

# **Lecture 7: Machine Architecture and Stored Program Concept (in Hardware)**

# The Architecture

- CPU
  - ALU
  - Control Unit
    - PC
    - IR
    - MM – memory address
  - Registers
  - Buses connecting ALU and registers
- Main memory
  - Memory cell
  - Address
- Buses connecting CPU and Main memory

# ALU

- The **arithmetic logic unit (ALU)** is the collection of circuitry that performs actual operations on data.
- **Basic operations** include
  - Addition
  - Subtraction
  - Bit manipulation (such as shifting or combining bits)

# Registers

- **Registers** are memory locations that are built into the CPU.
- Data in registers can be accessed more quickly than the data in memory (as much as 5-10 times faster).
- Limited number of registers in CPU due to the cost (commonly 16 or 32 registers).

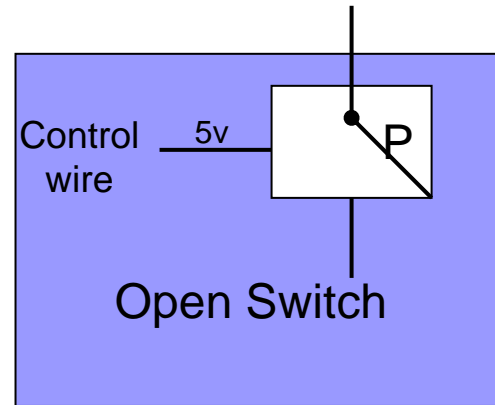
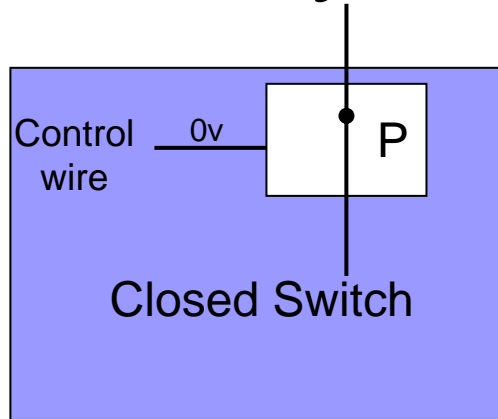
# Buses

- **Bus** is a collection of **wires** which are responsible for transferring data between computer components.
- A set of buses inside CPU connect the registers to ALU.
- A bus Between CPU and memory connect the memory to CPU.

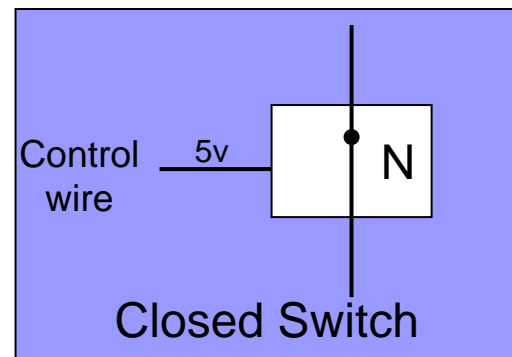
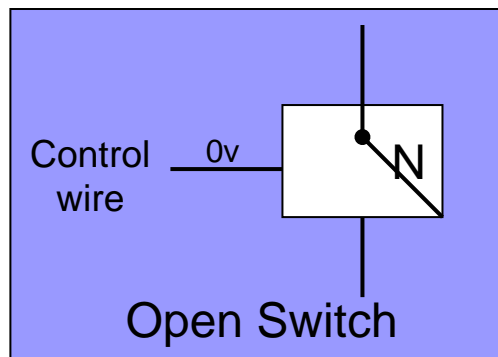
# Control Unit (CU)

- The **control unit (CU)** can be thought as “the brain within the brain”, in that it oversees the various functions of the CPU.
- The control unit is a set of circuitry.
- Control unit is in charge of
  - Fetching **data** from main memory to CPU
  - Fetching **instructions** from main memory to CPU
  - Controlling the **flow of data** from **registers to the ALU** as well as from **ALU to registers**
  - Controlling the **operations of ALU**
  - Storing **data** from CPU to main memory
  - Storing **instructions** from CPU to main memory
- Basic controlling means are setting the **switches**.

