

# DATA MANIPULATION

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OVERVIEW** BY J. GLENN BROOKSHEAR AND DENNIS BRYLOW

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# Data Manipulation

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- Computer Architecture
- Machine Language
- Program Execution
- Arithmetic/Logic Instructions
- Communicating with Other Devices
- Other Architectures

# Computer Architecture

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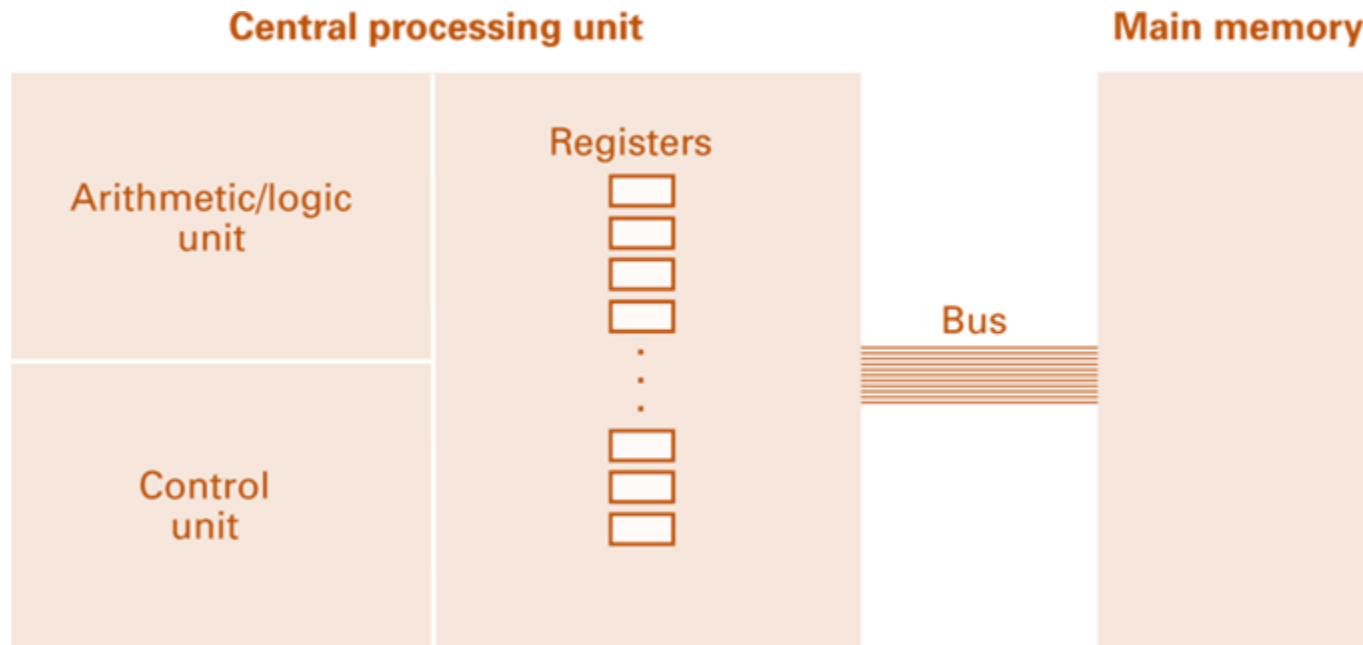
# Computer Architecture

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- Central Processing Unit (CPU) or processor
  - Arithmetic/Logic unit versus Control unit
  - Registers
    - General purpose
    - Special purpose
- Bus
- Motherboard

# CPU and main memory connected via a bus

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# Motherboards

- The motherboard
  - is the main printed circuit board.
  - contains the buses, or electrical pathways found in a computer. Buses allow data to travel among the various components.
  - accommodates CPU, RAM, expansion slots, heat sink/fan assembly, BIOS chip, chip set, sockets, internal and external connectors, various ports, and the embedded wires that interconnect the motherboard components.



# Central Processing Unit

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- The Central Processing Unit (CPU) is known as the brain of the computer. It is also referred to as the processor.
- The CPU executes a program, which is a sequence of stored instructions.



# Central Processing Unit

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- Some CPUs incorporate **hyperthreading** or **hypertransport** to enhance the performance of the CPU.
- The amount of data that a CPU can process at one time depends on the size of the processor data bus.
- Speed of the CPU is measured in **cycles per second** - megahertz (MHz) or gigahertz (GHz).
- **Overclocking** is a technique used to make a processor work at a faster speed than its original specification.



# Central Processing Unit

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- The latest processor technology has resulted in CPU manufacturers finding ways to incorporate more than one CPU core onto a single chip.
  - Dual Core CPU - Two cores inside a single CPU
  - Triple Core CPU - Three cores inside a single CPU
  - Quad Core CPU - Four cores inside a single CPU
  - Hexa-Core CPU - Six cores inside a single CPU
  - Octa-Core CPU - Eight cores inside a single CPU

# The Arithmetic/Logic Unit

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- Subsystem that performs addition, subtraction, and comparison for equality
- Components
  - Registers, interconnections between components, and the ALU circuitry
- Register
  - Storage cell that holds the operands of an arithmetic operation and holds its result
- Bus
  - Path for electrical signals

# The Arithmetic/Logic Unit

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- Registers are similar to RAM with following minor differences
  - They do not have a numeric memory address but are accessed by a special register designator such as A, X or R0
  - They can be accessed much more quickly than regular memory cells
  - They are not used for general purpose storage but for specific purposes such as holding the operands for an upcoming arithmetic computations.
- A typical ALU has 16, 32 or 64 registers.

# The Control Unit

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- Control unit
  - Tasks: fetch, decode, and execute

# Machine Language

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# Stored Program Concept

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- A program can be encoded as bit patterns and stored in main memory.
- From there, the CPU can then extract the instructions and execute them.
- In turn, the program to be executed can be altered easily.

# Terminology

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- Machine instruction: An instruction (or command) encoded as a bit pattern recognizable by the CPU
- Machine language: The set of all instructions recognized by a machine

# Machine Language Philosophies

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- Reduced Instruction Set Computing (RISC)
  - Few, simple, efficient, and fast instructions
  - Examples: PowerPC from Apple/IBM/Motorola and ARM
- Complex Instruction Set Computing (CISC)
  - Many, convenient, and powerful instructions
  - Example: Intel



# Machine Instruction Types

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- **Data Transfer:** copy data from one location to another
- **Arithmetic/Logic:** use existing bit patterns to compute a new bit patterns
- **Control:** direct the execution of the program

# Adding values stored in memory

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

# Dividing values stored in memory

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**Step 1.** LOAD a register with a value from memory.

