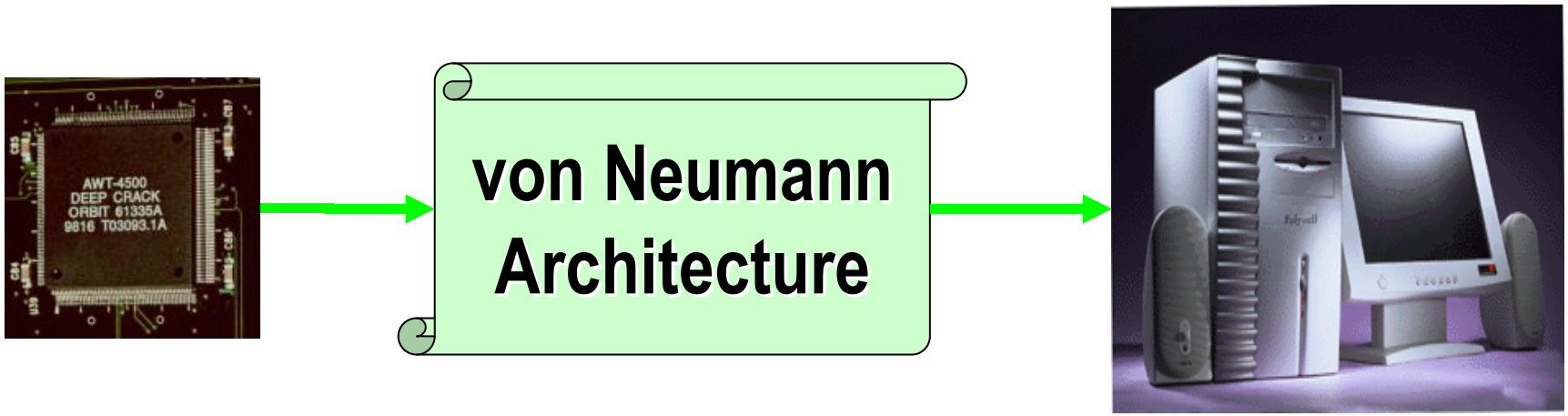
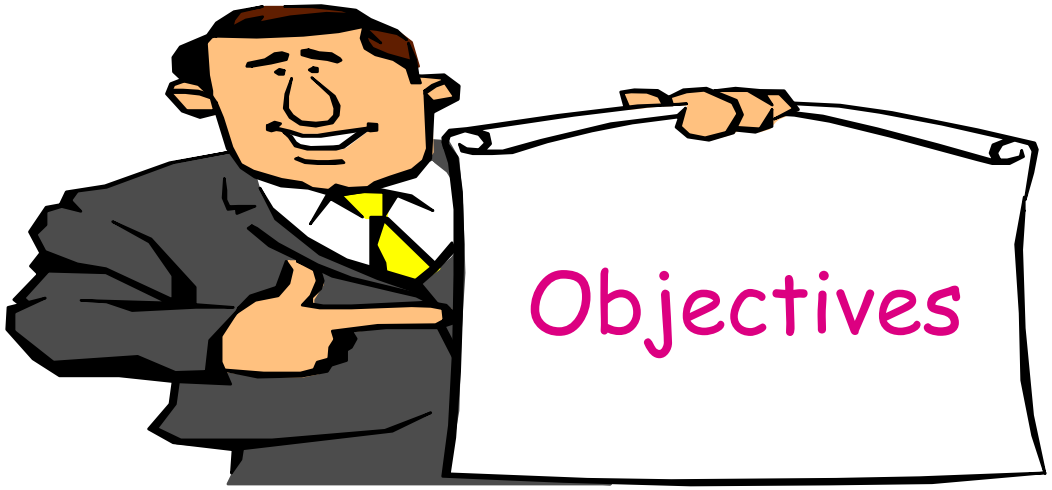
Computer Organization I

Lecture 3: von Neumann Architecture (Part I)



- ✓ General Architecture of von Neumann Machine
  - Memory Subsystem;
  - Arithmetic Logic Unit;
  - Control Unit;

