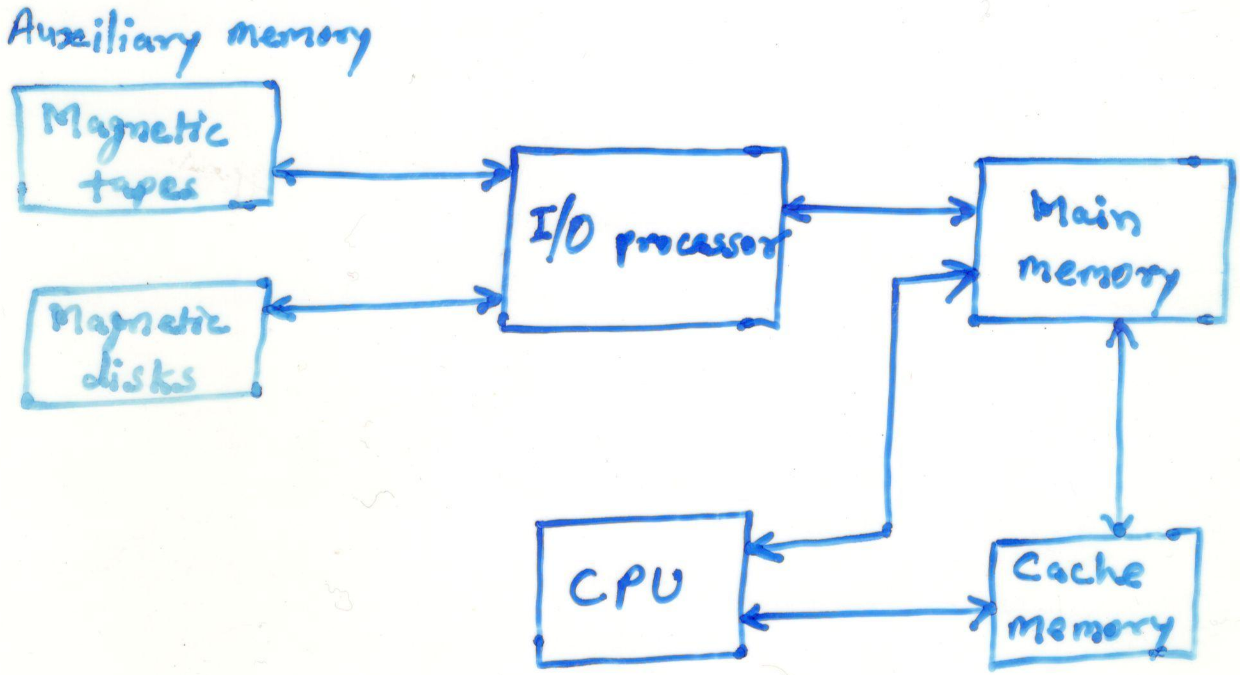
Memory Organization

Memory Hierarchy



- The memory unit that communicates directly with the CPU is called the main memory.
- Devices that provide backup storage are called auxiliary memory.

Cache memory:- A special very-high-speed memory that is used to increase the speed of processing by ~~making~~ making current programs and data available to the CPU at a rapid rate.

The cache memory is employed in computer systems to compensate for the speed differential between main memory access time and processor logic.

→ The I/O processor manages data transfers between auxiliary memory and main memory. ~~the~~

→ The cache organization is concerned with the transfer of information between main memory and CPU.

→ The storage capacity of the memory increases, the cost ~~of~~ per bit for storing binary information decreases and the access time of the memory ~~bec~~ becomes longer.

Main Memory

The main memory is the central storage unit in a computer system. It is based on semiconductor integrated circuits technology. Integrated circuit RAM (Random-Access Memory) chips are available in two possible operating modes.

- Static
- Dynamic

The static RAM consists of internal flip-flops that store the binary information. The stored information remains valid as long as power is applied to the unit.

The dynamic RAM stores the binary information in the form of electric charges that are applied to capacitors. The stored charge on the capacitors tend to discharge with time and the capacitors must be periodically recharged by refreshing the dynamic memory.
The dynamic RAM offers reduced power consumption and larger storage capacity in a single memory chip.

