CME 2003 Digital Logic

MEMORY

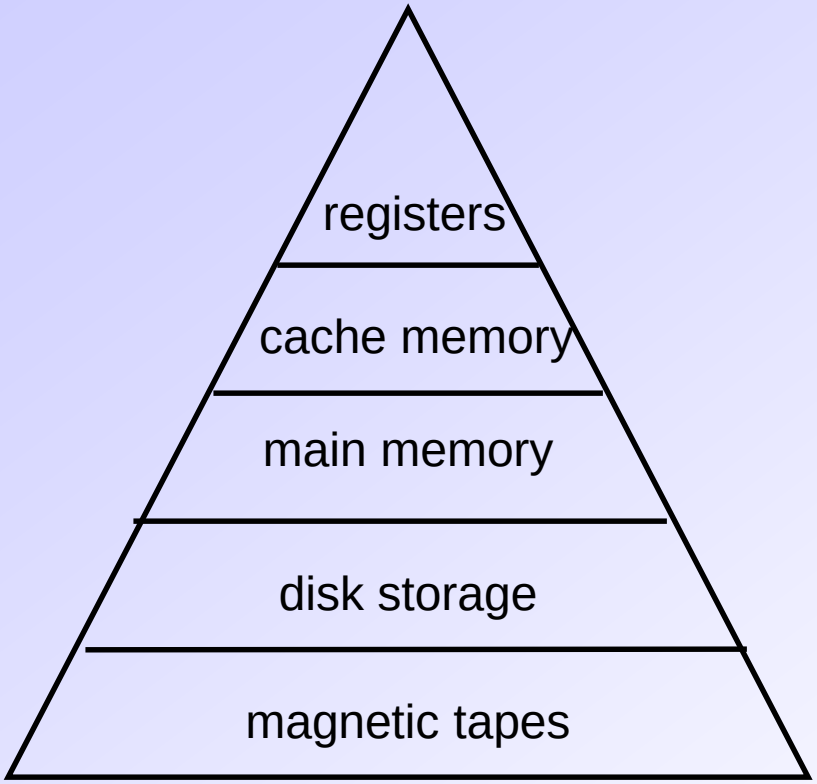
Lecture 8 Memory

- Basics
- Memory Hierarchy
- Data Transfer
- Memory Unit
- Read/Write Operations
- Memory Cell
- Memory Array

Basics

- Memory stores programs and data.
- Definitions:
  - 1 byte = 8 bits
  - 1 word: in multiple of bytes; a unit of transfer between main memory and registers, usually size of register.
  - 1 KB (kilo-bytes) = 2^{10} bytes; 1 MB (mega-bytes) = 2^{20} bytes; 1 GB (giga-bytes) = 2^{30} bytes; 1TB (tera-bytes) = 2^{40} bytes.
- Desirable properties: fast access, large capacity, economical cost, non-volatile.
- However, most memory devices do not possess all these properties.

