National 5
Computing Science

Systems

Pupil Notes

Contents

Data Representation

Why Binary?

Binary only uses 2 digits, 1 and 0 to represent all values

A computer is a **two state machine**. It uses two states (**on and off**) to represent **all** data.

The *binary system* is perfect for this as we can use a **1 for on** and **0 for off**.

Units of Storage

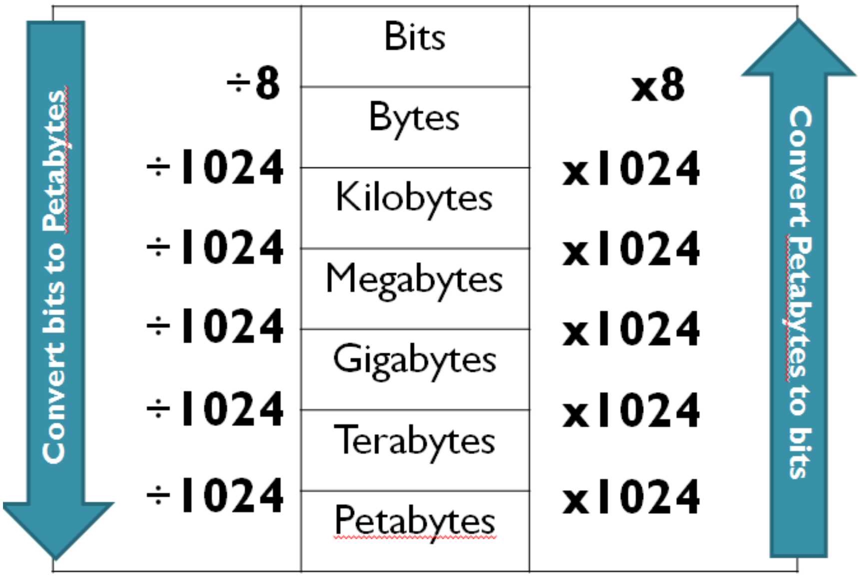
Bit stands for **Binary Digit.** A bit is the smallest unit of data in a computer.

8 bits	**1 Byte**
1024 bytes	**1 Kilobyte (KB)**
1024 kilobytes	**1 Megabyte (MB)**
1024 Megabytes	**1 Gigabyte (GB)**
1024 Gigabytes	**1 Terabyte (TB)**
1024 Terabytes	**1 Petabyte (PB)**

Converting between units

To convert a small unit to large unit – **Divide**

To convert a large unit to a small unit - **Multiply**



Storing Integers

Using several bits together allows the computer to represent any number.

Decimal (base 10)

1000	100	10	1
2	**3**	**2**	**5**

2 x 1000
3 x 100
2 x 10
5 x 1

= 2325

Binary (base 2)

8	4	2	1
1	**1**	**1**	**0**

1 x 8
1 x 4
1 x 2
0 x 1

= 14

-

Example

Convert the following binary number to decimal:

1 0 1 0 0 1 0 1

Insert the column headings starting with **1** on the **far right**. As you move along the columns, the heading doubles each time.

128	64	32	16	8	4	2	1
1	0	1	0	0	1	0	1

Now simply add together the column headings that have a 1 beneath them

128	64	32	16	8	4	2	1
1	0	1	0	0	1	0	1

128 + 0 + 32 + 0 + 0 + 4 + 0 + 1

= 165

Example

Convert the following decimal number to binary:

239

Write down the column headings starting with 1 on the far right. As you move along the columns, the heading doubles each time

128 64 32 16 8 4 2 1

Start on the left. Each time you can use a column put a **1** beneath it. If the column is too big, put a **0**.

128	64	32	16	8	4	2	1
1	1	1	0	1	1	1	1

239 – 128 = 111
111 – 64 = 47
47 – 32 = 15
15 is less than 16

15 – 8 = 7
7 – 4 = 3
3 – 2 = 1
1 – 1 = 0

Reading Review 1

Having read pages 4 – 7, answer the questions below in preparation.

1. Convert the following whole numbers into an 8 bit binary number.

a) 25

b) 119

c) 201

d) 74

2. Convert the following binary numbers into a whole number.

a) 00110011

b) 01101100

c) 10101111

d) 110011

Storing Real Numbers

Numbers with a decimal point are known as **real** numbers.

15.215 is an example of a real number.

In computers, real numbers are represented by storing two parts of the number:

- **Mantissa**
- **Exponent**

In the decimal system:

The main number is the **MANTISSA**

The positions moved is the **EXPONENT**

20.125 is the same as saying .20125 X 10^2

10 is the **BASE**

The decimal point is fixed and the numbers have moved **two places to the right**.

