PHYSICAL COMPUTING

WHY PHYSICAL COMPUTING?

Software is no longer the only domain that practitioners of Human-Computer Interaction (HCI) find themselves involved in. There is a "*hardware renaissance*" underway in Silicon Valley, and as a result the computing industry is in need of user experience designers, interaction designers, and HCI specialists who understand how to work with people and hardware as well as with software.

The goal of this course is to teach students how to rapidly prototype systems that combine hardware and software.

LEARNING OBJECTIVES

Use basic electronic components and sensors / actuators to design and construct interactive artifacts and/or environments from scratch

Construct more advanced interactive devices or systems based on standalone microcontrollers

Utilize 3D printers to print CAD models

Integrate electronic circuits with 3D prints

Prototype a working Physical Computing system according to a project brief provided during class

Evaluate and reflect on the work done in class from a technological, user experience and multimodal interaction perspective

Support prototype design choices with scientifically grounded arguments, referencing related work in HCI, Psychology, and Physical Computing.

Week	Date	Lectures	Practical Exercise	Project
35	26/8 & 28/8	Introduction Physical and Multimodal Interaction Design	Soldering Station Fan	
36	2/9 & 4/9	Basic Components (Simon) Microcontrollers (Simon)	Arduino on a Breadboard	
37	9/9 & 11/9	Sensors Actuators	Sensing: Analog and Digital	
38	16/9 & 18/9	Project Pitches Powering Prototypes (Simon)	Actuation	Project Pitches (Tuesday 16th)
39	23/9 & 25/9	Digital Communication (Simon) Debugging (Simon)	I2C	
40	30/9 & 2/10	3D Prototyping - Models and Printing (Simon) 3D Prototyping - Other Methods	3D Print Enclosures	
41	7/10 & 9/10	No lectures - work on assignment		
42				Assignment 1 due - Circuit Diagram and Breadboard Prototype
43	21/10 & 23/10	PCBs No lecture on Thursday - lab work on PCBs	PCB Design and Production	
44	28/10 & 30/10	No lectures - lab work on PCBs	PCB Design and Production	
45	4/11 & 6/11	Hackathon Session?	Scavenger Hunt	
46	11/11 & 13/11	Guest Lectures - EIT and Wearables?	3D Print Complex Parts	
47	18/11 & 20/11	No lectures - project work		
48	25/11 & 27/11	No lectures - project work		
49	2/12 & 4/12	Summary Lecture (2/12), Demos (4/12)		Project Demos (4/12), Report (5/12)

TEAM

Simon Hoggan Christensen – co-teacher

simon@cs.au.dk

TAs

Mai Ricaplaza Thøgersen
Mie Grøftehave Nielsen

TIMESLOTS

Lectures: usually 1st hour of each timeslot

Lab work (practical exercises and assignment): 2 hours after lecture

ASSESSMENT

Pre-Requisite

- Complete at least 8 out of 9 practical exercises (individually or as a group, depending on the exercise)

To pass this course, you must complete the assignment (group), the project (group), and the oral exam (individual). No re-handin (genaflevering).

- Assignment = 20%
- Oral Exam (based on group project report and prototype) = 80%

IMPORTANT!!!

You will not be allowed to take the oral exam if you have not completed 8 out of 9 practical exercises

Late Submissions – you will need to obtain special permission from me if you want to extend the deadline

BOOKS AND OTHER RESOURCES

O'Sullivan, D., & Igoe, T. (2004). *Physical computing: sensing and controlling the physical world with computers*. Course Technology Press.

Paul, S. (2016). Practical electronics for inventors. 4th Edition. McGraw-Hill

Additional articles or datasheets mentioned in the lectures will be available through Brightspace.

STUDY CULTURE

Be open, openminded and helpful

Questions = knowledge

Help each other!

Lab culture:

- Tidy up!
- Hang around!
- Invest in some components, equipment etc.
- Keep your fingers from other stations
- Music...

LABTOOLS

Labtools@cs.au.dk

Components and equipment!

Techy students ready to assist

Open (for a bit) every day in Chomsky

- Respect opening hours

Check out chomskylab.dk

"ChomskyLab Lending" app

In charge of the "licenses" for prototyping facilities

ASSIGNMENT

DESIGN AND CONSTRUCT A TOY

Design and build a new physical toy (or a coherent set of toys) that sparks a specific kind of learning (e.g., counting, phonics, motor skills, emotional regulation, STEM concepts).

You may hack or remix existing objects, but the final artefact must stand on its own and meet the technical constraints.