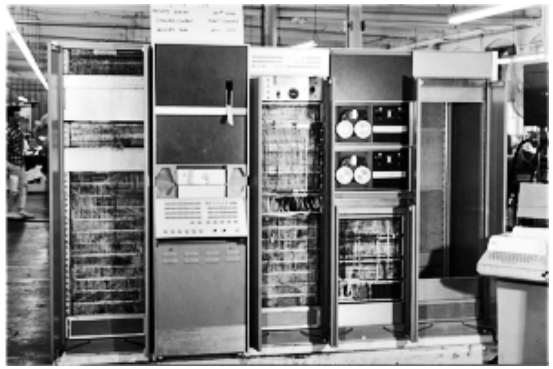


- ✓ Understand how the von Neumann machine works
- ✓ Understand the main functions of components included in von Neumann architecture

von Neumann Architecture - why it is important?

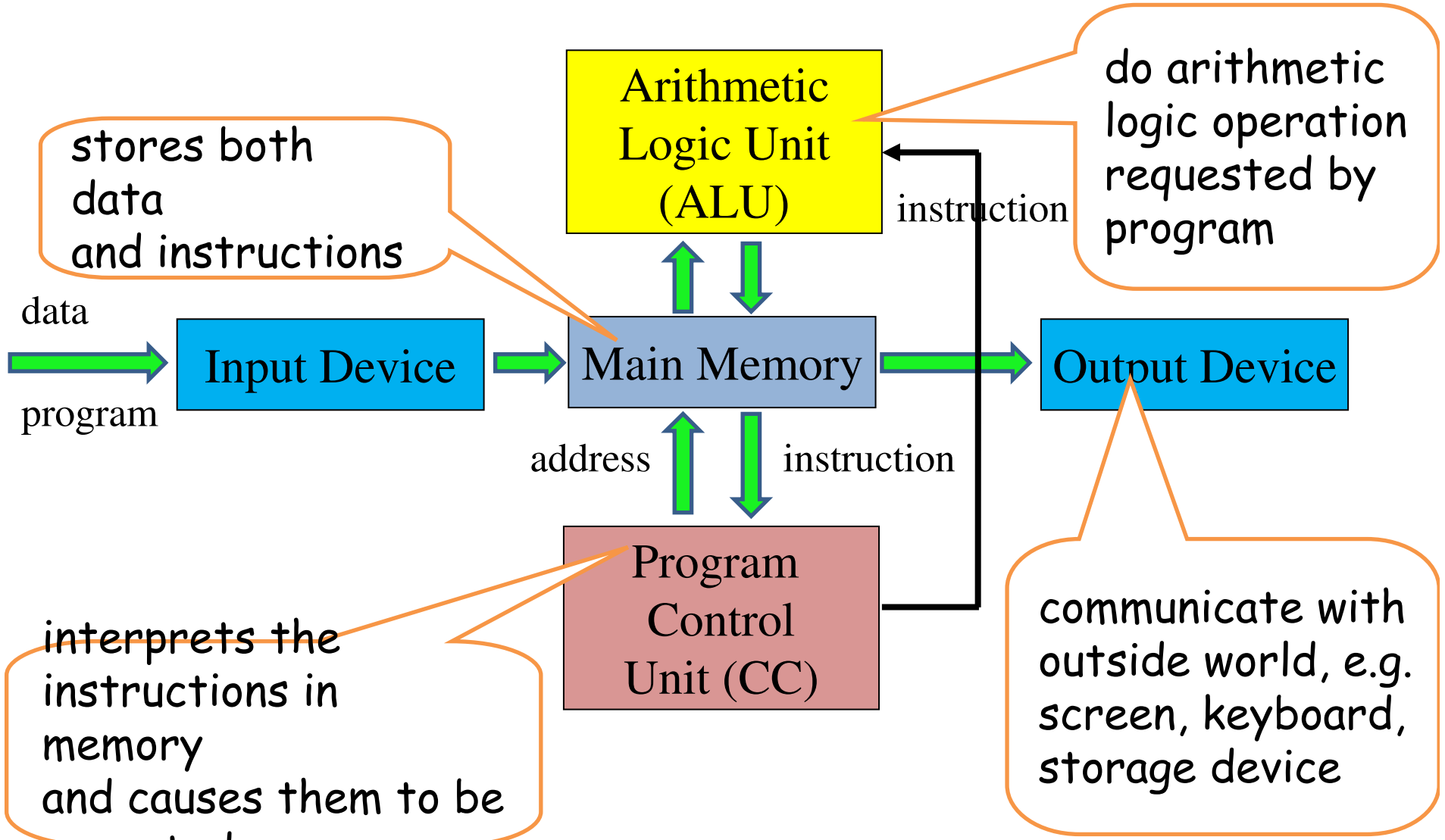
- All computers more or less based on the same basic design, the von Neumann Architecture! what ever it be a multi-million dollar mainframe or a Palm Pilot.



