

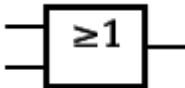
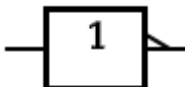
Logic gate

In [electronics](#), a **logic gate** is an idealized or physical device implementing a [Boolean function](#); that is, it performs a [logical operation](#) on one or more logical inputs, and produces a single logical output. Depending on the context, the term may refer to an **ideal logic gate**, one that has for instance zero [rise time](#) and unlimited [fan-out](#), or it may refer to a non-ideal physical device^[1] (see [Ideal and real op-amps](#) for comparison).

https://en.wikipedia.org/wiki/Logic_gate

Most of the materials in this course are from Wikipedia, the free encyclopedia

Logic gate

Type	Distinctive shape (IEEE Std 91/91a-1991)	Rectangular shape (IEEE Std 91/91a-1991 IEC 60617-12 : 1997)	Boolean algebra between A & B	Truth table																		
<u>AND</u>			$A \cdot B$ or $A \& B$	<table><tr><th colspan="2">INPUT</th><th>OUTPUT</th></tr><tr><th>A</th><th>B</th><th>A AND B</th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td></tr></table>	INPUT		OUTPUT	A	B	A AND B	0	0	0	0	1	0	1	0	0	1	1	1
INPUT		OUTPUT																				
A	B	A AND B																				
0	0	0																				
0	1	0																				
1	0	0																				
1	1	1																				
<u>OR</u>			$A + B$	<table><tr><th colspan="2">INPUT</th><th>OUTPUT</th></tr><tr><th>A</th><th>B</th><th>A OR B</th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>1</td></tr></table>	INPUT		OUTPUT	A	B	A OR B	0	0	0	0	1	1	1	0	1	1	1	1
INPUT		OUTPUT																				
A	B	A OR B																				
0	0	0																				
0	1	1																				
1	0	1																				
1	1	1																				
<u>NOT</u>			$\overline{A}$ or $\sim A$	<table><tr><th>INPUT</th><th>OUTPUT</th></tr><tr><th>A</th><th>NOT A</th></tr><tr><td>0</td><td>1</td></tr><tr><td>1</td><td>0</td></tr></table>	INPUT	OUTPUT	A	NOT A	0	1	1	0										
INPUT	OUTPUT																					
A	NOT A																					
0	1																					
1	0																					

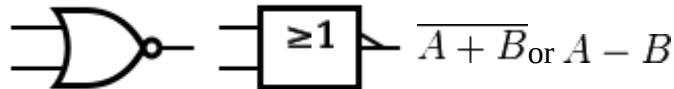
Logic gate

NAND



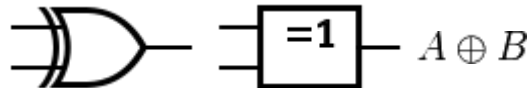
INPUT		OUTPUT
A	B	A NAND B
0	0	1
0	1	1
1	0	1
1	1	0

NOR



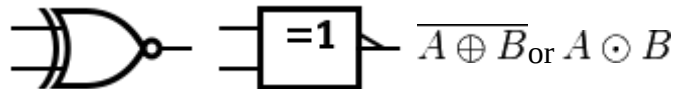
INPUT		OUTPUT
A	B	A NOR B
0	0	1
0	1	0
1	0	0
1	1	0

XOR



INPUT		OUTPUT
A	B	A XOR B
0	0	0
0	1	1
1	0	1
1	1	0

XNOR



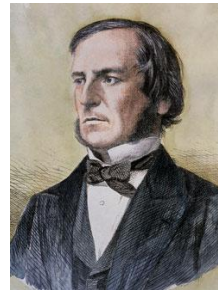
INPUT		OUTPUT
A	B	A XNOR B
0	0	1
0	1	0
1	0	0
1	1	1

Boolean algebra

Boolean algebra was introduced by [George Boole](#) in his first book *The Mathematical Analysis of Logic* (1847), and set forth more fully in his [An Investigation of the Laws of Thought](#) (1854).^[1] According to [Huntington](#) the term "Boolean algebra" was first suggested by [Sheffer](#) in 1913.^[2]

Boolean algebra has been fundamental in the development of [digital electronics](#), and is provided for in all modern programming languages. It is also used in [set theory](#) and [statistics](#).^[3]

https://en.wikipedia.org/wiki/Boolean_algebra



https://en.wikipedia.org/wiki/George_Boole

Basic operation

https://en.wikipedia.org/wiki/Boolean_algebra

Computer



A **computer** is a general-purpose device that can be programmed to carry out a set of arithmetic or logical operations automatically. Since a sequence of operations can be readily changed, the computer can solve more than one kind of problem.

Analog computer

An **analog computer** is a form of [computer](#) that uses the continuously changeable aspects of physical phenomena such as [electrical](#), [mechanical](#), or [hydraulic](#) quantities to [model](#) the problem being solved. As an analog computer does not use discrete values, but rather continuous values, processes cannot be reliably repeated with exact equivalence. Analog computers were widely used in scientific and industrial applications where digital computers of the time lacked sufficient performance. Analog computers can have a very wide range of complexity. [Slide rules](#) and [nomographs](#) are the simplest examples. https://en.wikipedia.org/wiki/Analog_computer

Analog computer



A typical ten-inch student slide rule (Pickett N902-T simplex trig). It is a mechanical [analog computer](https://en.wikipedia.org/wiki/Slide_rule).

https://en.wikipedia.org/wiki/Slide_rule

Mechanical computer

[Mechanical analog computers](#) started appearing in the first century and were later used in the medieval era for astronomical calculations. In [World War II](#), mechanical analog computers were used for specialized military applications such as calculating torpedo aiming. During this time the first electronic [digital](#) computers were developed. Originally they were the size of a large room, consuming as much power as several hundred modern [personal computers](#) (PCs).^[1]



Mechanical computer

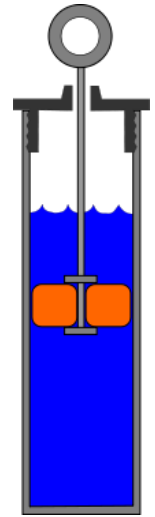
Mechanical computers continued to be used into the 1960s, but were quickly replaced by electronic calculators, which—with [cathode-ray tube](#) output—emerged in the mid-1960s. Mechanical computers were ailing in 1970s and dead by 1980s.

