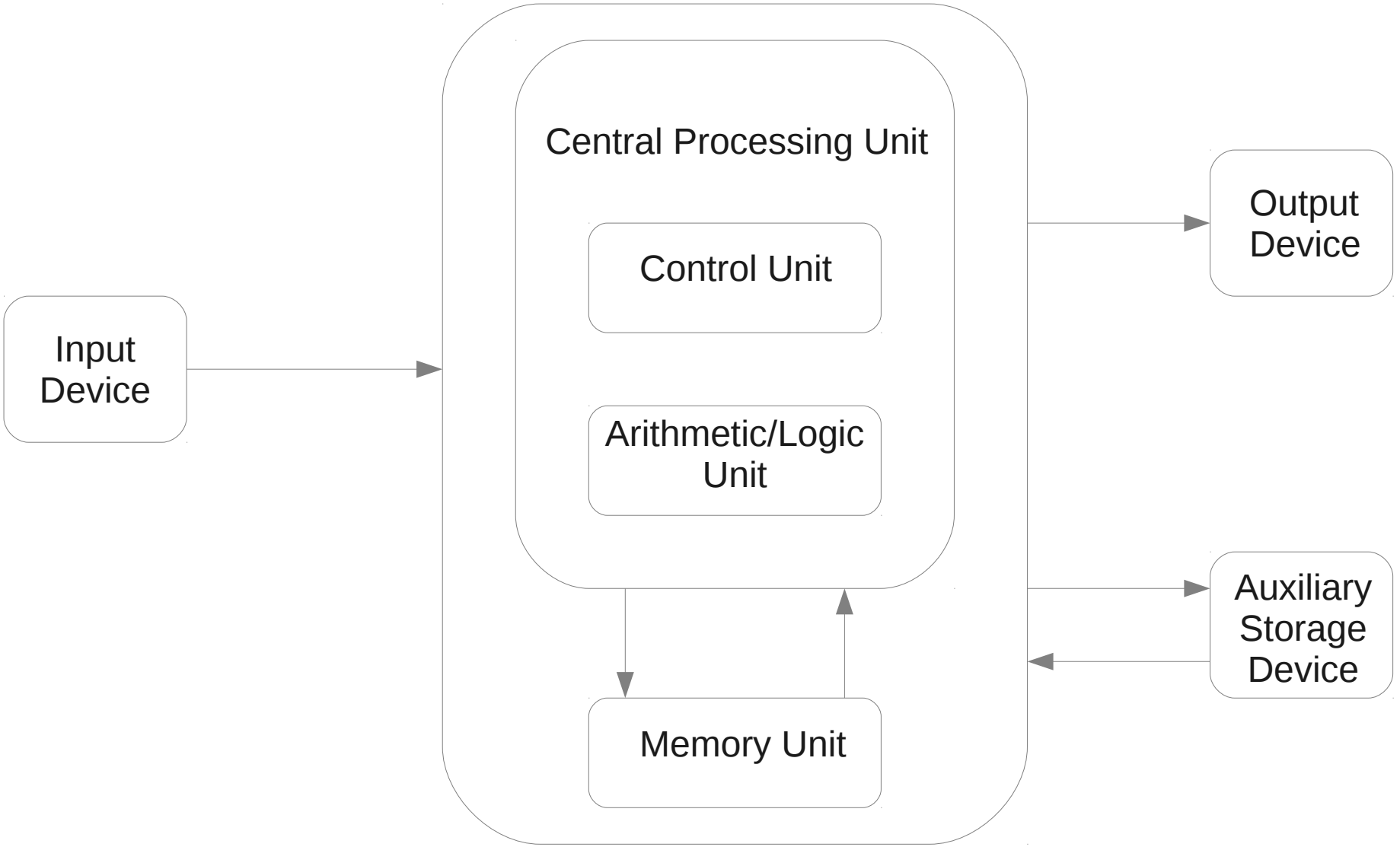
Von Neumann Architecture

- Data and instructions to manipulate data – logically same – could be stored in the same place.
- Discovered during 1944—1945
- Principle known as Von Neumann architecture.
- Also known as Stored-Program concept.
- Basis of computers even today.

Von Neumann Architecture

- Units that process information are separate from units that store information.
- Components of Von Neumann architecture:
  - Memory unit containing data and instructions
  - Arithmetic/logic unit performing operations on data
  - Input unit moves data from outside into the computer
  - Output unit moves data from computer to outside
  - Control unit which manages the operation of all the other components

The von Neumann Architecture



Memory

- Each storage unit – bit – can store a binary value.
- Bits --> Bytes --> Words.
- Memory is a collection of cells, each with a unique physical address.
- Size of a cell – addressability – varies from machine to machine.
- Modern computers are mostly byte addressable.

Memory

- The number of memory locations a computer can access is a function of the word length of the machine.
  - A machine with n bits can access 2^n different locations.
- Cells numbered consecutively from 0.
- The content of a memory address can be either instructions or data with no way to distinguish between both without any context.
- The bits in a byte or word are numbered from right to left beginning with zero.

Arithmetic/Logic Unit

- The Arithmetic/Logic unit is capable of performing :
  - Basic arithmetic operations – addition, subtraction, multiplication and division – on two numbers.
  - Logical operations – AND, OR, NOT.
- Operates on words.
- Use special storage units called Registers.
- Access to registers is much faster than access to memory.

Input/Output Units

- Input Unit – device through which data and programs from outside are entered into the computer.
  - Keyboard, Mouse etc.
- Output Unit – device through which results stored in the computer are made available to the outside world.
  - Monitors, Printers etc.

Control Unit

- Organizing force in the computer.
- In charge of the fetch-execute cycle.
- Includes two registers:
  - Instruction register (IR) – contains the instruction being executed.
  - Program Counter (PC) – contains the address of the next instruction to be executed.
- The ALU and control unit are often thought of as a single Central Processing Unit (CPU).

The Fetch-Execute Cycle

- In the von Neumann architecture, instructions and data are both addressable.
- Instructions are stored in a contiguous memory locations
- Data are stored together in another part of memory.
- Address of the first instruction is loaded into the program counter.

The Fetch-Execute Cycle

- The processing cycle includes four steps
  - Fetch the next instruction.
  - Decode the instruction.
  - Get data if needed.
  - Execute the instruction.
- The cycle is repeated for each instruction.

Von Neumann Bottleneck

- Occurs due to separation between the CPU and memory.
- CPU is many times faster than the rate at which data can be fetched from memory.
- CPU often idles while waiting for data.
- Mitigated somewhat by using caches in the CPU, producing separate paths for instructions and data and increased branch prediction.
- Can also be reduced by using parallel computing architectures like Non-Uniform Memory Access (NUMA).

Non-von Neumann Architectures

- Few architectures which are not based on the von Neumman model are also available.
- Most common is Content Addressable Memory.
  - User supplies the data word and the CAM searches its contents to see whether the word exists.
  - If found it returns the list of addresses where the data word was found.
  - Also known as associative memory.
  - Expensive than normal memory.
  - Commonly found in networking equipment.