CPE 390: Microprocessor Systems

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Lecture 1

Introduction to Microprocessors

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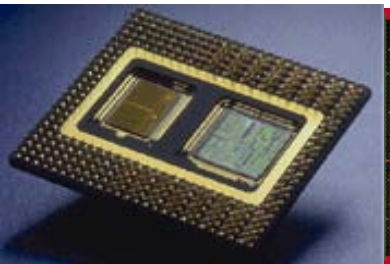
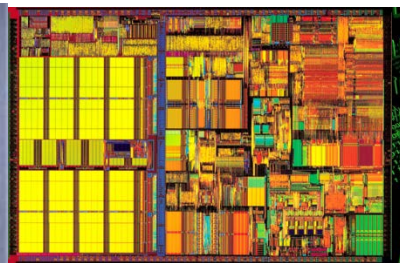
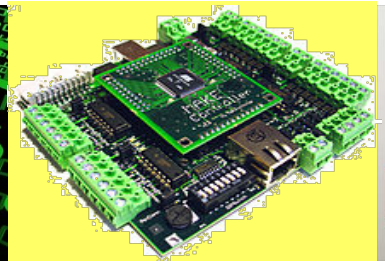
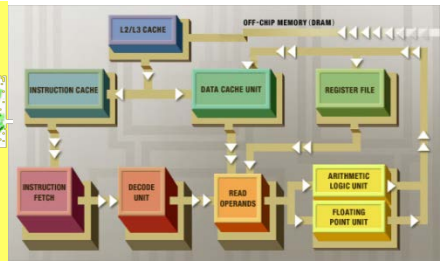



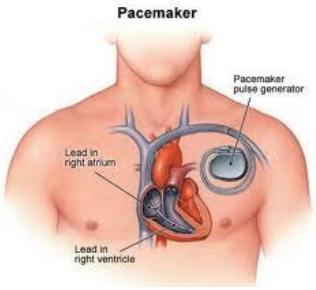



What is a microprocessor?

- Yes, but so much more than these…
- Traditional Computers
  - PCs, MACs, Linux, workstation, desktop, laptop, tablet etc.
  - account for < 1% of microprocessors manufactured each year
- Almost every electronic device employs one or more microprocessors to implement required functionality

Ubiquity of Embedded Microprocessors

All enabled by software running on embedded microprocessor



Why software implementation?

- Why not implement functionality as a dedicated chip?

Application Specific Integrated Circuit	Software implementation on embedded microprocessor
High Performance	Much lower performance - orders of magnitude
Low Power	Much higher power
Low per-unit cost	Higher per-unit cost
Little flexibility – dedicated functionality	Functionality easily changed
Large upfront design cost	Low cost off-the-shelf components
Highly specialized design skills	Readily available programmers
Complex test & debug	Much simpler software debug
Huge redesign cost	Simple to modify program - even after product is sold
1-2 years from concept to market	Fast to market

What is a microprocessor?

- A microprocessor is the central processing unit (CPU) of a stored program digital computer implemented as a single chip integrated circuit.