In the binary system:

10100.001 can be stored as:

Binary point has floated **5** places so **101** is the **EXPONENT**

.10100001 X 2^{101}

10100001 is the **MANTISSA**

Since the **BASE** is always 2, the computer only has to store the **MANTISSA** and **EXPONENT**

Storing Characters

Computers can only store data using binary numbers.

Each character has to be given a code number to allow it to be represented in binary.

Example:

A = **65** 01000001

B = **66** 01000010

C = **67** 01000011

This code is known as **ASCII** (America Standard Code for Information Interchange)

ASCII

ASCII uses **7 bits** to represent each character giving a total of **128** different characters. However, each ASCII character is made up for **8 bits** but only uses 7 bits to represent the character and 1 bit for error checking during transmission.

Dec	Hx	Oct	Char	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr	Dec	Hx	Oct	Html	Chr
0	0	000	NUL (null)	32	20	040		Space	64	40	100	@	@	96	60	140	`	`
1	1	001	SOH (start of heading)	33	21	041	!	!	65	41	101	A	A	97	61	141	a	a
2	2	002	STX (start of text)	34	22	042	"	"	66	42	102	B	B	98	62	142	b	b
3	3	003	ETX (end of text)	35	23	043	#	#	67	43	103	C	C	99	63	143	c	c
4	4	004	EOT (end of transmission)	36	24	044	$	$	68	44	104	D	D	100	64	144	d	d
5	5	005	ENQ (enquiry)	37	25	045	%	%	69	45	105	E	E	101	65	145	e	e
6	6	006	ACK (acknowledge)	38	26	046	&	&	70	46	106	F	F	102	66	146	f	f
7	7	007	BEL (bell)	39	27	047	'	'	71	47	107	G	G	103	67	147	g	g
8	8	010	BS (backspace)	40	28	050	(	(	72	48	110	H	H	104	68	150	h	h
9	9	011	TAB (horizontal tab)	41	29	051	)	)	73	49	111	I	I	105	69	151	i	i
10	A	012	LF (NL line feed, new line)	42	2A	052	*	*	74	4A	112	J	J	106	6A	152	j	j
11	B	013	VT (vertical tab)	43	2B	053	+	+	75	4B	113	K	K	107	6B	153	k	k
12	C	014	FF (NP form feed, new page)	44	2C	054	,	,	76	4C	114	L	L	108	6C	154	l	l
13	D	015	CR (carriage return)	45	2D	055	-	-	77	4D	115	M	M	109	6D	155	m	m
14	E	016	SO (shift out)	46	2E	056	.	.	78	4E	116	N	N	110	6E	156	n	n
15	F	017	SI (shift in)	47	2F	057	/	/	79	4F	117	O	O	111	6F	157	o	o
16	10	020	DLE (data link escape)	48	30	060	0	0	80	50	120	P	P	112	70	160	p	p
17	11	021	DC1 (device control 1)	49	31	061	1	1	81	51	121	Q	Q	113	71	161	q	q
18	12	022	DC2 (device control 2)	50	32	062	2	2	82	52	122	R	R	114	72	162	r	r
19	13	023	DC3 (device control 3)	51	33	063	3	3	83	53	123	S	S	115	73	163	s	s
20	14	024	DC4 (device control 4)	52	34	064	4	4	84	54	124	T	T	116	74	164	t	t
21	15	025	NAK (negative acknowledge)	53	35	065	5	5	85	55	125	U	U	117	75	165	u	u
22	16	026	SYN (synchronous idle)	54	36	066	6	6	86	56	126	V	V	118	76	166	v	v
23	17	027	ETB (end of trans. block)	55	37	067	7	7	87	57	127	W	W	119	77	167	w	w
24	18	030	CAN (cancel)	56	38	070	8	8	88	58	130	X	X	120	78	170	x	x
25	19	031	EM (end of medium)	57	39	071	9	9	89	59	131	Y	Y	121	79	171	y	y
26	1A	032	SUB (substitute)	58	3A	072	:	:	90	5A	132	Z	Z	122	7A	172	z	z
27	1B	033	ESC (escape)	59	3B	073	;	;	91	5B	133	[	[	123	7B	173	{	{
28	1C	034	FS (file separator)	60	3C	074	<	<	92	5C	134	\	\	124	7C	174			|
29	1D	035	GS (group separator)	61	3D	075	=	=	93	5D	135	]	]	125	7D	175	}	}
30	1E	036	RS (record separator)	62	3E	076	>	>	94	5E	136	^	^	126	7E	176	~	~
31	1F	037	US (unit separator)	63	3F	077	?	?	95	5F	137	_	_	127	7F	177	&#127;	DEL

Source: www.LookupTables.com

ASCII characters are stored in plain text files and use the **standard file format** (**.txt**)

Because ASCII (.txt) files can be opened on any computer they are portable.