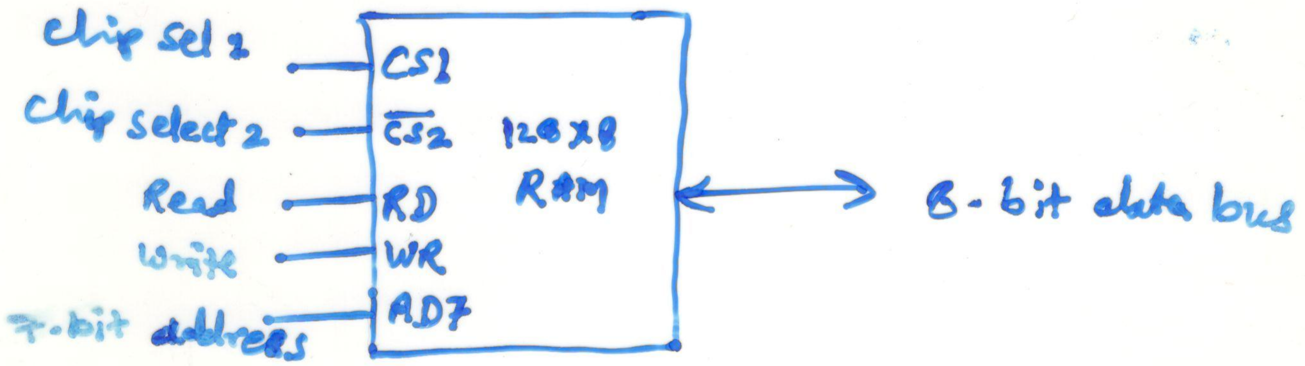
Read-Only-Memory (ROM):-

ROM is used for storing programs that are permanently resident in the computer. It is part of main memory. The ROM portion of main memory is needed for storing an initial program called a bootstrap loader.

The bootstrap loader is a program whose function is to start the computer software operating when power is turned on.

When power is turned on of a computer, the H/w of the computer sets the program counter to the first address of the bootstrap loader. The bootstrap program loads a portion of the operating system from disk to main memory and control is then transferred to the operating system which prepares the computer for general use.

