Introduction to Computer Science
Lecture 2: Data Manipulation

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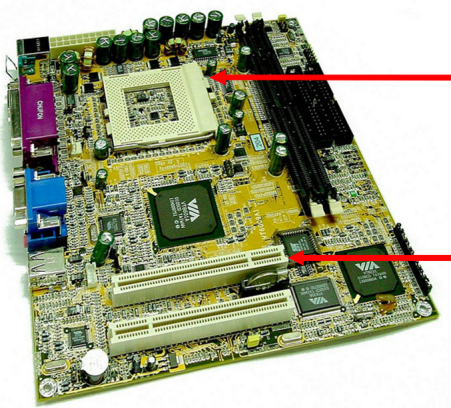
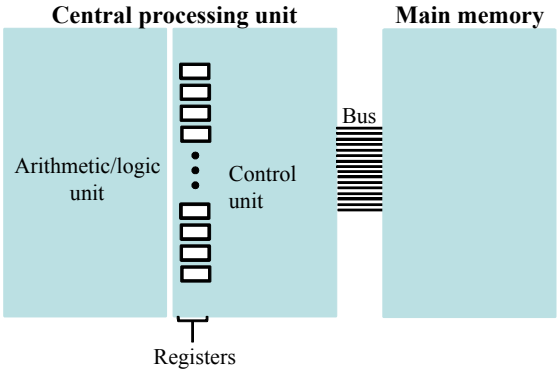
Motherboard



Computer Architecture

- CPU
  (central processing unit)
- Registers
- Memory
- Bus
- Motherboard



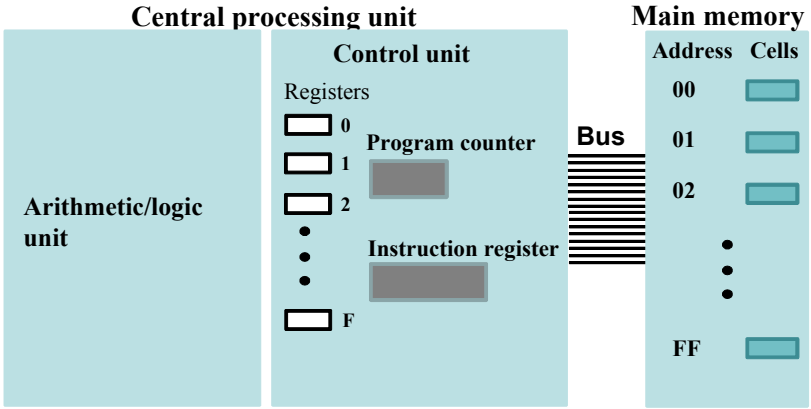
Adding Values Stored in Memory

1. Get one of the values to be added from memory and place it in a register.
2. Get the other value to be added from memory and place it in another register.
3. Activate the addition circuitry with the registers used in Steps 1 and 2 as inputs and another register designated to hold the result.
4. Store the result in memory.
5. Stop.

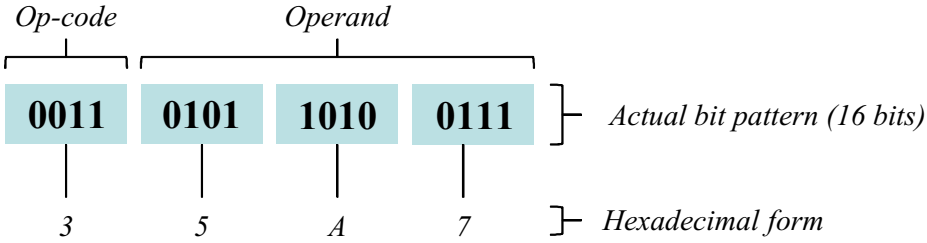
Machine Instructions

- Data transfer
  - LOAD, STORE, I/O
- Arithmetic/logic
  - AND, OR, ADD, SUB, etc.
  - SHIFT, ROTATE
- Control
  - JUMP, HALT
- RISC (Reduced Instruction Set Computing) (PRC, SPARC) vs. CISC (Complex instruction set computing) (x86, x86-64)

