PHY405-L01

Introduction to Electronics Lab

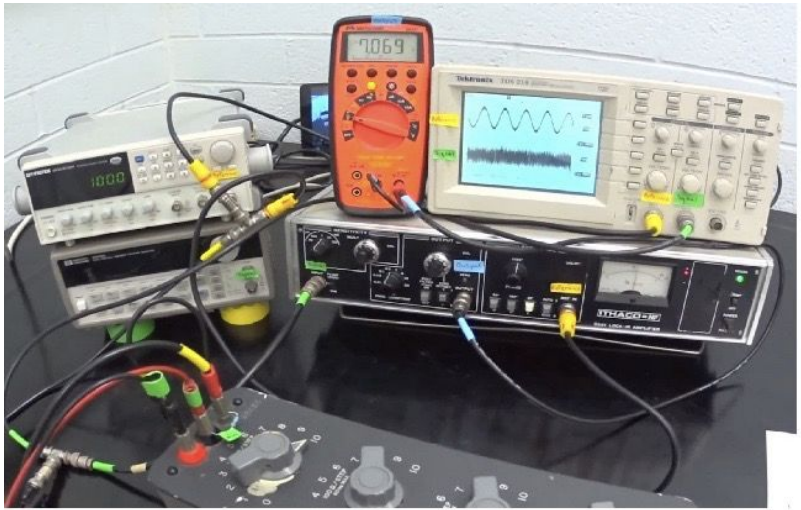
What is the point?

- Physicists use electronics to measure and process signals
- We want to be able to
  - Design and build simple circuits
  - Recognize and debug problems
- But this course is not going to transform you into an electrical engineer
  - You'll need a bit more work for that

Gamma Ray Detector Pre-Amplifier Circuit

Modelling and Debugging

- All models are wrong, but some are useful
- Physicists need to be able to model systems, and to recognize and debug discrepancies between their model and reality.