RAM Chip

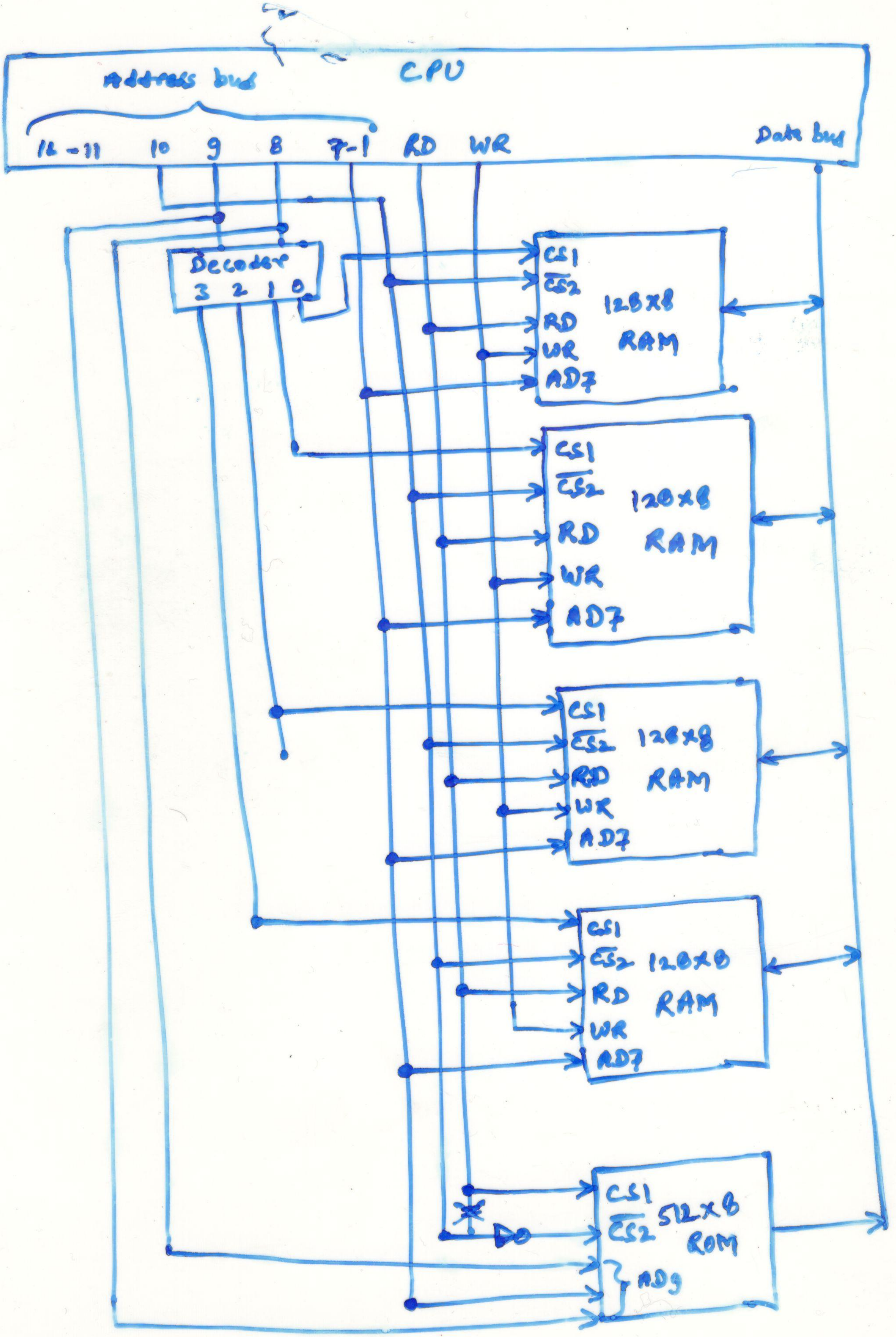


(a) Block diagram

CS1	$\overline{CS2}$	RD	WR	Memory function	State of data bus
0	0	×	×	Inhibit	High-impedance
0	1	×	×	Inhibit	High-impedance
1	0	0	0	Inhibit	High-impedance
1	0	0	1	Write	Input data to RAM
1	0	1	×	Read	Output data from RAM
1	1	×	×	Inhibit	High-impedance