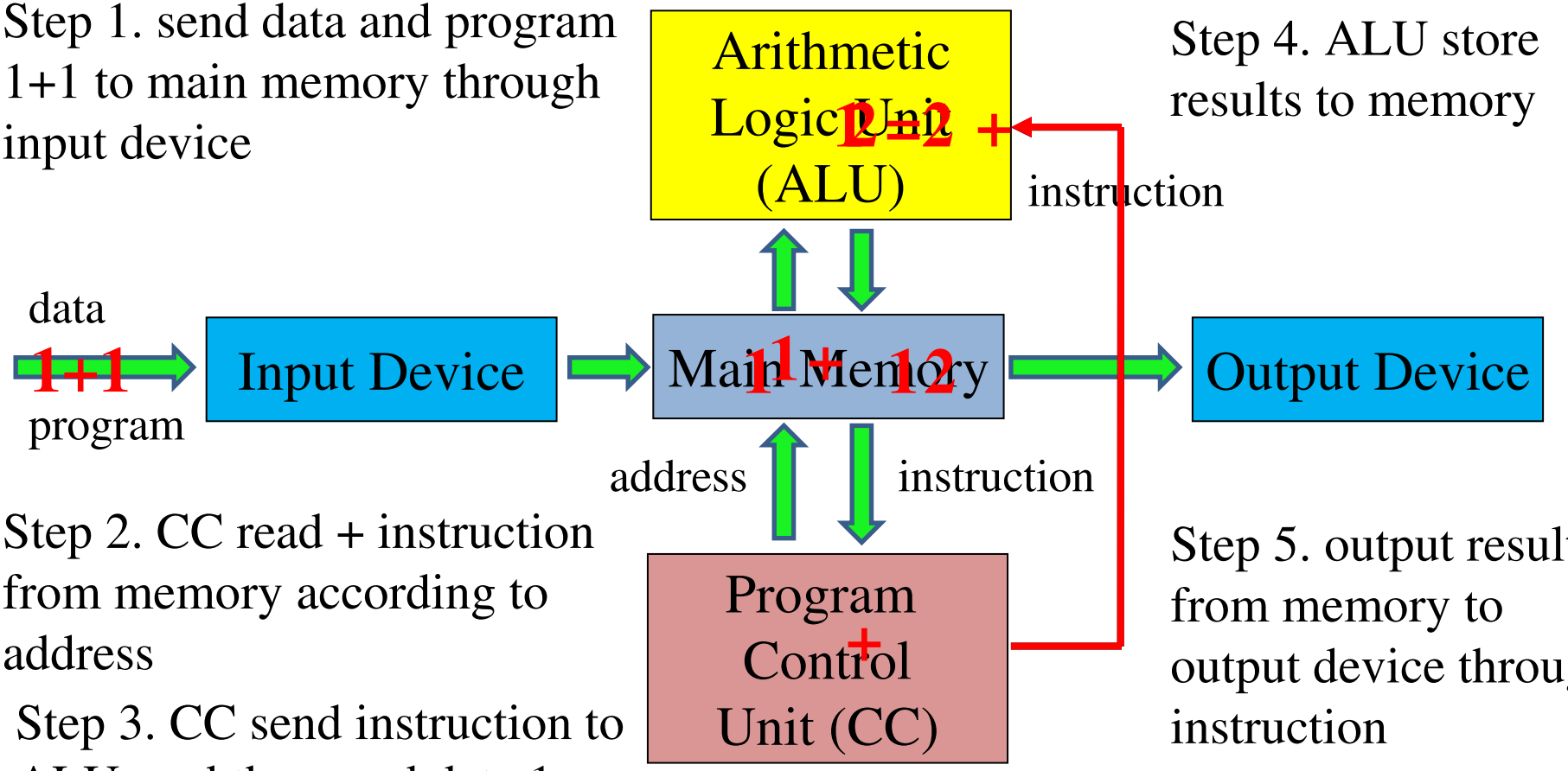
- The von Neumann architecture describes a general framework, or structure, that a computer's **hardware**, **programming**, and **data** should follow.

