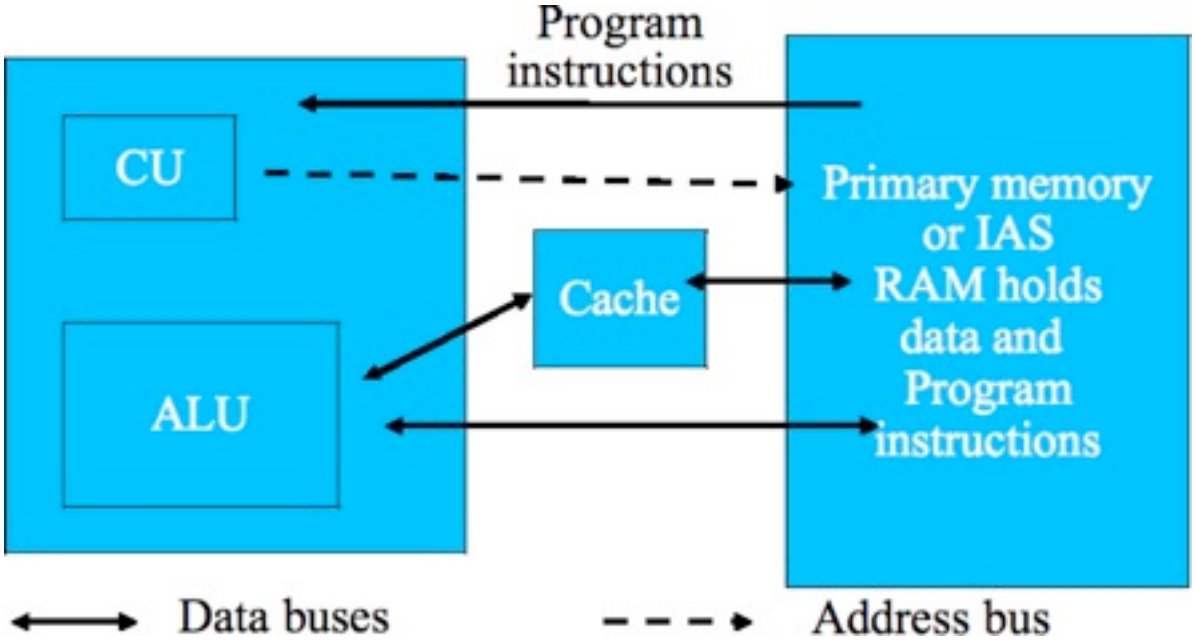
## 3.2.1 The CPU

- **Central Processing Unit** = 'chip' = processor = device controlling the computer.
- It follows a sequence of instructions (the **program**) in order to carry out particular tasks, handles calculations and directs data to appropriate memory locations or peripherals.
- It has to be able to distinguish between the **instructions** and the **data** itself (both of which are in binary form), applies **logical operations** (e.g. is A greater than B?) to the bits using relatively simple logic circuits and if the instruction set is kept fairly simple many operations can be carried out very quickly.
- Four main components: the **control unit** (CU), the **arithmetic and logic unit** (ALU), **registers** (simple memory locations) and **buses** (connections carrying data).
- The role of the **CU**: decoding program instructions, controlling the sequence in which instructions are executed by the ALU, controlling access to the main memory store, regulating the timing and synchronisation of the processor and sending/ receiving control signals to/from peripheral devices.
- The role of the **ALU**: performing calculations on data, making logical comparisons between values, holding the answers to these in operations various registers until they are stored for later in the program.
- **Registers** provide: immediate storage for the results of simple operations, **program counters** e.g. for loops.
- Registers in the ALU that store intermediate results of calculations are called **accumulators**.
- **Buses** are the connectors and subsystems that transfer data within the CPU, computer and peripherals.
- Three types of bus: **data** bus, **address** bus (memory locations) and **control** bus (control signals)