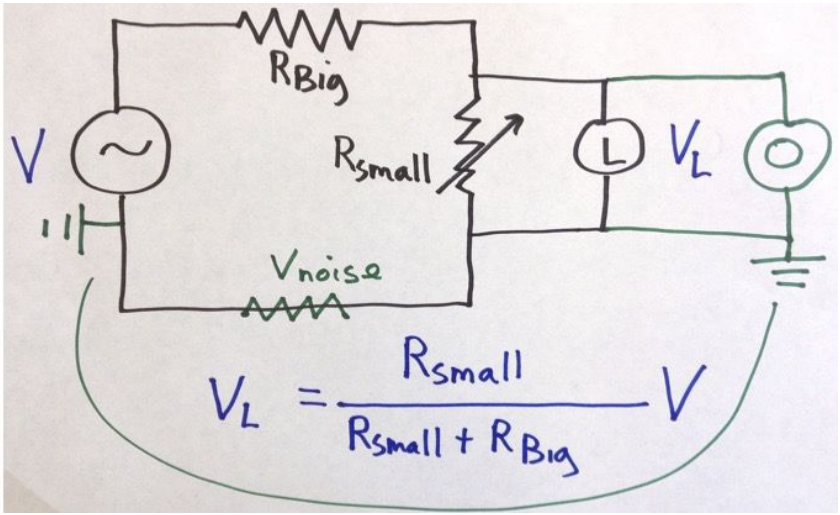


Photo and diagram of lock-in amplifier test setup from APL instructional video

Or like this…

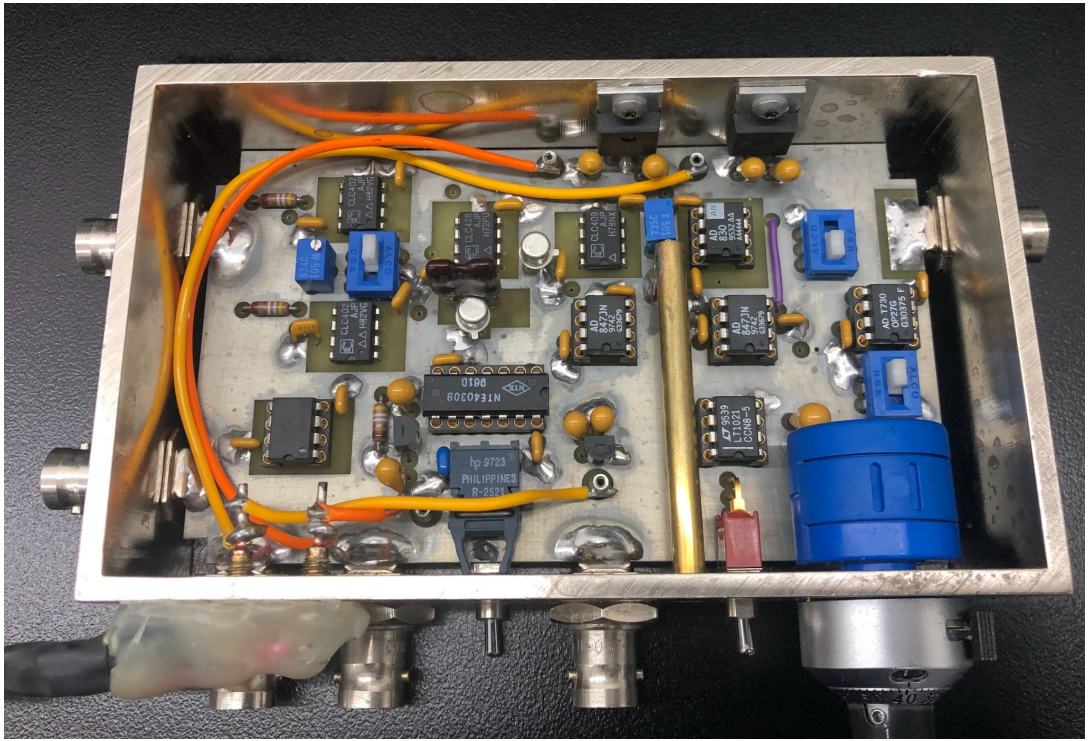


Photo of lock-in amplifier in my lab

Logistics of this class

- Course Home page
  https://www.physics.utoronto.ca/apl/405/index.html
  - Course schedule can be found on this webpage
  - Also contact information for the TAs and myself
  - Lectures and Lab manuals will be posted on this webpage
- Quercus
  - Announcements will be broadcast over Quercus
  - Lab reports will be submitted on Quercus

PHY405 Electronics, Winter 2025

Last updated: Jan. 9, 2025

Adapted from Prof. David Bailey's website in 2022

This laboratory course is an introduction to the world of electronics. Students will learn the joys and perils of electronics, by designing, constructing and debugging circuits and devices.

The course will try to cover topics ranging from filters and operational amplifiers to micro-controllers, and will introduce students to concepts such as impedance, transfer functions, feedback and noise.

Class policies

Please read the Syllabus
Extra information is provided at the bottom of the page.

People

Instructor:

- Ziqing Hong: zqhong@physics.utoronto.ca

TAs:

- Elspeth Cudmore (Lab S-5): elspeth.cudmore@mail.utoronto.ca
- Nixon Vida-Michelle (Lab 5-P): vidam.nixon@mail.utoronto.ca
- Graham Johnstone (Grading): graham.johnstone@mail.utoronto.ca
- Vasilii Pustovoit (Grading): vasily.pustovoit@mail.utoronto.ca

Course Calendar

Students must enrolled in one of the two lab sections.

Day	Time	Content
Thursday	2:10-3:00 PM	Lecture, SS1073
Monday	2:10-5:00 PM	PRA 0101, MP238
Friday	2:10-5:00 PM	PRA 0201, MP238

First lab (Jan 13/16) will be done virtually, with zoom-based support provided during the normal lab time.