von Neumann Architecture
- what is von Neumann architecture?



von Neumann Architecture
- how von Neumann computer works?

Step 1. send data and program 1+1 to main memory through input device



Step 4. ALU store results to memory

Step 2. CC read + instruction from memory according to address

Step 3. CC send instruction to ALU, and then read data 1 and 1 from memory to ALU according to address

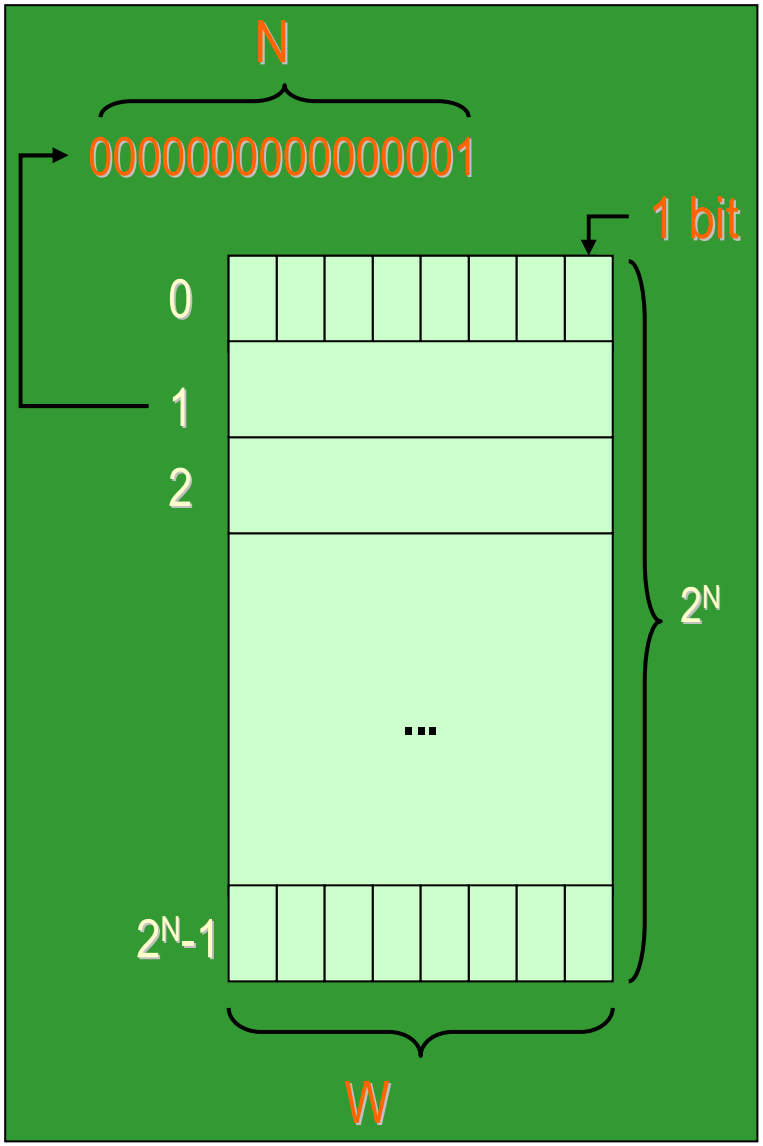
Step 5. output results from memory to output device through instruction

von Neumann Architecture - what is memory subsystem?