## 3.2.2 Bits and Bytes

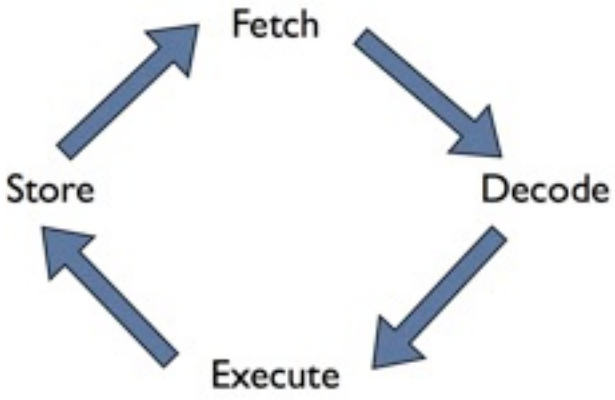
- The smallest unit of storage in memory or storage is the **bit** (b), which can store a zero or a one.
- Bits represent the fact that the transistors that make up computer memory are switches that can only be **ON** (1) or **OFF** (0).
- Bits are grouped together in eights to form a **byte** (B) e.g. 10011010
- Sometimes a group of bytes representing one item of data or one instruction is referred to as a word (typically 2, 4 or 8 bytes, depending on the computer, hence 32- or 64-bit processors).
- The same prefixes as for other SI units are used: **kB** - a kilobyte holds 1024 bytes (about 1000), **MB** - a **megabyte** holds 1024 kB (about a million bytes), **GB** - a **gigabyte** holds 1024 MB (about a thousand million bytes), **TB** - a **terabyte** holds 1024 GB (about a million million bytes), etc.
- Note that the increases are not in 1000s but in 1024s - computer storage is measured in units of $2^{10}$ (1024), not in units of $10^3$ (1000), so in computing only, *kilo-* represents $2^{10}$, *mega-* represents $2^{20}$, etc.
- $2^1 = 2$, $2^2 = 4$, $2^3 = 8$, $2^4 = 16$, $2^5 = 32$, $2^6 = 64$, $2^7 = 128$, $2^8 = 256$, $2^9 = 512$, $2^{10} = 1024$.

## 3.2.3 Registers and Addresses

- CPU works with chunks of bits at a time (**words**), word size is always a multiple of 8 (a byte), some PCs have CPUs using 32-bit processing (i.e. their words are 4 bytes long), 64-bit processors are becoming commoner.
- **Registers** are temporary storage locations in the CPU capable of holding one word, if larger data items are to be stored e.g. an 8-byte integer on a 32-bit computer, adjacent registers are used.
- Registers can hold data, instructions or memory addresses.
- 32-bit processors can reference $2^{32}$ = approx. 4 billion addresses, hence their limit of 4GB of RAM.

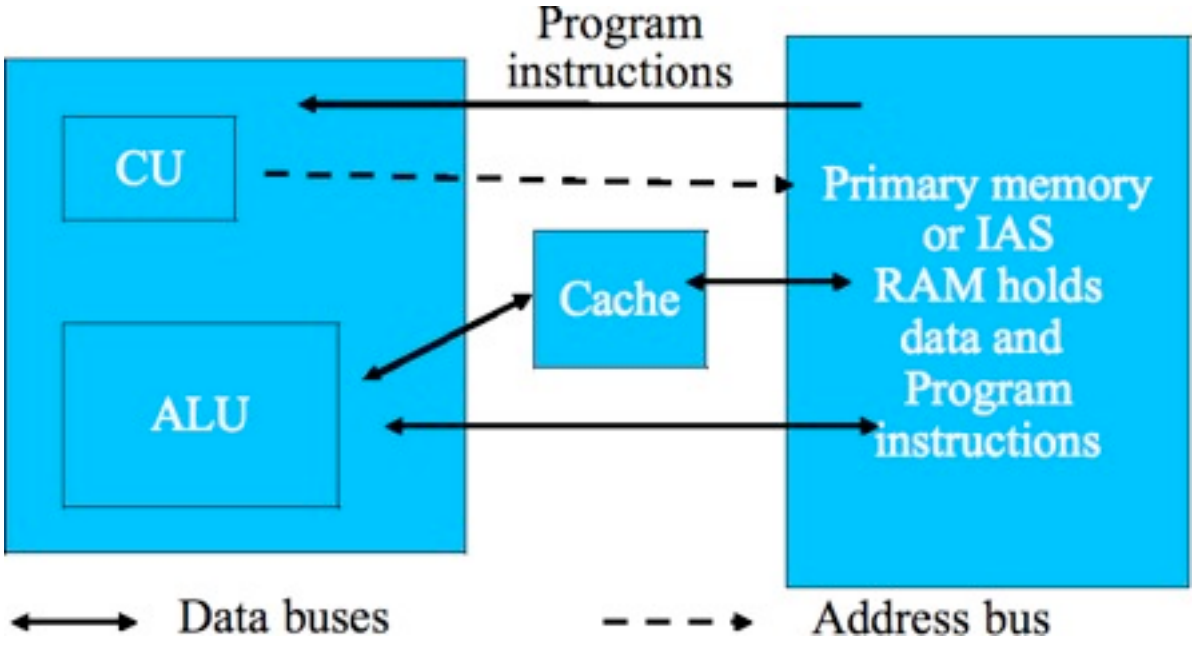
## 3.2.4 The Machine Instruction Cycle

- When a program is being executed, lines of machine code are loaded one by one from primary memory into the CPU