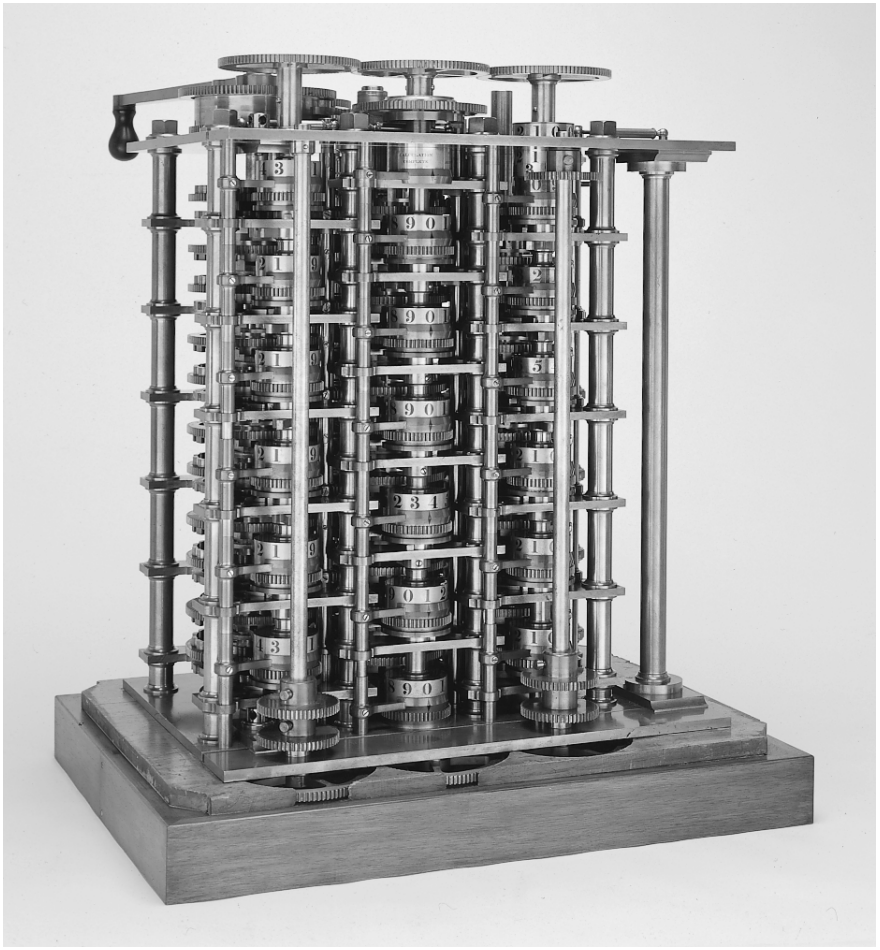
- OK – so what is a stored program digital computer ?
- Let's start with what is a computer?

- A computer is machine that can be programmed to perform a set of logical & mathematical operations on data

- Earliest computers were mechanical

First Digital Computer: Babbage Difference Engine

(1832)



- Executed basic operations (add, sub, mult, div) in arbitrary sequences
- Operated in two-cycle sequence, “Store”, and “Mill” (execute)
- Included features like pipelining to make it faster.
- Complexity: 25,000 parts.
- Cost: £17,470 (in 1834!)

Electronic Computers: Analog or Digital?

- Electronic computers required invention of electronic amplifying device – vacuum tube
- During 1930's and '40's, two competing concepts for electronic computers:

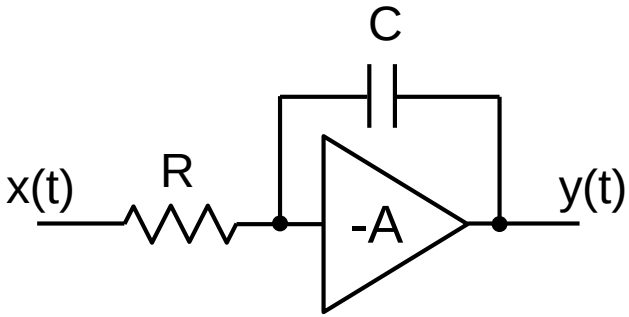
Analog

- Data is input, output, stored and processed as continuous signal
  - voltage or current proportional to data value
- Pioneering work at MIT

Digital

- Data is input, output, stored and processed as finite length binary numbers
  - high or low voltages represent bit value of '1' and '0' respectively
- Pioneering work at U. of Pennsylvania

