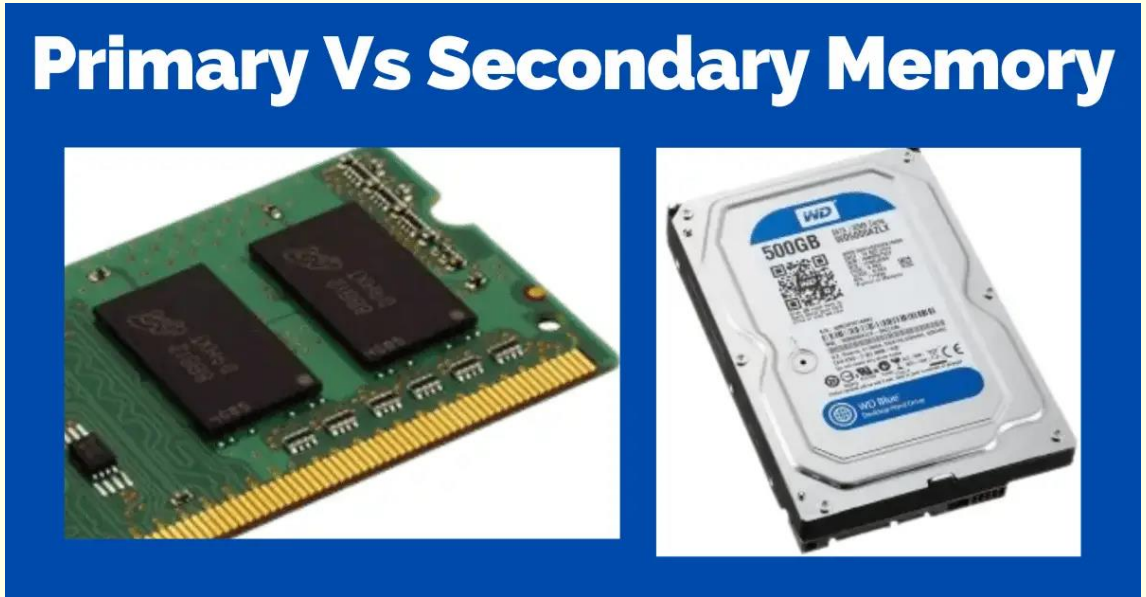
COMPUTER MEMORY

Learning Objectives

- ✓Know the difference between primary and secondary and volatile and non-volatile storage
  - RAM is primary storage. It is volatile so only retains its contents when there is a connected power supply
  - A hard disk is secondary storage. It is non-volatile so retains its contents even if there is no connected power supply
- ✓Explain the relationship between the width of the address bus and the number of memory locations that can be addressed.
  - Each unique address identifies one memory location.
  - The more 'bandwidth' that is available in the address bus, the more uniquely identifiable memory locations there are
- ✓Calculate the number of addressable memory locations provided by an address bus of a specified width.
  - Use 2^n to calculate the number of unique binary patterns that can be produced by *n* bits.

Memory (RAM)

- Random Access Memory (RAM) is **volatile memory** – this means that its contents are erased when its power supply is turned off.
- RAM is often referred to as '**primary storage**', as it sits close to the CPU and instructions are sent to RAM before being processed by the CPU
- However, it isn't possible to keep a computer on permanently. So it is necessary to have somewhere to store the programs and data (that make a computer general purpose) when the power is switched off.
- The **non-volatile storage** required for this job is most often a hard disk.
- Hard disks are often referred to as 'secondary storage', to make them distinct from 'primary storage'.



Main memory Instructions and data

- Instructions and data are stored in RAM until they are needed by the CPU.
- Each instruction and item of data is stored in a location in memory.
- Each element of the memory has a unique address.
- This means that each instruction has an address.

Address	Data
0001	LOAD 0101
0010	ADD 0110
0011	STORE 0111
0100	STOP
0101	23
0110	12
0111	

Opcode and operand

The instruction is split into an **Opcode** and an **Operand**

Opcode is which operation to carry out. A processor has an instruction set.