The most common examples are [adding machines](#) and [mechanical counters](#), which use the turning of gears to increment output displays.



Electronic analog computer

The similarity between linear mechanical components, such as [springs](#) and [dashpots](#) (viscous-fluid dampers), and electrical components, such as [capacitors](#), [inductors](#), and [resistors](#) is striking in terms of mathematics. They can be modeled using equations of the same form.



Example: Testing a simple mass–spring system, constructing the physical system would require making or modifying the springs and masses. That means it will take long time and expensive.

Electronic analog computer

The electrical equivalent can be constructed with a few [operational amplifiers](#) (op amps) and some passive linear components; all measurements can be taken directly with an [oscilloscope](#). In the circuit, the (simulated) 'stiffness of the spring', for instance, can be changed by adjusting the parameters of a [capacitor](#). The electrical system is an analogy to the physical system, hence the name, but it is less expensive to construct, generally safer, and typically much easier to modify.



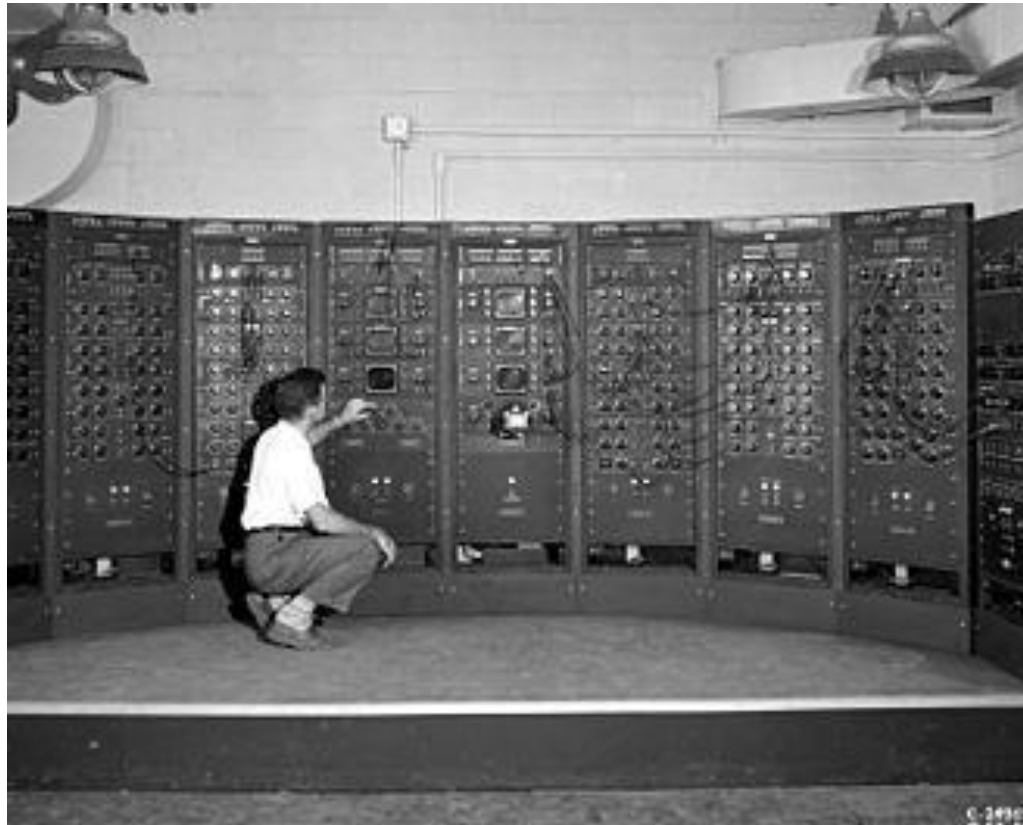
Electronic analog computer

Electronic analog computers typically have front panels with numerous jacks (single-contact sockets) that permit patch cords (flexible wires with plugs at both ends) to create the interconnections which define the problem setup. In addition, there are precision high-resolution potentiometers (variable resistors) for setting up.

Stable, accurate voltage sources provide known magnitudes.

Typical electronic analog computers contain anywhere from a few to a hundred or more operational amplifiers ("op amps"), named because they perform mathematical operations.

Electronic analog computer



Analog computing machine at the Lewis Flight Propulsion Laboratory in 1949.

Electronic analog computer

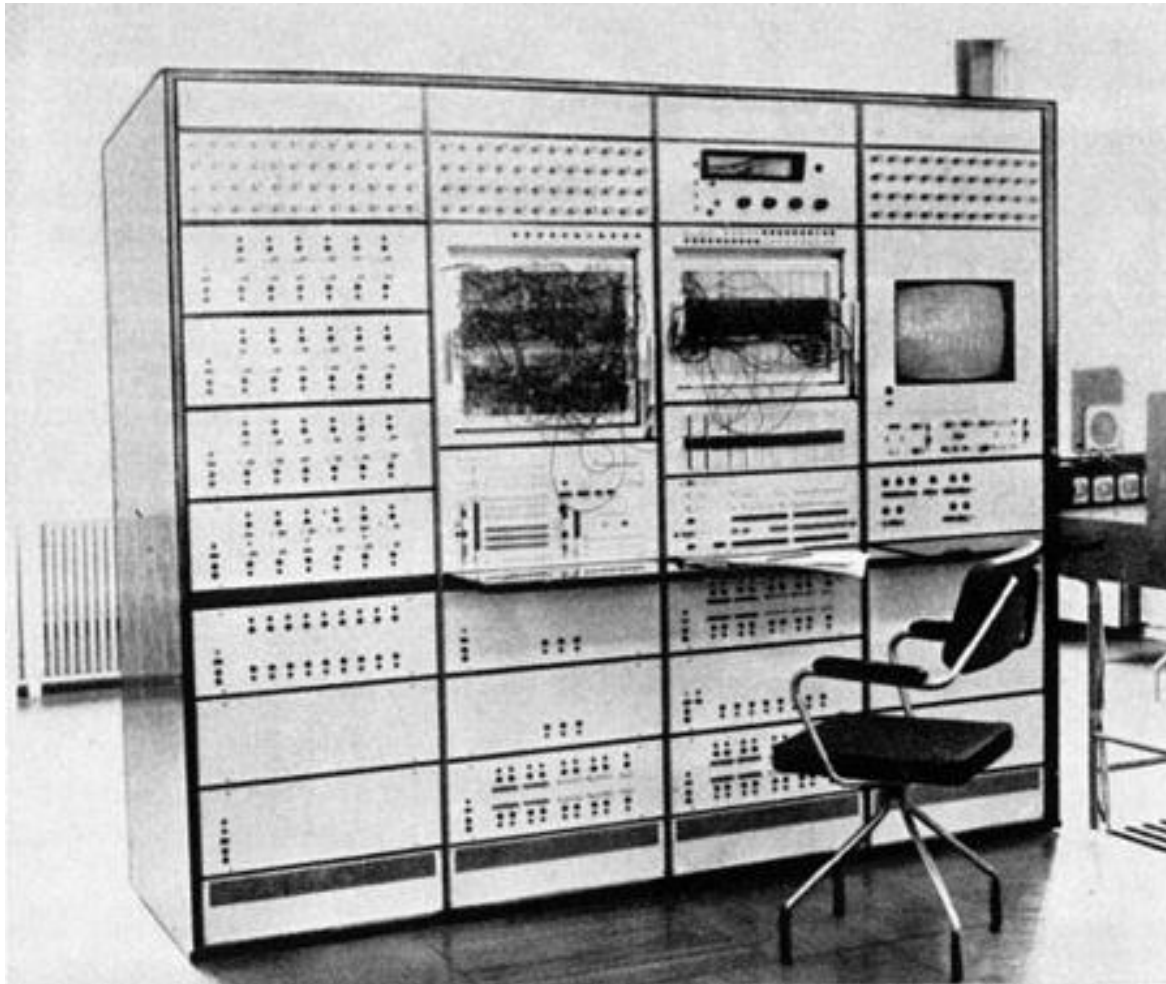
One key to the speed of analog computers was their fully parallel computation, but this was also a limitation.

