CS140E: embedded OS

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Stanford win 2022

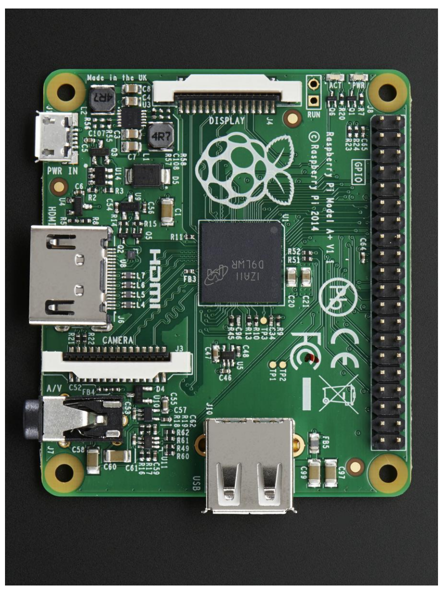
Outline

- What
- Why

What

Write small, clean OS on an r/pi A+:

https://en.wikipedia.org/wiki/Raspberry_Pi



What

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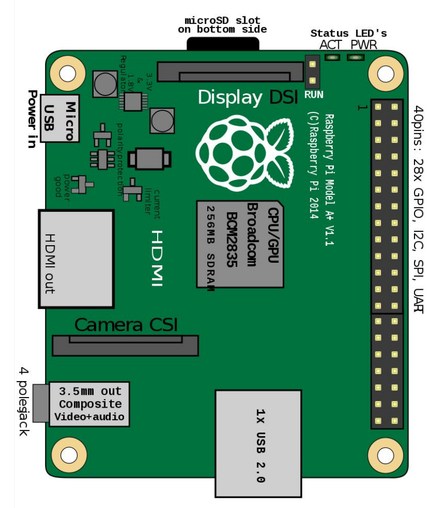


What you will build (tentative)

Bootloader (ship code from your laptop to the pi)

Device drivers

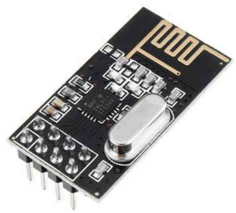
Threads + interrupts

Virtual Memory

Fuse file system to export pi to laptop

Simple file system on SD card.

Networking code that uses the cheap nrf24L01 chip



End result: simple, clean OS where you wrote (almost) every line.

Why OS?

If you can write a real OS, you can write almost anything (non-math-y).

- Once you get this, easy to delta to something else.

Classes are fake: real world is not a clean, textbook of systematized knowledge

- Difficult to understand documents
- Wrong
- Incomplete
- Not written to be used
- You will learn to operate in such a world without a lot of panic/drama.

Your OS

You will write (almost) all code.

Small + lightweight = you can do things impossible on modern OSes.

- Nanosecond latencies for messages
- Real time guarantees faster than expensive digital tools
- Exception tricks that let you build valgrind in < 1KLOC.
- ….

Why R/PI A+?

Most OSes write code on a fake simulator

- Alot of work, not that cool at the end.

R/pi = real computer for about $20 and an ounce of weight.

- Many examples / blog posts of how to do various things.
- Unlike most machines, makes interacting with the real world easy.
- Can build many interesting systems b/c can use weird hardware easily (motion sensors, IR sensors, accelerometer, gyroscope, light sensor…)

Class philosophy

Write a complete, narrow OS all the way down to the bare metal.

We cover less material than most OS classes (multi-level schedulers, multi-level page tables)

However, you will understand much more thoroughly

Hope: easy to do delta off of your knowledge to more fancy things.

Labs vs lectures:

Always try to have you be writing code. You will actually understand what is going on.

Common tragedy of OS: missing a key sentence, mistake in key document. We will use lab to fill this in, saving you many hours/days.

Goal: you do pre-work to pre for lab, walk in, by the end of the lab, you have a complete working simple version of a key trick.

Goal: you will develop two super-powers

Power 1: Differential debugging.

Efficiently answering “why doesn’t work” for complex things.

Swap working pieces + Binary search

Power 2: Epsilon development.

Foundational paradox: When building systems, the smaller the step you take, the faster you can run.

Differential debugging

You write code, it doesn’t work, the error could be:

The code you wrote

Hardware fault (bad manufacturing, smoked something)

Wiring mistake

Subtle cache issue

Compiler problem (more on this)

…

You will get good at breaking down problems by swapping pieces between a working system (yesterday’s code, your partners lab) and a non-working system (today’s code, your lab)

Example from next lab.

You get the following set of stuff:

To run you:

Copy blink.bin to sd

Wire up led

Wire up serial device

Plug into your laptop

It doesn’t work.

But your partner’s does

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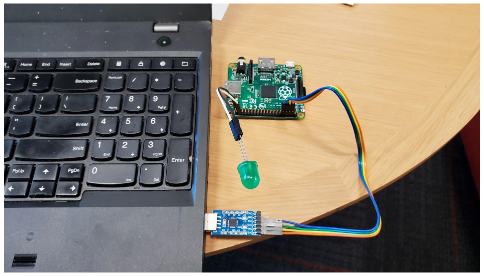
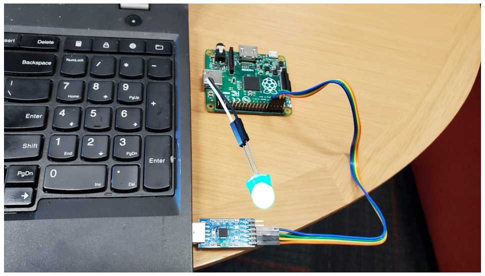
What is messed up?