The **operand** specifies the data that needs to be acted on.
For example: ADD 5

Address	Data
0001	LOAD 0101
0010	ADD 0110
0011	STORE 0111
0100	STOP
0101	23
0110	12
0111	

Storing instructions/ data/memory addresses

Instruction Set

INP
OUT
LOAD
ADD
COMPARE
JUMP IF
JUMP

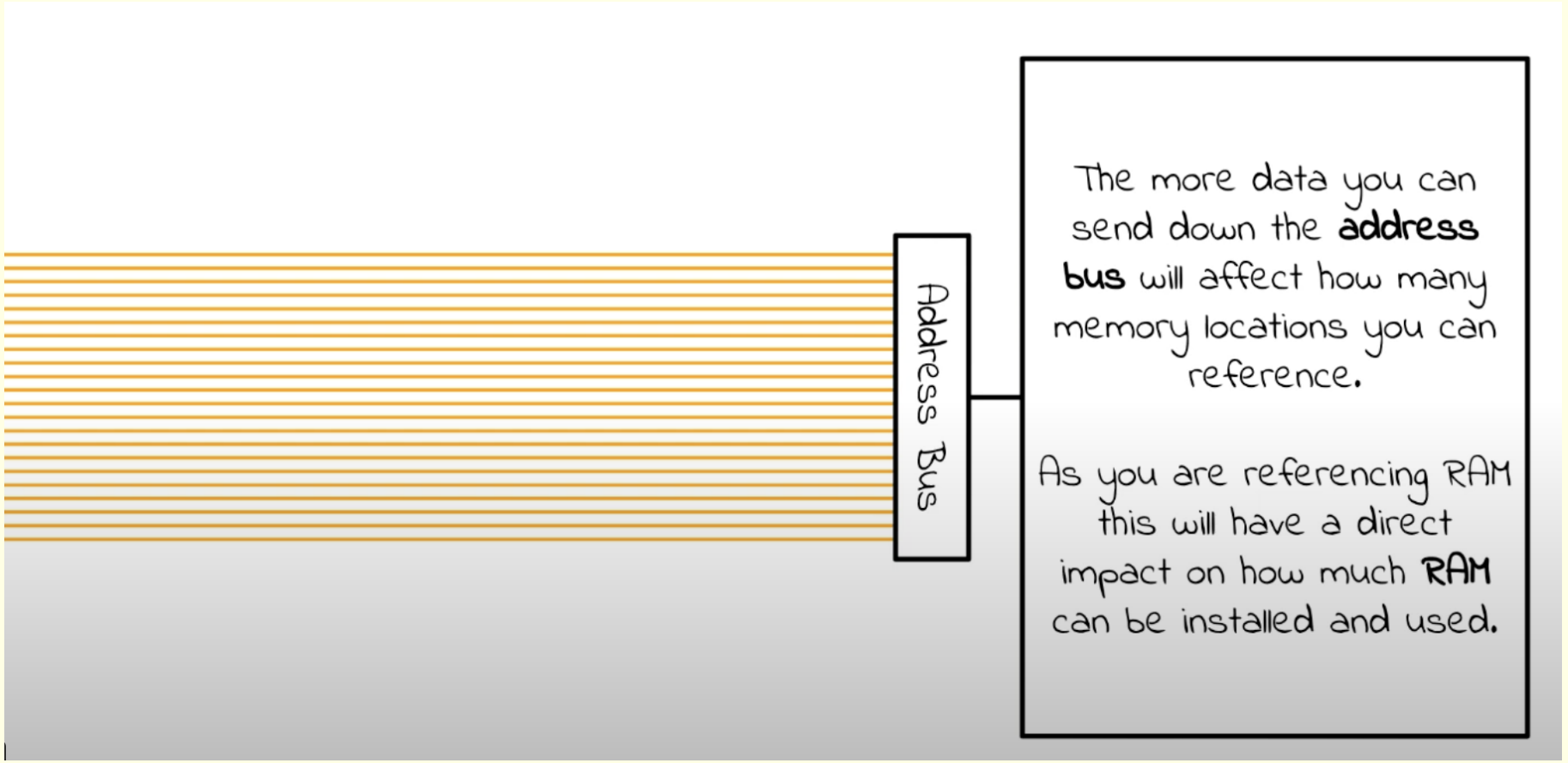
Memory Addresses

Recap Buses

Data bus	Carries instructions from RAM that is being transferred to the CPU. Carries instructions from CPU to RAM. Bidirectional
Control bus	Carries signals that control the CPU components. For example a signal to start reading the next instruction from RAM Bidirectional
Address bus	Carries the address of a memory location – for example the address of an instruction being fetched from memory. unidirectional