Open Lab

Open labs will be offered on Mon., Wed. and Fri. outside the regular lab hours. TA support will only be available

Week	Lec/PRA0201/PRA0101	Topic	Lab & Due Date (PRA0201/PRA0101)
1	Jan. 9/10/13	Introduction & Simulation	**Lab S**: Jan. 17/20
2	Jan. 16/17/20	Basic Physics of R, L, C	**Lab 1**: Jan. 24/27
3	Jan. 23/24/27	R, L, C, Computer Control	**Lab 2**: Jan. 31/Feb. 3
4	Jan. 30/31/Feb. 3	Design, Diodes	**Lab 3**: Feb. 7/10
5	Feb. 6/7/10	Op Amps	**Lab 4**: Feb. 14/**24**
6	Feb. 13/14/24	Analog Meets Digital: Arduinos	**Lab 5**: Mar. Feb. 28/**3**
Reading week			
7	Feb. 27/28/3	Transistors	**Lab 6**: Mar. 7/10
8	Mar. 6/7/10	Fast Pulses, Digitization, High Voltage	**Lab 7**: Mar. 14/17
9	Mar. 13/14/17	Fun and Projects	**Lab 8**: Mar. 21/24
10	Mar. 20/21/24	Noise Modeling / Micro-project-1	**Lab P**: Apr. 4
11	Mar. 27/28/31	Micro-project-2	**Lab P**: Apr. 4

Course sections

- One lecture, every Thursday 2:10 PM, SS1073
  - You probably already know it if you're here…
- Every student must be enrolled in one of the two lab sections
  - PRA0101: Mondays 2:10 - 5 PM
  - PRA0201: Fridays 2:10 - 5 PM
- Labs are in MP238
  - Work in pairs for Lab 1-8 and micro-project
  - Each pair will get assigned a locker and a set of tools
  - Components available in the lab

Schedule

- Lab S (Simulation) first week
  - Friday Jan. 17 & Monday Jan. 20
  - Done at home
  - TA support will be provided during lab time via zoom
- 8 Labs following
- All lab reports due a week later
  - Any deadline fall in reading week gets postponed by a week
- Final project for the last 3 weeks
  - Due last day of the term, Apr. 4

Week	Lec/PRA0201/PRA0101	Topic	Lab & Due Date (PRA0201/PRA0101)
1	Jan. 9/10/13	Introduction & Simulation	**Lab S**: Jan. 17/20
2	Jan. 16/17/20	Basic Physics of R, L, C	**Lab 1**: Jan. 24/27
3	Jan. 23/24/27	R, L, C, Computer Control	**Lab 2**: Jan. 31/Feb. 3
4	Jan. 30/31/Feb. 3	Design, Diodes	**Lab 3**: Feb. 7/10
5	Feb. 6/7/10	Op Amps	**Lab 4**: Feb. 14/**24**
6	Feb. 13/14/24	Analog Meets Digital: Arduinos	**Lab 5**: Mar. Feb. 28/**3**
		Reading week	
7	Feb. 27/28/3	Transistors	**Lab 6**: Mar. 7/10
8	Mar. 6/7/10	Fast Pulses, Digitization, High Voltage	**Lab 7**: Mar. 14/17
9	Mar. 13/14/17	Fun and Projects	**Lab 8**: Mar. 21/24
10	Mar. 20/21/24	Noise Modeling / Micro-project-1	**Lab P**: Apr. 4
11	Mar. 27/28/31	Micro-project-2	**Lab P**: Apr. 4

Grading

- Each of the lab S, 1-8, Project is worth 10% of the final course grade
  - Lowest score from labs 1-8 will be replaced by the average of the rest from Labs 1-8
- Lab S is marked entirely on the report
  - Work individually and submit your own lab report and short videos
- Labs 1-8 marks are based 30% on in-lab work and 70% on the report
  - **Work in pairs** on the lab exercises but **submit your own** lab report
- The micro-project (lab P) is marked on the basis of individual report and a short team video

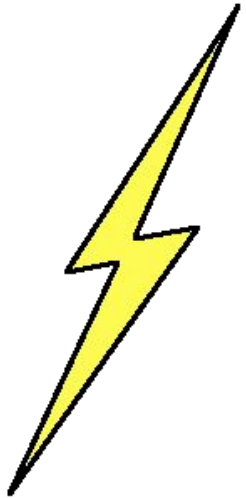
Late assignments

- 10% penalty of the assignment value per calendar day
- Unless medical or similar accommodations are required, or if prior arrangement has been made with the course instructor

Safety

As in any lab, there are potential risks.