**Step 2.** LOAD another register with another value from memory.

**Step 3.** If this second value is zero, JUMP to Step 6.

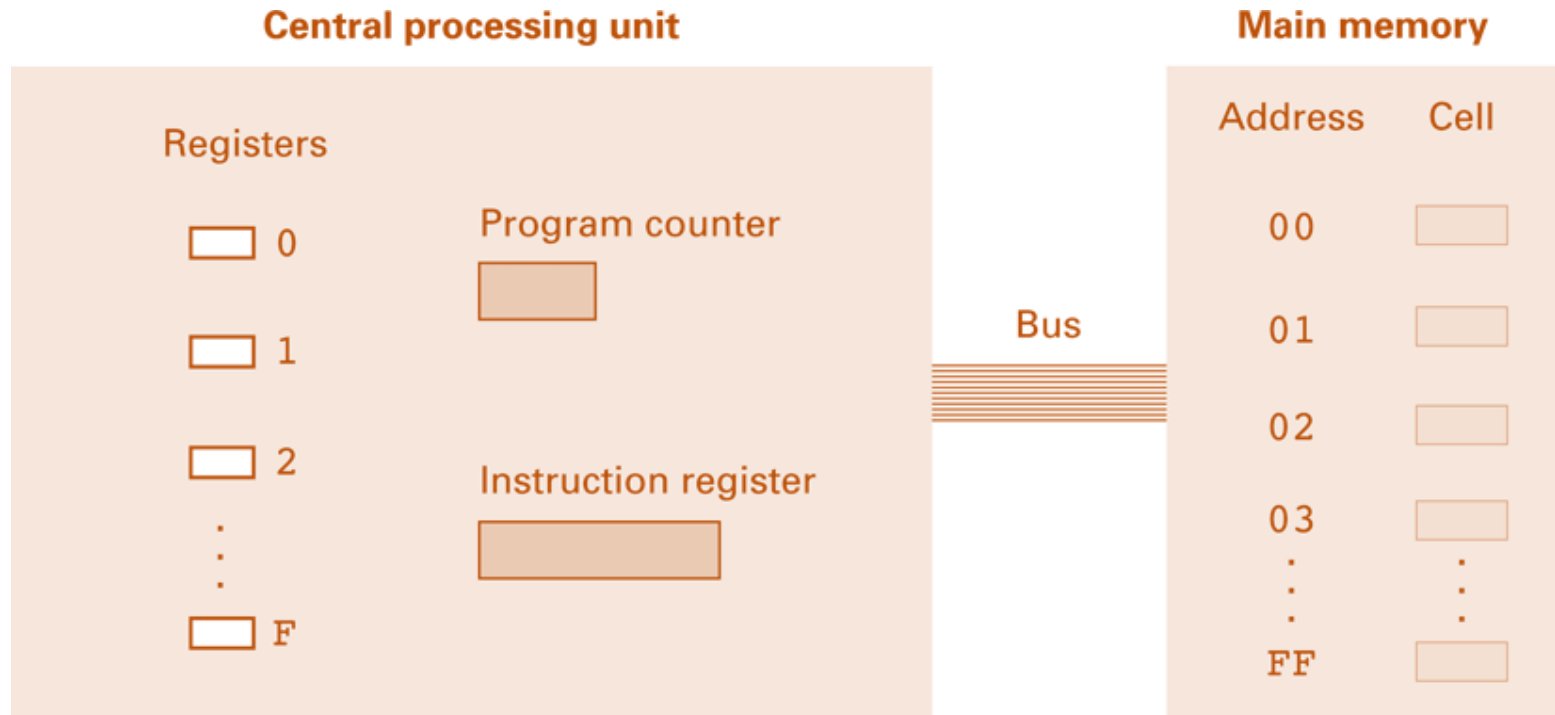
**Step 4.** Divide the contents of the first register by the second register and leave the result in a third register.

**Step 5.** STORE the contents of the third register in memory.

**Step 6.** STOP.

# An architecture of the machine

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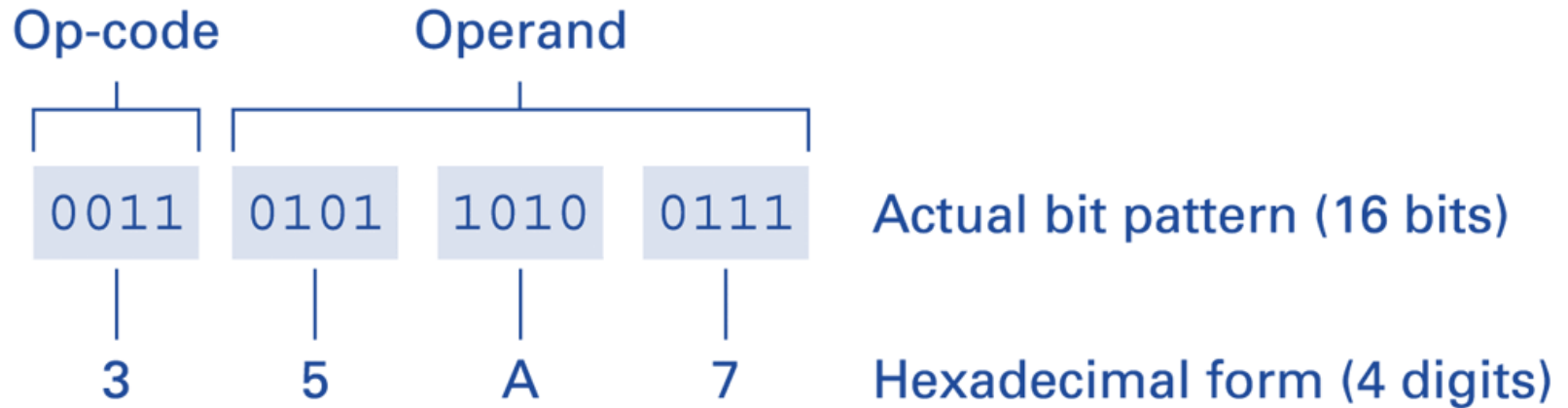
# Parts of a Machine Instruction

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- **Op-code:** Specifies which operation to execute
- **Operand:** Gives more detailed information about the operation
  - Interpretation of operand varies depending on op-code

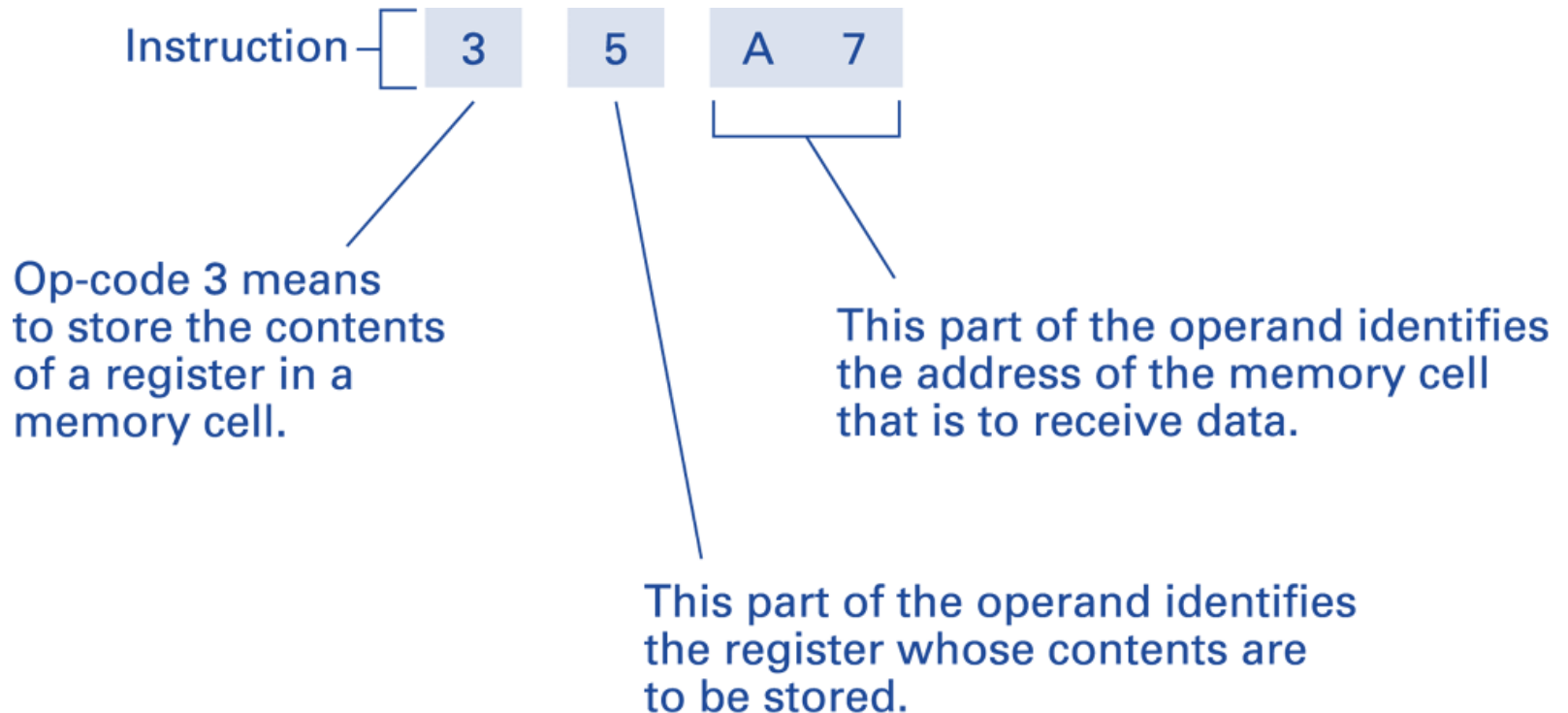
# The composition of an instruction

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# Decoding the instruction 35A7