MINIMUM TECHNICAL REQUIREMENTS

Electronics	One **custom PCB** centred on an **ATmega 328** (no Arduino, no breadboard in final build). ≥ 1 **sensor** (anything that acquires data from the world). ≥ 1 **actuator** (anything that outputs force, light, sound, motion, etc.).
Mechanics	≥ 1 **custom 3-D printed part** that is structural or functional (not just a decorative badge).
Power & comms	**Battery-powered** (unless you justify tethered power). **Wireless communication** is encouraged where it clearly improves play (optional).
Polish	No loose jumper wires; use JST, solder joints + shrink-tubing, visible 3D-printed parts should be sanded and painted. Prototype must survive normal use by its target age-group.

EXAMPLES OF PREVIOUS PROJECTS


START
CLOSE
CHECK
RED
BLUE
GREEN
YELLOW
BLACK
WHITE


Start


PLAST
TEKSTILAFFALD
FARLIGT AFFALD

PROJECT PITCH

PITCH SESSION 16TH SEPTEMBER

Prepare 2 ideas/concepts for your prototype

- One of the ideas should be very detailed (your favourite idea) and the other should include some basic details (your plan B)
- You should present these ideas to the class (1 slide per idea)
- or, if you've already decided on a design, just present 1 slide

Your pitch should last no longer than 3 minutes.

Include preliminary list of components and use-case

Your slides should be self-explanatory (so include some text)

Fun!

ASSIGNMENT 1

ASSIGNMENT 1 (APPROX. 20% OF GRADE) – DEADLINE 23/10/2025

Circuit Diagram and Breadboard Version of Chosen Prototype

1.1 Circuit Diagrams

Draw a schematic of your prototype using Eagle. Include as many components as possible, and make sure to follow schematic layout guidelines.

1.2 Breadboard Prototype

Wire up a breadboard version of your prototype with the ATmega

As a group, students should submit 1 PDF and 1 video.

The PDF should include a quick introduction to your project idea, chosen target user group and then continue onto the schematic, a paragraph that describes how the circuit works in relation to your project prototype, and a description of the components on the breadboard and how they relate to the circuit diagram.

The video should show the functioning breadboard prototype. No voiceover is needed, just focus on showing working electronics

ASSIGNMENT 1: SUBMISSION CHECKLIST

Submission: 1 PDF with project introduction including target group. Then include schematic from Eagle, a paragraph that describes how the circuit works in relation to your project prototype, a clear and detailed description of the components on the breadboard and how they relate to the circuit diagram, quality of video should be good enough to demonstrate the prototype's functionality clearly, adequate complexity level (e.g. a very basic prototype with very simple components is not as complex as a prototype with multiple different sensors and wireless communication.)

Schematic: the schematic should contain names and values for all components, follow layout guidelines from the lecture, use junctions to make it more readable, aim for minimal complexity, and should match the functionality required by the project.

Breadboard: this should be a representation of your full prototype not just an example of a small part of the prototype, missing components should be described and explained in the pdf, everything should be fully functional, no Arduino board, aim for minimal complexity (in terms of wiring). If your final prototype will include two (or more) of the exact same circuits (for example two controllers), it's okay to only include one in the breadboard prototype

FINAL PROJECT

PROJECT DEADLINE 4TH DECEMBER (ORAL EXAM IS BASED ON THIS)

Fully Functional Prototype (including PCB, 3D printed components, report, and video)

2.1 PCB

Design and make the PCB for the prototype

2.2 3D Print

Design and print the 3D-printed components of the prototype

2.3 Completed, fully-functioning, painted prototype with report and video.

Each group will give a demonstration of their prototype on the 4th December. Then, submit everything in WiseFlow.

PROJECT SUBMISSION CHECKLIST

Students should submit: 1 pdf that includes a 6 to 8-page report along with appendices* (Eagle schematic and board, 3D model from Fusion top view and side view, photos of PCB with and without attached components top and bottom view, exploded diagrams of 3D model, and photos of 3D printed object, along with a short description of what role the 3D-printed parts play in the prototype. Explain your 3D prototyping methods and choices. Lastly, include the URL for a video that shows your fully-functioning prototype. Students should also submit a zipped folder containing all code.

Appendices do not count towards the page limit. They are additional.

Submit to WiseFlow

The report should use the template provided in Brightspace

ASSESSMENT RUBRICS

Live demo works and meets tech reqs.

PCB quality

- DRC-clean, compact, labelled, no overlaps

3-D print and enclosure quality

- fit, finish, matches CAD

Report clarity

Video clarity

Ambition / complexity

- extra sensors, wireless, etc.

