ECE 471 – Embedded Systems
Lecture 3

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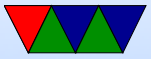
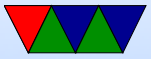
Announcements

- New classroom: Stevens 365
- HW#1 was posted, due Friday
- Reminder: The class notes are posted to the website.

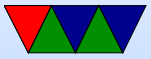


The ARM Architecture



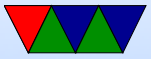
Brief ARM History

- **A**corn **R**ISC **M**achine. Acorn was a computer company in the UK in the 1980s
- Wanted a chip to succeed 6502. Decided to make one themselves. (Good idea, 65816 a pain and only 16-bit)
- 6502 was the chip in Commodore 64, Apple II, NES, Atari 2600
- Fun fact: 6502 co-designed by UMaine alum Chuck Peddle
- Bought by Softbank (Japan) in 2016



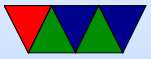
RISC / CISC Discussion

- Simple decode. Load/store. Fixed instruction width. 3-operand.
- MIPS is classic RISC
- x86 is classic CISC (with complex instructions)
  Though internally x86 executes uops, RISC
- ARM (predication, auto-increment, barrel shifter)
  Called RISC but has complex instructions



ARM Business Plan

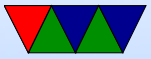
- IP Licensing company. Does not fab own chips. License to other companies
- Other companies take the design, put on SoC, attach whatever other logic blocks are needed
- Relatively small company compared to Intel which not only deigns the chip, but fabs, etc.
- Can buy full core (Cortex-AX) or just rights to ISA and make your own (Apple A10)



AMBA Bus Protocol

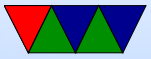
Advanced Microcontroller Bus Architecture

- ARM System Bus (ASB), ARM Peripheral Bus (APB)
- ARM High Performance Bus (AHB)
- Common bus, various companies can provide logic blocks for it, can swap in and out ARM cores as needed.



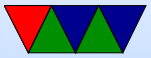
ARM Architecture vs Family

- ARMv1 : ARM1
- ARMv2 : ARM2, ARM3 (26-bit, status in PC register)
- ARMv3 : ARM6, ARM7
- ARMv4 : StrongARM, ARM7TDMI, ARM9TDMI
- ARMv5 : ARM7EJ, ARM9E, ARM10E, XScale
- ARMv6 : ARM11, ARM Cortex-M0 (Raspberry Pi A/B)
- ARMv7 : Cortex A8, A9, A15, A7, Cortex-M3 (iPad, iPhone, Pandaboard, Beagleboard, Beaglebone, Pi2)
- ARMv8 : Cortex A50, A53, A57 (64-bit), Pi3



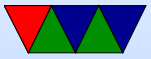
Various abbreviations in Model Names

- Modern Cortex Processors
  - “Application” ARM Cortex-A
  - “Real-time” ARM Cortex-R
  - “Micro-controller” ARM Cortex-M
- ARM7 Processors (example armv4 ARM7TDMI)
  - “E” means DSP instructions
  - “M” improved multiplier
  - “T” THUMB
  - “J” Jazelle (java bytecodes)



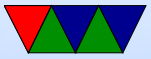
- “D” Debug
- “I” ICE (In-circuit Emulator)
- “EE” ThumbExecutionEnvironment, Just-in-time
- NEON – SIMD

- ARM11 Processors (Raspberry Pi is armv6 BCM2835 ARM1176JZF-S)
  - (All have Thumb)
  - S – Synthesizable
  - J – Java Extension
  - Z – TrustZone
  - F – Vector Floating Point Coprocessor



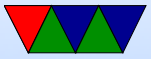
Cortex A9

- Pandaboard, iPad2, etc
- Up to 2GHz.
- Multi-core (1-4 cores)
- Also on-board Cortex-M codec decoders
- L1 cache 32kB i/d
- configurable L2 cache
- out-of-order super-scalar
- neon SIMD
- VFP3 floating point (optional)



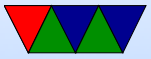
STM32L-Discovery

- Used in 271
- ARM Cortex M3 core, 128kB flash, 16kRAM
- ADC, DAC
- Low-power consumption
- i2c, spi, usart
- LCD display
- USB
- Timers
- Thumb2

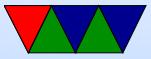


STM32F4

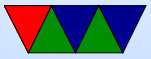
- Used in Hummels Class
- ARM Cortex-M4F core, 180 MHz. F is for Floating point
- Static RAM, 64K core coupled memory (CCM), 4K battery-backed, 80B tamper-detect erase.
- Flash ROM: 512 - 2048 KB general purpose, 30 KB system boot
- Lots of busses: USB, CAN, SPI, I^2S, I^2C, UART, SDIO for SD/MMC, ADCs, DACs, GPIOs, DMA, RTC, CRC engine, RNG



- Some packages support external memory bus
- Instruction set: Thumb, Thumb-2, Saturating Math, DSP, FPU
- ARMv7E-M architecture
- 1-cycle 32-bit hardware multiply, 2-12 cycle 32-bit hardware divide, saturated math support
- DSP extension: Single cycle 16/32-bit MAC, single cycle dual 16-bit MAC, 8/16-bit SIMD arithmetic.
- Floating-Point extension (silicon option): Single-precision floating point unit, IEEE-754 compliant.
- 3-stage pipeline with branch speculation

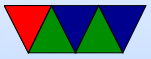


- optional 8 region memory protection unit (MPU)



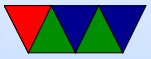
Cortex-M0

- Small core, optimized for small die size (cheaper!)
- ARMv6-M architecture[6]
- Thumb (most), missing CBZ, CBNZ, IT (predication)
- Thumb-2 (subset), only BL, DMB, DSB, ISB, MRS, MSR.
- 32-bit hardware multiply, 1-cycle or 32-cycles (silicon option)
- 3-stage pipeline (in-order)

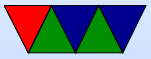


Other Craziness

- big.LITTLE

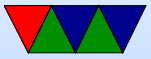


Raspberry Pi

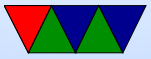


What is a Raspberry Pi?

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

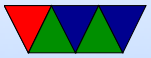


- Can run many operating systems. Even write your own (see ECE598) or bare metal. We'll be running Linux.

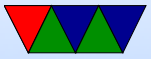


Raspberry Pi Models

- 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
  - Model B – 700MHz ARM1176, 512MB RAM, SD, USB hub+USB Ethernet
  - 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
  - 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
  - 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

- Model2 B (v1.2) – like Model 2 but with the Cortex A53
- Compute 3
- Model3 B+ – better thermal, faster Ethernet, power over Ethernet header. Still only 1GB (cost?)