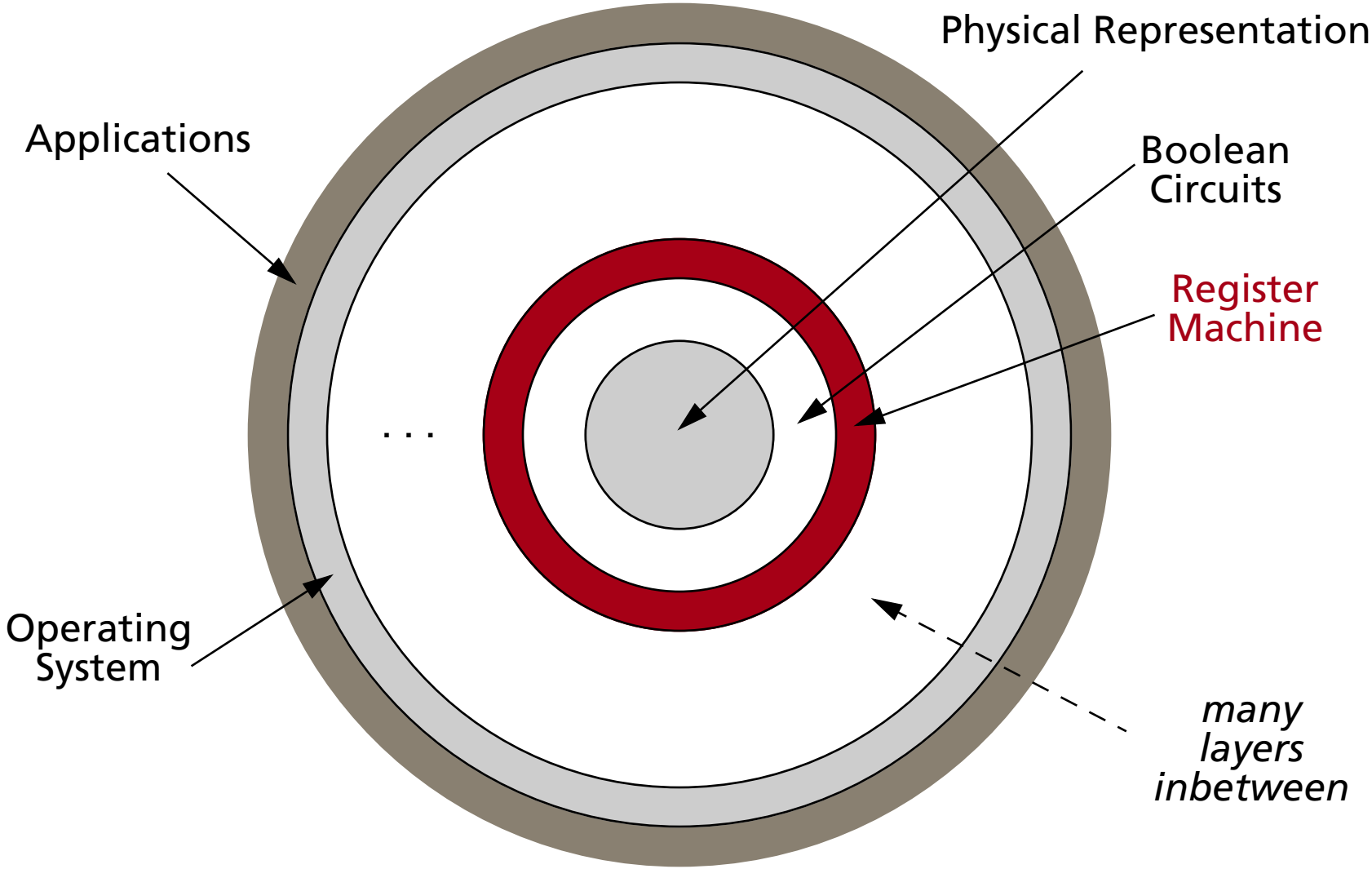
Chapter 2

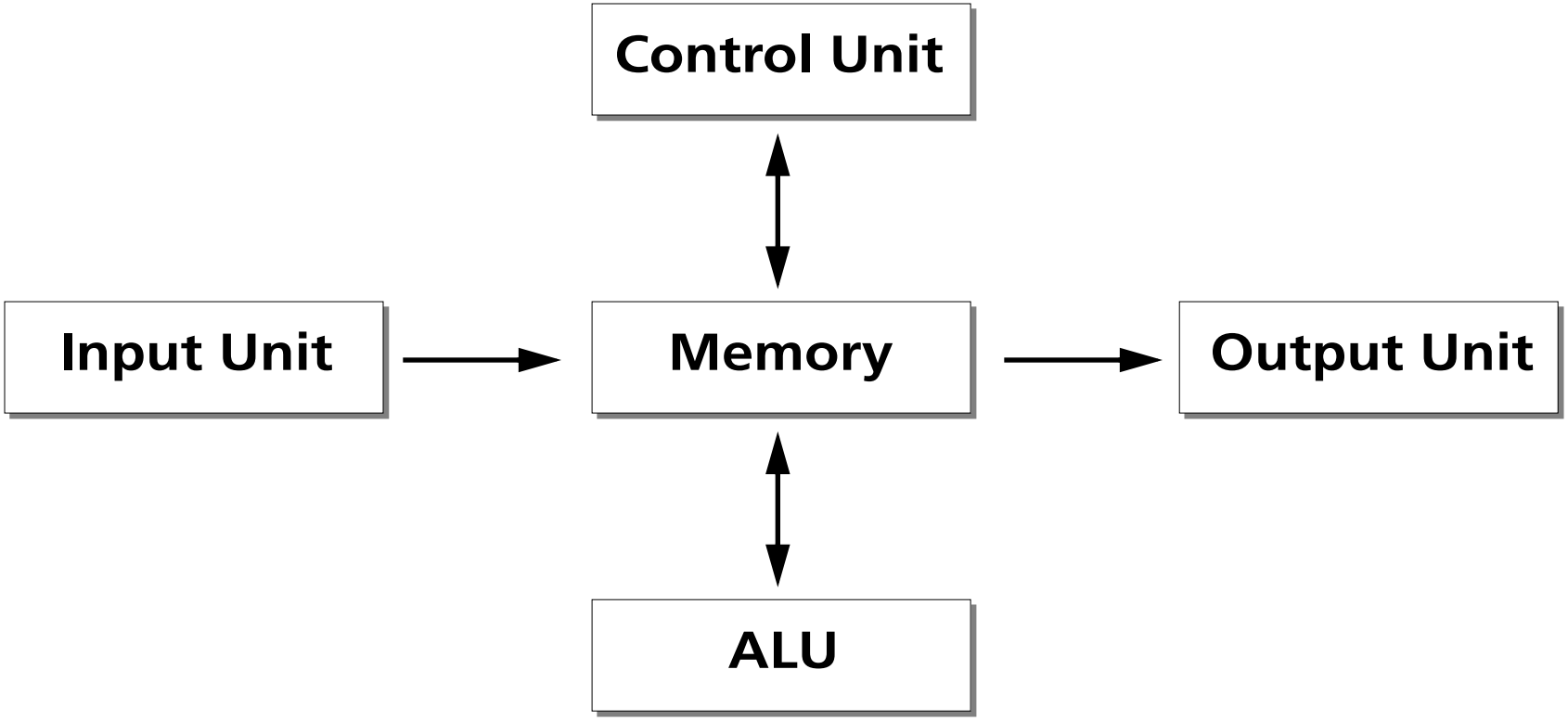
Anatomy of a computer

2.1 Layers of Virtual Machines



2.2 The Register Machine Model

2.2.1 Main components of a von Neumann computer architecture



Burks, Goldstine, von Neumann (Princeton, 1946/47)

"Von Neumann Architecture"