Electricity can kill!



- The Workstation DC power supply provided in the lab can output up to 1A @ 25 V.
  - They can only deliver voltages that are usually safe, but the current could cause damage if it could penetrate your skin
  - You may create circuits in this course that amplify voltage.
  - **Do not go above 30 V without permission from the Instructor**
- Do not use any power supplies not provided
- **Power off while changing circuit**
- **Always double check your circuit before power on!**

Electricity can make things hot!

- $P = V^2/R$, a 100 Ohm resistor may get hot with merely 5 V across
  - Be cautious applying increasing voltages to your circuit
  - Be careful touching components in your circuit
  - **If you smell something burning, turn off the power to the circuit!**
  - **Keep flammable materials, e.g. paper, away from your circuits!**
- Soldering irons are burning hot - don't touch!
  - Wear safety glasses when soldering!
  - Wait a few seconds for components to cool after soldering before touching
- Soldering and overheated components can produce smoke
- Capacitors can explode with a loud pop and a cloud of smoke if too much voltage is applied
  - Some can only take voltages in one direction. Check before power up!

Power strips

- Power strips are sometimes heating up
- Don’t pile cozy winter jackets onto them…

Other risks

- Never apply excess force to anything
  - Your small pliers are useful to straighten wires and insert them into breadboard
  - Ask for advice before reaching for a hammer
- Keep unprotected eyes away from sharp wires
  - When trimming a wire, small pieces may fly out
- Some LEDs can be painfully, even dangerously, bright just before they die, if too much voltage is applied
  - Always increase LED voltages gradually and never stare directly at a bright LED

Be mindful in the lab… It's your skin…

Lab notebooks

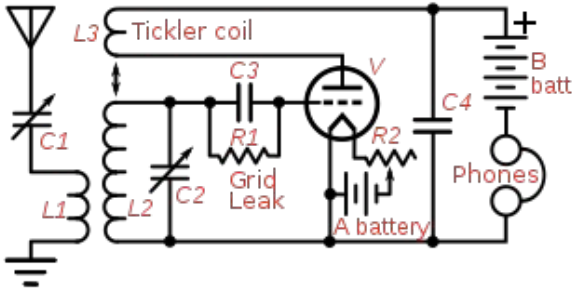
- Students must document their work and learning in this course. Read the notebook guidelines.
- These notebooks will not be graded, but must be available if the Instructors or TAs ask to see it.
  - e.g. while helping you debug a problem
- Paper and/or electronic notebooks are allowed.
- Typical uses are:
  - keep a paper notebook for quick sketches, notes, and calculations
  - record any data in an Excel file with lots of notes, dates, times, as well as photos, and screen captures embedded right in the file.

Lab reports

- A short pdf lab report (and sometimes a video or other files) must be submitted through Quercus for every lab.
- See the report guidelines for more information on the requirements.
- The report should briefly describe what you did and clearly provide any information requested.
  - When answering specific questions in the write-up, provide sufficient context for answers.
  - – e.g. a data plot that is the basis for an answer
- But be succinct!

Final MicroProject

- The final two weeks of the semester are dedicated to ”Lab P” – a microproject that will be marked on the basis of originality, execution, and testing, and the quality of the final report.
  - i.e. you are going to build an interesting circuit that can be constructed with available components.
  - Topics are up to you but can be discussed with the instructor.
- See the project guidelines for more information.



Reference Resources

- Because this is an 400-level physics lab course, students are expected to be able to research needed information on their own. Everything you need to know may not be on the course webpages!
  - There is no textbook for this course, but The Art of Electronics by Paul Horowitz and Winfield Hill is a good reference
  - Google is powerful. Or Bing…
  - Also see the course Resources for other recommended texts, online resources, circuit simulators, manuals, ….

