

# ECE 471 – Embedded Systems

## Lecture 3

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# Announcements

- Homework 1 was posted Thursday.  
Due before class Thursday. Be sure to \*e-mail\* the answers.
- If you are having trouble sourcing a Raspberry Pi, let me know



# 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
- There are other small embedded boards (BeagleBone,



etc.) but Pi is a nice combination of performance, cost, and available software

- Can run many operating systems. Even write your own (see ECE598) or bare metal. We'll be running Linux though.



# Raspberry Pi Models

- All have more or less same SoC. VideoCore IV GPU runs show
- BCM2835/BCM2708 – ARM1176
  - Model A / Model A+ – less RAM (256MB/512MB), no Ethernet, no USB hub, cheaper, less power
  - Zero – 1GHz, smaller, cheaper, \$5
  - Model B – 700MHz ARM1176, 512MB RAM, SD, USB hub+USB Ethernet
  - Compute Node – like B but on SO-DIMM backplane,



## eMMC

- Model B+ – 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
- BCM2836/BCM2709 – ARM Cortex A7
  - Model2 B – like B+ but with 1GB RAM, 900MHz Quad-core Cortex A7
- BCM2837/BCM2710 – ARM Cortex A53
  - Model3 B – 64-bit, 1.2GHz Cortex A53, wireless Ethernet, bluetooth



# Using the Pi for this Class – Two Challenges

- Getting to the point you can log in
- Getting files onto and off of the board. (Definitely needed for homework)



# Why is Linux used in Embedded Systems?

- Linux popular in embedded space because it is cheap/free and source code is available.
- You can run Windows IoT (would you want to?)
- Linux on ARM is widely supported (although upstream support is a mess)
- Licensing issues
  - Linux under GPLv2.





- The Free Software Foundation has moved most of its software (including gcc compiler) to the less popular GPLv3 which most companies don't like.
- Companies often prefer BSD type license which has fewer restrictions; companies can use code and release binaries without having to release the source (a GPL requirement).
- Apple and Google both trying to replace as much code as possible with BSD versions.



# Installing Linux

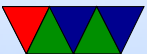
- Any Linux fine, I typically use Raspbian  
Using the same that I do is easiest and I can more easily help
- Easiest way is to buy SD card with image pre-installed  
Also can get NOOBS which will give you the option to select from a variety of images via menu (allowing to install Raspbian)
- If starting with a blank SD card,



<https://www.raspberrypi.org/downloads/>  
has good step by step instructions for getting an image  
and putting it on a card for a variety of operating  
systems.

Warning: it's a large download (900MB?) and takes a  
while to write to SD (which is slow)

dd on Linux, be sure **to get right partition**



# Booting Linux

- Why called booting? Bootstrapping? Pull oneself up by own bootstraps? Meant to do something impossible
- Easiest if you have a USB keyboard and HDMI display connected.
  - Put SD card in
  - Hook up input/output (see later)
  - Plug in the USB power adapter; **\*NOTE\*** can also draw power over serial/usb and HDMI
  - Lights should come on and blink and should boot



- A number of raspberries should appear and some Linux boot messages
- Things can also go wrong in ways hard to troubleshoot
  - First boot a menu comes up. You probably want to do a number of things:
    - Expand to fill disk.
    - Change password if you want  
pi/raspberry is default
    - Change locale— probably defaults to England giving pound char for  $\#$ . en\_US.UTF8, not GB
    - change hostname?



- for this class, advanced options, enable i2c and spi
- You can get back to the original menu with `sudo raspi-config`
- Don't make fun of the text interface, once upon a time it's all we had.



# Other Optional things you can do

- Install updates  
sudo apt-get update  
sudo apt-get upgrade
- Add a user account  
adduser vince
- Give new user sudo access  
involves text editing /etc/sudoers



# Connecting to the Pi

- Monitor/Keyboard (Easiest)
- Serial Connection
- Network Connection





# Monitor and Keyboard

- HDMI monitor, USB keyboard, USB mouse (optional)
- Need HDMI cable.
- Can probably use the equipment in the Electronics Lab. Do not mess with the HDMI cables, it's what got lab access restricted in the first place. Might not have USB keyboards anymore. Let me know if you want to use lab and can't.



# Serial Connection

- Old fashioned, but very good skill to have.
- Need USB/serial adapter
- Need another machine to hook to, with a comm program minicom, putty
- Thankfully unlike old days don't need specific NULL modem cable. Still might need to set some obscure COM port settings (BAUD, stop bits, parity) and console TERM settings (ANSI, VT102).