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# A Simple Machine Language

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Op-code	Operand	Description
1	RXY	LOAD reg. R from cell XY.
2	RXY	LOAD reg. R with XY.
3	RXY	STORE reg. R at XY.
4	ORS	MOVE R to S.
5	RST	ADD S and T into R. (2's comp.)
6	RST	ADD S and T into R. (floating pt.)



# A Simple Machine Language

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Op-code	Operand	Description
7	RST	OR S and T into R.
8	RST	AND S and T into R.
9	RST	XOR S and T into R.
A	ROX	ROTATE reg. R X times.
B	RXY	JUMP to XY if R = reg. 0.
C	0	HALT.

# A Simple Machine Language

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- **14A3**: Load
  - The contents of the **memory cell** located at address **A3** to be placed in register 4.
- **20A3**: Load
  - The value **A3** to be placed in register 0.
- **35B1**: Store
  - The contents of register 5 to be placed in the memory cell whose address is **B1**.
- **40A4**: Move
  - The contents of register **A** to be copied into register **4**.

# A Simple Machine Language

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- 5726: Add
  - The binary values in registers 2 and 6 to be added and the sum placed in register 7.
- 634E: Add
  - The values in registers 4 and E to be added as floating-point values and the result to be placed in register 3.

# A Simple Machine Language

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- **7CB4: Or**
  - The result of ORing the contents of registers **B** and 4 to be placed in register **C**.
- **8045: And**
  - The result of ANDing the contents of registers 4 and 5 to be placed in register 0.
- **95F3: Xor**
  - The result of XORing the contents of registers **F** and 3 to be placed in register 5.
- **A403: Rotate**
  - The contents of registers 4 to be rotated 3 bits to the right in a circular fashion.

# A Simple Machine Language

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## ■ B43C:

- Compare the contents of register 4 with the contents of register 0.
- If equal, the pattern 3C would be placed in the program counter so that the next execution executed would be the one located at that memory address.
- Otherwise, nothing would be done.

## ■ C000:

- Stop program execution.

# An encoded version of the instructions

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Encoded instructions	Translation
<b>156C</b>	Load register 5 with the bit pattern found in the memory cell at address 6C.
<b>166D</b>	Load register 6 with the bit pattern found in the memory cell at address 6D.
<b>5056</b>	Add the contents of register 5 and 6 as though they were two's complement representation and leave the result in register 0.
<b>306E</b>	Store the contents of register 0 in the memory cell at address 6E.
<b>C000</b>	Halt.

# Quiz

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The following are instructions written in the above simple machine language. Rewrite in English.

- 368A
- BADE
- 803C
- 40F4

# Quiz

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What is the difference between the instructions **15AB** and **25AB** in the simple machine language?



# Quiz

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Here are some instructions in English. Translate each of them into the simple machine language.

- LOAD register number 3 with the hexadecimal 56.
- ROTATE register number 5 three bits to the right.
- AND the contents of register A with the contents of register 5 and leave the result in register 0.

# Quiz

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Here are some instructions in English. Translate each of them into the simple machine language.

- LOAD register number 3 with the hexadecimal 56.

2356

- ROTATE register number 5 three bits to the right.

A503

- AND the contents of register A with the contents of register 5 and leave the result in register 0.

80A5

# Program Execution

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# Program Execution

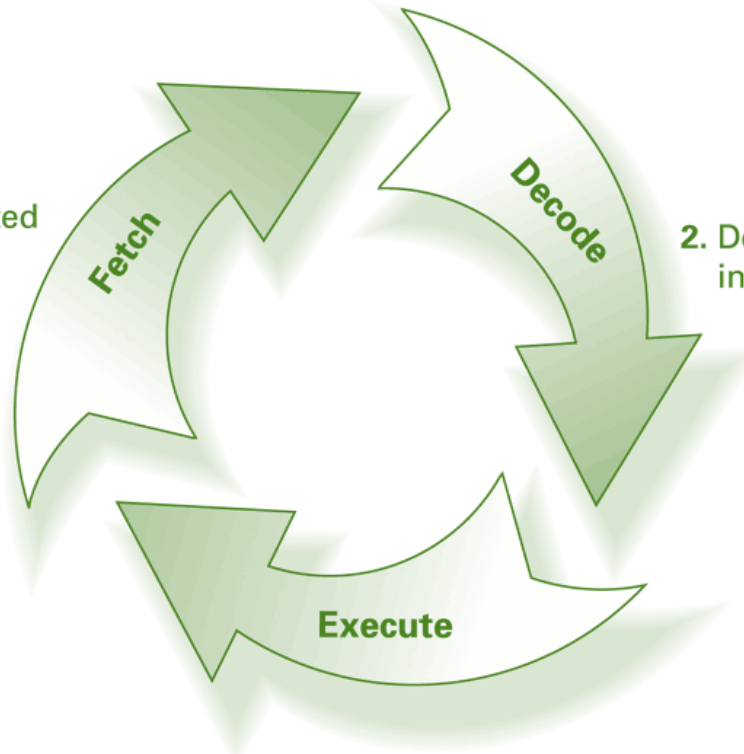
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- Controlled by two special-purpose registers
  - Program counter: address of next instruction
  - Instruction register: current instruction
- Machine Cycle
  - Fetch
  - Decode
  - Execute

# The machine cycle

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1. Retrieve the next instruction from memory (as indicated by the program counter) and then increment the program counter.