(b) Function table

Memory Connection to the CPU



Associative Memory

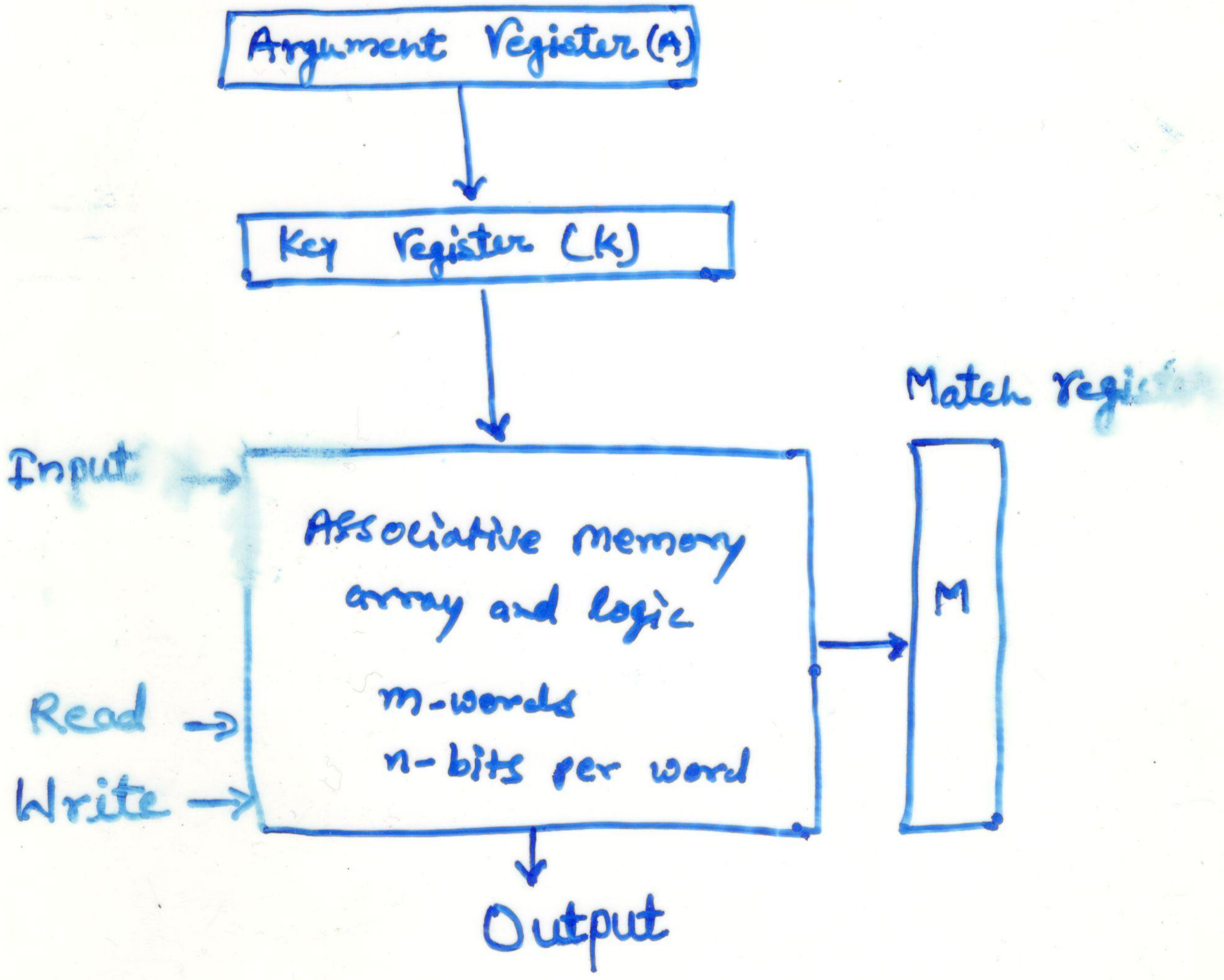
A memory unit accessed by ~~contentents~~ contents is called an associative memory or content addressable memory. This type of memory is accessed simultaneously and in parallel on the basis of data content rather than by specific address or location.

- When a word is written in an associative memory, no address is given. The memory is capable of finding an empty unused location to store the word.

- When a word is to be read from an associative memory, the content of word, or part of the word, is specified.