# Basic Components: Switches (made by transistors)



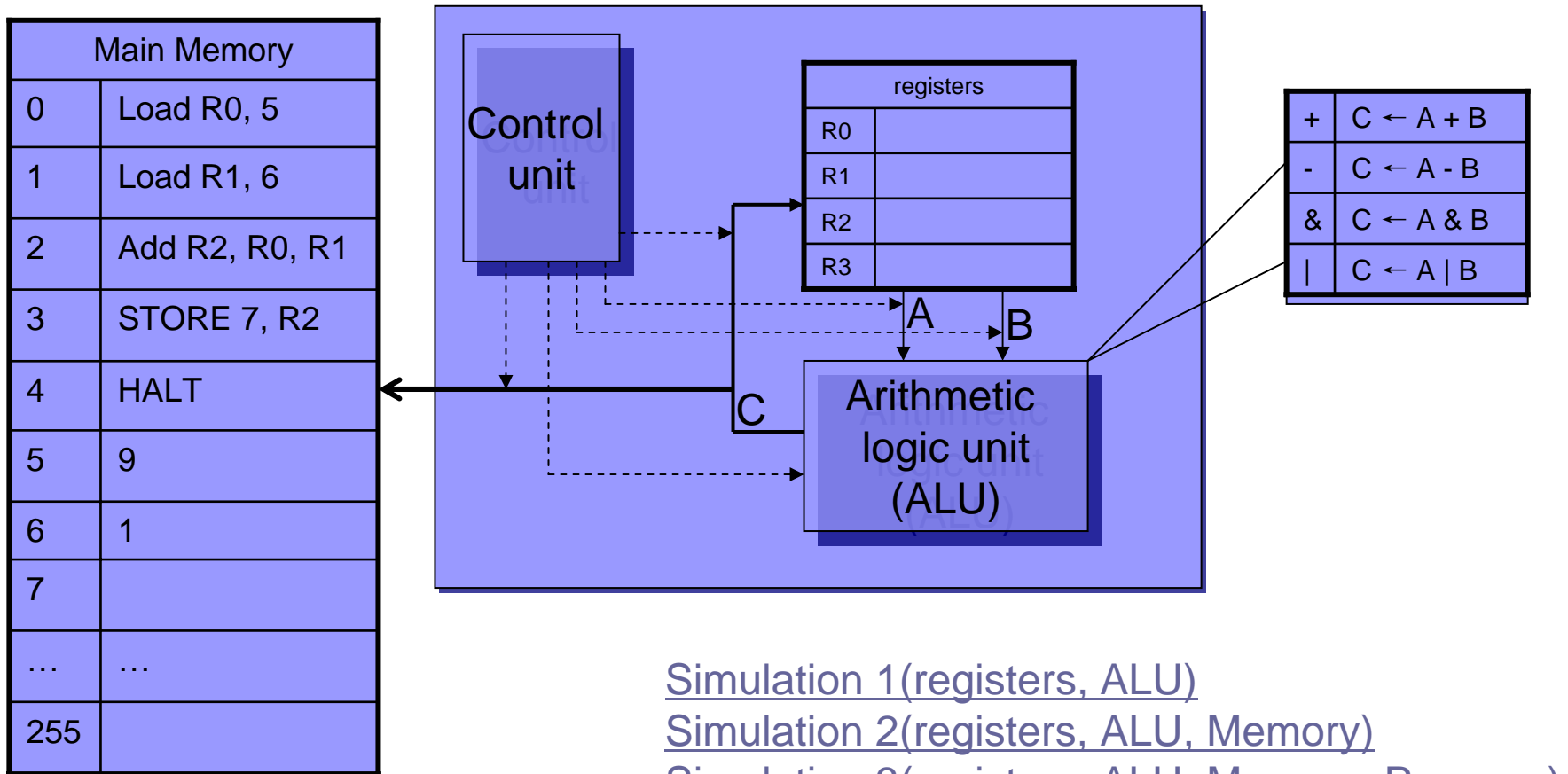
PMOS transistor



NMOS transistor

[The simulation link](#)

# CPU and Main memory



Simulation 1(registers, ALU)

Simulation 2(registers, ALU, Memory)

Simulation 3(registers, ALU, Memory, Program)



# Main Memory

- We can think of main memory as a large collection of **memory locations (cells)**.
- Each location is labeled by an address (binary number).
- Each location can be accessed by given its address.
- A **bus** connects main memory to CPU.
- A little bit details
  - A memory address (a sequence of 0s and 1s) will activate a **set of switches** which **select** a specified memory location.
  - The switches connect this specified memory location to **an interface** connecting to the Memory-CPU bus.

# More Details about Control Unit

- **Program Counter (PC)** contains the memory address of next instruction to be executed.
- **Instruction register (IR)** contains the instruction that the control unit is currently executing.
- Configuration of switches for
  - ALU
  - ALU-register bus
  - Memory-CPU bus
  - Addresses of selected registers
  - Address of selected memory

# Instruction Cycle

- Fetch the instruction from main memory whose address is in the PC (program counter).
  - Store the instruction in IR (instruction register)
  - Increase the instruction address in PC by 1
- The control unit (CU) decodes the instruction and figure out the configuration of the switches to select the registers, buses, memory, etc.
- The control unit (CU) executes the instructions by activating the switches following the configuration given figured out above.
- A little bit more details: Some instruction (e.g. Jump xxx) is just intended to modify the content of PC, so as to modify the execution path of the program.



# Speed of Today's Computer

- Millions or billions of instructions are being executed in one second in modern computer

# Summary

- The computer architecture
- CPU: ALU, Control Unit, Buses
- Main memory
- Instruction cycle