The more equations required for a problem, the more analog components were needed, even when the problem wasn't time critical.

Analog–digital hybrids

Analog computing devices are fast, digital computing devices are more versatile and accurate, so the idea is to combine the two processes for the best efficiency.

Analog–digital hybrids



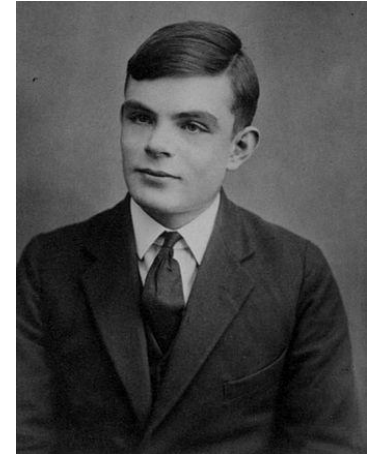
https://en.wikipedia.org/wiki/Hybrid_computer

Analog–digital hybrids

After 1980, purely digital computers progressed more and more rapidly and were fast enough to compete with analog computers. Today there are no more big hybrid computers.

Digital computer

The principle of the modern computer was first described by [mathematician](#) and pioneering [computer scientist Alan Turing](#), (1912-1994) who set out the idea in his seminal 1936 paper, [\[20\]](#) *On Computable Numbers*.



Turing aged 16

He also introduced the notion of a 'Universal Machine' (now known as a [Universal Turing machine](#)), with the idea that such a machine could perform the tasks of any other machine, or in other words, it is provably capable of computing anything that is computable by executing a program stored on tape, allowing the machine to be programmable.

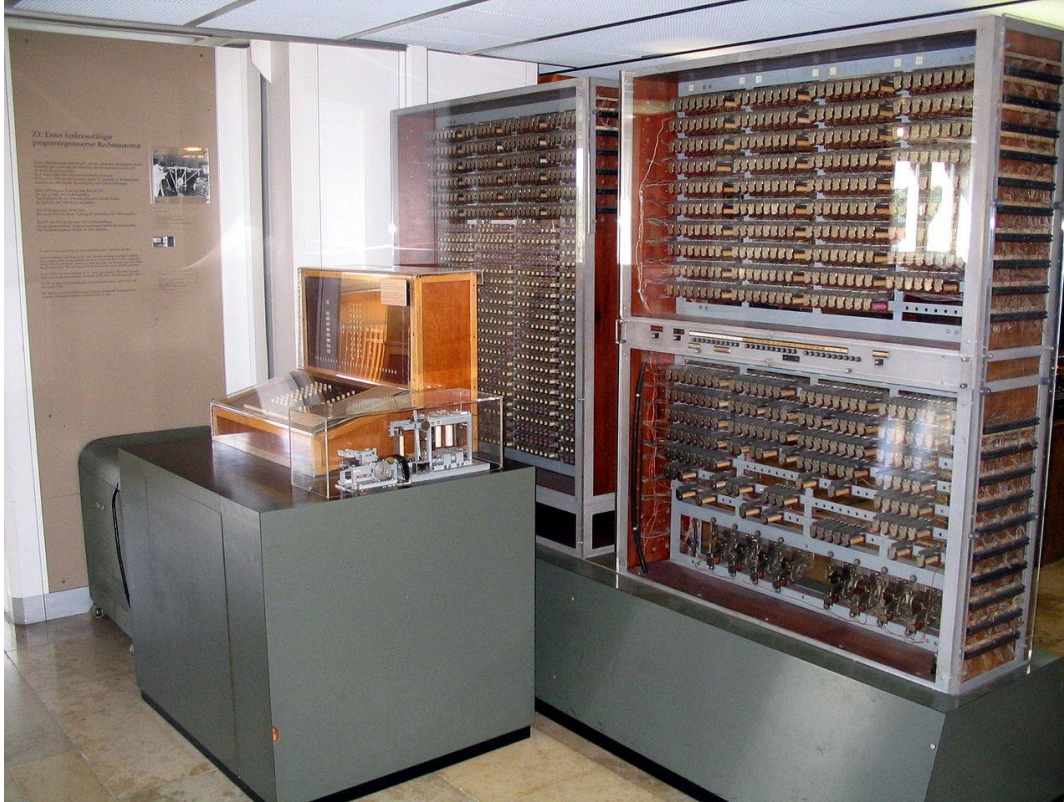
Digital computer

- Early digital computers were electromechanical; electric switches drove mechanical relays to perform the calculation.
- The [Z2](#), created by German engineer [Konrad Zuse](#) in 1939, was one of the earliest examples of an electromechanical relay computer.[\[22\]](#)