Academic Integrity

Students must follow the standards of academic honesty when writing assignments and collaborating with fellow students.

- Any work you submit must represent your own honest efforts.

Plagiarism — representing someone else's work as your own or submitting work that you have previously submitted for marks in another class or program — is a serious offence that can result in sanctions. Speak to the Instructor if you are at all unsure about what might constitute plagiarism.

In PHY405

- Any data you report must have been taken by you or very clearly attributed.
- Borrowing code or discussing work with other students is fine as long as it is properly acknowledged.
  - Any code based on online sources must be attributed.
  - Any code shared from another student must be attributed.
  - It is plagiarism for you to copy what another student did without attribution.
- You are only required to turn in lab reports, but the Instructor or TA may ask to see your notebook and associated computer files.
  - Fail to provide them might result in zero for that report, or even more severe sanctions if the Instructor believes there has been a violation of the University of Toronto Academic Code.

Academic Accommodations

Specific Medical Circumstances

- If you become ill and it affects your ability to do your academic work, consult me right away. Normally, I will ask you for documentation in support of your specific medical circumstances.This documentation can be an Absence Declaration (via ACORN) or the University's Verification of Student Illness or Injury (VOI) form.

Personal Reasons

- There may be times when you are unable to complete course work on time due to non-medical reasons. If you have concerns, speak to me or to an advisor in your College Registrar's office;

Academic Accommodations

Religious Accommodation

- If you anticipate religious observance may cause you to miss a course deadline, please let the Instructor know ASAP.

Students with Disabilities or Accommodation Requirements

- Students with diverse learning styles and needs are welcome in this course.

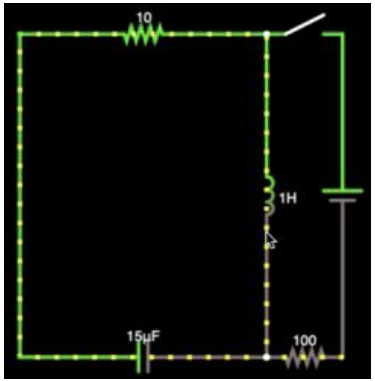
Mental Health & Well-being

- Everyone feels stressed now and then – it is a normal part of university life.
- As a student, you may experience challenges that can interfere with learning.
- An important part of the University experience is learning how and when to ask for help:
  - Course Instructor
  - Physics Undergradute Office
  - College Registrar
  - http://studentlife.utoronto.ca/
  - http://www.studentlife.utoronto.ca/feeling-distressed

Lab S - Simulations

An introduction to our usual pedagogical circuit simulator

- Falstad
  - Circuit simulator
  - Analog filter applet



and a taste of a more serious tool

- LTSpice

R, L, C

- In previous courses you probably have learned about resistance (R), capacitance (C), and inductance (L).
- We'll talk about them more in subsequent lectures and labs, but for these simulations you mostly just need to remember that:
- R – resists current flow and converts electrical energy into heat ($P=V^2/R$)
- C – impedes low frequency AC
- L - impedes high frequency AC

Filters

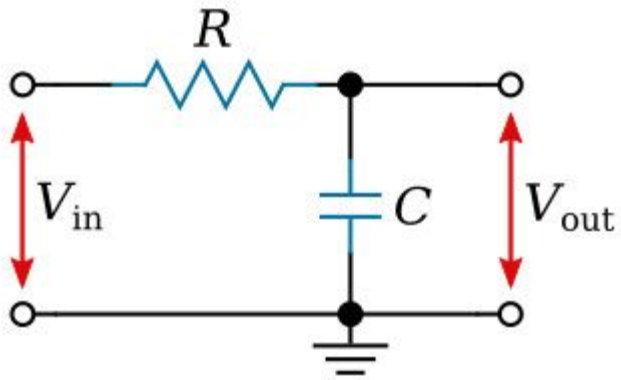
Electronic components can be used to build filter circuits that pass only a range of frequencies. Such filters are characterized by their steady-state transfer function :