2. Decode the bit pattern in the instruction register.

3. Perform the action required by the instruction in the instruction register.

# Decoding the instruction B258

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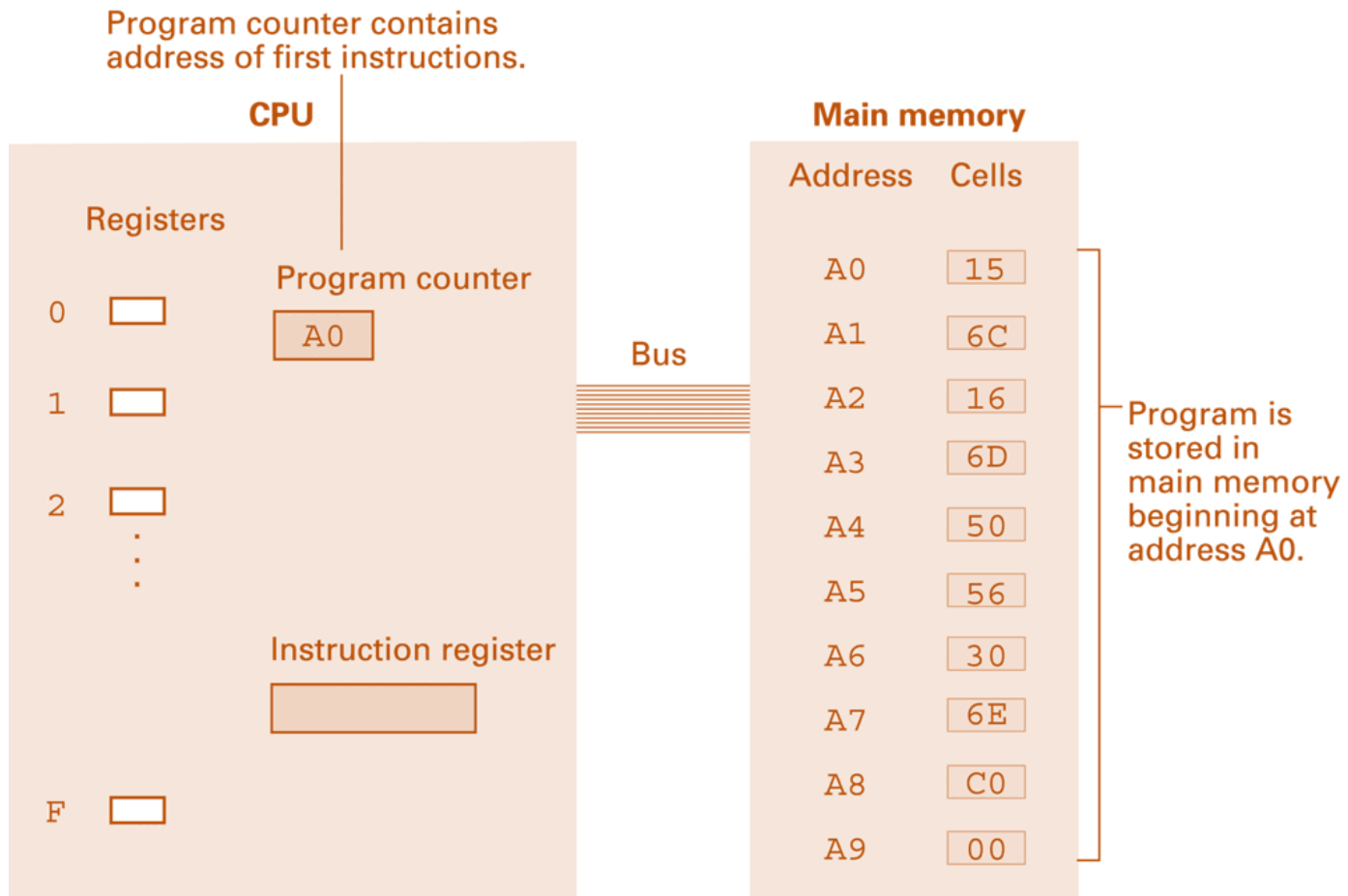


Op-code B means to change the value of the program counter if the contents of the indicated register is the same as that in register 0.

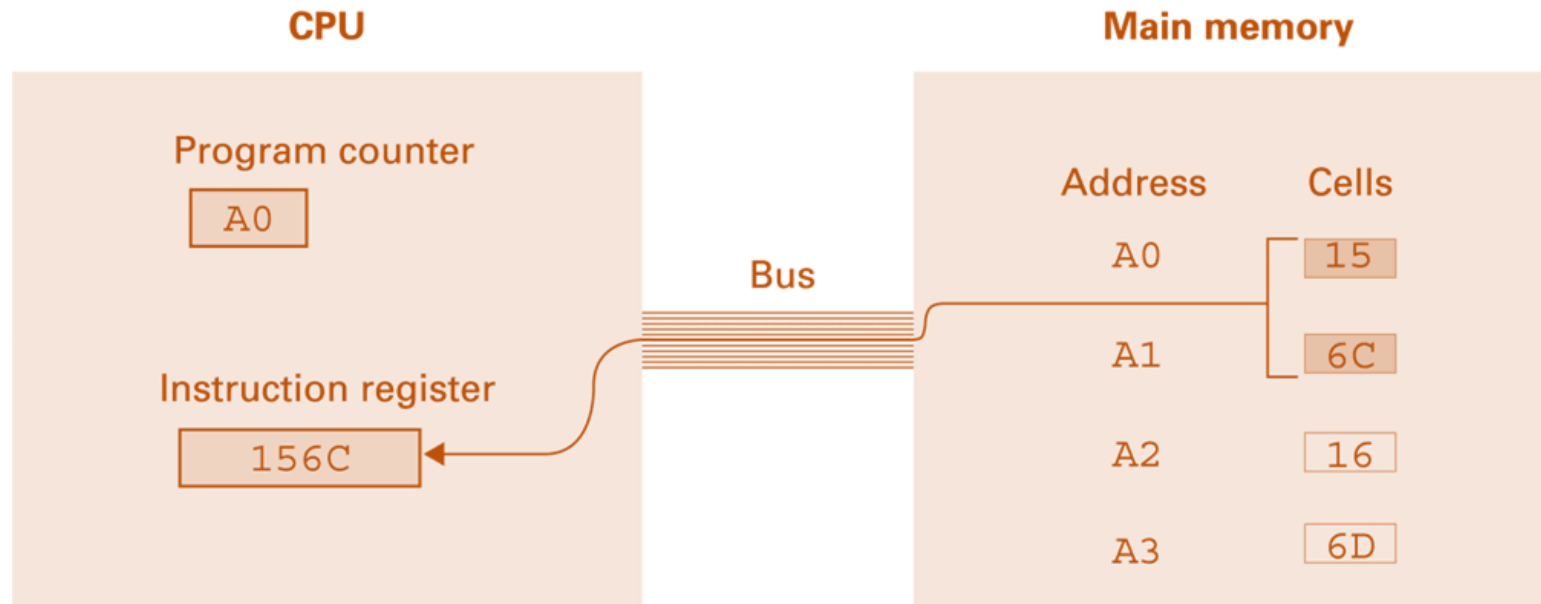
This part of the operand is the address to be placed in the program counter.

This part of the operand identifies the register to be compared to register 0.