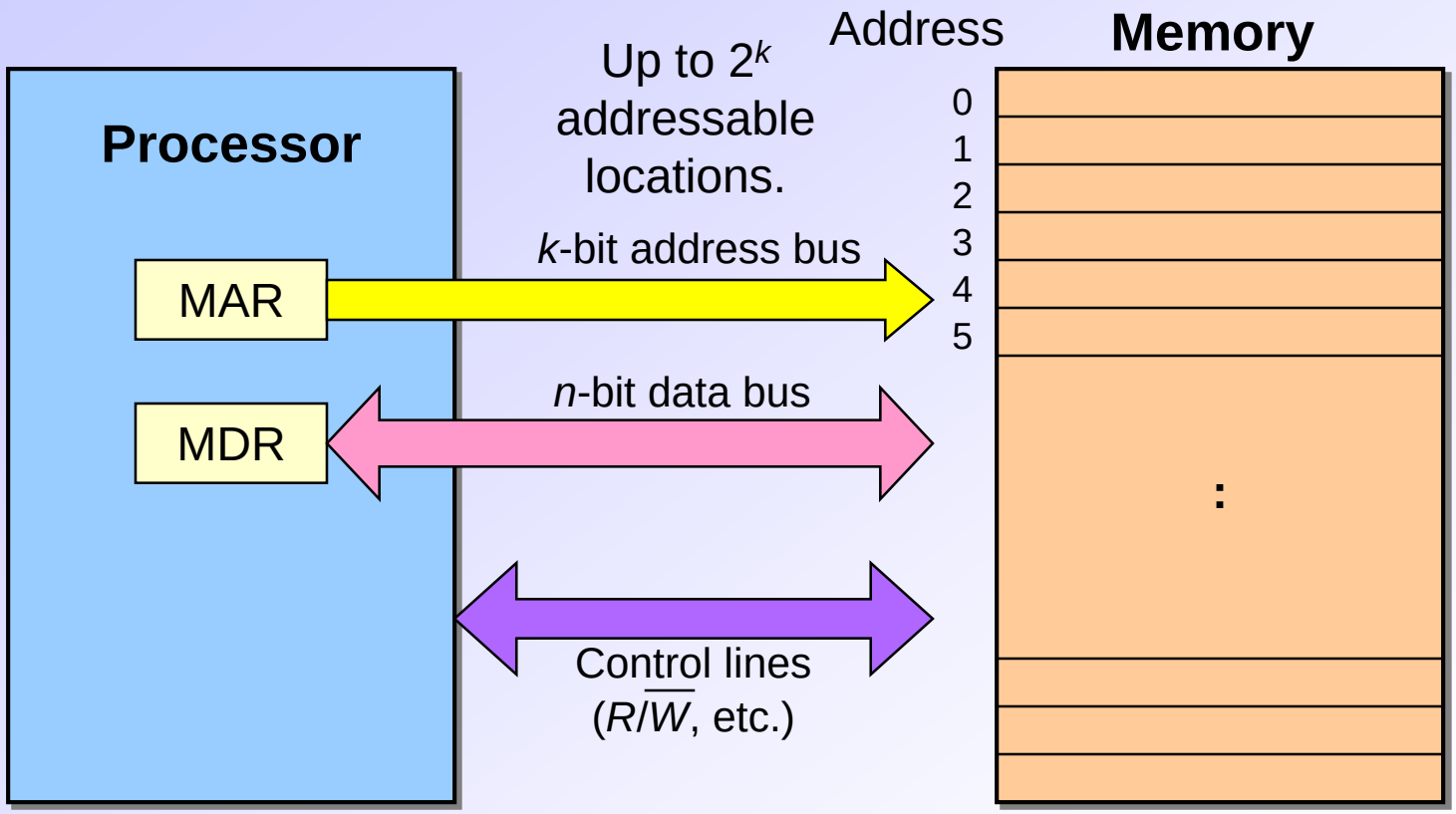
Memory Hierarchy



Fast, expensive
(small numbers),
volatile

Slow, cheap
(large numbers),
non-volatile

Data Transfer (1/2)

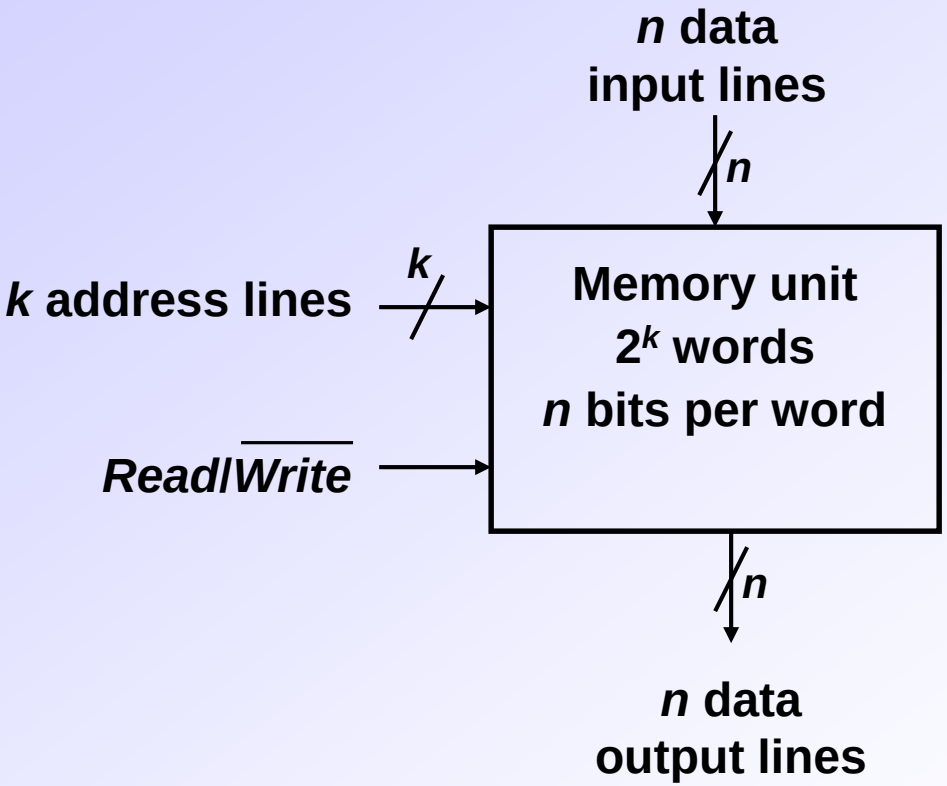


Data Transfer (2/2)