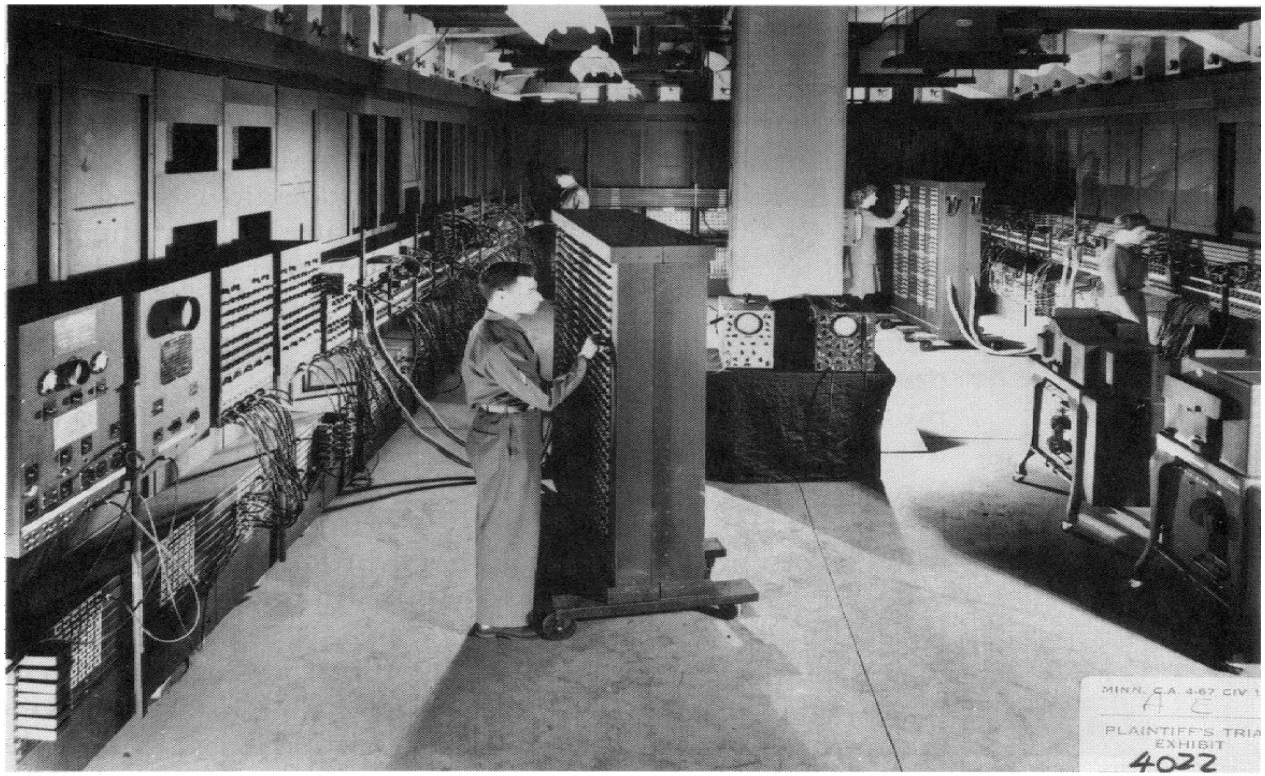
Analog Computers



$$y(t) = \frac{-1}{RC}\int_0^t x(t).dt$$

- Included amplifiers, potentiometers, switches, resistors, capacitors, voltage sources, meters etc.
- Programmed by patch cord interconnect
- Complex operation with just a few components
- Well suited to solving differential equations
  - weapons applications in 1940's and '50's
- Complexity ultimately limited by analog precision
- Program storage, retrieval and modification cumbersome

ENIAC – Early digital electronic computer (1946)