# A program stored in main memory



# The fetch step of the machine cycle

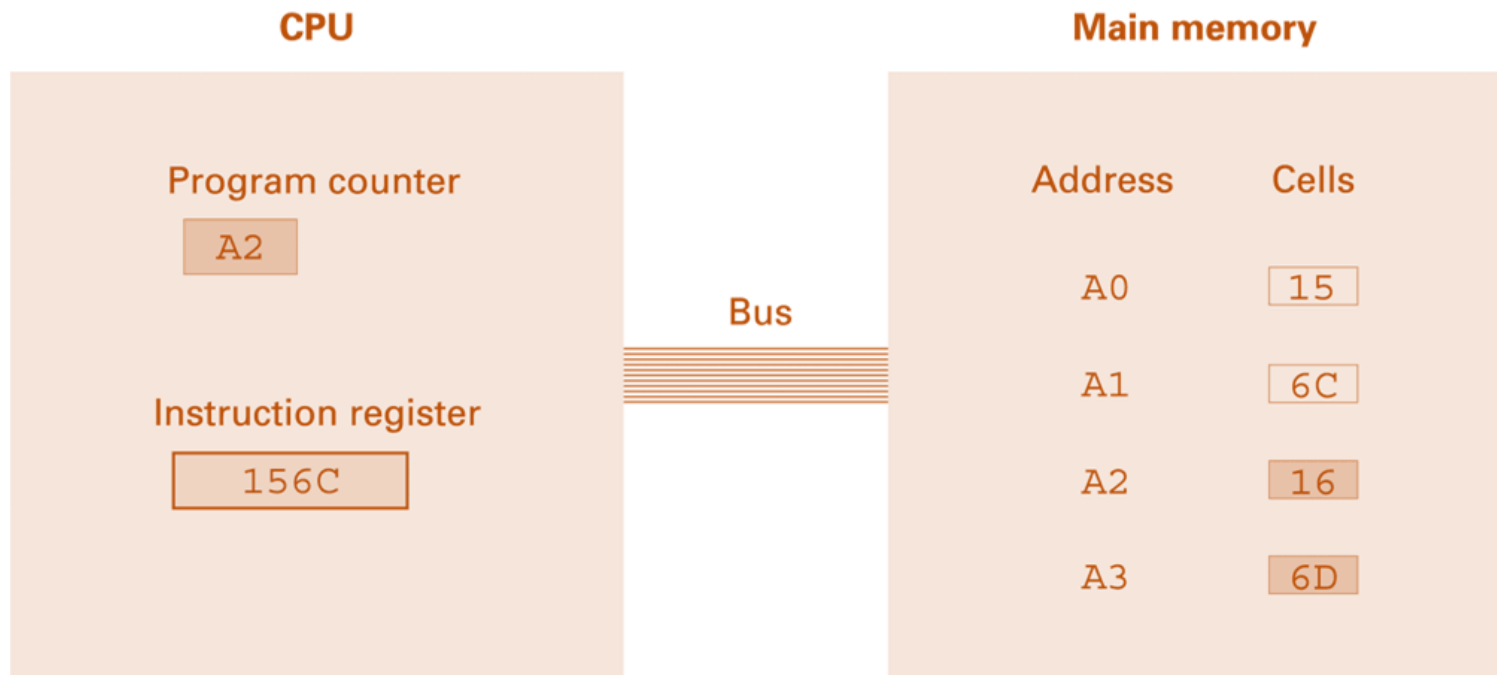


- a. At the beginning of the fetch step the instruction starting at address A0 is retrieved from memory and placed in the instruction register.



# The fetch step of the machine cycle

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**b.** Then the program counter is incremented so that it points to the next instruction.

# Arithmetic/Logic Instructions

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# Arithmetic/Logic Operations

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- Logic: AND, OR, XOR
  - Masking
- Rotate and Shift:
  - circular shift (rotation)
  - logical shift
  - arithmetic shift
- Arithmetic: add, subtract, multiply, divide
  - Precise action depends on how the values are encoded (two's complement versus floating-point).

# Masking

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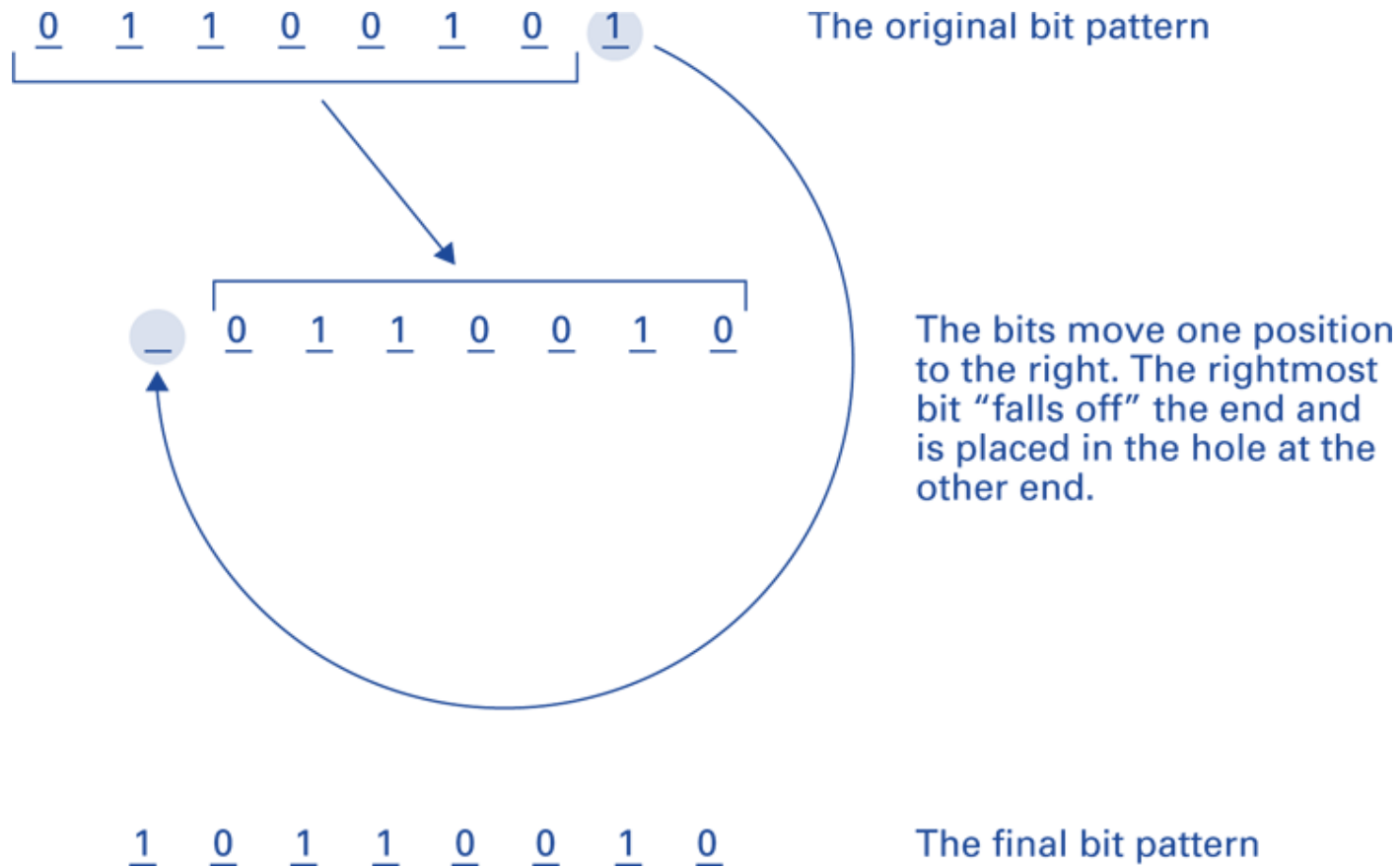
00001111  
AND 10101010  
00001010

11110000  
OR 10101010  
11111010

11111111  
XOR 10101010  
01010101

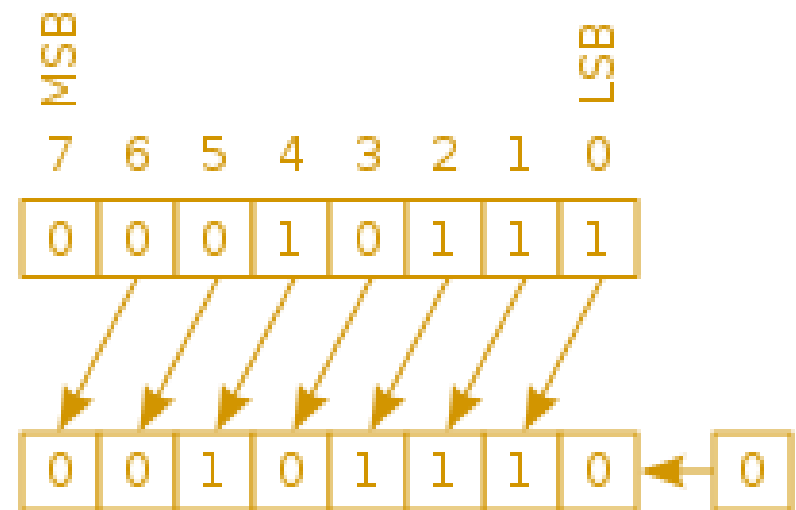
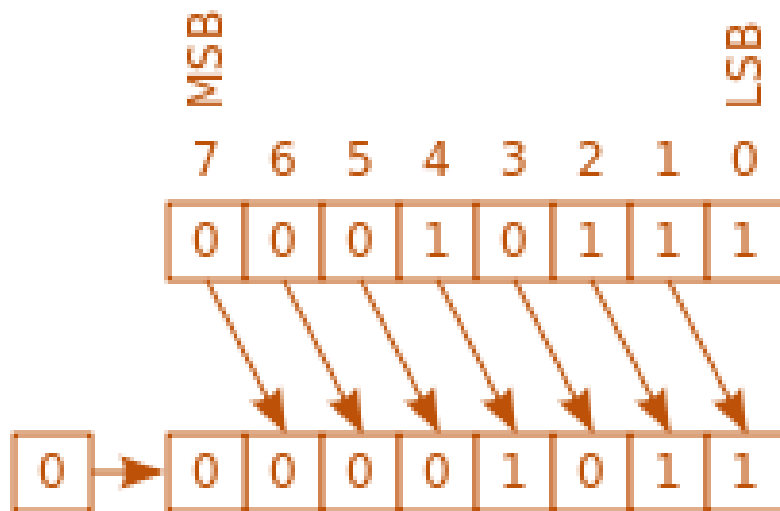
# Circular shift

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# Logical shift

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# Quiz

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What logical operation together with what mask can you use to change ASCII codes of lower characters to uppercase? What about uppercase to lowercase?

