Computer Basics

Regardless of how much computers have changed over the last 50 years (think of our first lecture), they are still characterized by the same basic principles

Abstractly, A Computer Is…

- Computers process information by deterministically following instructions, called *executing* instructions
- Unlike humans, computers follows instructions *exactly*
  - Computers have no imagination or creativity
  - Computers have no intuition
  - Computers are literal: they have no sense of irony, subtlety, proportion…
  - Computers don't joke, they're not vindictive or cruel
  - Computers are not purposeful (they don't have their own changing agenda!)

…Computers execute instructions. Nothing more.

Remember this when you feel like screaming at your monitor….!

If a computer has any useful characteristics, it's because someone has programmed it –in other words, given it the instructions – to behave usefully

Interpreting the Instructions

- To perform instructions, a computer's hardware implements a process called the *fetch/execute cycle*

Fetch/Execute Cycle

•Instruction Fetch (IF)
•Instruction Decode (ID)
•Data Fetch (DF)
•Instruction Execution (EX)
•Return Result (RR)

- The F/E Cycle is an unending process

An Analogy…

- Entering your name to a contest to predict the number of candy pieces in a jar

The person who processes the entries works just like the F/E Cycle

Dear MGH Staff,

There are exactly

** 5089 **

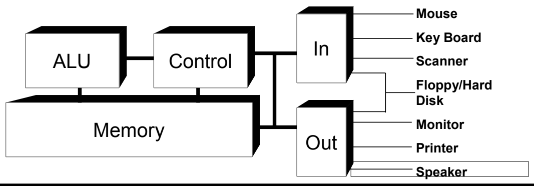
M&M's in the jar

Grace Whiteaker
The Information School
gbwhit23

•Get next entry (IF)
•Find number guessed (ID)
•Get card with that number (DF)
•Enter name (EX)
•Return Card to file (RR)

Anatomy Of A Computer

- A computer is essentially made up of 5 components:
  - Arithmetic/Logic Unit (ALU) – the part doing computations
  - Control – the part that follows the Fetch/Execute Cycle of the program and tells the ALU what to compute
  - Memory – where data, programs are kept while computing
  - Input – ports to peripheral devices that allow/bring data in
  - Output -- ports to peripheral devices that allow/send data out



Memory

- The memory component is passive, storing programs and data

address:	0	1	2	3	4	5	6	7
value:	M	J	i	s	!	23	2	3

byte

- Memory is like a series of "byte-size" boxes – each has an address and some contents called its value
- Memory is called RAM for "random access memory" because the control can access any random location in the memory
- RAM is volatile memory – it disappears when the power does

There always needs to be something in Control: Control Rules!

- The control follows through the instructions, executing them by telling other parts what to do
- The instructions come from the program stored in the memory

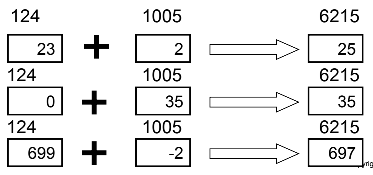
The instructions are in the end expressed in a *machine language,* which the control can understand. A typical machine instruction is

add 124, 1005, 6215

Which means "*add the number in memory location 124 to the number in memory location 1005 and put the result in memory location 6215*"

Just to be clear…

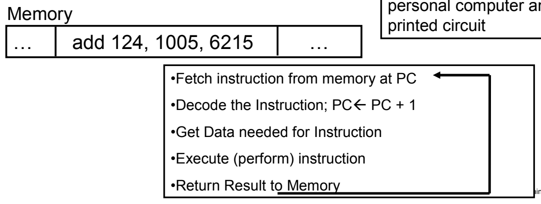
- The instruction add 124, 1005, 6215 does not add 124, 1005 and 6215 together. We can do that in our heads or with a calculator
- It simply adds whatever has been stored at those memory locations
- Different numbers in those locations produce different results: ADD 124, 1005, 6215



Following Instructions

- The control maintains the correct place in the program by using a program counter, or PC. A better name might be "instruction pointer".
- The control also prepares for data-fetches from and result-returns to the memory

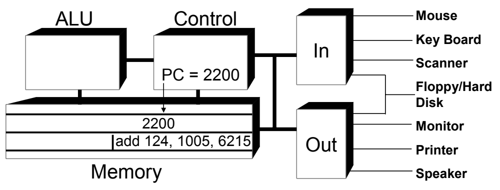
PC: program counter, personal computer and printed circuit



•Fetch instruction from memory at PC
•Decode the Instruction; PC← PC + 1
•Get Data needed for Instruction
•Execute (perform) instruction
•Return Result to Memory

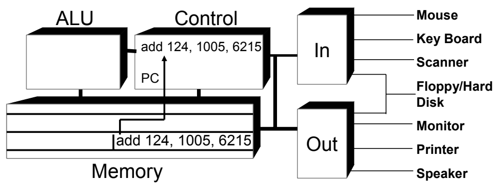
The Fetch/Execute Process

- Just before the Instruction Fetch….