Digital computer

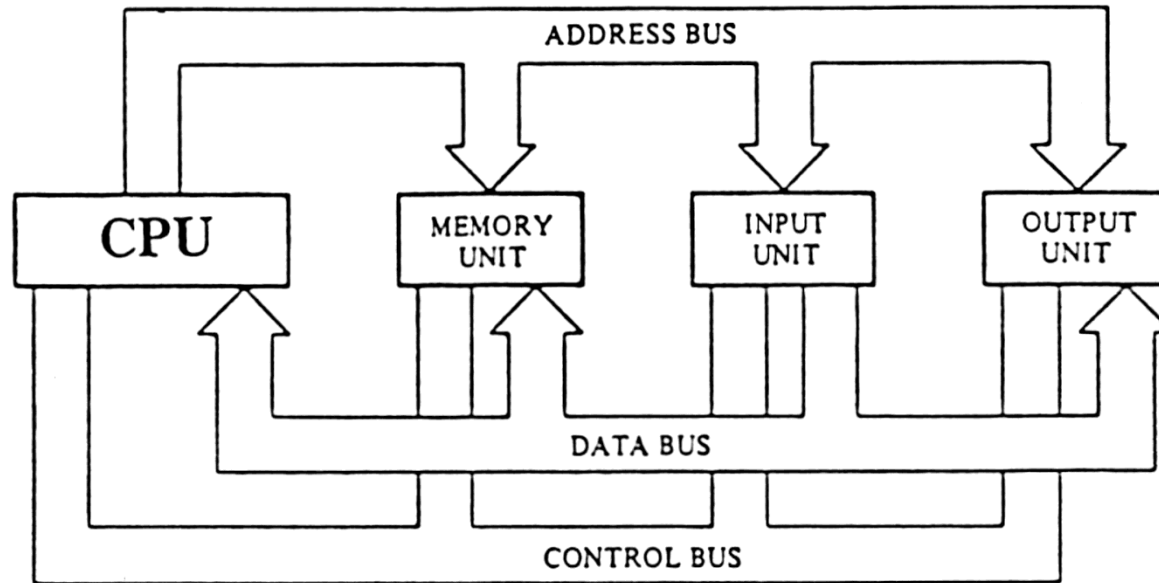
- In 1941, Zuse followed his earlier machine up with the [Z3](#), the world's first working [electromechanical programmable](#), fully automatic digital computer.^{[23][24]} The Z3 was built with 2000 [relays](#), implementing a 22 [bit word length](#) that operated at a [clock frequency](#) of about 5–10 [Hz](#).^[25] Program code was supplied on punched [film](#) while data could be stored in 64 words of memory or supplied from the keyboard. It was quite similar to modern machines in some respects, such as [floating point numbers](#). Replacement of the hard-to-implement decimal system by the simpler [binary](#) system meant that Zuse's machines were easier to build and potentially more reliable. The Z3 was probably a complete [Turing machine](#).

Digital computer



Replica of Zuse's Z3, the first fully automatic, digital (electromechanical) computer.

Structure of a Basic Digital Computer



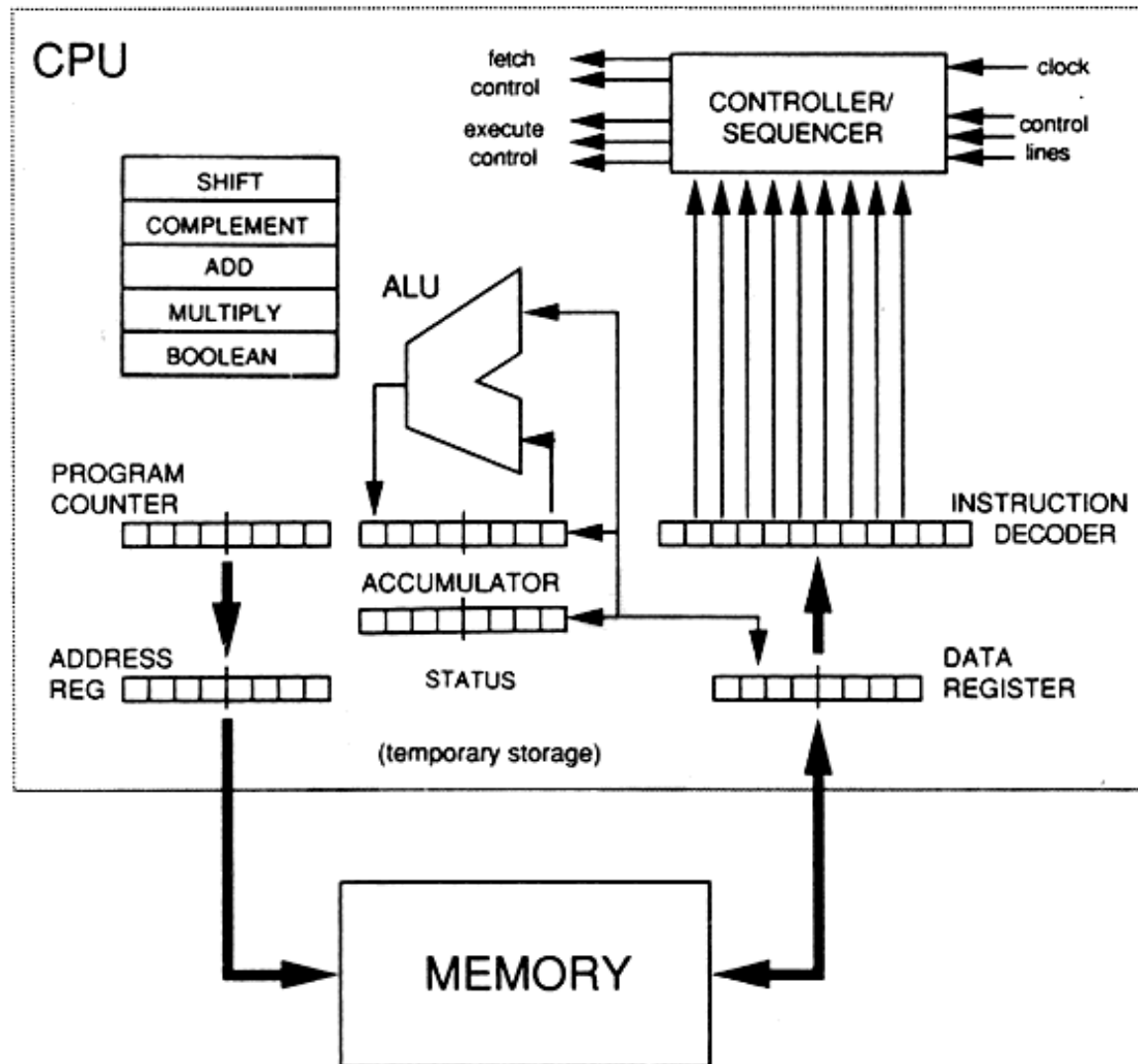
All memories, input units and output units have a unit address

The Central Processing Unit (CPU)

The CPU sequences the operation of the computer, controlling the actions of all other units. (Master)

It **fetches** the instructions from memory, **decodes** them, and **executes** them.