Symbol	ASCII	Hex	Symbol	ASCII	Hex
>	00111110	3E	^	01011110	5E
?	00111111	3F	_	01011111	5F
@	01000000	40	`	01100000	60
A	01000001	41	a	01100001	61
B	01000010	42	b	01100010	62
C	01000011	43	c	01100011	63
D	01000100	44	d	01100100	64
E	01000101	45	e	01100101	65
F	01000110	46	f	01100110	66
G	01000111	47	g	01100111	67
H	01001000	48	h	01101000	68
I	01001001	49	i	01101001	69
J	01001010	4A	j	01101010	6A
K	01001011	4B	k	01101011	6B
L	01001100	4C	l	01101100	6C

# Quiz

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Identify both the mask and the logical operation needed to accomplish each of the following objectives:

- Put 1s in the upper 4 bits of an 8-bit pattern without disturbing the other bits.
- Complement the most significant bit of an 8-bit pattern without changing the other bits.
- Complement a pattern of 8 bits.
- Put a 0 in the least significant bit of an 8-bit pattern without disturbing the other bits.



# Quiz

---

Identify both the mask and the logical operation needed to accomplish each of the following objectives:

- Put 1s in the upper 4 bits of an 8-bit pattern without disturbing the other bits.

**OR 1111 0000**

- Complement the most significant bit of an 8-bit pattern without changing the other bits.

**XOR 1000 0000**

- Complement a pattern of 8 bits.

**XOR 1111 1111**

- Put a 0 in the least significant bit of an 8-bit pattern without disturbing the other bits.

**AND 1111 1110**

# Quiz

---

Identify both the mask and the logical operation needed to accomplish each of the following objectives:

- Put 1s in all but the most significant bit of an 8-bit pattern without disturbing the most significant bit.
- Filter out all of the green color component from an RGB bitmap image pixel in which the middle 8 bits of a 24-bit pattern store the green information.
- Invert all of the bits in a 24-bit RGB bitmap
- Set all the bits in a 24-bit RGB bitmap pixel to 1, indicating the color “white”.

# Quiz

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Identify a logical operation (along with a corresponding mask) that, when applied to an input string of 8 bits, produces an output string of all 0s if and only if the input string is **1000 0001**.

# Communicating with Other Devices

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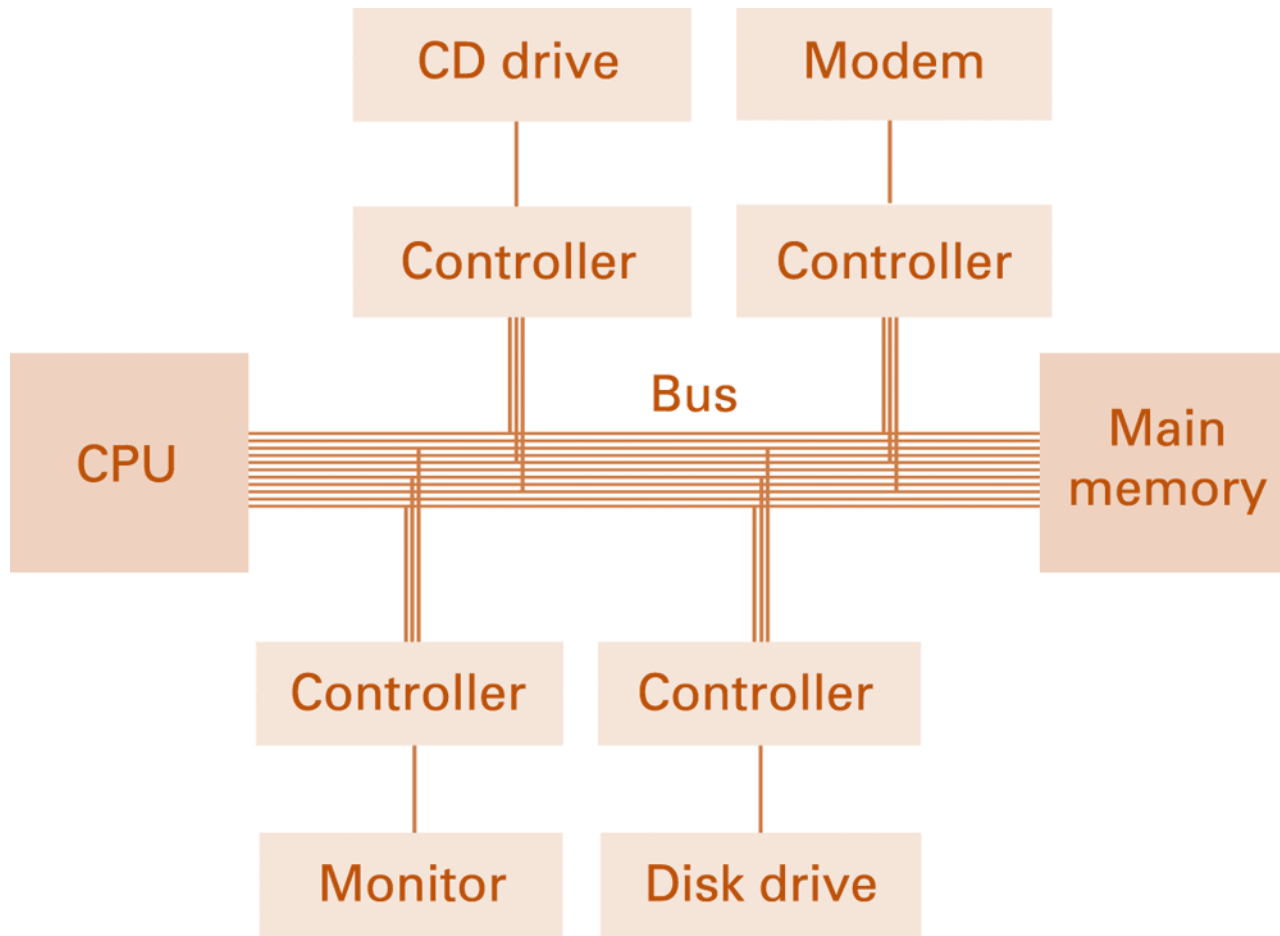
# Communicating with Other Devices

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- **Controller:** An intermediary apparatus that handles communication between the computer and a device
  - Specialized controllers for each type of device
  - General purpose controllers (USB and FireWire)
- **Port:** The point at which a device connects to a computer
- **Memory-mapped I/O:** CPU communicates with peripheral devices as though they were memory cells

