ECE 471 – Embedded Systems
Lecture 4

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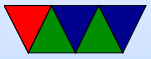
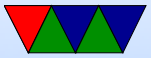
Announcements

- Any questions on HW#1?
- HW#2 will be posted Friday
- Let me know if you don't have a Raspberry Pi yet

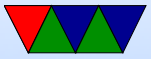


Single Board Computers

- Small boards with lots of I/O, often for use in embedded systems
- Often put out by companies trying to encourage use of their chips
- Examples
  - TS-7600 (ECE has a zillion of these)
  - Pandaboard / Beagleboard/ Beaglebone
  - Gumstix (used in 471 years ago)
  - Raspberry Pi



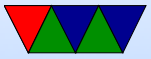
- Pi clones (Orange, Banana, etc)
- Arduino, Pi-pico, esp32
- STM boards (like used in ECE271)
- MOS KIM-1 (1976)



Raspberry Pi

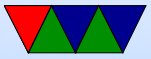
Note there are two separate (but related) organizations:

- Raspberry Pi Foundation – charitable group to encourage computer science education
- Raspberry Pi, Ltd – company that makes and sells Raspberry Pi Boards
- Their goals don't always line up
- During parts shortage extremely limited board availability, Ltd was prioritizing businesses over education institutions



What is a Raspberry Pi?

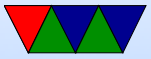
- Raspberry Pi Foundation wanted small board to encourage CS in schools
- Easy to use and cheap enough that students can experiment without worrying too much about bricking it
- Back in the day small micro-computers encouraged hacking, modern Windows systems not so much



Why use a Raspberry Pi?

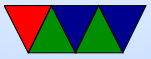
- There are other small embedded boards (Beaglebone, etc.) but Pi has many nice features
  - high performance (especially pi4/pi5)
  - low cost
  - using Linux so no software-lock-in (STM hal?)
  - relatively well documented (but still not great)
  - available software/support (this is big!)

  Other ARM boards give kernel blob with no support and quickly gets out of date / no commits upstream



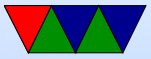
Raspberry Pi Models

- Model Names originally from BBC Micro
- Up through pi4 all have more or less same SoC. VideoCore IV GPU runs show (VI pi4, VII pi5)
- First released in 2012
- They like to release new models just after I've bought the older models for my cluster



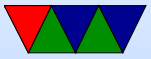
BCM2835/BCM2708 – ARM1176 (ARMv6)

- Single core, slow ethernet
- **Model 1B** – 700MHz, 512MB RAM, SD, USB hub+USB Ethernet
- **Model 1B+** – like B but micro-SD, composite video-out inside of audio jack, 4 USB ports, longer GPIO header, re-arranged outputs, more mounting holes, fewer LEDs, lower power
- **Model 1A / Model 1A+** – less RAM



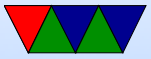
(256MB/512MB), no Ethernet, no USB hub, cheaper, less power

- **Zero** – 1GHz, 512MB, smaller, cheaper, $5
- **Zero W** – 1GHz, has wireless, $10
- **Compute Node** – like B but on SO-DIMM backplane, eMMC



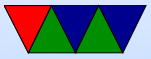
BCM2836/BCM2709 – ARM Cortex A7 (ARMv7)

- **Model 2B** – like 1B+ but with 1GB RAM, 900MHz Quad-core Cortex A7



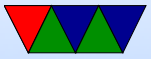
BCM2837/BCM2710 – ARM Cortex A53 (ARMv8)

- **Model 3B** – 64-bit, 1.2GHz, wireless Ethernet, bluetooth (crash on OpenBLAS Linpack)
- **Model 2B (v1.2)** – like Model 2 but with the Cortex A53
- **Model 3B+** – better thermal, faster Ethernet (1GB but maxes at 300MB), power over Ethernet header. Still only 1GB RAM
- **Model3 A+**, **Compute 3**



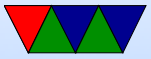
BCM2711 – ARM Cortex A72 (ARMv8)

- **Model 4B**
- 1.5GHz, Videocore VI at 500MHz
- USB-C power connector
- 1, 2, 4 or 8GB RAM
- USB3, microHDMI*2
- PCIe if you de-solder USB chip
- Real gigabit Ethernet
- GPIO header has more i2c/spi etc options
- **pi400**: built into keyboard (4GB 1.8GHz)



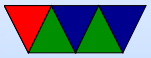
BCM2712 – ARM Cortex A76 (ARMv8.2)

- **Model 5**: 4GB or 8GB RAM (recent 2GB)
- Power button!
- Videocore VII
- USB-C power (wants 5V at 5A if possible)
- Official PCIe support
- Drop headphone jack (composite video via header)
- Move peripherals to separate chip built with older process
- Real time clock (no battery by default)
- PIO (programmable I/O), on-board Cortex M3?



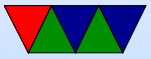
Pi Pico - RP2040

- Pi Pico
  - Can't run Linux
  - Completely new design, custom SoC
  - 133MHz Dual core ARM-cortex M0+
  - 264k SRAM / 2MB Flash / $4
- Pi Pico2
  - ARM and RISC-V processors
  - TODO: Fill this in more



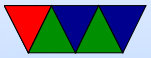
Software/Programming the Pi

- Many, many options
- Can even write your own on bare metal (see ECE531)
- We'll use C on Linux



Why Linux?

- Open source
- Free
- Widely used for ARM-based embedded systems
- I like Linux.



Brief Linux History

- UNIX history, UNIX lawsuit, rise of the BSDs
- Linus Torvalds (from Finland) gets a 386, announces his custom OS in 1991
- No free UNIX? FreeBSD caught up in AT&T lawsuit
- Don't be afraid of Linus (or open-source projects in general)
  The media over-hypes how angry some developers get.
- Recently turned 30 years old