Basic internal structure of a CPU



Instruction decoding within the CPU.

Arithmetic Logic Unit (ALU)

It performs arithmetic and logical operations on data.
Some common operations are:

Arithmetic operations:

Addition, Subtraction, multiplication, division etc.

Logical operations:

AND, OR, Exclusive-OR etc.

The list of ALU functions varies from one processor to another.

The Memory Unit

The memory is used to store program and data.

The memory is arranged sequentially into a number of units. Each unit is referred to as a memory location and **identified by a unique address**.

Currently, the unit for memory is byte (8-bit).

Each computer word may be 8bit, 16bit, 32bit, 64bit etc.

The Input/Output Units

- These units handle the transfer of data between the computer and external devices or peripherals. **Each unit is also identified by a unique address.**

[Keyboard](#)

[Image scanner](#)

[Microphone](#)

[Pointing device](#)

[Graphics tablet](#)

[Joystick](#)

[Light pen](#)

[Mouse](#)

[Pointing stick](#)

[Touchpad](#)

[Touchscreen](#)

[Trackball](#)

[Webcam](#)



.....

The Input/Output Units

- Monitor
- Printer
- Speakers
- Plotter
-



Bus

Address Bus; Data Bus; Control Bus

Address Bus

- These are the wires that carry the CPU generated address signals **out** to memory and to I/O devices.
- The address signals only travel outwards from the CPU (**unidirectional**). **True for basic computer only.**
- The *number of address lines* that a microprocessor has determines the *size of the memory* space that it can access.

Address Bus

No of Addrss lines	Size of memory space
8	$2^8 = 256$
16	$2^{16} = 65\,536 = 64\text{ K}$
20	$2^{20} = 1\,048\,576 = 1\text{ M}$
24	$2^{24} = 16\,777\,216 = 16\text{ M}$
32	$2^{32} = 4\,294\,967\,296 = 4\text{ G}$

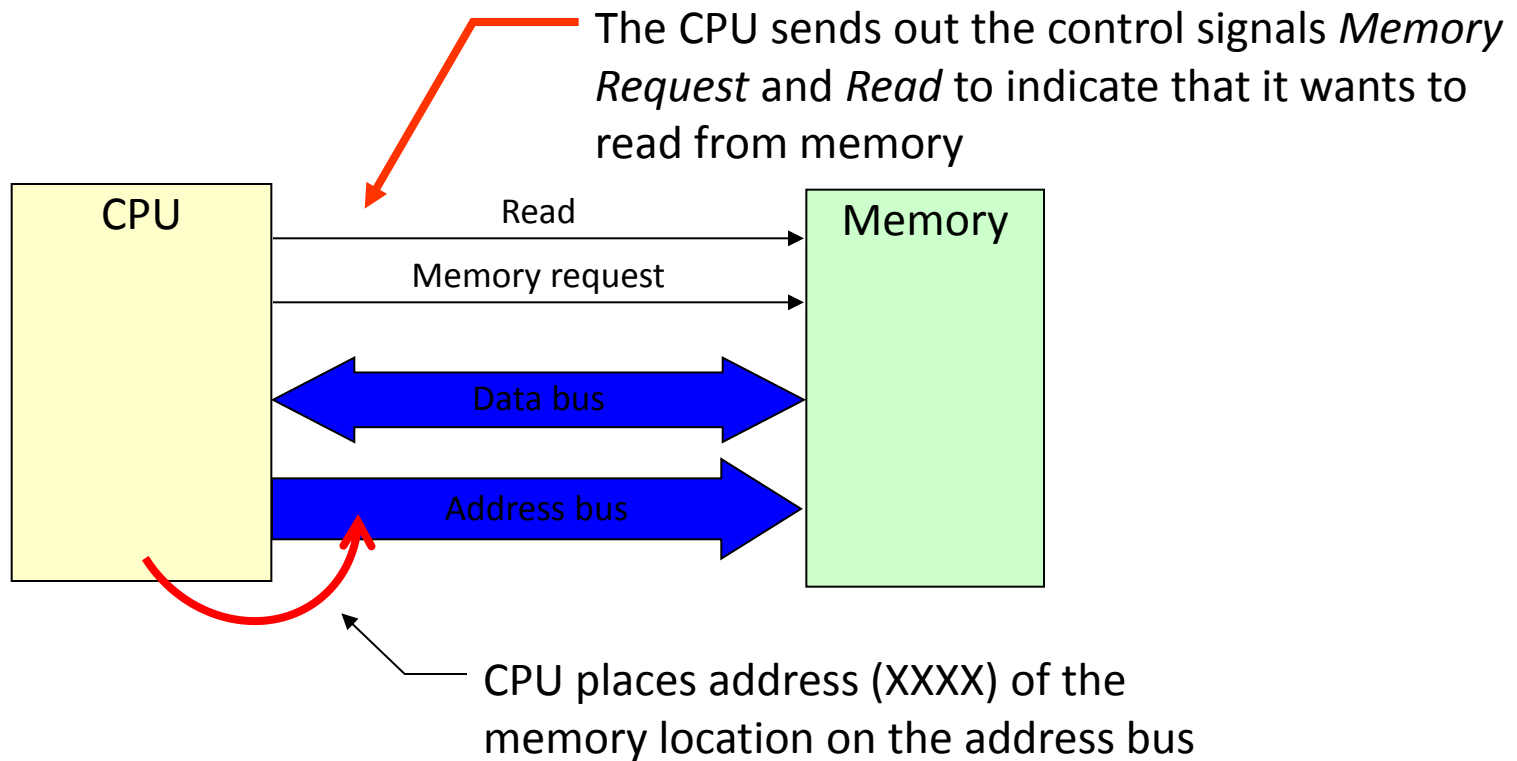
Data Bus

- These are the data signals that travel out of and into the μP (**bi-directional**).
- The *number of wires* in the data bus may depend on the *word size that the μP operates with*.
- An 8-bit μP will have a data bus consisting of 8 wires and a 32-bit μP **MAY** have a data bus with 32 wires.