## 3.2.5 Primary Memory

- There are basically two types of computer memory: **primary** memory (**immediate access storage**, IAS, often called RAM) and **secondary** memory (or **backing storage**).
- **Random Access Memory** really refers to a method of storage, not a location.
- Used for temporary storage of programs and data while the computer is running, short term, **volatile** (loses its contents when computer is switched off) since it requires power to be maintained, can be written to i.e. read/write, typically 4GB for a personal computer.
- Different voltages in transistors represent 0 and 1.
- **Read Only Memory** retains its contents without power (**non-volatile**), is used to store programs permanently e.g. the start-up (**boot**) instructions or in a **microprocessor** (**embedded systems** in machinery).
- Dynamic RAM (DRAM) is the cheapest, slowest, commonest type, static RAM (SRAM) is faster but more expensive,
- Non-volatile RAM (NVRAM) = flash memory, is even more expensive (e.g. memory stick, smart phone).
- **Cache** memory is SRAM (faster) placed between main IAS and the processor as a temporary store for blocks of recent or regularly used program instructions (level 2 cache is usually about 1MB).
- Level 1 cache is incorporated into the processor itself (internal cache) - this is speedier still because of the very short distance to the processor.
- Extra RAM is sometimes found on peripheral devices e.g. video cards, printers, etc. for their own use.
- **Virtual memory** is space set aside on the hard disk that can serve as IAS, also known as swap files because of the continual exchange between the HD and CPU (a process known as **paging**).



## 3.2.6 Secondary Memory (Storage)

- It is necessary to keep data which is not needed in primary memory all of the time, and which may be too large to fit into the primary memory.
- The **medium** (pl. **media**) is the physical material the data are kept on.
- **Magnetic tape** e.g. Digital Linear Tape (DLT), often used for backing up large volumes of data, can store about 100GB, slow to access but can be removed and stored somewhere physically secure, use **sequential** access.
- **Magnetic disk** e.g. hard disk are faster to access (**direct** access), consist of a spinning disk coated in a layer that can be magnetised/detected by a read/write head, the different directions of magnetism represent the 0's and 1's.
- Hard drives are permanently enclosed in their drive mechanism (the read/write heads are only a fraction of a mm away from the disk), spin constantly and comprise a stack of metal or ceramic platters that have magnetic coating on both sides. Typically 1 TB.
- **Optical discs** e.g. compact disc (CD-ROM, CD-R, CD-RW), DVD, Blu-ray) do not use a magnetic surface but encode the data onto a reflective surface which is then read by a laser, CDs up to 720MB, DVDs up to 17GB, Blu-ray up to 50GB.
- CD/DVD-R and -RW can be written to (R once, RW multiple times), are resistant to damage, are cheap and portable but comparatively slow to access compared to other types of memory and use **direct** access.
- **Solid-state drives** (**SSD**) e.g. **flash drives** (memory sticks) are electronic NVRAM, have no moving parts but are expensive.
- Access methods **serial** (data are written and accessed one record at a time, one after the other with no particular regard to order, magnetic tape can be a serial access medium: to find a given record, you must first pass by all of the preceding ones checking each in turn, very slow), **sequential** access (data are kept in a specified order according to a certain **key field** e.g. alphabetical order by surname, computer will still have to go through the previous records but access is quicker as the computer can estimate where a record is and jump there) and **direct** (or **random**) access (going directly to the location of the data required, giving fast storage and access, possible with discs and flash memory, records in a random access file can be stored anywhere, so an addressing system needed (e.g. an **index table** or a **hashing** calculation).

## 3.2.7 Microprocessors

- Similar to a CPU, with CU, ALU, registers etc., but lacking (much) primary memory, their programs are inflexible and stored in non-volatile memory (usually ROM).
- Programmed in the factory, designed to perform one or a very limited number of functions.
- In cars, control: fuel injection, Automatic Braking System (ABS), airbags, SatNav, etc.

- In a washing machine, control: water level,temperature, cycle time, spin speed, etc.
- In a digital camera, control: exposure, autofocus, image compression (e.g. JPEG), etc.
- In a CD/DVD player, control: track selection, track data calculation, conversion of optical data to sound, etc.
- In the home, control: TV remote, central heating and AC, digital clocks, microwave ovens, mobile phones, burglar alarms, etc.
- In school, control: calculators, digital watches, heating and AC, security system, interactive whiteboards, etc.

### 3.2.8 Input Devices

- Manual input devices: mouse, keyboard, trackpad, touch screen, scanner and OCR, digital camera, joystick, microphone, games controller, bar code reader.
- Automatic input devices: sensors, OCR, MICR.

### 3.2.9 Output Devices

- Monitors (CRT and TFT)
- Printers (dot matrix, inkjet, laser and plotters)
- Speakers and LEDs
- Actuators (produce movement) e.g. motors, hydraulics.