- A memory unit stores binary information in groups of bits called *words*.
- The data consists of *n* lines (for *n*-bit words). Data input lines provide the information to be stored (*written*) into the memory, while data output lines carry the information out (*read*) from the memory.
- The address consists of *k* lines which specify which word (among the 2^k words available) to be selected for reading or writing.
- The control lines *Read* and $\overline{Write}$ (usually combined into a single control line *Read*/$\overline{Write}$) specifies the direction of transfer of the data.

Memory Unit

- Block diagram of a memory unit:



Read/Write Operations (1/2)

- The Write operation:
  - Transfers the address of the desired word to the address lines.
  - Transfers the data bits (the word) to be stored in memory to the data input lines.
  - Activates the *Write* control line (set *Read*/$\overline{\textit{Write}}$ to 0).
- The Read operation:
  - Transfers the address of the desired word to the address lines.
  - Activates the *Read* control line (set *Read*/$\overline{\textit{Write}}$ to 1).

Read/Write Operations (2/2)

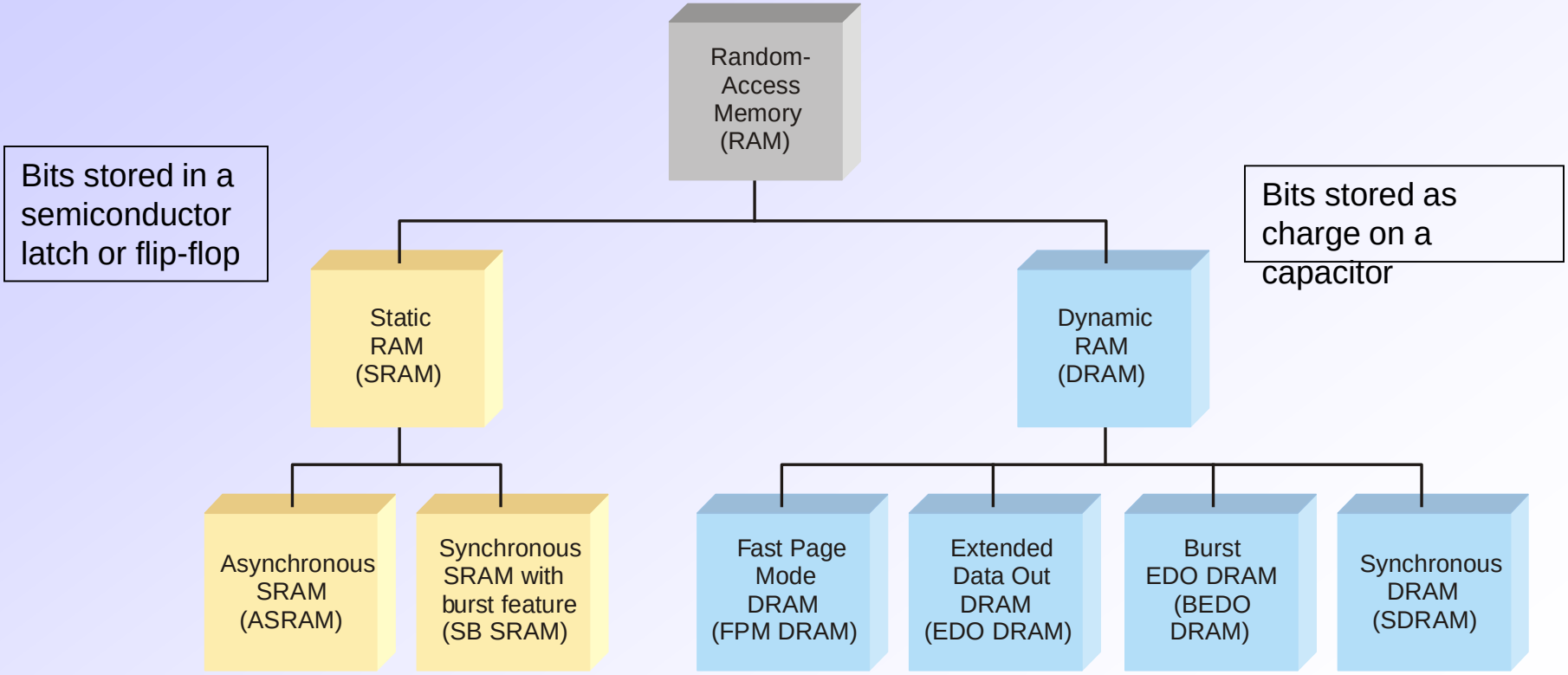
- The *Read*/$\overline{\textit{Write}}$ operation:

Memory Enable	*Read*/$\overline{\textit{Write}}$	Memory Operation
0	X	None
1	0	Write to selected word
1	1	Read from selected word

- Two types of RAM: Static and dynamic.
  - Static RAMs use flip-flops as the memory cells.
  - Dynamic RAMs use capacitor charges to represent data. Though simpler in circuitry, they have to be constantly refreshed.