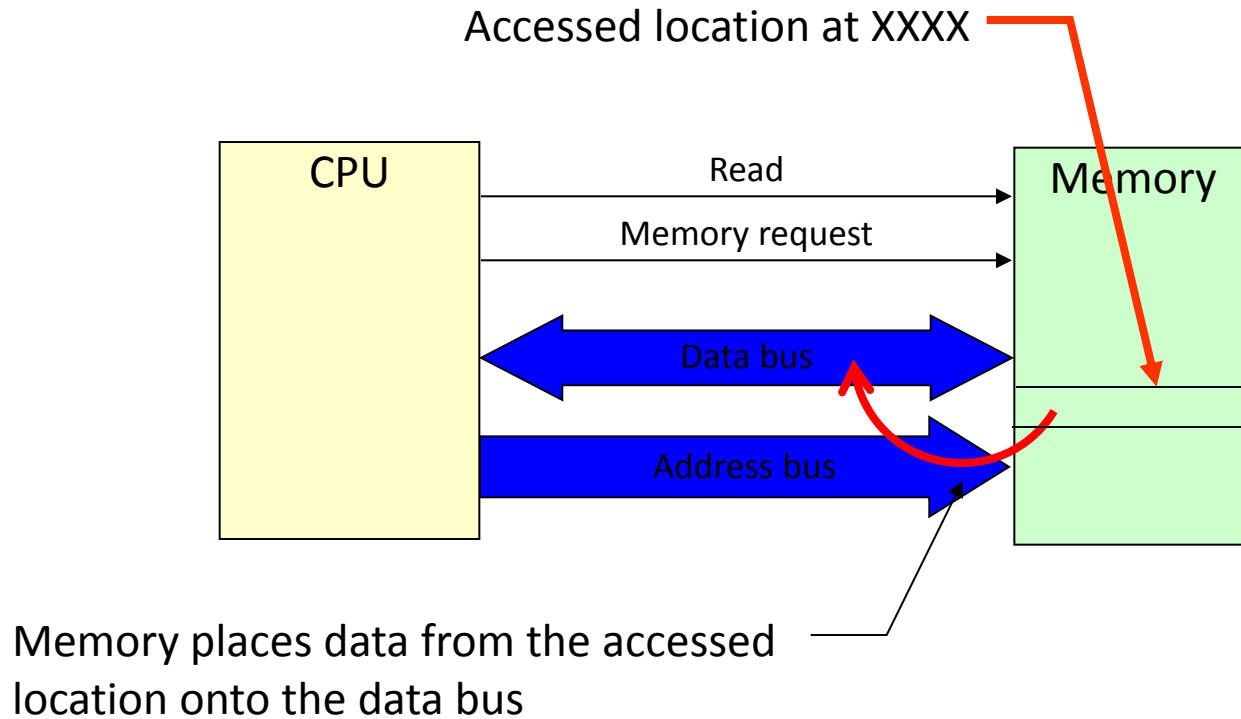
Control Bus

- The control bus consists of wires, some of which carry signals from the CPU to external devices, while others carry signals from external devices to the CPU.
- The number of wires present in the control bus varies from one μP to another.
- Examples of control bus signals are READ/, WAIT, READY, and HOLD.