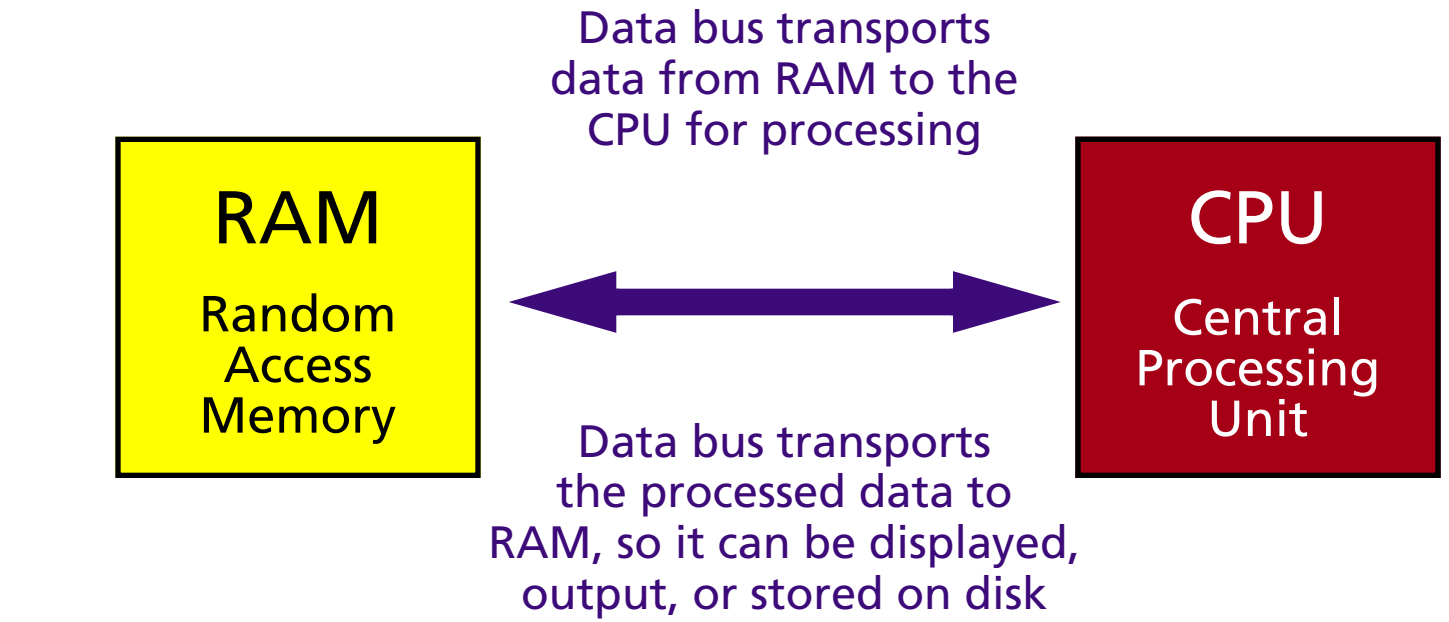
- The computer architecture is problem-independent.

  $\Rightarrow$ Universal Computer:

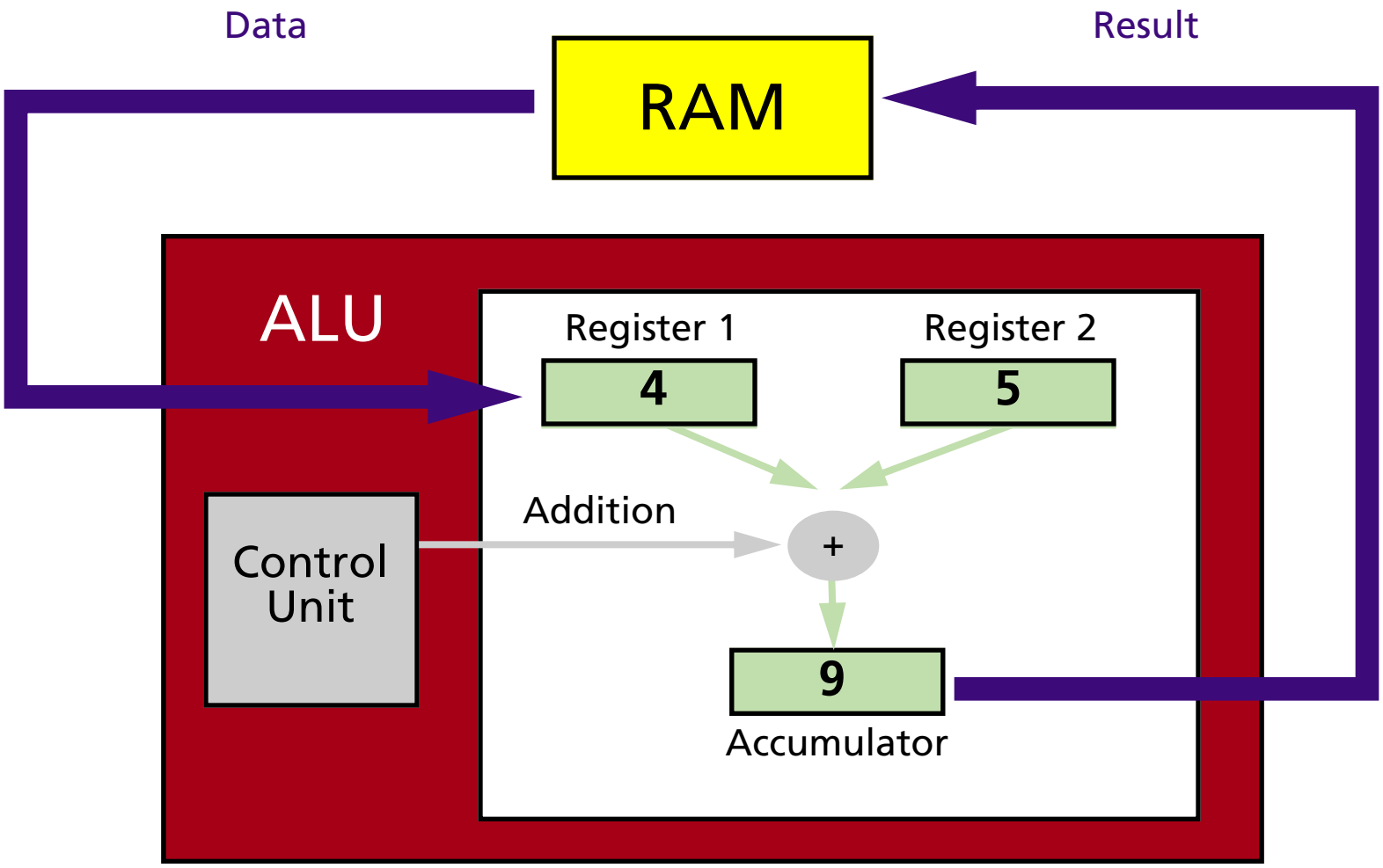
  - Arithmetic Logical Unit — Memory — Control Unit — Input / Output Unit