- 100 kHz clock
- 20 words memory
  (~ 100 bytes)
- 5000 operations/sec

10 feet tall, 30 tons 1,000 square feet of floor- space

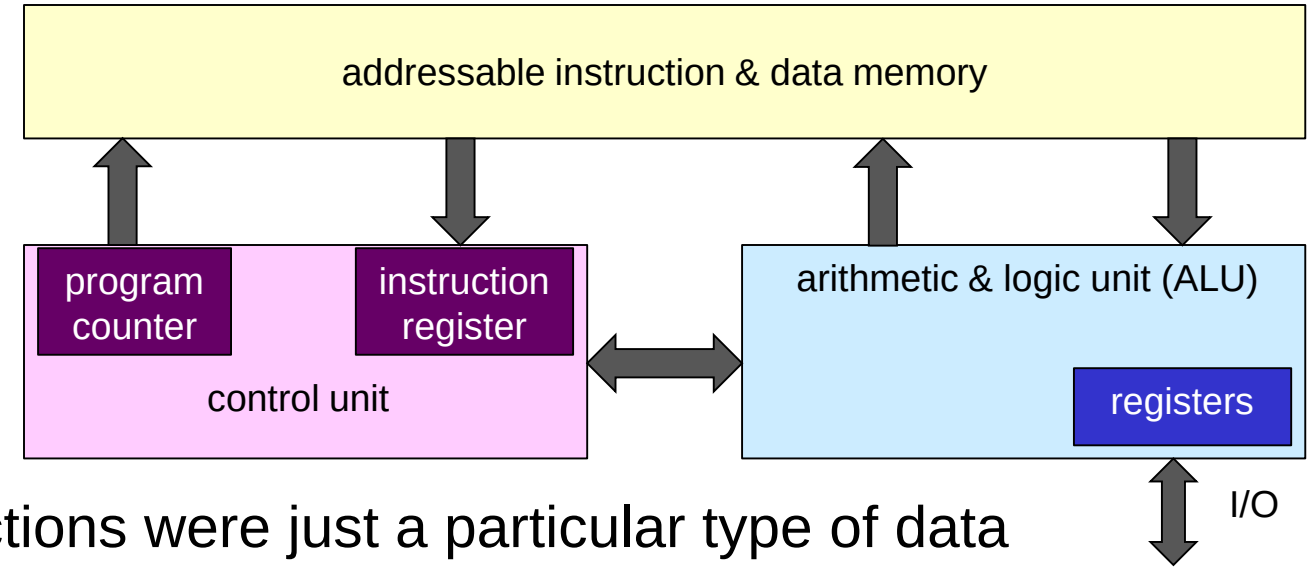
More than 70,000 resistors
10,000 capacitors
6,000 switches
18,000 vacuum tubes

