ECE 471 – Embedded Systems
Lecture 2

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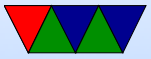
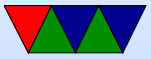
Announcements

- Reminder: The class notes are posted to the website.
- HW#1 will be assigned Friday, watch your e-mail



Processor Types / ISAs

- Intel/AMD x86/x86_64 (mostly in desktop/laptop/server)
- ARM (extremely common in embedded)
- RISC-V (newish, has relatively open licensing)
- Older RISC systems: Power, MIPS, SPARC
- Older CISC systems: m68k, VAX
- Many many more

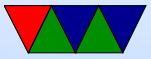


Embedded Systems 20 years ago

- Somewhat dated list, from EE Times 2003. Multiple answers so doesn't necessarily sum up to 100%

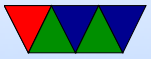
- 8-bit processors
  - Microchip PIC – 43%
  - AVR, etc. 8051 – 55%
  - Motorola 68xx – 36%
  - Zilog Z80 – 15%

- 16-bit processors
  - 8086/80186/80286 – 41%
  - 68HC12 – 21%



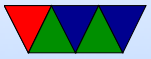
Are 8-bit Systems Still Used?

- One popular example is the Arduino with 8-bit AVR ATmega
- Also, some chips like 8051 were popular for years, so legacy systems still around at companies that need to be maintained.



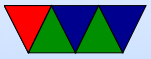
We'll Mostly Use ARM in this Class

- Widely used
- You'll see if it you move to industry
- Other classes in ECE using it

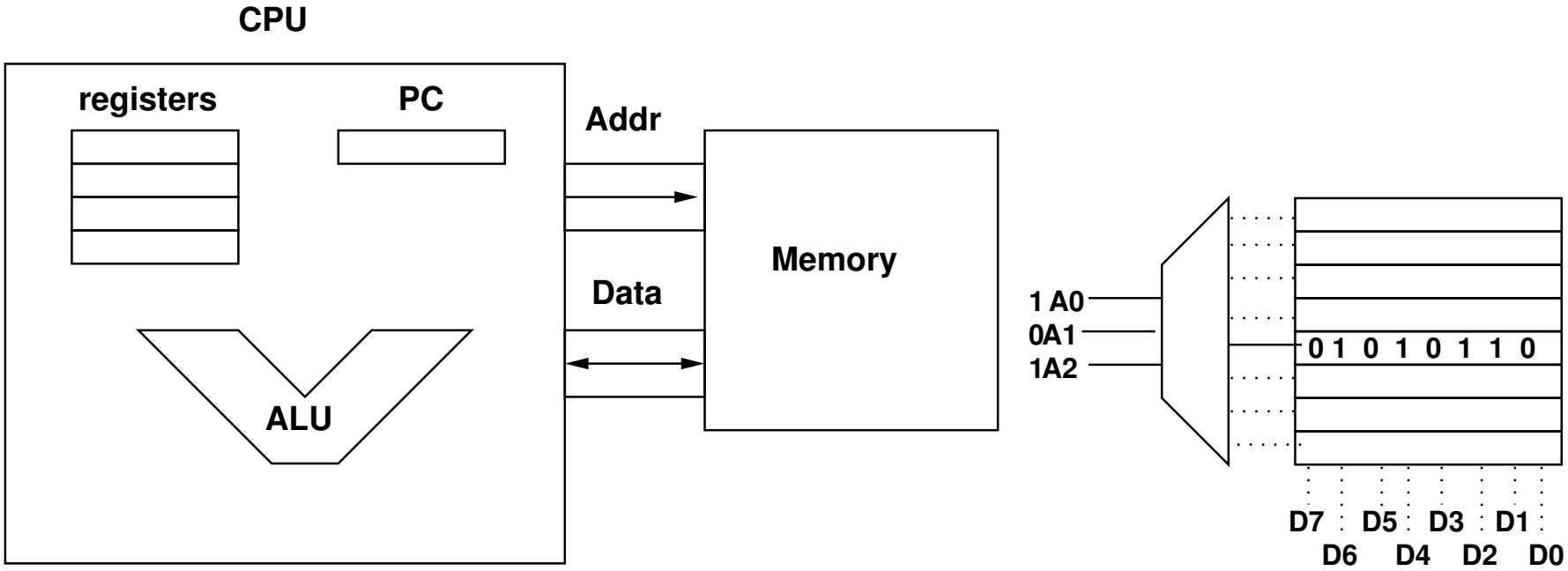


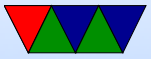
Microprocessors

- First one considered to be 4004 by Intel (for use in calculator)
- First to include all of a CPU on one chip. Before that there were processors, but often were made out of many discrete chips (sometimes entire boards full of logic)