- **Program** and **data** both reside in memory.
- Each memory location has an **address**, through which its contents can be accessed.
- In general, program commands are stored in consecutive memory locations.
- There are **jump** commands.
- There are conditional jumps.
- The **binary** number system is used.

2.2.2 CPU and RAM



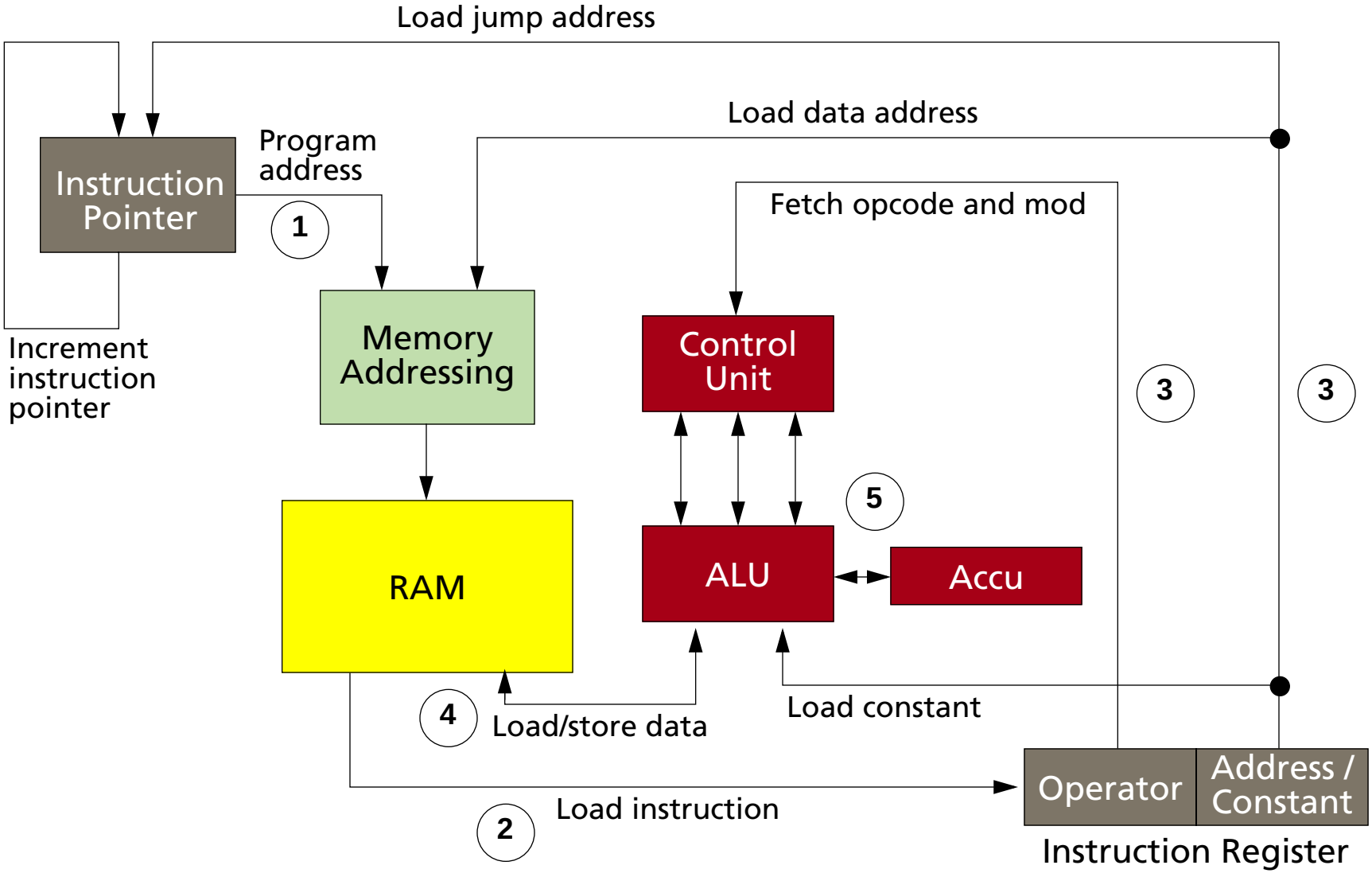
2.2.2 Arithmetic Logical Unit (ALU)