- **Memory, also RAM (Random Access Memory)**
  - Consists of many memory cells (storage units) of a fixed size.
    Each cell has an address associated with it: 0, 1, …
  - Each cell has two important characteristics:
    (1) its address (where it is),
    (2) its contents (what's stored at the given location).

von Neumann Architecture - what is memory subsystem?

- Memory width (W)
  - How many bits is each memory cell, typically one byte (=8 bits)
- Address width (N)
  - How many bits used to represent each address, determines the maximum memory size = address space
  - If address width is N-bits, then address space is 2^N (0,1,…,2^N-1)
- Address space
  - the number of uniquely identifiable memory locations.



von Neumann Architecture - what is memory subsystem?

For example, for a 256 Mbyte memory, suppose its memory width is 8 bits (or 1 bytes)

What is its address space?

2^{28}

What is its address width?

28

von Neumann Architecture - what is memory subsystem?

For another example

a memory space is as follows:

000	
001	
010	
011	
100	0000 0110
101	
110	0000 0010
111	

- what is its memory width?

  8 bits
- what is its address space?

  8 bytes
- what is its address width?

  3
- what is the content of memory location address (4 = 100)?

  (6 = 0000 0110)

von Neumann Architecture - what is memory subsystem?

Measurements about RAM Size & Speed

- **Memory sizes:**
  - Kilobyte (KB) = 2^{10} = 1,024 bytes ~ 1 thousand
  - Megabyte(MB) = 2^{20} = 1,048,576 bytes ~ 1 million
  - Gigabyte (GB)= 2^{30} = 1,073,741,824 bytes ~ 1 billion
- **Memory access time (read from/ write to memory)**
  - 50-75 nanoseconds (1 nsec. = 0.000000001 sec.)
- **RAM is:**
  - volatile (can only store when power is on)

von Neumann Architecture - what is memory subsystem?

Operations on Memory

- Fetch (address):
  - Fetch a copy of the content of memory cell with the specified address.
  - Non-destructive, copies value in memory cell.
- Store (address, value):
  - Store the specific value into the memory cell specified by address.
  - Destructive, overwrites the previous value of the memory cell.

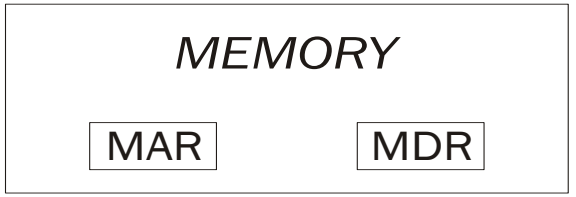
von Neumann Architecture - what is memory subsystem?

Interface to Memory

- How does processing unit get data to/from memory?