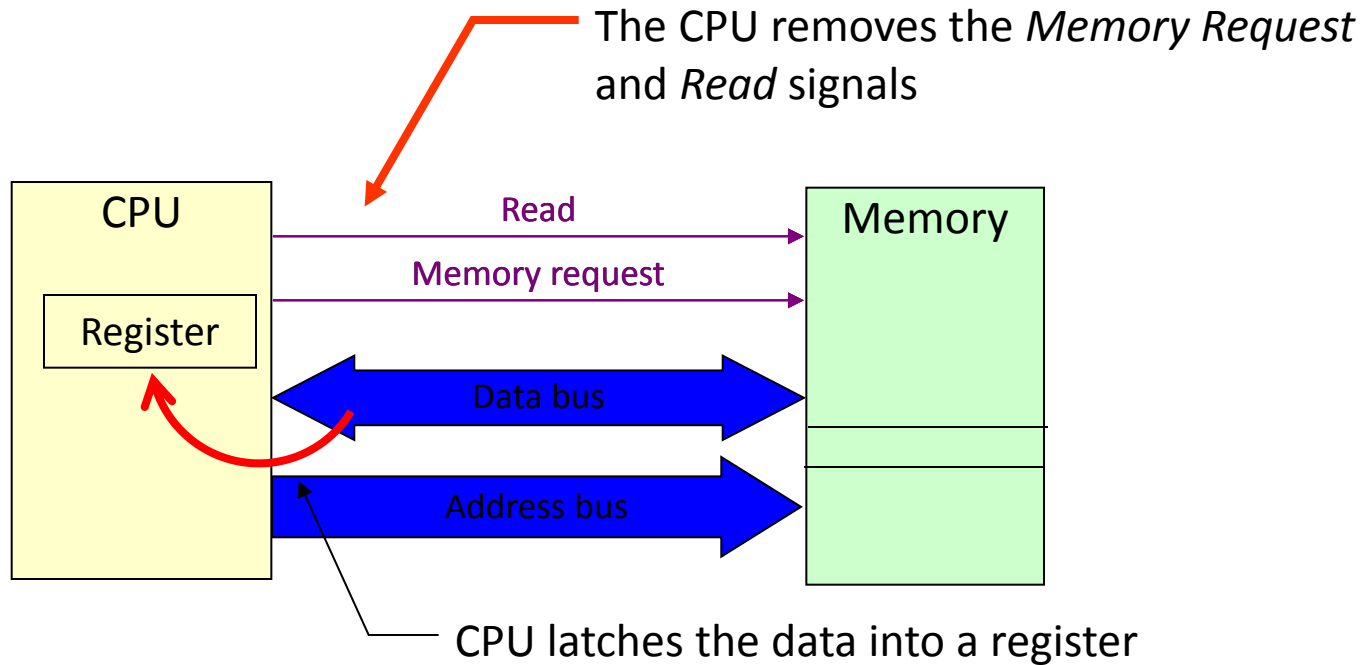
Memory Read Operation - Step 1



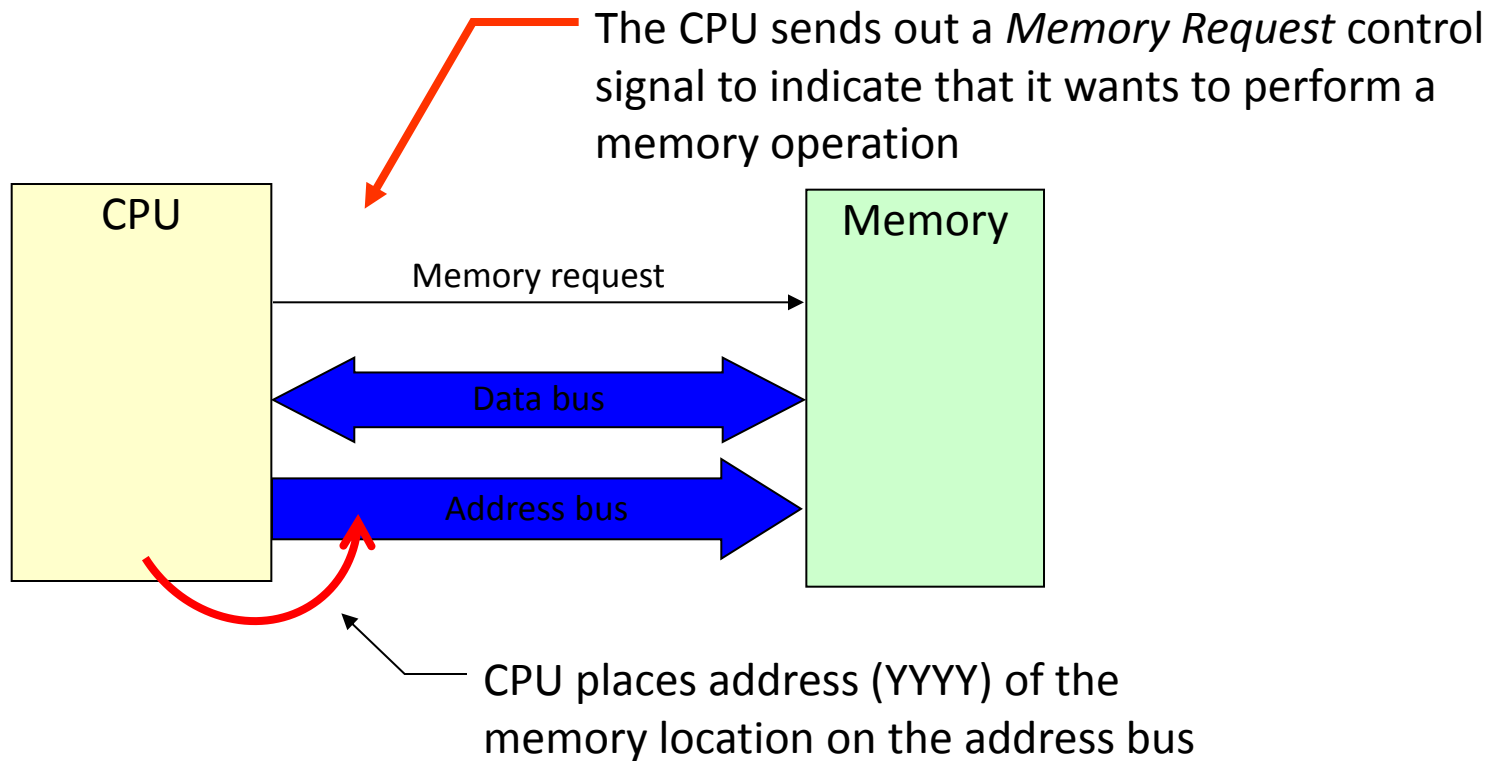
Memory Read Operation - Step 2



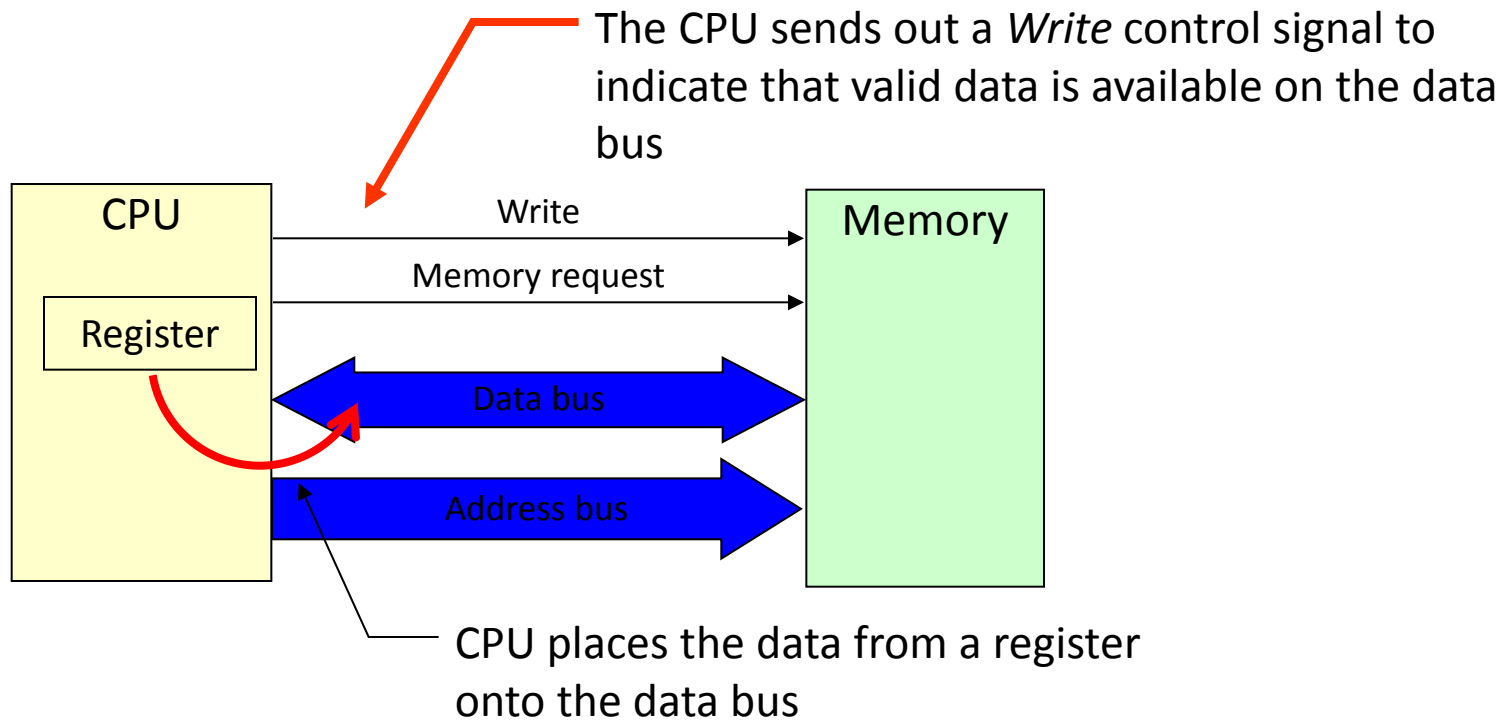
Memory Read Operation - Step 3



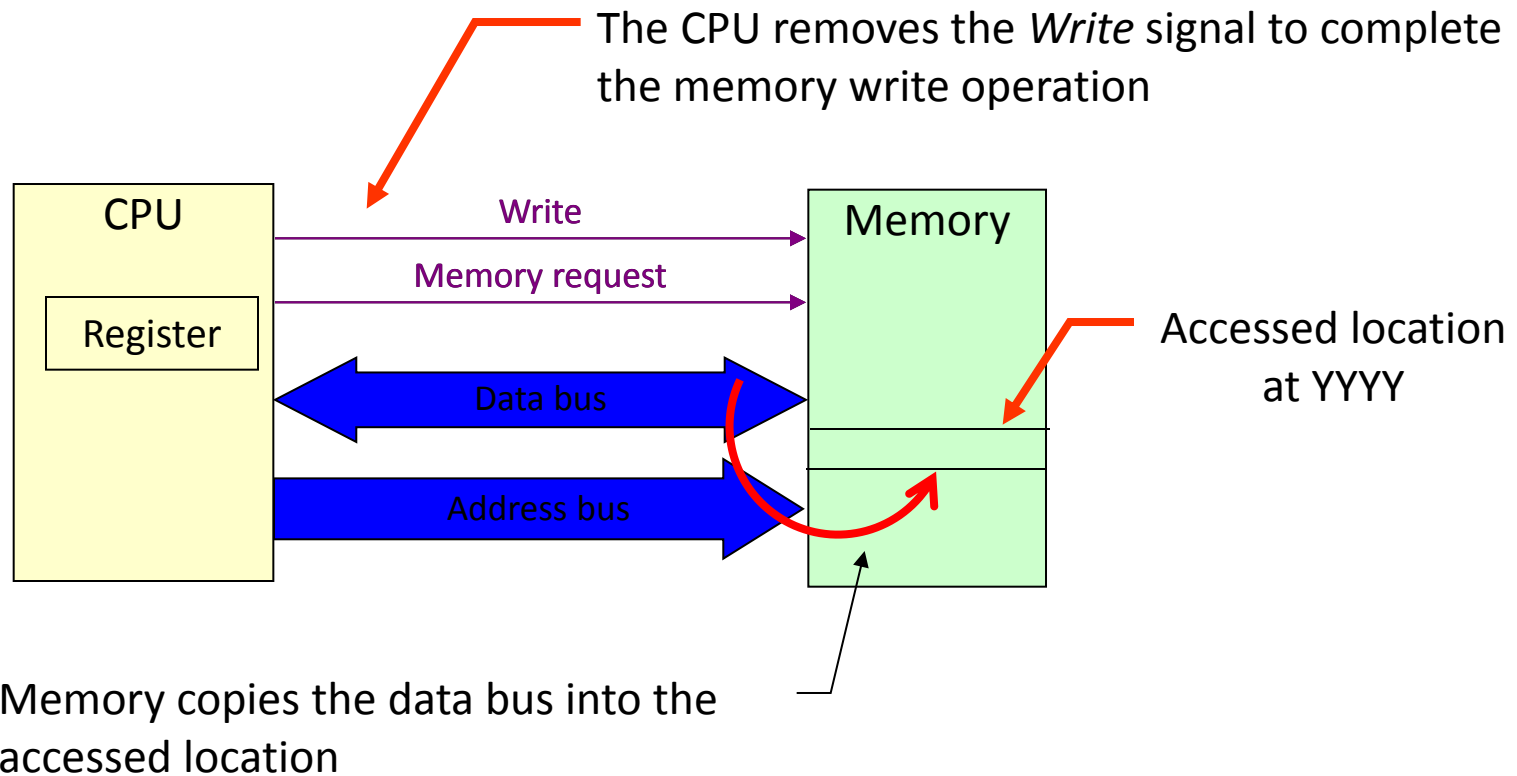
Memory Write Operation - Step 1



Memory Write Operation - Step 2



Memory Write Operation - Step 3



Some Technical Terms

Microprocessor (uP)

A complete processor implemented on one integrated circuit (IC, also called a chip).

Normally no on chip input/output ports, needs external peripheral chips to interface with I/O devices to construct a product.

Microcomputer – a computer that uses a microprocessor as its CPU.

Microcontroller (MCU)

A computer implemented on a single very large scale integrated (VLSI) circuit.

Some microcontrollers may have memory, I/O ports, timer/counters, ADC, DAC, ... etc all on one chip.

What are Embedded systems

https://upload.wikimedia.org/wikipedia/commons/a/af/DM_IBM_S360.jpg



Are computers all look like these?

Computers are in everywhere



Embedded systems

An **embedded system** is a [computer system](#) with a dedicated function within a larger mechanical or electrical system, often with [real-time computing](#) constraints.^{[1][2]} It is *embedded* as part of a complete device often including hardware and mechanical parts.

Embedded systems are commonly found in consumer, cooking, industrial, automotive, medical, commercial and military applications.

https://en.wikipedia.org/wiki/Embedded_system

Some common characteristics of embedded systems

- Single-functioned
 - Executes a single program, repeatedly
- Tightly-constrained on design metrics
 - Low cost, low power, small, fast, etc.
- Reactive and real-time
 - Continually reacts to changes in the system's environment
 - Must compute certain results in real-time without delay

How about cell phones?