ALU / RAM Performance:

- 1. The data to be processed arrives from RAM and is held in **registers**.
- 2. A **signal** from the Control Unit indicates which arithmetic or logical operation to perform.
- 3. The ALU performs the operation and places the result in the **accumulator**.
- 4. The results are usually sent to RAM so that they can be output or stored on disk.

2.2.3 Execution of Machine Instructions



2.2.4 Machine Language

- Elementary operations:
  - data transfer
  - program control
  - arithmetic and logic operations
  - move operations
  - interrupt handling
- Binary command representation
- Regular structure of all the commands

Command formats:

- 1-address command

Operation	Address of Operand 2

- 2-address command

Operation	Address of Operand 1 & Result	Address of Operand 2

- 3-address command

Operation	Address of Operand 1	Address of Operand 2	Address of Result

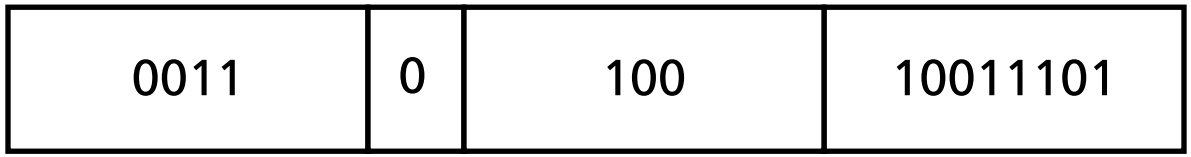
Machine Language Example

Opcode dual	hex.	Description of the Operation	Mnemo.
0000	0	**Halt. End of program execution**	**HLT**
0001	1	**Load operand to accumulator**	**LOA**
0010	2	**Store accumulator at designated address**	**STI**
0011	3	**Add operand to accumulator**	**ADD**
0100	4	**Subtract operand from accumulator**	**SUB**
0101	5	**Multiply operand with accumulator**	**MUL**
0110	6	**Divide accumulator by operand**	**DIV**
0111	7	**Unconditional jump**	**JMP**
1000	8	**Jump if accumulator = 0**	**JEZ**
1001	9	**Jump if accumulator > 0**	**JGZ**
1010	A	**Jump if accumulator < 0**	**JLZ**
1100	C	***Stack commands***	**-**
1101	D	**Jump to subroutine**	**JSR**
1110	E	**Return from subroutine**	**RET**
1111	F	***Index commands***	**-**

Example:

The word 0011 0100 1001 1101 in a memory cell can be …

- a decimal number: 13469
- a command:



- 0011: add operand to accumulator
- 0: one word command
- 100: constant operand (“immediate operand”)
- 10011101: 157_{10}

⇒ “Add 157 to the contents of the accumulator.”

2.3 Hardware Components of a Computer

Central Components:

- CPU
- Main memory (RAM)

Peripheral Devices

- Input devices
  - Keyboard
  - Pointing devices: mouse, trackpads, trackballs, pens, joysticks
  - Scanners, optical character readers (OCR)
  - Microphone

- Output devices
  - Monitor (+ special-purpose processor: video card)
  - Printer
  - Speakers (+ special-purpose processor: sound card)
- Input-output devices
  - Floppy disk drive (capacity: 1.44M to 2.88M, M = Mega Byte)
  - Hard disk drive (capacity: > 20G, G = Giga Byte)
  - Optical storage devices (CD-ROM, DVD)
  - Modem
  - Connections to Local Area Networks (LANs)
  - Connections to Wide Area Networks (WANs)
- Input and output drivers (= software to interface to external devices)

2.4 References

- G. Blank and R. Barnes, *The Universal Machine*, Boston, MA: WCB/ McGraw-Hill, 1998. Chapters 1.3 and 8.