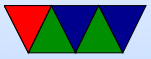
8-bit vs 16-bit vs 32-bit vs 64-bit





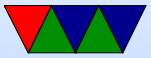
What makes a processor 8-bit vs 16-bit vs 32-bit?

- The size of the registers?
- The size of the address bus?
- The size of the data bus?
- The size of the ALU (integer math unit)?
- The size of the PC (program counter)?



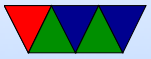
Answer Not Always Clear

- On modern systems it typically is the integer registers, as well as the maximum size of a memory pointer (which typically is the same as the integer register size)
- On many systems though it is not as clear cut.



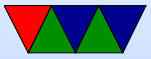
8-bit Systems

- A “pure” 8-bit system would have 8-bit registers (0-255), 8-bit ALU, and an 8-bit data bus.
- However an 8-bit address bus (only 256 bytes of RAM) is too limiting so most 8-bit processors (6502, z80, 8080, etc) had 16-bit address busses, 16-bit PCs, and often 16-bit register capability



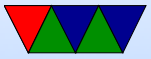
16-bit Systems

- Most 16-bit processors were equally complex.
- The 8086 had 16-bit registers and 16-bit data bus, but a 20-bit address bus with complex addressing.
- To complicate things, the 8088 was 8086 compatible but had only an 8-bit data bus (to save cost, with the side effect of making memory accesses take twice as long)



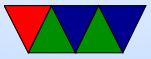
32-bit Systems

- Most 32-bit processors have 32-bit registers and 32-bits of address space, but that limits to 4GB
- Some have extensions (x86 and ARM) allowing 36-bits of address space.
- Data bus has been made complex by caches and are often quite large
- Often there are larger registers on chip (64-bit or 80-bit floating point, 128-bit SSE, 256-bit or 512-bit AVX)



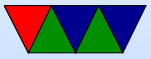
64-bit Systems

- Most 64-bit processors have 64-bit registers, but their address bus is often limited (to 36 - 40 bits, sometimes 48-bits, this is complicated by virtual memory)



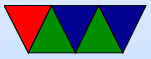
Other Possibilities?

- 128-bit systems? RISCV has a spec
- Do machines have to be a power-of-two in bitness? No, not necessarily. 36-bit machines were once quite popular.



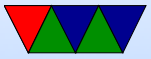
System-on-a-Chip / Microcontroller

- Moore's law allows lots of transistors
- Discrete Chips: CPU, GPU, Northbridge, Southbridge, (and older days, FPU, MMU, etc)
- System-on-a-Chip (SoC): All parts of computer on-chip CPU, DSP, memory, timers, USB, voltage regulators, memory controllers
- System-in-Package (SiP): various chips in one package



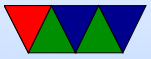
Extra Features on SoCs

- Parallel and Serial I/O
- A/D, D/A converters
- GPIO pins
- i2c, CAN, SPI, 1-wire, USB busses
- FPGA?
- Low-power
- Sound, DSP
- Video, GPU, Video Codecs
- Timers, PWM



ASIC, FPGA, Micro-controller

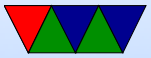
- ASIC – Application Specific Integrated Circuit
  direct wiring of state machines / logic on silicon die
- FPGA – reprogrammable low-level logic
- Microcontroller – can do what above do, but in software
- Why use ASIC: could be faster, but what if mistake?
  Why use FPGA: could be faster, more expensive
  Why use microcontroller: Cost. Time to market. Bug-fixes (easier to fix in software)



Tradeoffs

It's all about tradeoffs

- Power
- Performance
- Cost
- Compatibility
- Time to Market
- Features



Challenges vs Regular Systems

- Programming in constrained environment (cross-compiling?)
- Security
- Safety
- Real-time
- Power consumption
- Long-life (embedded device might be in use for decades)
- Testing
- Bug-fixing