Required 150 kilowatts of power

Programmed via switches and patch cables

Stored Program Digital Computer

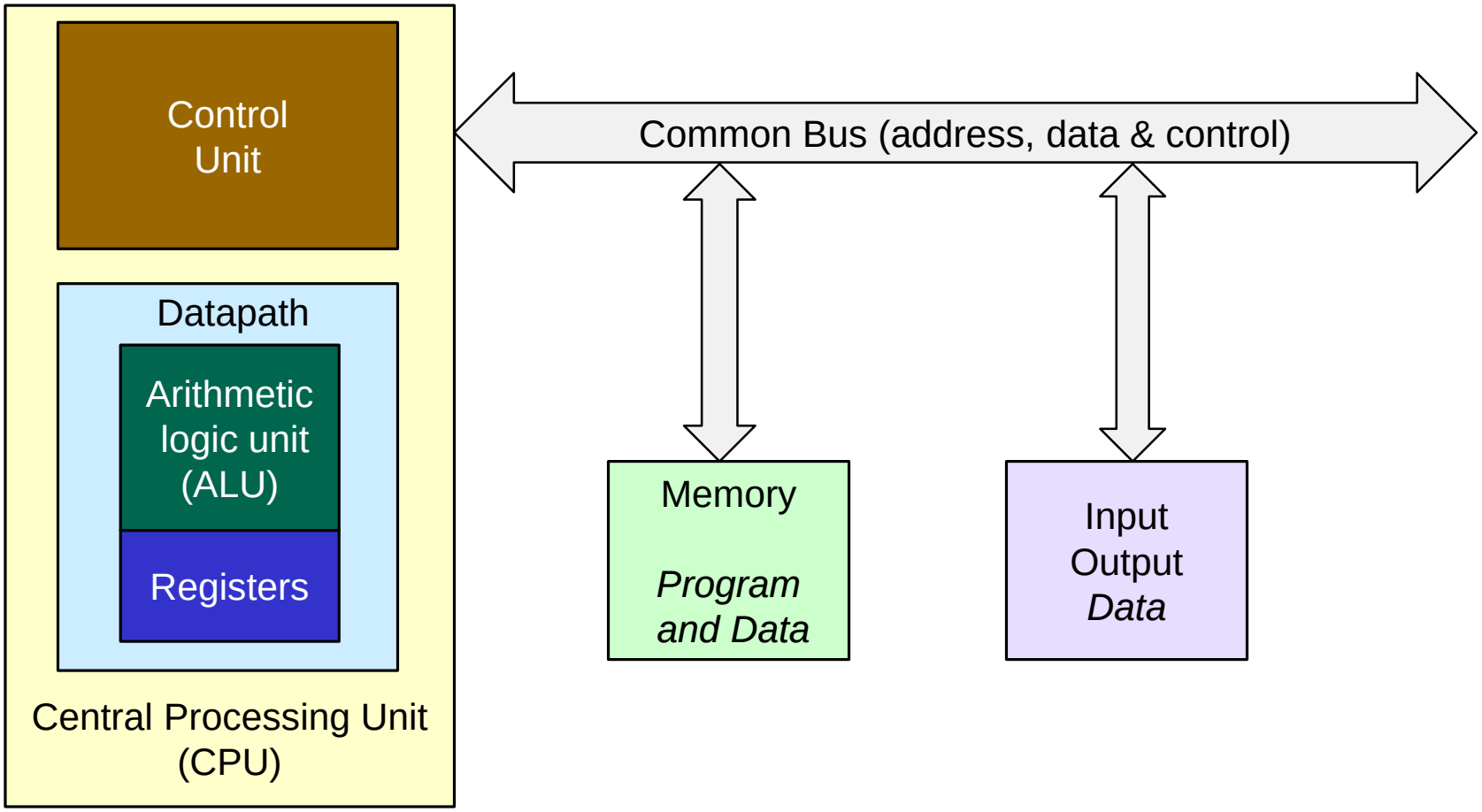
- Turing (1936) proposed idea of a computing engine that:
  - could solve arbitrarily complex problems using a small set of primitive operations
  - use a single memory to store both data and instructions
  - instructions would determine sequence of operations to be performed
- Van Neumann (1945) proposed an architecture for this concept:



- Instructions were just a particular type of data
  - that could be read, modified and written
  - separation of instructions from CPU that distinguishes a stored program computer from a general finite state machine
- **This was a revolutionary concept!**

Computer Hardware Organization

- Concept evolved into well known digital computer architecture:



Evolution of Digital Computers

High level architecture evolved slowly while underlying technology rapidly got smaller, faster and more power efficient:

- Early 1950's: vacuum tubes
  - UNIVAC, IBM 701

- Late 1950's: transistors
  - IBM 1401, CDC 6600

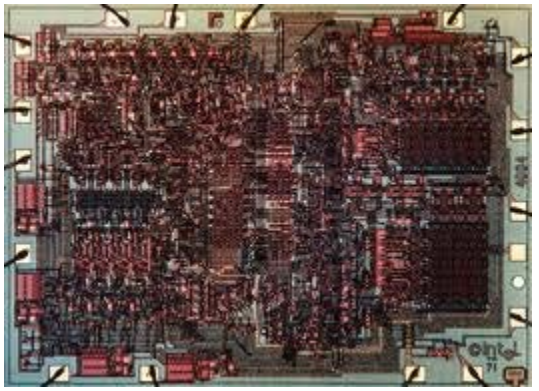
- Late 1960's; integrated circuits
  - IBM 360, DEC PDP-8

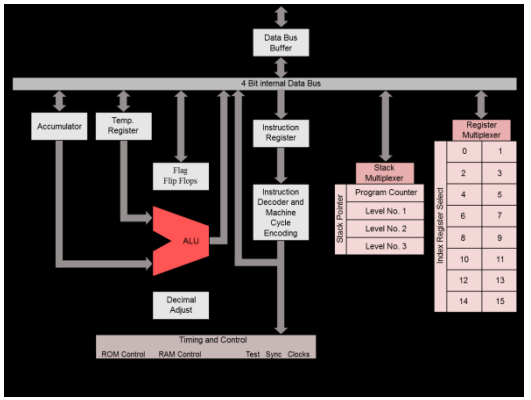
First Microprocessor: 4004

- Next step: integrate a complete CPU on a single chip
- 1971: Ted Hoff at Intel designs the first microprocessor.