# Ethernet Connection

- Ethernet cable
- Either an Ethernet port, or connect direct to PC
- If something goes wrong on boot hard to fix
- Can also try this with a wireless connector
- Can hook it onto dorm network, but need to request a static IP. Can also direct connect between PC (configure pi with a local address like 192.168.1.2 and set your



wired Ethernet on PC side to something like 192.168.1.1  
and then use ssh to connect)



# Transferring Files

- Easiest: Putting USB key in rasp-pi  
Easier on B+ (4 USB ports)  
In theory the Pi should auto-mount the drive for you  
May need to mount / umount by hand or be root
- Network: just use ssh/scp
- Serial: sz/rz ZMODEM
- Putting sd-card (after unpowering!) in another machine.



Challenge: Filesystem is in Linux format (ext4) so Windows and Macs can't read it by default.



# What you will do before starting HW2

- Get Linux installed
- Login with the default user/password (on Raspbian it is pi / raspberry)  
You can use `adduser` to add a new user and/or `passwd` to change a password.
- Learning a little bit of Linux. Most importantly compiling C/asm programs and transferring HW assignments in and out



# SD Card Digression

- Why are they so slow?
- **BACK UP YOUR WORK. ALL THE TIME.** SD cards corrupt easily. Why?
- **SHUTDOWN CLEANLY**
- Try to get things done a little before the deadlines, that way you have some time to recover if a hardware failure does happen.





# Using the Pi

- If using monitor/keyboard you can type `startx` after logging in and getting a nice GUI interface.
- You can do many things through that, but in this class we will use the command line for many things.
- You can select `lxterm` to get a terminal.
- Also if you log in over `ssh` or connect via serial port all you will get is the command line.



# Command-Line Linux

The way we did things in the old days.  
Some of us still prefer the command line.

You come up in the “shell”. Default is bash, the “Bourne Again Shell” (more computer person humor). There are various shells available (bash, sh, zsh, csh, tcsh, ksh) and you can select via `chfn`.



# Root Filesystem Layout

- Executables in `/bin`, `/usr/bin`
- System executables under `/sbin`, `/usr/sbin`
- Device nodes under `/dev`
- Config files under `/etc`
- Home directories under `/home`, also `/root`
- Temp Files under `/tmp`. Often wiped at reboot.



- Magic dirs under `/proc`, `/sys`
- Libraries under `/lib`, `/usr/lib`, sometimes `lib64` too
- Boot files under `/boot`
- `/usr` historically only files needed for boot in `/`, stuff that can be shared over network (or stored on a second drive if your first drive was too small) would be under `/usr`
- `/opt` often commercial software installed there



- `/srv`, `/run`, `/var` these are where server programs store data
- `/media`, `/mnt` places to mount external disks like memory keys and CD roms
- `/lost+found` where the disk checker may store lost files it finds when fixing a disk after unclean shutdown



# Interesting Config Files

- `/etc/fstab` – the filesystems to mount at boot time
- `/etc/passwd` – list of all users, world readable
- `/etc/shadow` – passwords stored here for security reasons
- `/etc/hostname` – name of the machine
- `/etc/hosts` – list of local machines, usually searched before resorting to DNS lookup over network



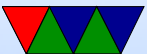
- `/etc/resolv.conf` – where your nameserver address is put
- `/etc/sudoers` – list of users allowed to use “sudo”
- `/etc/network/interfaces` – on Debian the network settings are stored here
- `/etc/rc*` – what gets run at boot



# Devices

## Block vs Char devices

- `/dev/sd*` – SCSI (hard disks)
- `/dev/tty*` – tty (teletype, logins, serial ports)
- `/dev/zero`
- `/dev/full`
- `/dev/random` , `/dev/urandom`





- `/dev/loop`

Network devices are an exception.



# Interesting /proc Files

These files are not on disk, but “virtual” and created on-the-fly by the operating system when you request them.