DETAILED RUBRICS

Prototype: should be fully functional, battery-powered (unless futile for project), no Arduino board, no breadboard, well soldered, high level of polish i.e. at least one 3D printed part should be post-processed, all exposed wiring should be robust (e.g. use shrink tubing, JST-connectors etc.), wireless communication would be nice (if necessary for the project), meet all the requirements stated in the beginning -custom-made PCB, custom 3D-printed features, >=1 sensor, and >=1 actuator. Adequate complexity level –as before -a very basic prototype with very simple components is not as complex as a prototype with multiple different sensors and wireless communication. Grades will reflect this.

Report (6 to 8 pages): clearly and thoroughly describe the use case, prototype design, limitations, and future work. If the team worked in separation, then briefly describe the main responsibilities of each team member, explain how each person contributed to all of the assignments. For each of the main components, there should be a link to the datasheet and mention of important specs/info. Also, describe some alternatives to each of the main components. For each sensor, you should explain how the raw data from the sensor relate to real-world values.

Code: all code should be readable and commented clearly, it should compile and run according to the requirements of the project.

ATTRIBUTION

There will be a lot of creation in this course.

For some of the work you do, there will be resources you can find online.

- It's ok to use libraries, code samples, and help from online, but you **must give proper attribution** to your sources!

To give attribution for code, add a comment in your code clearly marking what you got from where..

To give attribution for ideas, images, papers, or anything else, include the source and a brief description of the material used.

SUGGESTED TIMELINE

Aug 18 – Sep 14: Ideation and Planning

- brainstorm toy, research, define target group, draft schematic

Sep 15 – Oct 23: Breadboard Prototype

- build & test circuit, video + PDF submission on Oct 23

Oct 24 – Nov 9: PCB and 3D Design

- design PCB, CAD model, complete 3D prints and lasercut parts

Nov 10 – Nov 23: Assembly and Testing

- solder PCB, assemble enclosure, debug, refine

Nov 24 – Dec 4: Final Report and Demo Prep

- polish prototype, finish report, record final demo video

REMEMBER

Custom PCB, custom 3-D print, at least one sensor and one actuator, no Arduino boards in the final build.

BEST PRACTICES AND EXAM

GROUP WORK

Each person in the group should do **technical, design, code, and written work.**

I know that you all have a variety of strengths in different areas, but each student is supposed to meet all the learning goals of the course.

This course is a good chance for you to improve your skills in all areas.

PROJECT SUPERVISION FROM US

The projects in this course will vary an insane amount, and neither me nor the TAs knows every last detail about every single electrical component, library, sensor and/or actuator.

This course will include a lot of debugging, problem solving, and researching solutions.

Do not expect any project supervision to include instant problem solving of your entire project –depending on the complexity we will probably need time to do our own problem solving. We might not even be able to fix your issues, and then you should have a plan b.

ORAL EXAM

Assignment 1: Breadboard Prototype = 20% OF FINAL GRADE

Oral Exam (based on group project report, demo and exam) = 80%

Individual oral exam:

You get to choose from two randomly selected topics. Topics will be announced, so you can prep 5-7 minute presentations for each topic.

Questions about anything and everything for 7-10 minutes. Project will most likely be brought up, or you can use it to draw parallels or for reference.