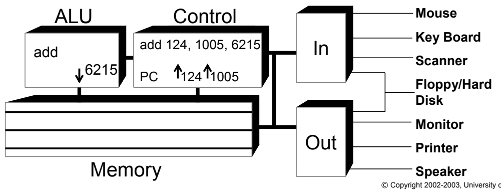
Instruction Fetch

- Get instruction at the memory location PC



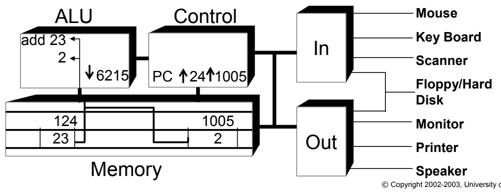
Instruction Decode

- Analyze Instruction and set up later steps
  - Specify the ALU operation (add)
  - Specify addresses to fetch (124, 1005) and to store (6215)



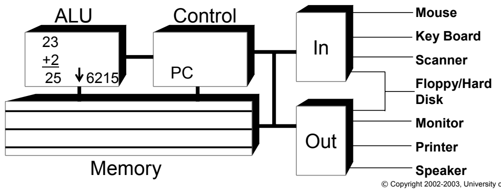
Data Fetch

- Move values stored at fetch–addresses to ALU for processing



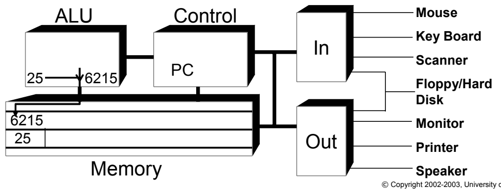
Execute

- The operation of the instruction (add) is performed



Result Return

- The result is returned to memory to the address specified in the instruction



The PC's PC

- After the instruction has been fetched and executed, the next instruction in sequence is fetched at PC +4
- This scheme should cause the computer to run through memory executing all instructions once and then "fall off the end of memory"
- Computers have machine instructions to branch and jump, i.e. go to some instruction other than the next
- Jump and Branch change the PC after increment
- Programs generally repeat many instructions

What's in a Number?

- A memory location can store one byte of information, enough for a keyboard character
- A "normal" whole number (integer) uses 4 bytes
- A machine instruction uses 4 bytes
- Units of memory size are …
  - KB, kilobyte, 1024 bytes … just over a thousand bytes, a "K"
  - MB, megabyte, 1,048,576 bytes … just over a million bytes, a meg
  - GB, gigabyte, 1, 073, 741, 824 bytes … just over a billion bytes, a "gig"
  - TB, terabyte, 1,099,511,627,776 bytes … just over a trillion bytes

Free Memory!

- Why do computers use such weird amounts to indicate 1000, 1 Million, etc?
  - These numbers are powers of 2

2^{10} = 1, 024	call it a thousand
2^{20} = 1,048,576	call it a million
2^{30} = 1, 073, 741, 824	call it a billion
2^{40} = 1,099,511,627,776	call it a trillion

- When you buy a megabyte of member, it's as if you get 48, 576 bytes for free!

The Intermediaries: BIOS and OS

- Computer hardware doesn't have the instructions needed to startup
- BIOS-Basic Input/Output System
  - Lowest level of software on system
  - Talks to Operating System
- Operating Systems:
  - Software that continues as intermediary between hardware and other applications
  - Without an operating system, nothing will happen
  - OS provides basic startup instructions, memory management, and ongoing interaction with programs
- All interaction between peripherals and software is done through the OS
  - Mouse moves, file navigation, saving, etc
  - Software (like Word) then doesn't have to deal with repeating those instructions in its code

Summary

- Computers deterministically execute instructions to process information
- Computers have five parts: ALU, Control, Memory, Input and Output
- The control implements a process called the Fetch/Execute Cycle
- The F/E cycles is a fundamental method of performing operations EXACTLY the same way specified, every time. This idea is used in many places in computation
- BIOS and Operating Systems are the go-betweens for hardware and software