. *Students will revise their layout.*
7. *Before the end of the lab, each student will have their schematic and layout checked off by their TA. Their TA will NOT correct their designs, but give a go, no go. If it is a no go, students will have to figure out why and make corrections.*

On wk 2, Monday by midnight, students must submit the 3 design files with appropriate names and extensions to the canvas dropbox.

On Tues morning, all board orders will be placed.

5.5 What you will turn in or complete for this lab

The Wk 2, Monday lab assignment is to submit your three design files to canvas.

Your score is 2 if you submit the design files on time.

Your score is 1 if the files are not correct, providing they are re-submitted before midnight, Monday wk 2.

Your score is 0 if they are not submitted. And your board will not be ordered, and you will not be able to complete the brd 1 report.

5.6 The schedule for the completion of brd 1

Wk 1, Wed: finish your design

Wk 2, Monday: complete CDR and submit your design files

Wk 2, Tues: boards will be ordered

Wk 5, Mon: bring up and measure your boards. Assembly ONLY by JLC

Wk 5, Friday: final report due, worth a midterm, 10% of your grade.