Storing Graphics

Graphics can be represented in two ways:

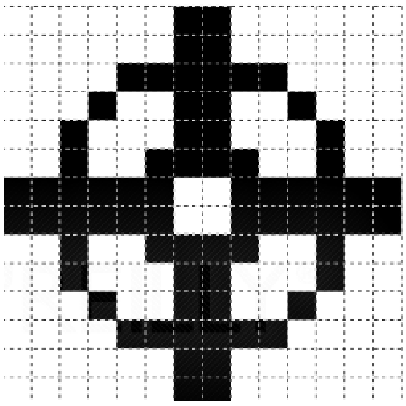
- **Bitmap**
- **Vector**

Bitmapped graphics are used to store **lifelike images** and they are created and edited in **PAINT** packages.

Vector graphics are made up of **shapes and lines** and are created and edited in **DRAW** packages.

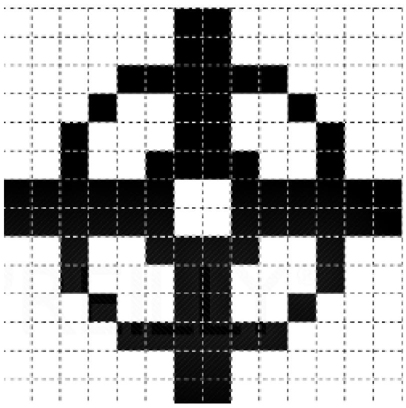
Bitmaps

Black & white **Bitmap Images** are made up of **an array of** tiny dots called **pixels** (picture elements)



Each Pixel can be set to on (black) or off (white)

Computers represent each pixel using a single binary number (bit). **1 for on** (black) and **0 for off** (white)

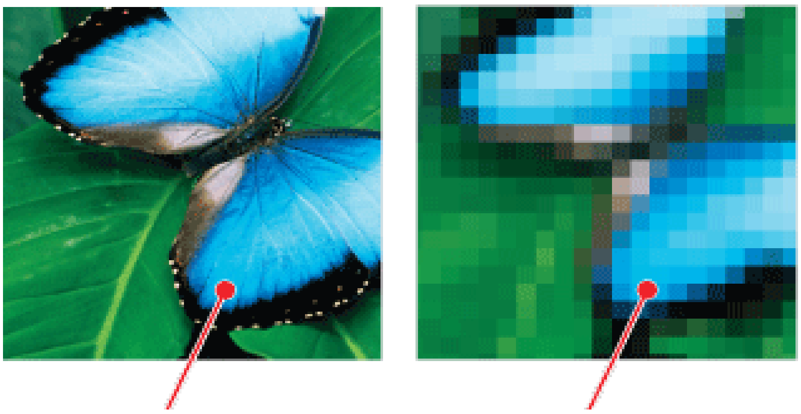


0 0 0 0 0 0 1 1 0 0 0 0 0 0
0 0 0 0 0 0 1 1 0 0 0 0 0 0
0 0 0 0 1 1 1 1 1 1 0 0 0 0
0 0 0 1 0 0 1 1 0 0 1 0 0 0
0 0 1 0 0 0 1 1 0 0 0 1 0 0
0 0 1 0 0 1 1 1 1 0 0 1 0 0
1 1 1 1 1 1 0 0 1 1 1 1 1 1
1 1 1 1 1 1 0 0 1 1 1 1 1 1
0 0 1 0 0 1 1 1 1 0 0 1 0 0
0 0 1 0 0 0 1 1 0 0 0 1 0 0
0 0 0 1 0 0 1 1 0 0 1 0 0 0
0 0 0 0 1 1 1 1 1 1 0 0 0 0
0 0 0 0 0 0 1 1 0 0 0 0 0 0
0 0 0 0 0 0 1 1 0 0 0 0 0 0

1 pixel = 1 bit

Resolution

The more pixels used to represent an image, the higher the **resolution** will be so the better the **quality** will be.

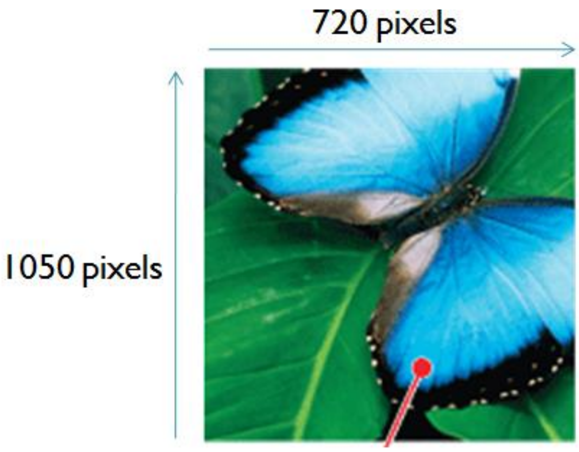


High resolution produces a clear image

Low resolution and the jagged pixels can be seen

Resolution is written using the **vertical pixels** by **horizontal pixels**. Multiplying these allows us to calculate the file size.