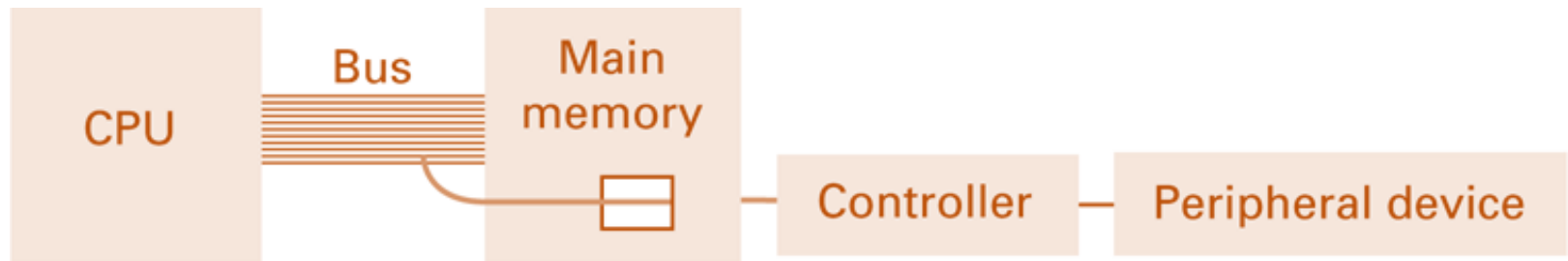
# Controllers attached to a machine's bus

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# A conceptual representation of memory-mapped I/O

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# Communicating with Other Devices

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- Direct memory access (DMA): Main memory access by a controller over the bus
- Von Neumann Bottleneck: Insufficient bus speed impedes performance
- Handshaking: The process of coordinating the transfer of data between components



# Communicating with Other Devices

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- **Parallel Communication:** Several communication paths transfer bits simultaneously.
- **Serial Communication:** Bits are transferred one after the other over a single communication path.

# Data Communication Rates

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- Measurement units
  - Bps: Bits per second
  - Kbps: Kilo-bps (1,000 bps)
  - Mbps: Mega-bps (1,000,000 bps)
  - Gbps: Giga-bps (1,000,000,000 bps)
- Bandwidth: Maximum available rate

# Quiz

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Assume that the machine (using the simple machine language as described) uses memory-mapped I/O and that the address B5 is the location within the printer port to which data to be printed should be sent.

- a. If register 7 contains the ASCII code for the letter A, what machine language instruction should be used to cause that letter to be printed at the printer?
- b. If the machine executes a million instructions per second, how many times can this character be sent to the printer in one second?

# Quiz

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Assume that the machine (using the simple machine language as described) uses memory-mapped I/O and that the address B5 is the location within the printer port to which data to be printed should be sent.

- c. If the printer is capable of printing five traditional pages of text per minute, will it be able to keep up with the characters being sent to it in (b)?

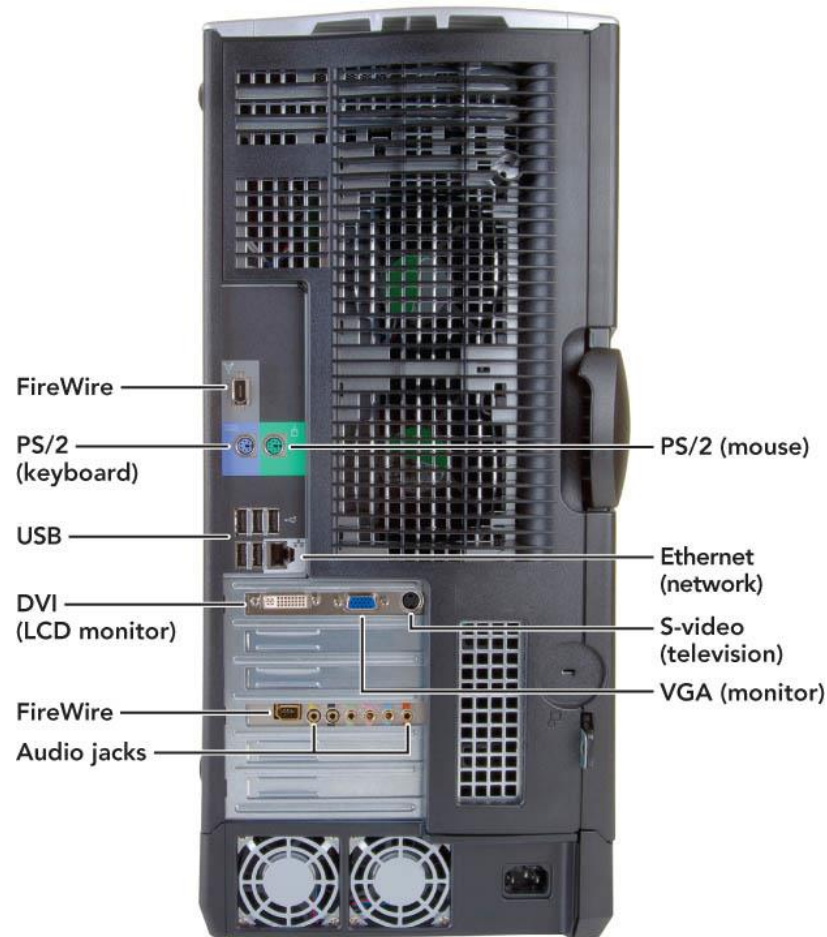
# Quiz

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Estimate how long it would take to transfer a 250-page novel (about 500,000 characters) encoded in 16-bit Unicode characters at a transfer rate of 54Mbps.

# What's on the Outside of the Box?

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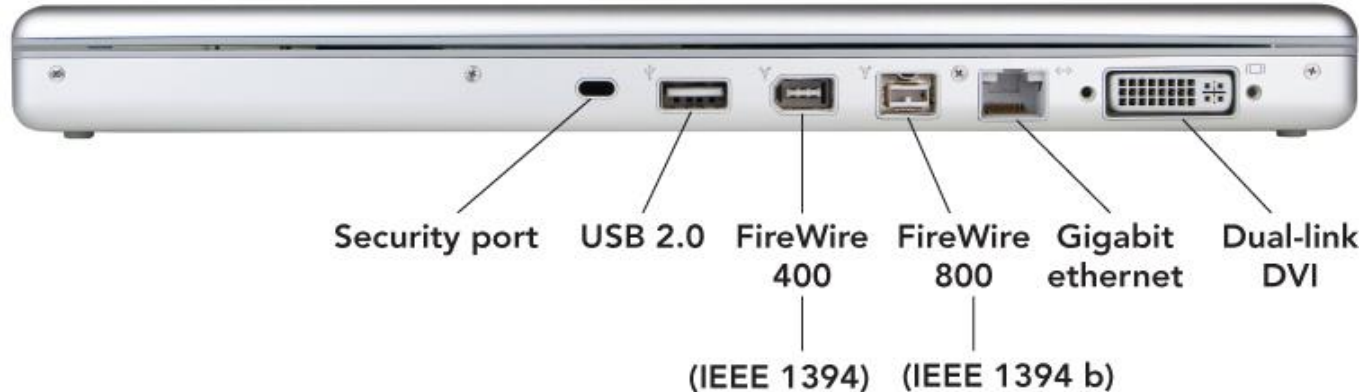


# What's on the Outside of the Box?

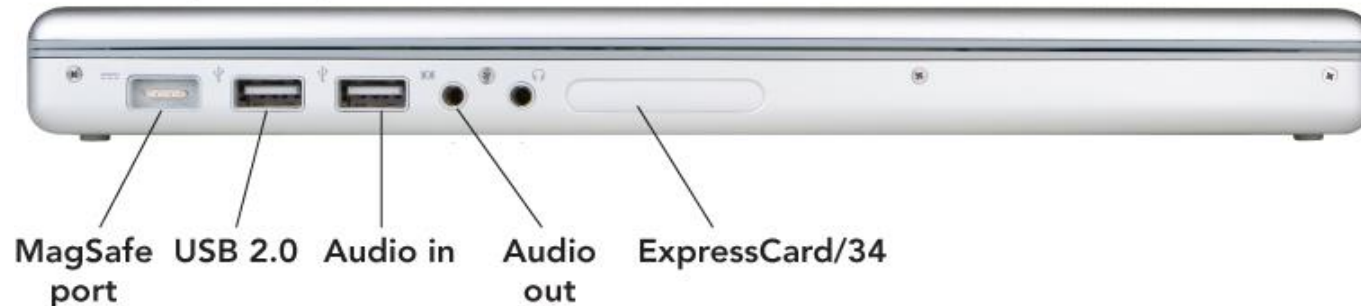
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- Connectors on a notebook may vary