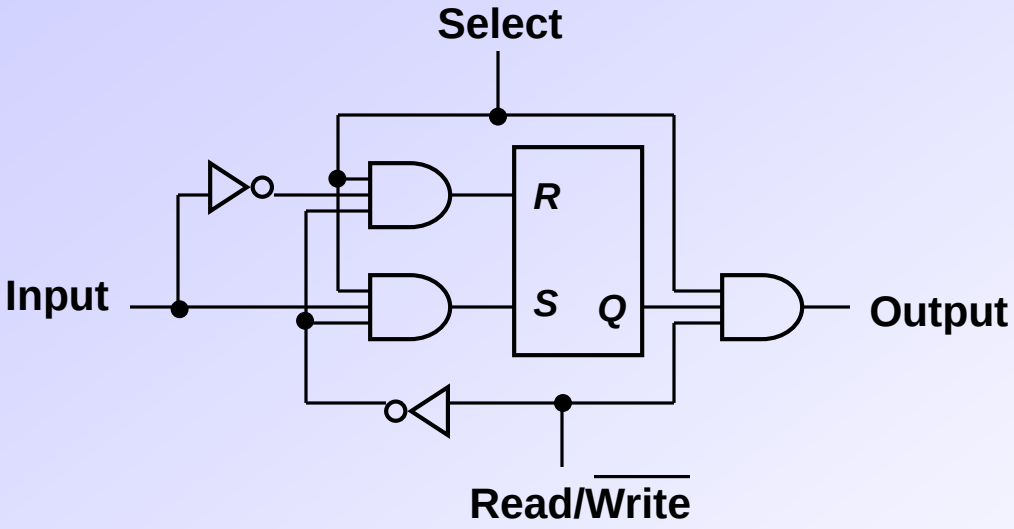
Random Access Memory

RAM is for temporary data storage. It is read/write memory and can store data only when power is applied, hence it is *volatile*. Two categories are static RAM (SRAM) and dynamic RAM (DRAM).

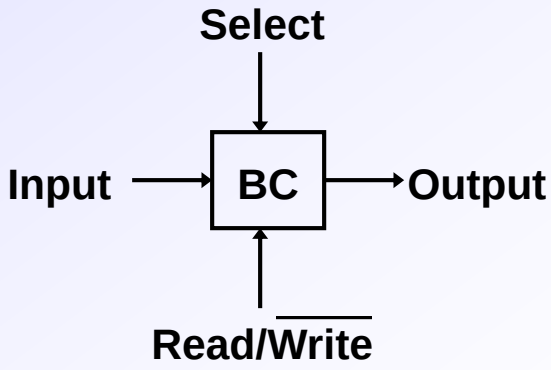


Memory Cell

- A single memory cell of the static RAM has the following logic and block diagrams:



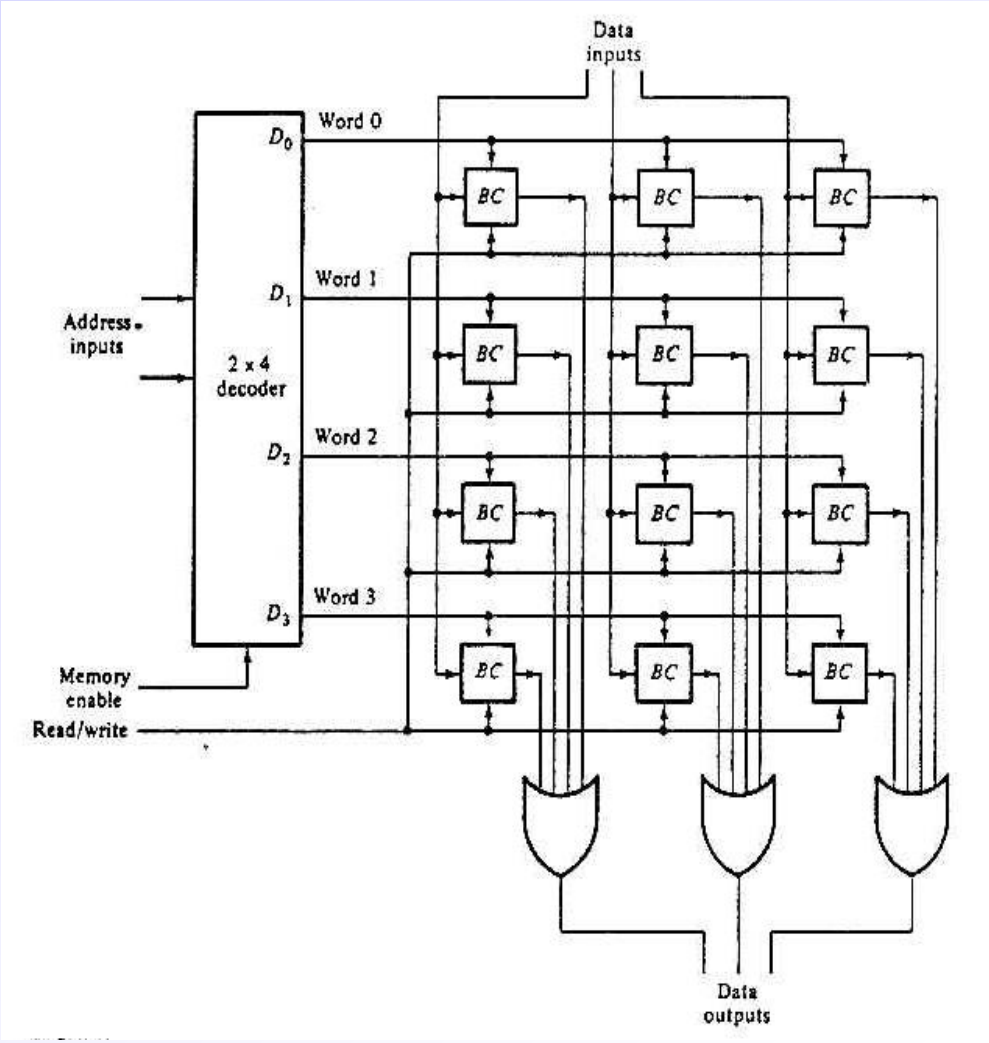
Logic diagram



Block diagram

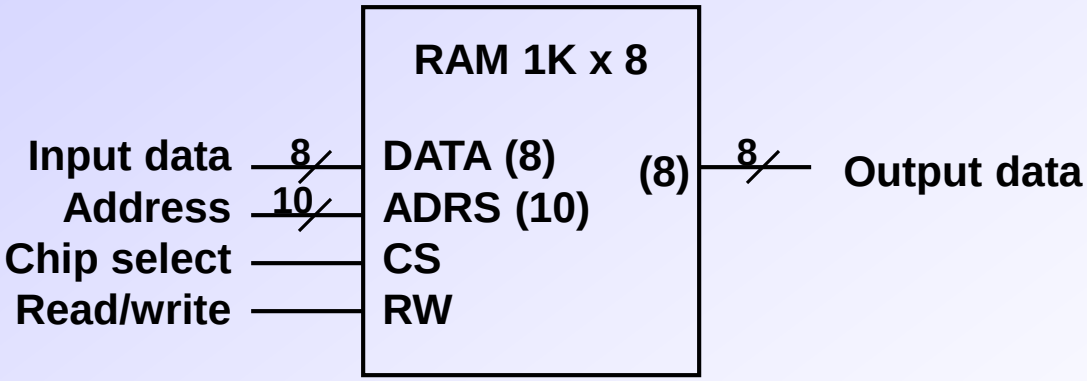
Memory Array (1/4)

- Logic construction of a **4 x 3 RAM** (with decoder and OR gates):