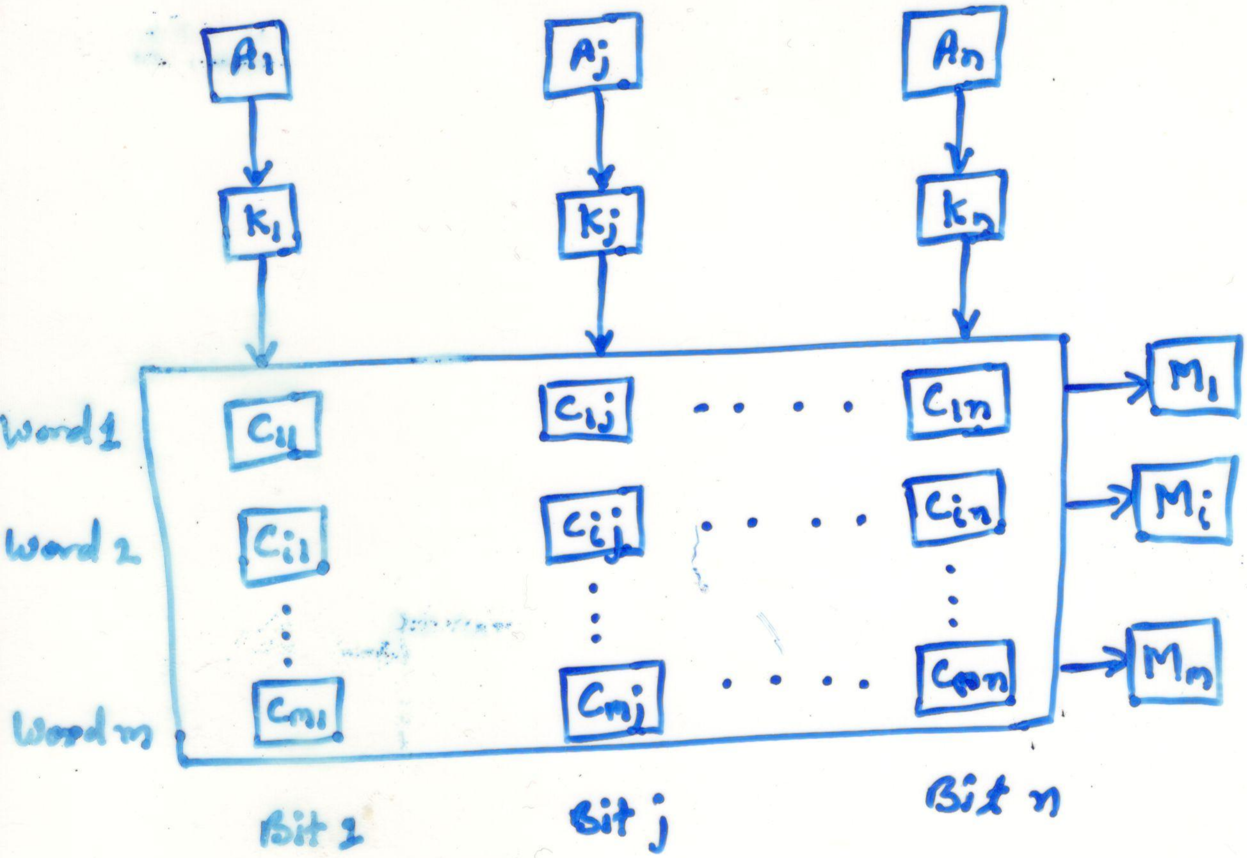
- An associative memory is more expensive than a random access memory because each cell must have storage capacity as well as logic circuits for matching its contents with an external argument.

Hardware Organization of an associative memory



(Block diagram)

- The argument register A and key register K each ~~for~~ have n bits, one for each bits of a word.
- The match register M has m bits, one ~~for each~~ for each memery word.
- Each word in memory is compared in parallel with the content of the argument register. The word that match the bits of the argument register set set a corresponding bit in the match register.
- Key register provides a mask.



(Associative memory of m word, n cells per word)

- Cell C_{ij}, ~~for~~ bit j in word i.
- A bit A_j in the argument register is compared with all the bits in column j of the array provided that $K_j = 1$.
- If a Match occurs between all the unmasked bits of the argument and the bits in word i, the corresponding bit M_i in the match reg. is set to 1.

Match Logic

First, we neglect the key bits and compare the argument in A with the bits stored in the cells of the words.

Word i is equal to the argument in A if $A_j = F_{ij}$ for $j = 1, 2, 3, \ldots, n$.

where F_{ij} - A flip-flop storage element.

The equality of two bits can be expressed as

$$x_j = A_j F_{ij} + A_j' F_{ij}'$$

For a word i to be equal to argument in A we have all x_j variables equal to 1.

$$M_i = x_1 x_2 x_3 \ldots x_n$$

We now include the key bit K_j in the comparison logic.

$$x_j + K_j' = \begin{cases} x_j & \text{if } K_j = 1 \\ 1 & \text{if } K_j = 0 \end{cases}$$

A term $(x_j + K_j')$ will be in the 1 state if its pair of bits is not compared.

$$M_i = (x_1 + K_1')(x_2 + K_2') \ldots (x_n + K_n')$$

$$\boxed{M_i = \prod_{j=1}^{n} (A_j F_{ij} + A_j' F_{ij}' + K_j')}$$

Virtual Memory

Virtual memory is a concept that the user can construct programs as though a large memory space were available, equal to the auxiliary memory.