Address Bus Width

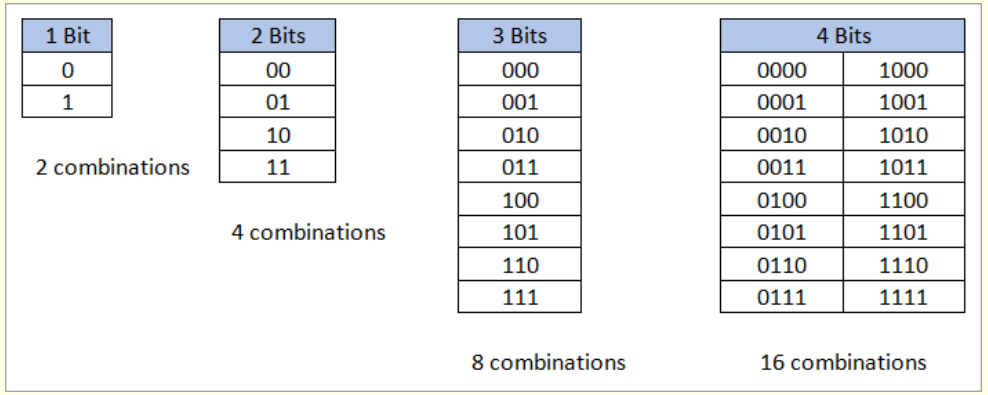
Address Bus Width refers to the number of unique memory addresses that can be accessed.



Calculating the maximum number of memory addresses

Formula finding the **maximum number of memory addresses**:

$$2^n$$



1 Bit
0
1

2 combinations

2 Bits
00
01
10
11

4 combinations

3 Bits
000
001
010
011
100
101
110
111

8 combinations

4 Bits	
0000	1000
0001	1001
0010	1010
0011	1011
0100	1100
0101	1101
0110	1110
0111	1111

16 combinations

Worked Example:

Consider a CPU with a 4-bit bandwidth (address bus). How many unique memory addresses can it access?

4-bit addresses range from 0000 to 1111 inclusive.

1111 in denary is 15 (plus 1 because we must include 0)

which gives 16 addresses

16 addresses is 2^4.

Learning Objectives

01

Identify the need for and purpose of secondary storage

02

Know the difference between magnetic, solid state and optical storage

03

Describe the advantages and disadvantages of different types of storage:

Capacity

Cost

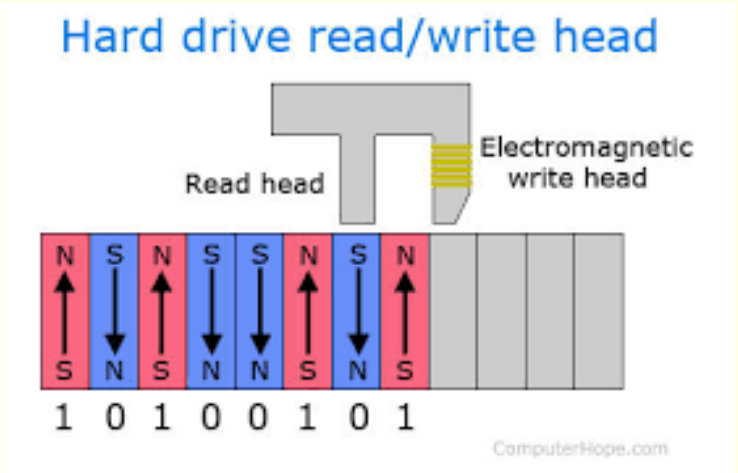
- Durability
- Reliability
- Portability
- Speed

Magnetic

- Devices such as hard disk drives use **magnetic coating on the surface of the media**
- The magnetic **state/polarity** can be changed to represents a **binary** '1' or '0'.
- These sections are so tiny that disks can contain **terabytes (TB)** of **data**.
- As the disk is spinning, a **read/write head** moves across the **platters**
- To **write data**, the head magnetises or demagnetises a section of the disk that is spinning under it.
- To **read data**, the head makes a note of whether the section is magnetised or not.

Examples:

- hard disk drive
- Tape drive.



Summary

Magnetic	Solid State	Optical
• **magnetic coating on the surface of the media** • **binary** '1' or '0' is represented by a magnetic **state** • As the disk is spinning, a **read/write head** moves across the **platters** • To **write data**, the head magnetises or demagnetises a section of the disk that is spinning under it. • To **read data**, the head makes a note of whether the section is magnetised or not.	SSDs use electrical circuits to store data If there are electrons stored in the memory cell(charge trap flash)represent a 1 and no electrons represent 0	Optical storage consists of 'marks' arranged in patterns. When writing to optical media the laser burns '**pits**' into the shiny surface (**land**). When reading optical media a light (**laser**) is shined on its surface. When it hits land the beam reflects (0) but when it hits the pits, it doesn't (1).

Magnetic - Pros and Cons

+They are a fairly cheap storage technology and can provide high storage capacities.

-Due to moving parts, they can damage easily if knocked.