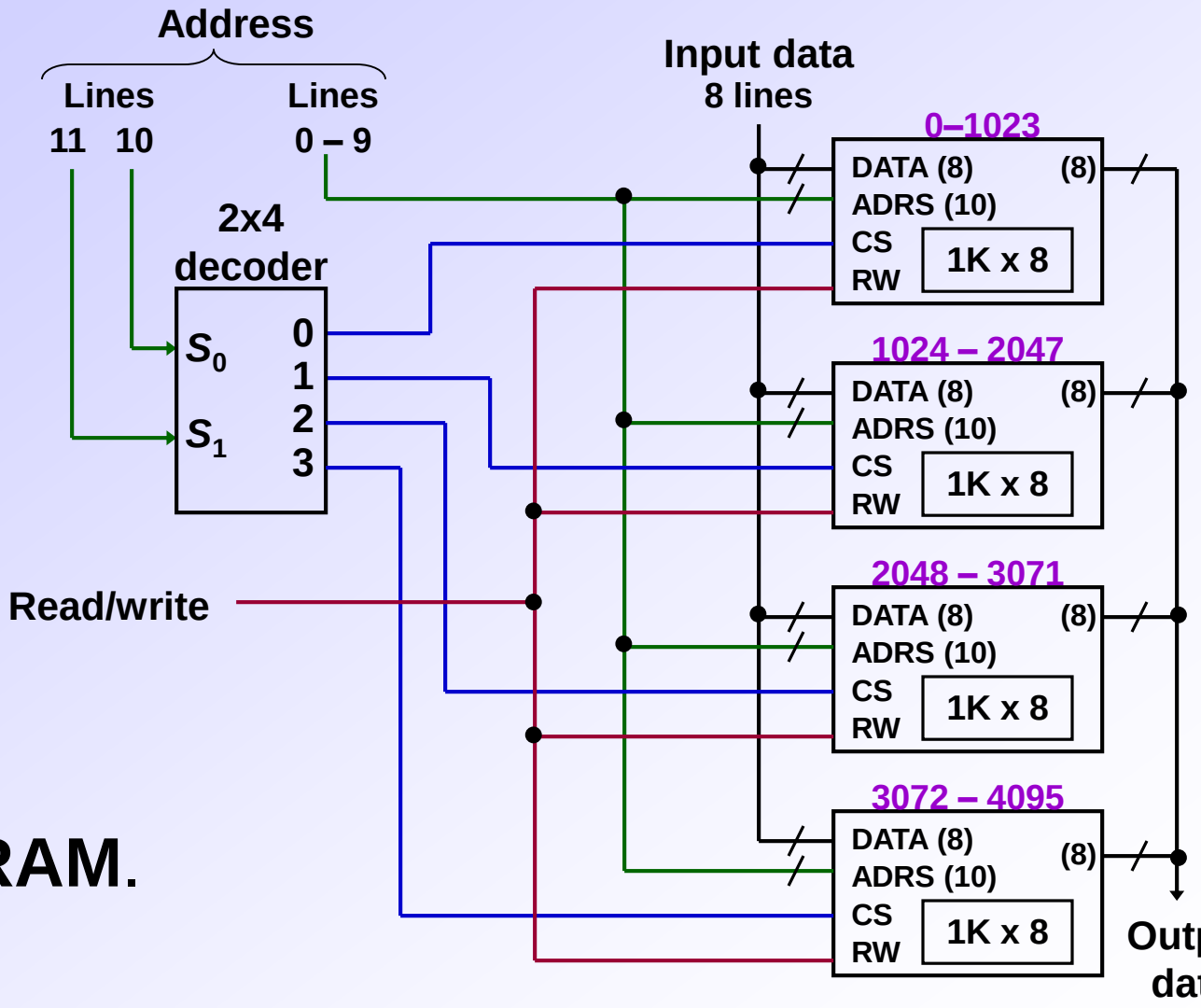
Memory Array (2/4)

- An array of RAM chips: memory chips are combined to form larger memory.
- A **1K x 8-bit** RAM chip:



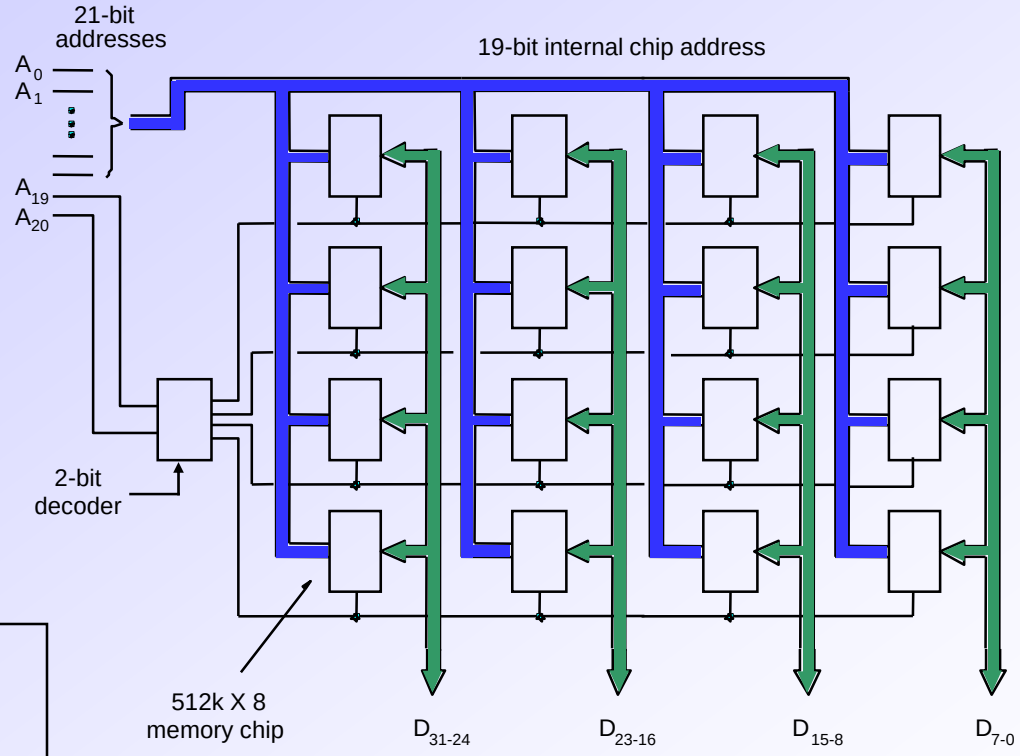
Block diagram of a 1K x 8 RAM chip

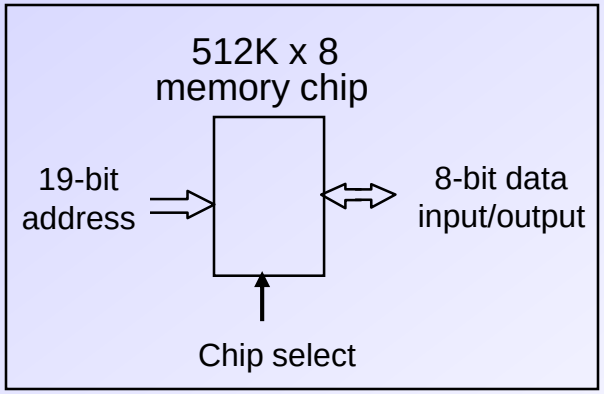
Memory Array (3/4)



- 4K x 8 RAM.

Memory Array (4/4)

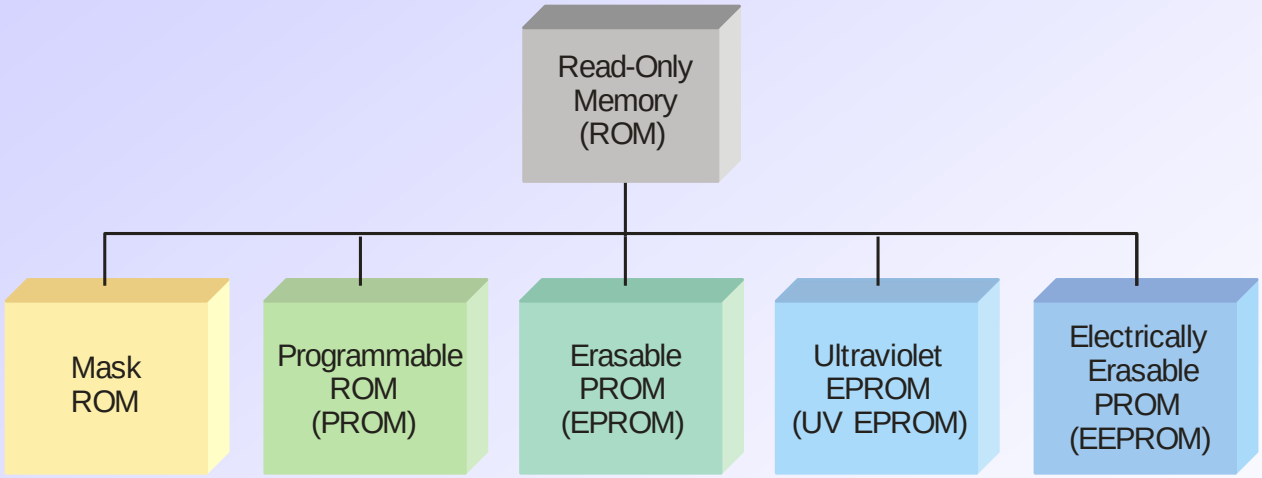




Another example:
Organization of a **2M** × **32** memory module using 512K × 8 static memory chips.

Read-Only Memory

The ROM family is all considered non-volatile, because it retains data with power removed. It includes various members that can be either permanent memory or erasable.