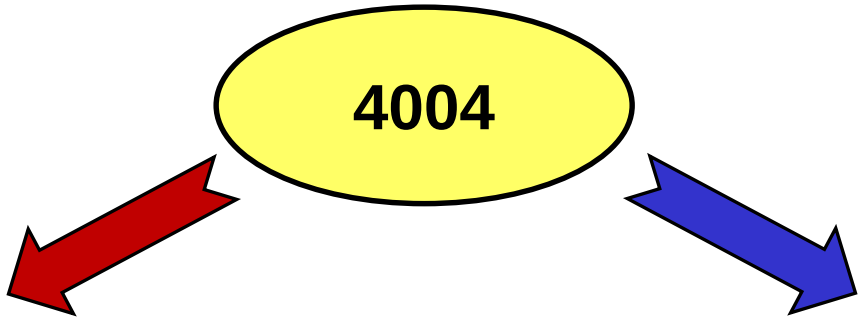
Some 4004 Spec's:

- 4-bit internal & external busses
- 8/16 bit instructions
- Separate instruction & data memory spaces
  - 1k instruction
  - 4k data
- 16 4-bit registers
- 4-bit BCD and binary arithmetic
- 740 kHz clock
- 10.8 μs instruction cycle (8 clock cycles)
- 2,300 transistors
- 10 μm NMOS process



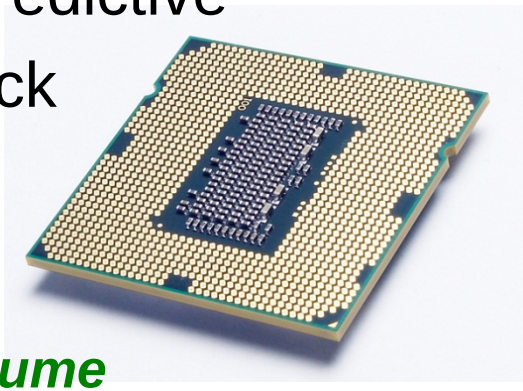


Evolution of Microprocessor 1974-2015



High Performance

- 32/64 bit (int & FP)
- Multicore/multithreaded
- On-chip caches
- Pipelined, predictive
- 2-5 GHz clock
- 50-150 W
- $200-$400



2% market volume
50% market value

Low Cost, Low Power

- 8/16 bit
- On-chip RAM, flash
- On-chip peripherals
- 6-8 I/O pins
- 10-20 MHz clock
- < 500 mW
- < $1

Some Definitions

- Microprocessor is a single-chip implementation of the central processing unit (CPU) of a stored program digital computer
  - CPU contains data-path (ALU + registers) and control unit
- Microcomputer is a computer with a microprocessor as its CPU
  - may include other chips for memory, I/O, clock etc.
- Microcontroller is a single chip microcomputer
  - usually includes memory and I/O
  - timers, serial communications, A/D, D/A, DMA, software debug, etc.

One More Definition

- Embedded System is a special purpose computer system (HW and SW) designed to perform some specific function
  - Unlike general purpose computer, performs few predefined tasks with well defined requirements and limitations
  - Usually includes task specific hardware (peripherals)
  - Often implemented using microcontroller
  - Applications range from small portable (digital watch, coffee maker, MP3 player) to large dedicated systems (power plant controller)
  - Often significant power constraints and real-time performance constraints
    - interacts directly with environment
  - Software usually stored in non-volatile media and known as firmware