$$H(\omega) = \frac{V_{output}(\omega)}{V_{input}(\omega)}$$

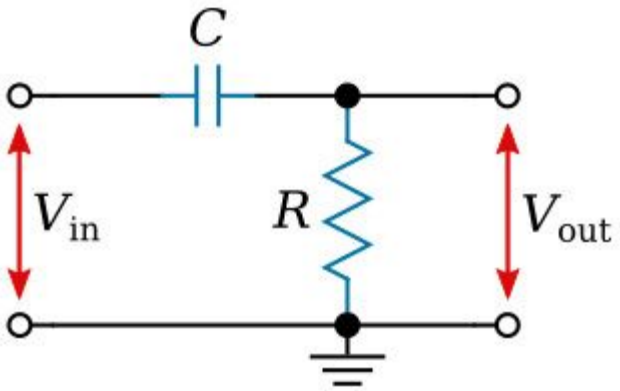
Where $\omega = 2\pi f$ is the radial frequency

Low pass and high pass filters

RC Low Pass Filter



RC High Pass Filter

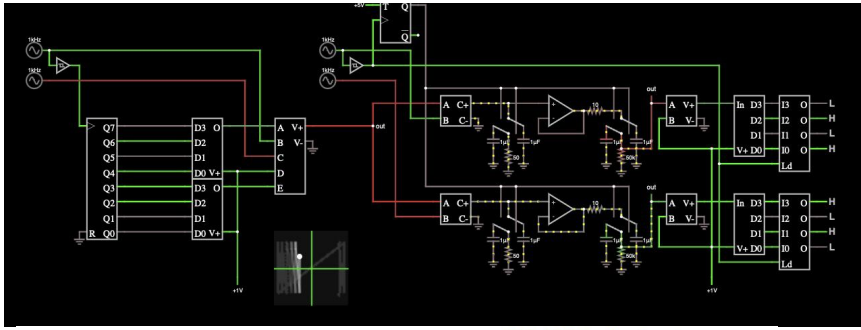


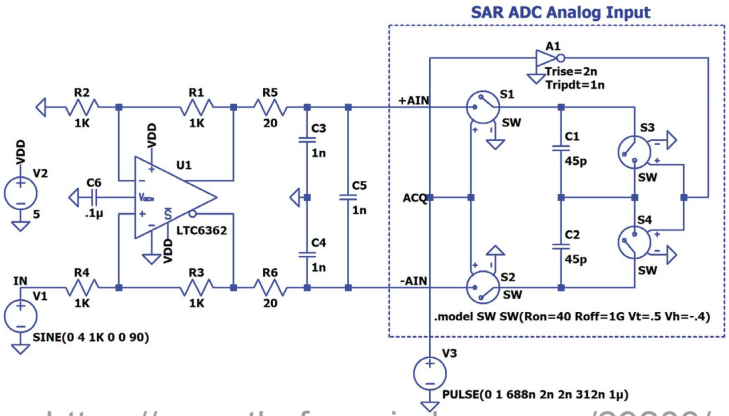
Can derive the transfer functions of them