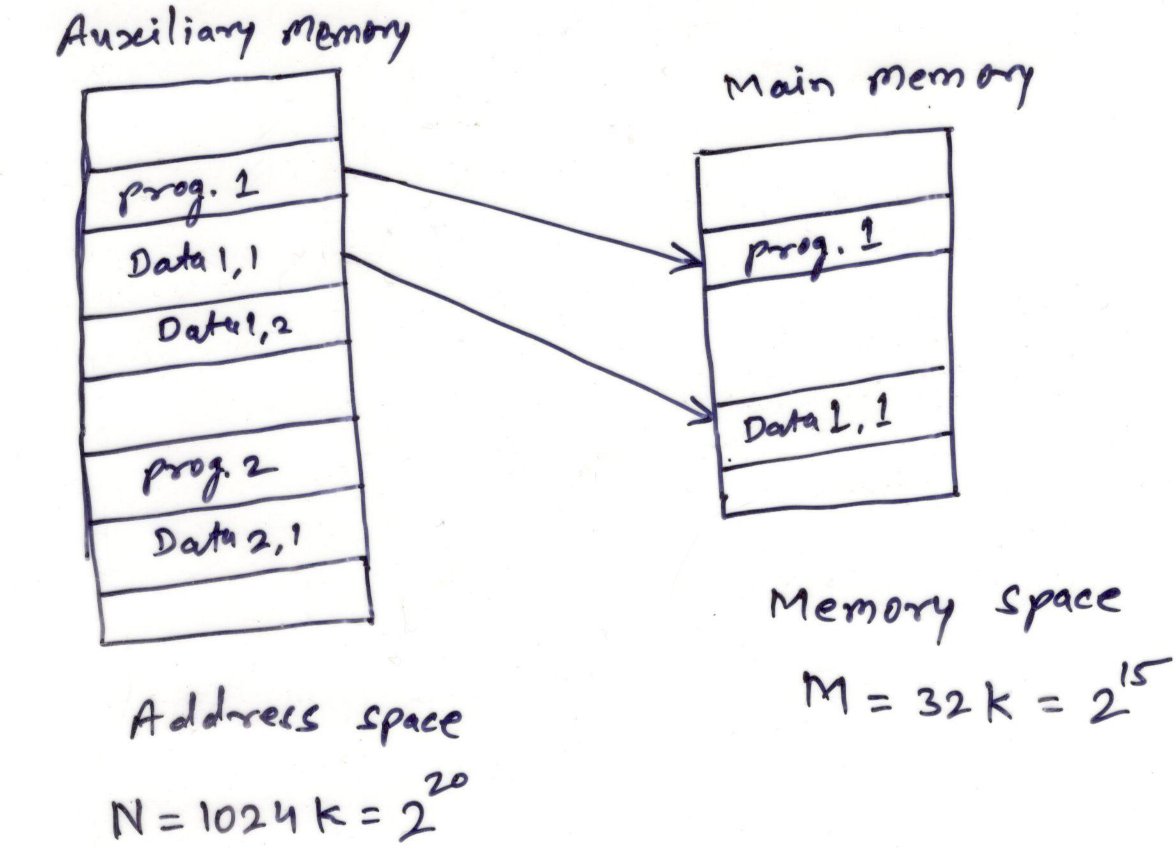
Each address that is referenced by the CPU goes through an address mapping from virtual address to a physical address in main memory.