Architecture of a Simple Machine



Example of a Machine Instructions



Store (**3**) the content of register no. **5** to the memory cell addressed **A7**

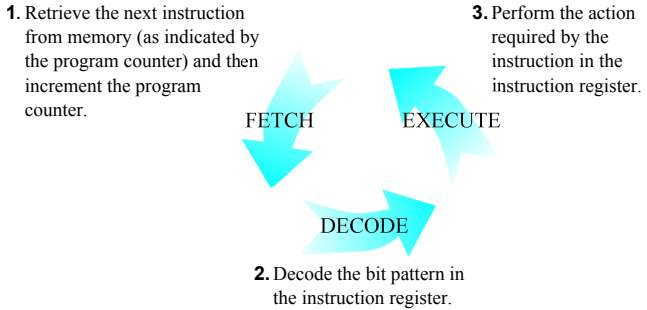
Memory reference: $2^8 = 256$ cells (bytes)

Adding Two Values Revisited

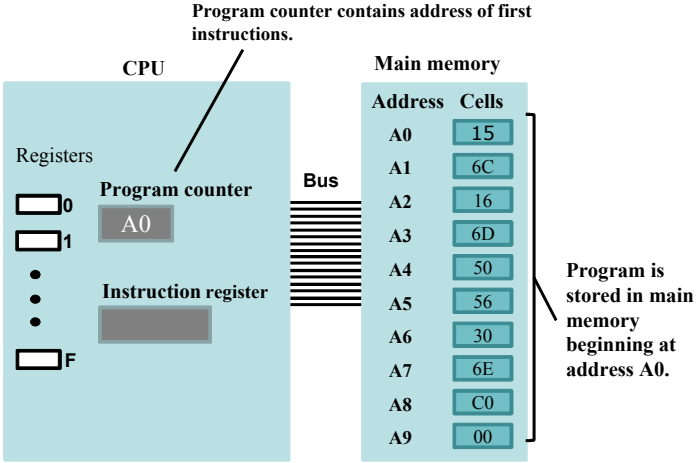
Encoded instructions	Translation	Possible assembly	Possible C
156C	Load register 5 with the bit pattern found in the memory cell at address 6C.	LOAD 5, 6C	
166D	Load register 6 with the bit pattern found in the memory cell at address 6D.	LOAD 6, 6D	
5056	Add the contents of register 5 and 6 as two complement representation and leave the result in register 0.	ADD 0, 5, 6	c = a + b;
306E	Store the contents of register 0 in the memory cell at address 6E.	STORE 0, 6E	
C000	Halt.	HALT	

Program Execution

- Instruction register, program counter
- Machine cycle
  - clock
  - benchmarking



Fetch


Program counter contains address of first instructions.
CPU
Main memory
Registers
Program counter
A0
Bus
0
1
F
Instruction register
Address
Cells
A0
15
A1
6C
A2
16
A3
6D
A4
50
A5
56
A6
30
A7
6E
A8
C0
A9
00
Program is stored in main memory beginning at address A0.

Logic/Bit Operations

- Masking

AND

```
  01010101
& 00001111
----------
  00000101
```

Setting the first 4 bits to 0.

OR

```
  01010101
| 00001111
----------
  01011111
```

Setting the latter 4 bits to 1.

XOR

```
  01010101
^ 00001111
----------
  01011010
```

Inverting the latter 4 bits.