Or… measure them, since this is a lab course

Learning how to use simulators

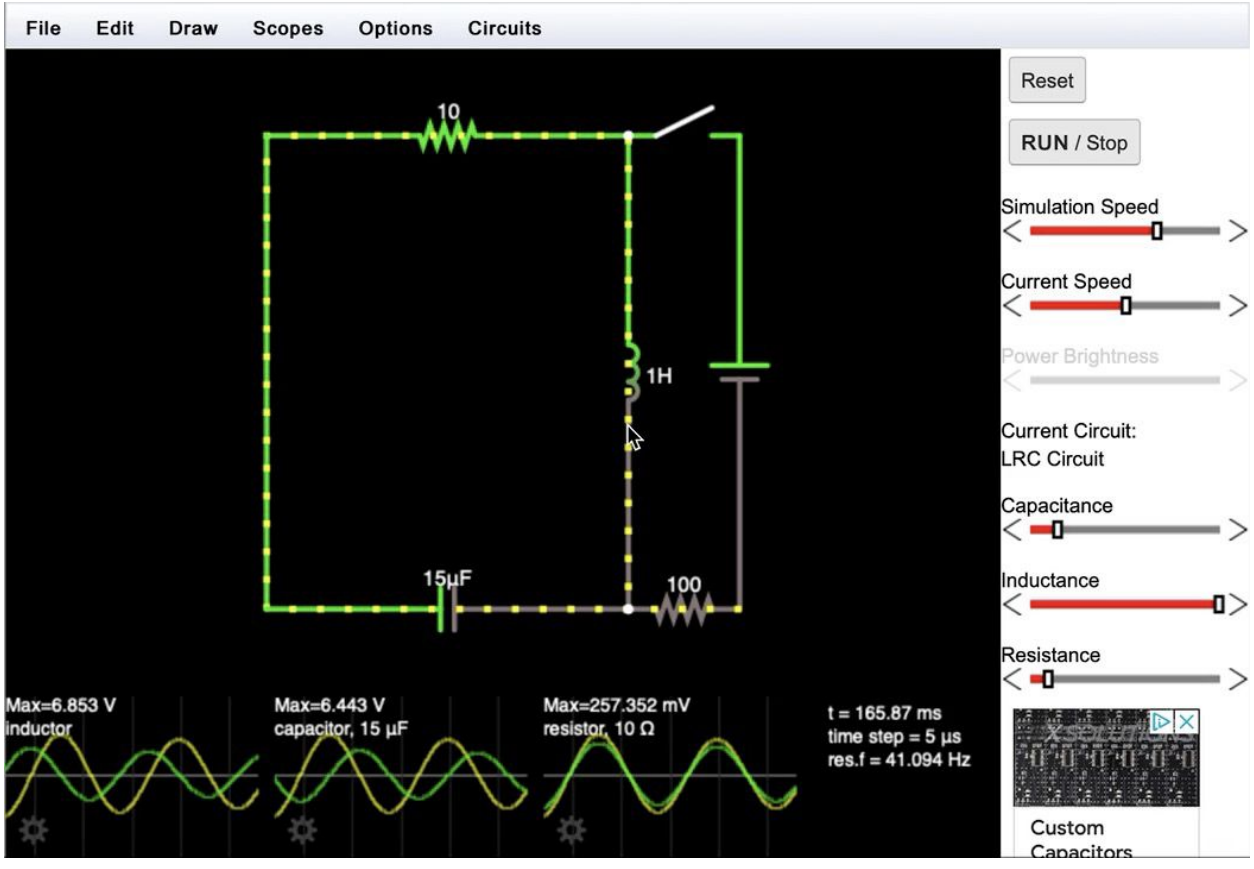
- Falstad
  - Web based, no installation required
  - Includes many simple examples
  - Fairly intuitive to use
  - Not for serious complex design
- LTSpice
  - Must be installed on your computer
  - Steep learning curve
  - Widely used
  - Industrial component databases
  - Can print out parts lists
  - …





https://www.thefreewindows.com/29203/

https://www.falstad.com/circuit/



LTSpice

- Windows and Mac versions have the similar instruction sets, but accessing the commands is different.
- On Windows, commands accessed through a menu at the top of the LTSpice window.
- On Mac, commands primarily accessed through a pop-up menu opened by right-clicking in the LTSpice window.

What's next?

- Starting with Lab S this week
  - TA help will be available via zoom
  - Zoom number is posted on quercus.
- Find your lab partner in a week
  - Fill out this google form: https://forms.gle/5cCyux8DeP16zywR6
  - I will assign a locker to you
  - You can indicate your preferences for the locker if you want
- If you don't fill out the form by next lecture, I will randomly assign lab partners
- In person lab starts next Friday & the following Monday

Questions?