Address Space and Memory Space

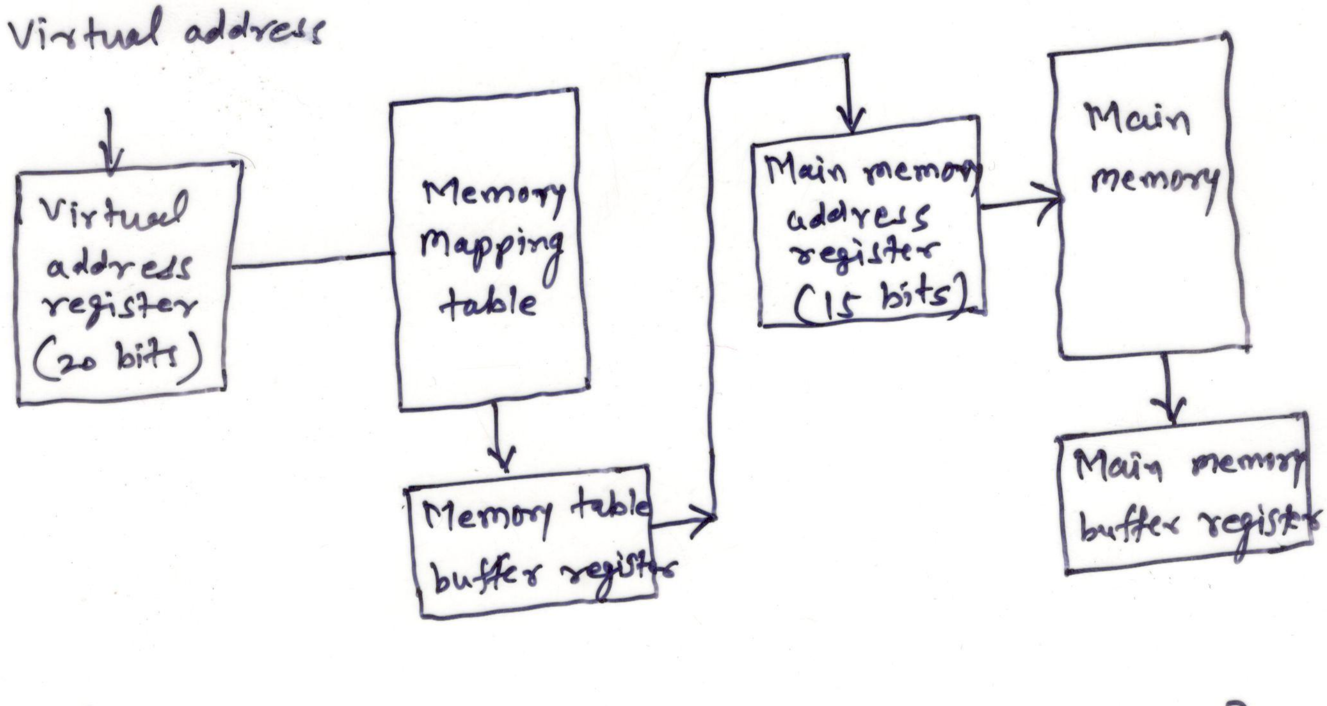
1. Address space :- An address used by a programmer
2. memory space :- An address in main memory.

The address space is allowed to be larger than the memory space in computers with virtual memory.

In a Multiprogram computer system, programs and data are transferred to and from auxiliary memory and main memory based on demands imposed by the CPU.



(Relation between address and memory space)



(Memory table for mapping a virtual address)

Address Mapping

In the mapping the address space and the memory space are divided into groups of fixed size. ~~are~~ called page and blocks respectivelly.

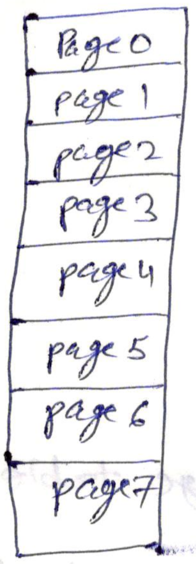
Considering a computer with

An address space = 8K

and a memory space = 4K

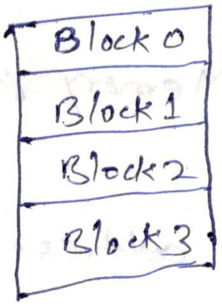
if we split each into groups of 1K words