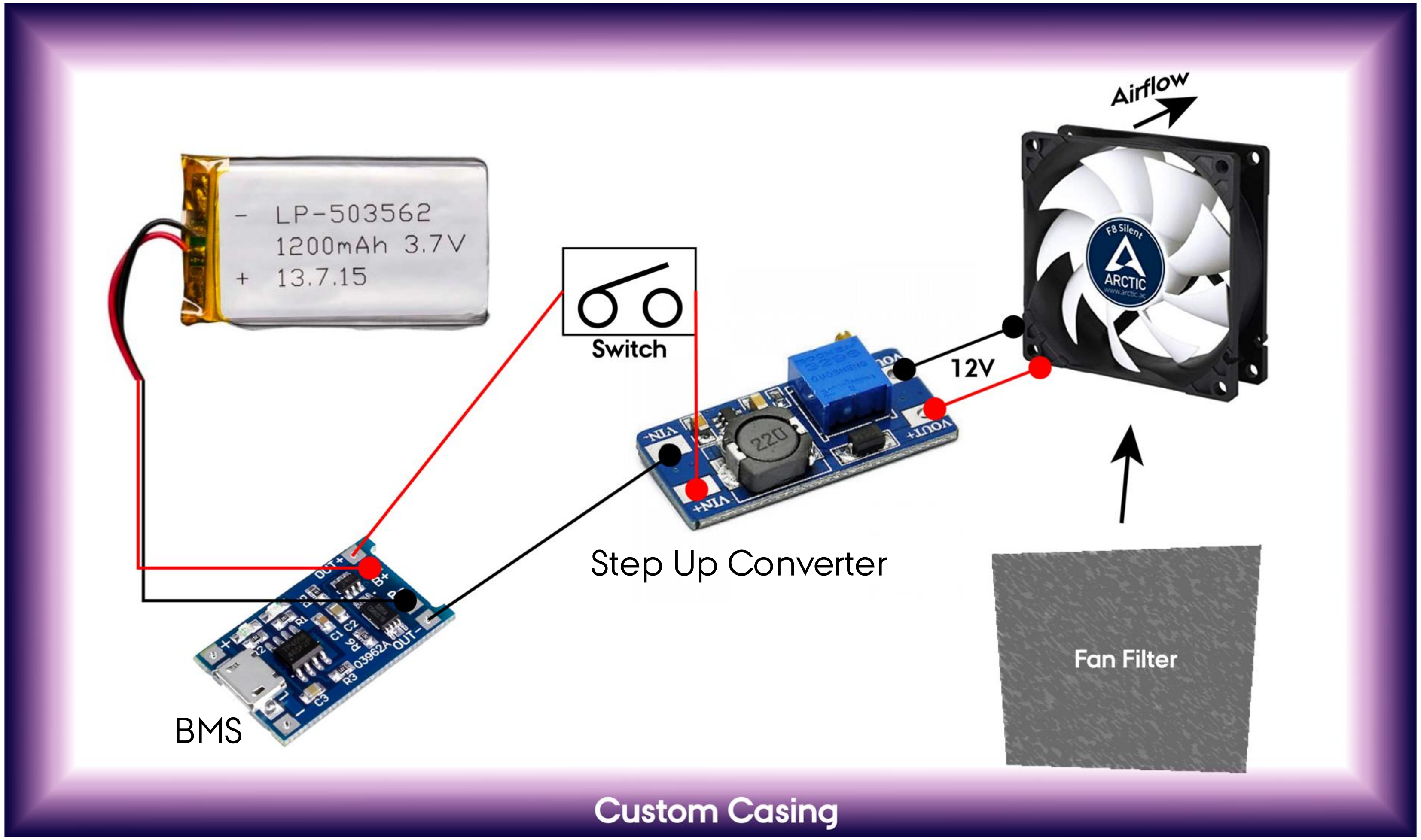
Grading for a few minutes.

Grade calculated based on all of the above factors.

PRACTICAL EXERCISE 1

Fun with soldering, multimeters, and fans!

SCHEMATIC

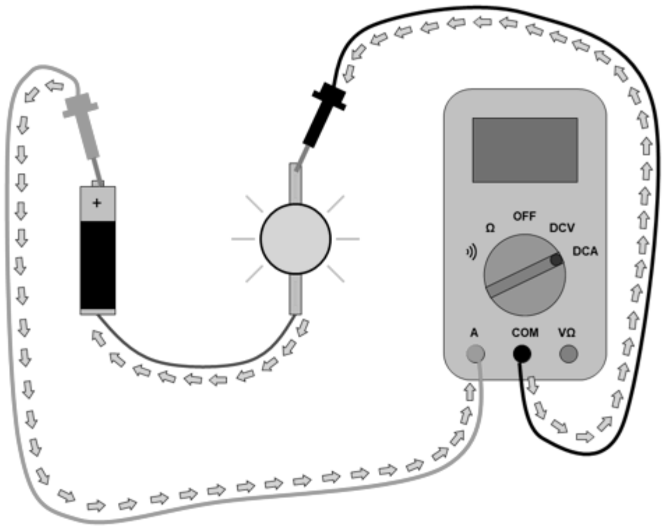


Airflow
- LP-503562
1200mAh 3.7V
+ 13.7.15
Switch
12V
Step Up Converter
BMS
Fan Filter
Custom Casing

HOW TO SOLDER AND HOW TO USE A MULTIMETER

https://www.makerspaces.com/how-to-solder/

https://learn.sparkfun.com/tutorials/how-to-use-a-multimeter



Measure voltages in parallel (plus to plus, minus to minus)

Measure amps in series –remember that a load is necessary (see picture)

Measuring ohms one probe on each leg


JAIL


REAL
WORKIN'
BUDDIES

HOW TO ”PASS” THE PRACTICAL EXERCISE

A quick demonstration of working prototype/finished practical exercise should be shown to Eve, Simon, or a TA.

- Ideally during lab session

The deadline for this exercise is **2nd September at 09:00**

If unable to attend at some point, so you can’t demonstrate, please write an email to eve.hoggan@cs.au.dk