- /proc/cpuinfo – info on cpu
- /proc/meminfo – memory info
- Each process (running program) has its own directory that has info about it



# Processes

- Each program assigned its own number, a process id, often called a “pid”
- Can list processes with `ps -efa`
- Also can get real-time view of what’s going on in a system with `top`



# Common Commands

- `ls` : list files
  - `ls -la` : list long output, show all (hidden) files. on Linux any file starting with `.` is hidden
  - `ls -la /etc` : list all in `/etc` directory
  - `ls *.gz` : show all ending in `gz`. `*` and `?` are wildcards and can be used as regular expressions.
- `cd DIR` : change directories (folders)
  - `cd ..` : go to parent directory
  - `cd .` : go to current directory



`cd /` : go to root directory

`cd ~` : go to home directory

- `cat FILE` – dump file to screen (originally used to conCATenate files together but more commonly used to list files)
- `more` / `less` – list contents of file but lets you scroll through them. `less` more advanced version of `more`
- `exit` / `logout` / `control-D` – log out of the machine
- `df` / `du` – show disk space



`df -h` pretty-prints it

- `man command` – show documentation (manual) for a command. For example `man ls`
- `rm` remove file. CAREFUL! Especially famous `rm -rf`. In general on Linux you cannot undo a remove.
- `cp` copy file. CAREFUL! By default will overwrite the destination without prompting you.
- `mv` move file. CAREFUL! Can overwrite!  
`mv -i` will prompt before overwrite



- `tar` create archive file `tar cvf output.tar dir`  
`tar xzvf output.tar.gz` uncompresses a `.tar.gz` file
- `gzip` / `gunzip` / `bzip2` / `bunzip2` compress/uncompress a file. `gzip` and `bzip2` are two common formats, many more exist



# Compiler / Devel Commands

- `make` – build a file based on list of dependencies in Makefile
- `gcc` – C compiler. Simplest something like this: `gcc -O2 -Wall -o hello hello.c`
- `g++` C++ `gfortran` Fortran
- `as`, `ld` – assembler and linker
- `gdb` – debugger





- `strace` – list system calls
- `git` – source code management



# Other Commands

- `shutdown` – used to shutdown / reboot
- `last` – list last people to log in
- `su` / `sudo` – switch to root, run command as root
- `uptime` – how long machine has been up
- `date` – show the date  
as root you can use `date -s` to set the date



- `whoami` – who are you
- `write` / `wall` / `talk` – write to other users
- `finger` – get info on other users
- `w` / `who` – see who is logged in
- `wc` – count words/bytes/lines in a file
- `dmesg` – print system and boot messages
- `ln` – link files together, sort of like a shortcut



`ln -s goodbye.c hello.c` – symbolic link. also hard links

- `dd` – move disk blocks around, often used for creating disk images
- `mount / umount` – mount or unmount filesystems
- `mkfs.ext3` – make new filesystem
- `e2fsck` – filesystem check
- `ifconfig / route` – show and setup network config



- `dpkg / apt-get update/upgrade/install` – Debian only package management
- `ssh / scp` – log into other machines, copy files remotely
- `lynx` – text-based web browser
- `reset` – clear the screen and reset settings (useful if you accidentally cat a binary file and end up with a screenful of garbage). `Control-L` also refreshes the screen
- `linux_logo` – my program



# Editing files

Linux and UNIX have many, many editors available. Most famous are vi and emacs. On our board using nano might be easiest.

- nano – a simple text editor.

`nano FILENAME` – edit a filename

It shows the commands you can do at the bottom. `^O`

means press control-O

control-O : writes

control-X : exits



control-W : searches

control-\ : search and replace

control-C : prints line number



# Redirection and Pipes

- redirect to a file : `ls > output`
- redirect from a file : `wc < output`
- pipe from one command to another : `ls | wc, dmesg | less`
- re-direct stderr : `strace 2> output`





# Suspend/Resume

- Press control-C to kill a job
- Press control-Z to suspend a job
- Type `bg` to continue it in the background
- Type `fg` to resume it (bring to foreground)
- Run with `&` to put in background to start with. (ie, `mpg123 music.mp3 &`).



# Permissions

- user, group – use chgrp
- read/write/execute – use chmod



# Shell Scripts

- Create a list of files in a dir
- Start with the shell, `#!/bin/sh` (or perl, etc)
- Make executable `chmod +x myfile`



# Command Line History

- Can press “tab” to auto-complete a command
- Can press “up arrow” to re-use previous commands
- Can use “control-R” to search for previous commands



# Environment Variables

- `env`
- Varies from shell to shell.
- `export TERM=vt102`
- `PATH`, and why “.” isn’t in it. This is why you have to run self-compiled binaries as `./blah`