-Furthermore, if a magnetic storage device comes in contact with strong magnets, the magnets can affect the device's magnetisable material, altering the data being stored, leading to data corruption.

Magnetic tape

- Used to backup or archive data
- **Backup** = second copy of data
  - in case original is lost
- **Archive** = data not in regular use
  - but may be needed again
- Suitable for backups and archives because:
  - can store **large volumes** of data (typically several terabytes)
  - **cheap** compared with hard disk drives
  - **portable** due to small size and light weight
- Slow to access data
  - **not** suitable for data in regular use
  - BUT not a problem for backups being made **overnight**

Solid State Storage (Flash)

Often referred to as **flash memory**

Includes:

- solid state drive (SSD)
- USB memory stick
- Memory card

SSDs use electrical circuits to store data
If there are electrons stored in the 'charge trap flash' aka **transistor** in the memory cell represent a 1 and no electrons represent 0

Solid state drive - SSD

Advantages over a HDD:

- SSDs have no moving parts
  - less likely to suffer damage
- SSDs are silent
- SSDs have faster access
- SSDs are physically smaller
- SSDs use less power

Disadvantages over a HDD

- SSDs are more expensive
- SSDs have smaller capacities

Why use solid state in a smartphone?

Solid state devices require little power, making them ideal for portable devices where battery life is a big consideration. They are also **portable** due to their small size and no moving parts so less likey to suffer damage.

Optical Storage

Optical storage consists of ‘marks’ arranged in patterns.

When writing to optical media the laser burns ‘**pits**’ into the shiny surface (land).

When reading optical media a light (**laser**) is shined on its surface.

When it hits land the beam reflects (0) but when it hits the pits, it doesn’t (1).

- This storage technology is **not very durable** as scratches on the surface of the disc can lead to data corruption.
+ However, a benefit is that the media itself is very **portable and cheap**.

Comparison Summary

	Advantages	Disadvantages
Magnetic (Internal/ External hard drives)	Large capacity Relatively cheap per GB Relatively Fast Access to retrieve data Fairly Reliable – data is not easily lost and be accessed many times	Moving parts so not portable Data loss if dropped, extreme heat and magnets
Solid State (USB memory sticks/ SD cards/ Solid state drives)	Portability – SSDs can be made smaller than HDDs and can be lighter in weight. Durability – SSDs have no moving parts, HDDs are more fragile. SSDs are typically lower-powered, make less heat and make no noise. [4] Speed: Quick access/ fast transfer of data/ Fast read-write Highly reliable: flash media is highly reliable (not affected by extreme temperatures or magnets)	Capacity - Currently quite expensive so smaller capacity Cost – solid-state drives cost more per GB Durability issue: solid-state drives have a limited amount of read/writes – if lots of file transferral occurs then they might start to fail.
Optical (CD/DVD)	Cheap Convenient to carry Universally readable by most computers	Durability issue – can be scratched and corrupt data Speed– slow to transfer data to it Not very reliable – needs protecting from extreme heat

Must know for the exam

Exam tip:

if choosing a suitable device in an exam, always say whether it is external or internal

e.g. an external hard drive would be suitable for transporting data from one place to another, but an internal hard drive would not be

Capacity

Until recently, standard decimal prefixes – kilo, mega, giga, etc. – have been used to represent binary multiples. This has caused some confusion.

To address this, the International Electrotechnical Commission (IEC) has produced a set of binary prefixes to represent binary multiples.

These are the units of measurement you are expected to use for data storage and memory capacity.

Unit	Abbreviation	Bytes	Equivalent to
bit			1 bit
nibble			4 bits
byte		2^0 bytes	8 bits or 2 nibbles
kibibyte	KiB	2^{10} bytes	1024 bytes
mebibyte	MiB	2^{20} bytes	1024 kibibytes
gibibyte	GiB	2^{30} bytes	1024 mebibytes
tebibyte	TiB	2^{40} bytes	1024 gibibytes

Binary multiples

Conversion between the units is straightforward.

Example:
A hard disk has a storage capacity of 1.5 TiB
Express this in:

- gibibytes, mebibytes & kibibytes

1TiB = 1024 GiB, so 1.5TiB = 1024 * 1.5 GiB

1GiB = 1024 MiB, so 1.5TiB = 1024 * 1024 * 1.5 MiB

1MiB = 1024 KiB, so 1.5 TiB = 1024 * 1024 * 1024 * 1.5 KiB

Exam note:

You are **not** allowed a calculator in the exam.

This means you are not expected to actually calculate the answers to questions like this.

Instead you should construct an **expression** to show **how** the answer would be calculated.