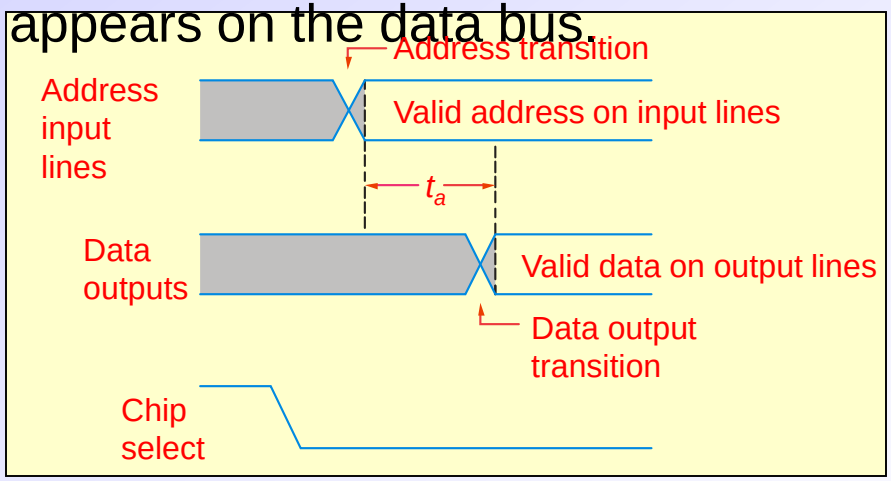


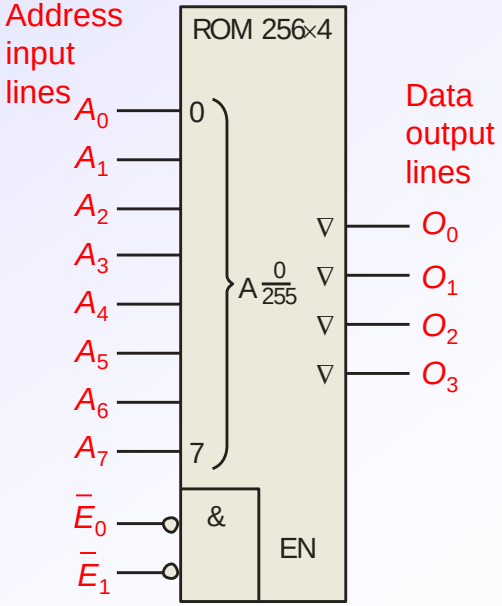
ROMs are used to store data that is never (or rarely) changed such as system initialization files. ROMs are *non-volatile*, meaning they retain the data when power is removed, although some ROMs can be reprogrammed using specialized equipment.

Read-Only Memory

A ROM symbol is shown with typical inputs and outputs. The triangles on the outputs indicate it is a tri-stated device.

To read a value from the ROM, an address is placed on the address bus, the chip is enabled, and a short time later (called the access time), data appears on the data bus.

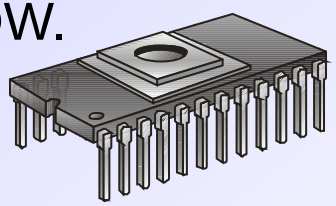




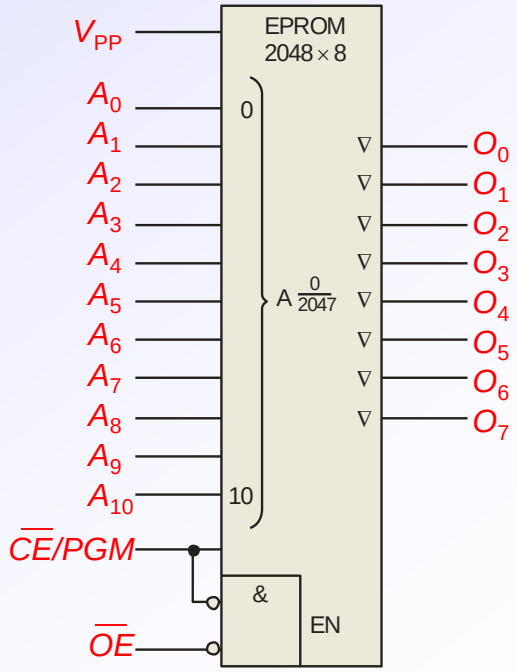
PROMs, EPROMs, EEPROMs

PROMs are programmable ROM, in which a fused link is burned open during the programming process. Once the PROM is programmed, it cannot be reversed.

An EPROM is an erasable PROM and can be erased by exposure to UV light through a window. To program it, a high voltage is applied to V_{PP} and OE is brought LOW.



Another type of erasable PROM is the EEPROM, which can be erased and programmed with electrical pulses.



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