Shift/Rotation

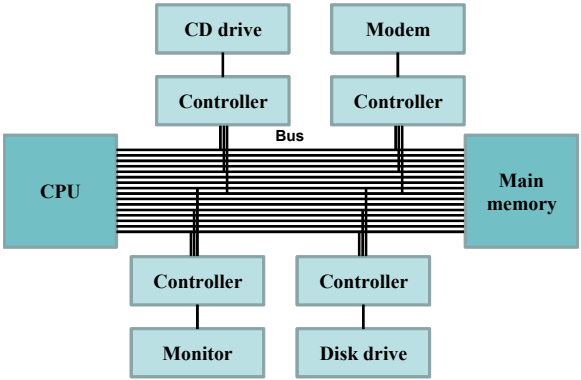
- Logic shift
  10100000 → 01010000 (right)
  → 01000000 (left)

- Arithmetic shift
  10100000 → 11010000 (right)
  → 11000000 (left)

- Rotation
  10100000 → 01010000 (right)
  → 01000001 (left)

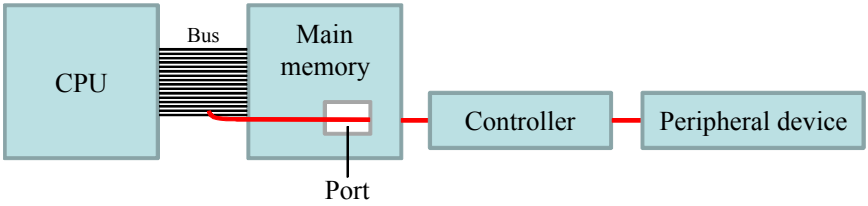
Controller

- Specialized
- General: USB, FireWire



Memory-mapped I/O

- I/O as LOAD, STORE

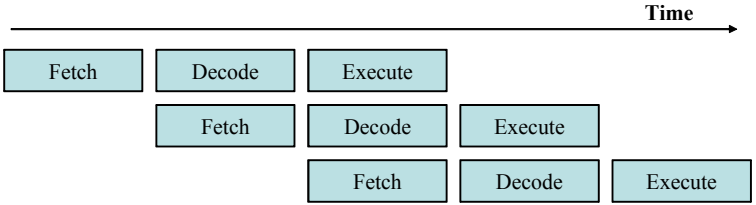


Communication with Other Devices

- DMA: direct memory access
  - Once authorized, controllers can access data directly from main memory without notifying CPU.
- Hand shaking
  - 2-way communication
  - Coordinating activities
- Parallel/Serial
- Transfer rate: **bit** per second (bps, Kbps, Mbps, etc)

Pipelining

- Throughput increased
  - Total amount of work accomplished in a given amount of time.
- Example: pre-fetching
  - Issue: conditional jump



Parallel/distributed Computing

- Parallel
  - Multiprocessor
  - MIMD, SISD, SIMD
- Distributed
  - Linking several computers via network
  - Separate processors, separate memory
- Issues:
  - Data dependency
  - Load balancing
  - Synchronization
  - Reliability

To Parallelize XOR Not to Parallelize

How to parallelize?

```
declare A[0]~A[99]
input A[0]

for (i = 1; i<100; i++)
    A[i] = A[i-1] * 2;
```

```
declare A[0]~A[99]
input A[0], A[1], A[2]

for (i = 3; i<100; i++)
    A[i] = A[i-2] + A[i-3];
```

2 CPUs

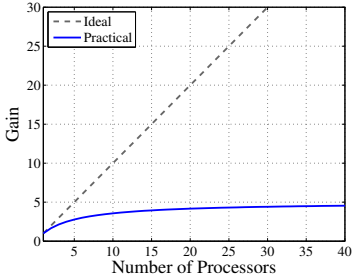
```
A[1]=A[0] * 2;
for (i = 2; i<100; i+=2) {
    A[i] = A[i-2] * 4;      ← CPU 0
    A[i+1] = A[i-1] * 4;    ← CPU 1
}
```

```
for (i = 3; i<98; i+=2) {
    A[i] = A[i-2] + A[i-3];     ← CPU 0
    A[i+1] = A[i-1] + A[i-2];   ← CPU 1
}
A[99] = A[97] + A[96];
```

Speedup & Scaling

- Speedup
  (Amdahl's law)

$$Gain = \frac{1}{\frac{P}{M} + S}$$



P : *parallelizable*
S : *serial only*

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