Yours: Not working



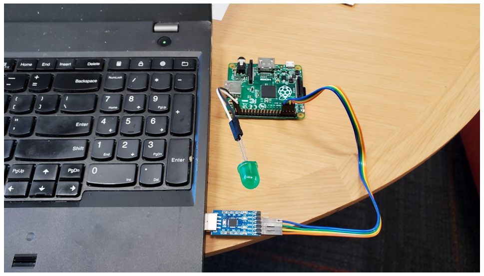
Partner's: Working



What to do first?

What is messed up?

Yours: Not working



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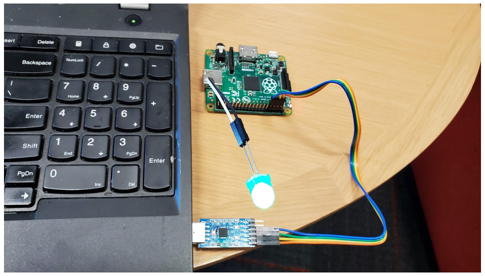

What does swapping tell you if doesn't work?

What does swapping tell you if works?

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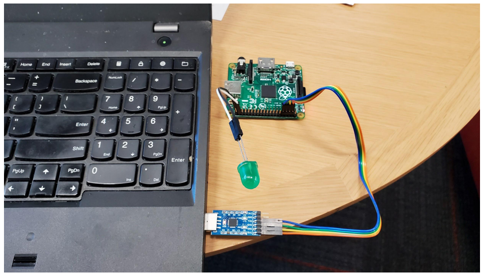

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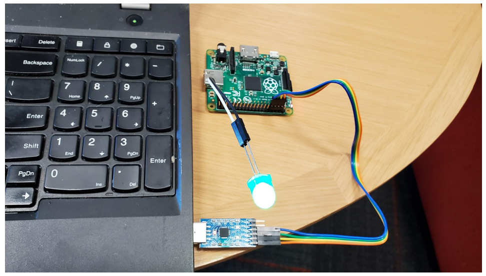
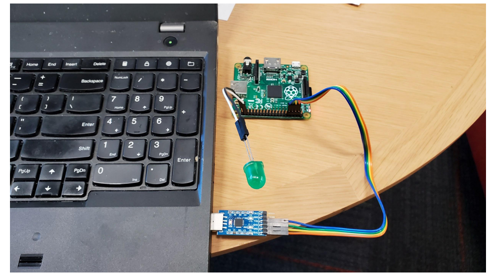


Swapping works: how to narrow down with least work?

What is messed up?

Yours: Not working



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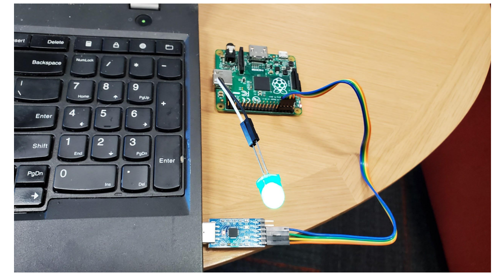

Entire class: whenever we control device, has some software component S (can be wrong) and some hardware component H (can be broken).

Doesn't work = linear equation solving with two variables. How to isolate?

Epsilon sprinting: Slow is fast.

What is wrong?

- If I did X, it's X.
- If I did X1+X2+...+Xn it could be any, or some combination.
  - Inverting crash / bug to root cause is much harder in the latter case.

My epsilon-sprint theorem:

Given a working system W□ and a change *C*, then as $|C| \Longrightarrow \epsilon$, the time + computation (IQ) it takes to figure out why { W□ + *C* } doesn't work goes to 0.

Related claim: the time it takes to debug why a change broke the system increases non-linearly with the size of the change.

Administrivia

We may or may not have a final project. Depends on how the class goes.

Grade breakdown if no final project:

- Labs = 65%, HW = 35%, participation = you move up a grade if on border.

If final project:

- Labs = 60%, Hw = 20%, project = 20%

Main thing: you absolutely must turn in lab within 7 days. No exceptions.

- We tried to do it differently in the past, was a disaster.

Administrivia

Two labs each week.

Each lab will have pre-lab work you should turn in before lab.

Ideally finish during the lab period (I will stay til everyone is done).

Must finish within a week of the lab, or start losing a letter grade each day.

Must pre-arrange missed labs. It's a problem to miss more than a couple.

There (tentatively) will be three "capstone" homework assignments that consolidate a chunk of labs together.

If you've done the lab, this shouldn't be a big deal.

Administrivia

You can work with other people!

However, you *must* type and turn in everything yourself.

Please post to the newsgroup.

If the rules on in-person meetings lift, it's great if you can do the labs in groups.

(We will pay for food you order during lab if this happens.)

What to do now

Go to / clone the class git repository:

https://github.com/dddrrreee/cs140e-22win

Go to the newsgroup, or let me know if you don't have an invitation.

cs140e-win22 - Google Groups

For lab thursday, make sure you:

have a way to write either a micro-SD or SD card.

Have a way to plug in a standard USB device

Read labs 0-trust pre-lab homework.