We obtain 8 pages and 4 blocks



Address space

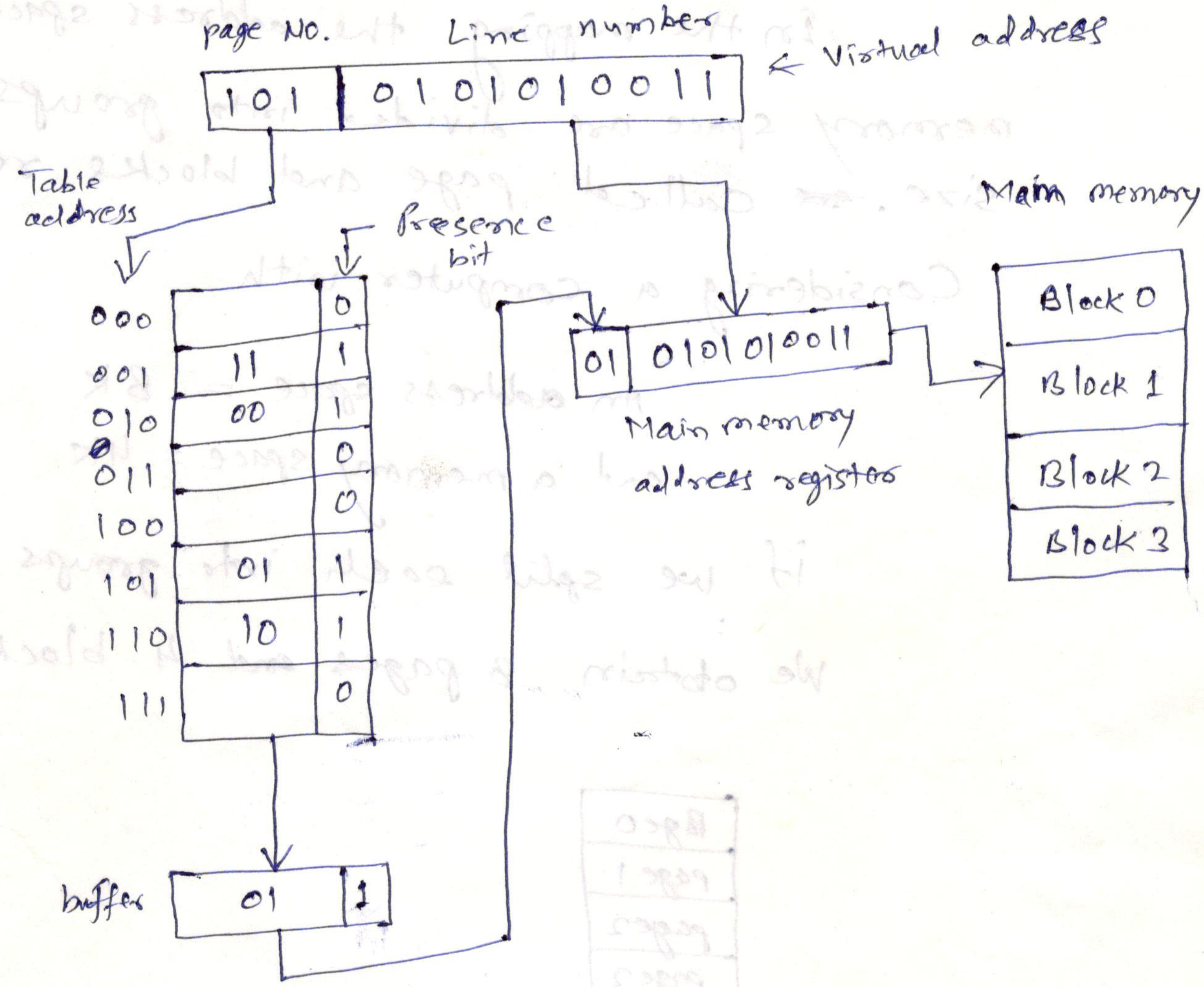
$N = 8K = 2^{13}$



Memory space

$M = 4K = 2^{12}$

- The virtual address (address space) dividedend in two numbers ① page number ② line number



Memory page table

→ The address in the page table denotes the page number and the content of the word gives the block number where that page is stored in main memory

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