**Right side (15-inch and 17-inch)**



**Left side (15-inch)**



# Universal serial bus

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- USB (universal serial bus) ports
  - Connects up to 127 peripheral devices
  - USB 2.0 (high-speed USB)—fully compatible with USB 1.1 products, cables, and connectors
  - Designed to replace older parallel and serial ports
  - Connects a variety of devices to the computer, including:
    - Keyboards
    - Mice
    - Printers
    - Digital cameras





# Universal serial bus

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- USB 2.0
  - Uses an external bus
  - Supports data transfer rates of 480 Mbps between the computer and the peripheral device
  - Supports hot swapping—ability to connect and disconnect devices without shutting down the computer
  - Plug-and-play (PnP)—allows computers to automatically detect the device when you plug it in
- USB 3.0 (2008): 5Gbps
- USB 3.1 (2013): 10Gbps
- USB hub
  - Device that plugs into existing USB port
  - Contains four or more additional ports

# FireWire

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- FireWire (1395 ports)
  - Created by Apple in 1995
  - IEEE 1394 Higher Performance Serial Bus, also known as Sony i.Link
  - Offers high-speed connections for dozens of peripheral devices (up to 63)
  - Enables hot swapping and PnP
  - Data transfer rates of FireWire
    - FireWire 400—400 Mbps
    - FireWire 800—800 Mbps
    - Declared “dead” by Steve Jobs.

# Video connectors

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- **VGA (video graphics array)**
  - 15-pin male connector—works with standard monitor cables
  - Transmits analog video signals
  - Used for legacy technology cathode ray (CRT) monitors
- **DVI (Digital visual Interface) port**—lets LCD monitors use digital signals
- **Onboard video**—video circuitry built into the motherboard where the video connector is on the back of the system unit case

# HDMI

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- High-Definition Multimedia Interface
  - A video/audio interface for transmitting uncompressed video data, and compressed/uncompressed audio data.
  - Digital replacement for analog video standards.
  - Designed: 2002 (7 companies).
  - HDMI 2.1: 48Gbps.
  - Newer version: 3D, Ethernet data connection, Consumer Electronics Control (CEC) extensions.

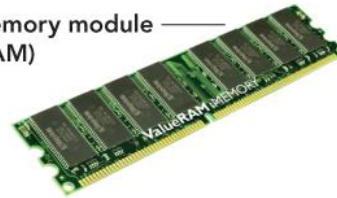


# Additional connectors

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- Telephone
- Network
- PC card slot
  - PC card
  - ExpressCard
- Sound card
- Game card
- TV/sound capture board

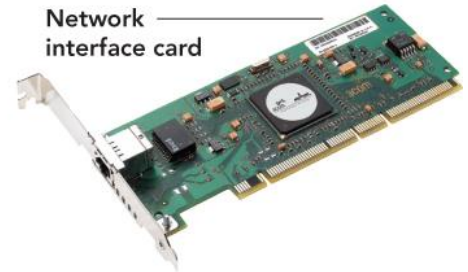
Memory module  
(RAM)



Modem card



Network  
interface card



Sound card



Video card



# Other Architectures

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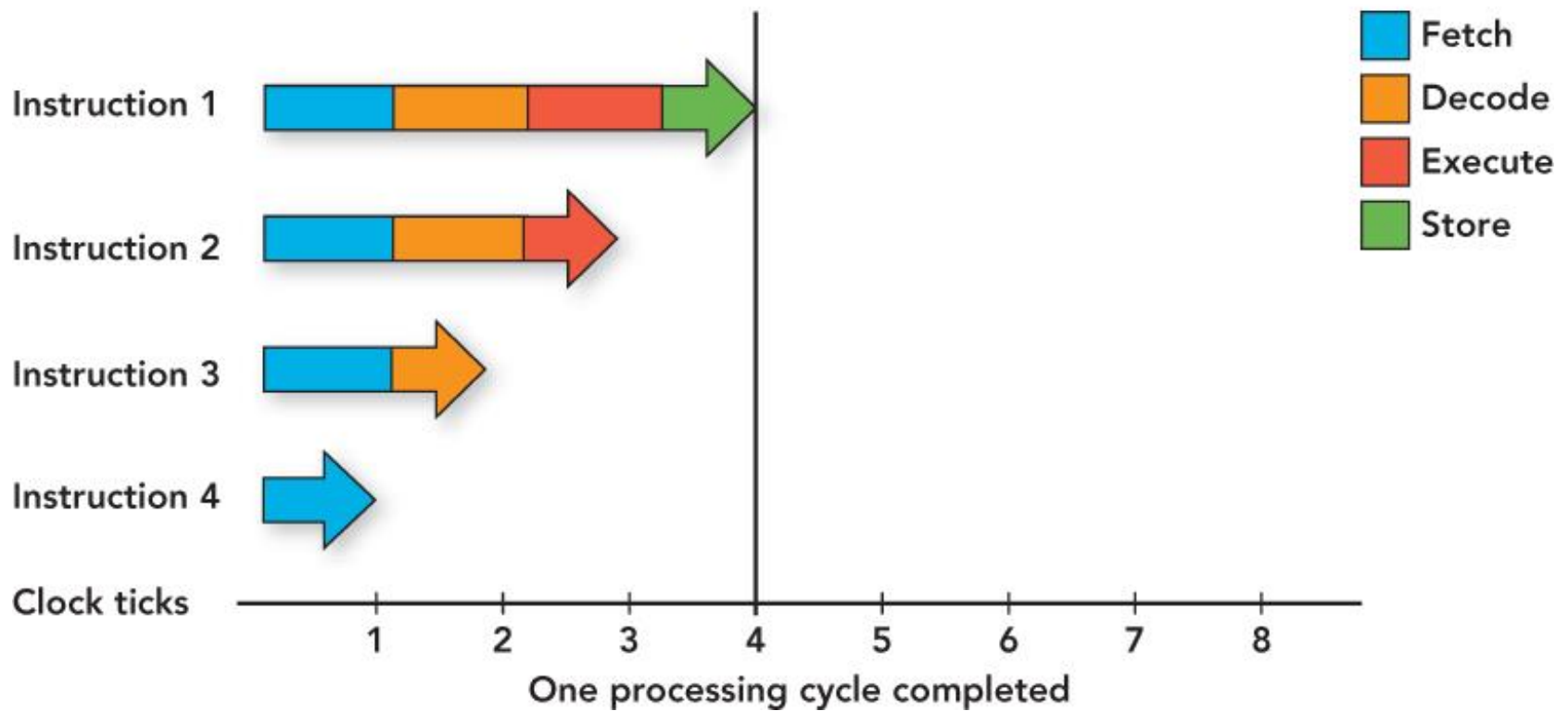
# Other Architectures

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- Technologies to increase throughput:
  - Pipelining: Overlap steps of the machine cycle
  - Parallel Processing: Use multiple processors simultaneously
    - SISD: No parallel processing
    - MIMD: Different programs, different data
    - SIMD: Same program, different data

# Pipelining

Processing cycle with pipelining





# Parallel processing

- Method where more than one processor performs at the same time—faster processing