  MAR: Memory Address Register

  MDR: Memory Data Register



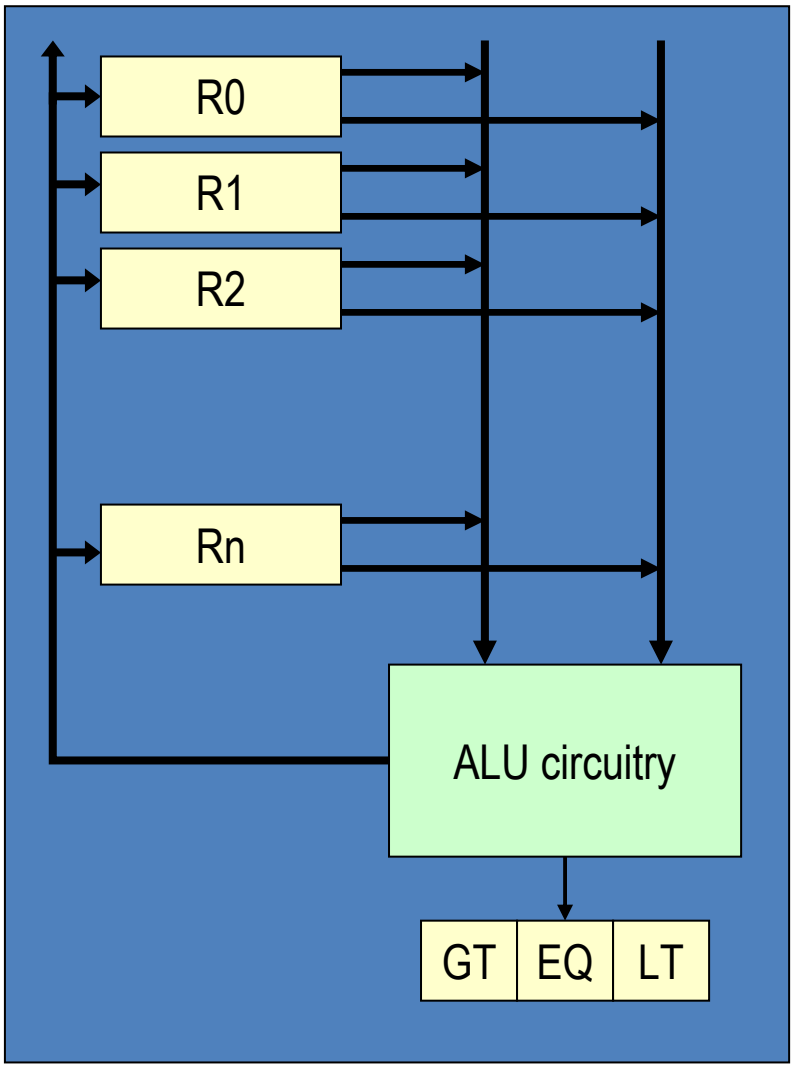
- Fetch (Address):
  1. Load the address (A) into the MAR.
  2. Copy the content of memory cell with specified address into MDR.
- Store (Address, Value):
  1. Load the address into MAR; load the value into MDR
  2. copy content of MDR into memory cell with specified address.

von Neumann Architecture - what is ALU subsystem?

- The ALU (Arithmetic/Logic Unit) performs
  - mathematical operations (+, -, x, /, ...)
  - logic operations (=, <, >, and, or, not, ...)
- In today's computers integrated into the CPU
- Consists of:
  - Circuits to do the arithmetic/logic operations.
  - Registers (fast storage units) to store intermediate computational results.
  - Bus that connects the two.

von Neumann Architecture - what is the structure of ALU subsystem?

- Registers:
  - very fast local memory cells, that store operands of operations and intermediate results.
  - CCR (condition code register), a special purpose register that stores the result of <, = , > operations
- ALU circuitry:
  - Contains an array of circuits to do mathematical/logic operations.
- Bus: Data path interconnecting the registers to the ALU circuitry.



von Neumann Architecture - what is control unit subsystem?

- Program is stored in memory
  - as machine language instructions, in binary
- The task of the control unit is to execute programs by repeatedly:
  - Fetch from memory the next instruction to be executed.
  - Decode it, that is, determine what is to be done.
  - Execute it by issuing the appropriate signals to the ALU, memory, and I/O subsystems.
  - Continues until the HALT instruction

von Neumann Architecture - what is control unit subsystem?

Machine Language Instructions

- A machine language instruction consists of:
  - Operation code/opcode, telling which operation to perform
  - Address field(s)/operands, telling the memory addresses of the values on which the operation works.
- For Example: ADD X, Y (Add content of memory locations X and Y, and store back in memory location Y).
- Assume: opcode for ADD is 9, and addresses X=99, Y=100

Opcode (8 bits)	Address 1 (16 bits)	Address 2 (16 bits)
00001001	0000000001100011	0000000001100100