Example



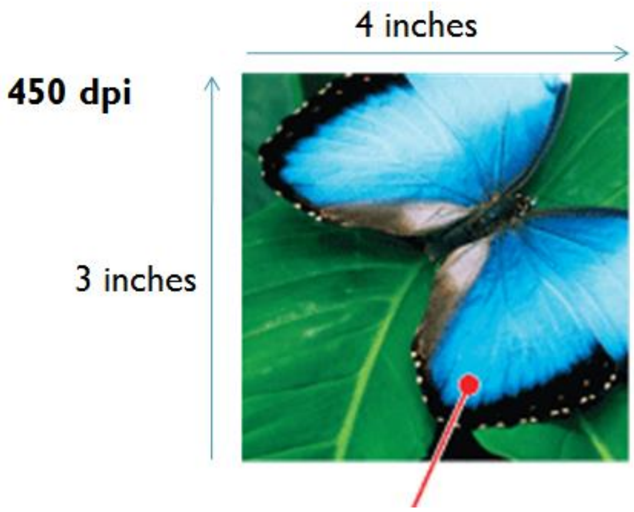
1050 x 720 = 756000 pixels = 756000 bits

756000 / 8 = 94500 Bytes

94500 / 1024 = 92.3 kilobytes

Sometimes, the image size is given in inches and we are told the number of **dots per inch** (dpi).

Example



4 x 450 = 1800   3 x 450 = 1350

1800 x 1350 = 2430000

2430000 / 8 / 1024 = 296.6 KB

Increasing number of pixels = **Increased Resolution** = **Improved Image Quality** = **Increased File Size**

Decreasing number of pixels = **Reduced Resolution** = **Reduced Image Quality** = **Decreased File Size**

Colour Depth

Colour images require extra information about each pixel to be stored. In colour images, pixels are not **on** or **off** (**1** or **0).**

Each pixel must contain details of its **colour**. The **<u>number of bits</u>** used to represent **each pixel** is called the **colour depth**.

The greater the bit depth of a pixel, the more colours it can represent.

1 bit per pixel	**=**	**2 possible colours**
8 bits per pixel	**=**	**256 possible colours**
16 bits per pixel	**=**	**65,536 possible colours**
24 bits per pixel	**=**	**16,777,216 possible colours**

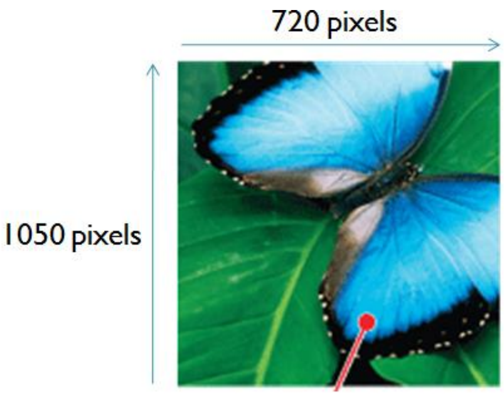
The more bits per pixel, the greater the file size will be also.

e.g.

A colour image with 8 bit colour depth will have a file size 8 times larger than a black and white image.

When calculating the file size of colour images an extra step is required to include colour depth.

Example



8 bit colour

1050 x 720 = 756000 pixels = 756000 bits

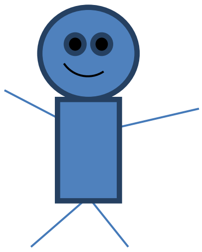
756000 **x 8** =6048000 bits

6048000 / 8 = 756000 Bytes

756000/ 1024 = 738.3 kilobytes

Vector Graphics

Vector graphics are used to draw **shapes and lines**. They **cannot** be used to represent life-like images like photographs.



Vector graphics **do not** store information about individual pixels.

Instead, **numeric definitions (instructions)** of how to create **each object** are stored in a **text file** as a list of **attributes:**

<rect x="175" y="275" width="250" height="50“ style="fill = “green” />

<ellipse rx="100" ry="50" stroke="black" stroke-width="2" fill="red"/>

<line x1="100" y1="300" x2="300" y2="100" stroke-width="250" stroke="blue“/>

<polygon fill="lime" stroke="blue" stroke-width="10" points="850,75 958,137.5 958,262.5 850,325 742,262.6 742,137.5"/>

File size is affected by the **number of objects**, not the size of them. This is because a new line of code is needed for each object. Therefore, the more objects, the larger the file size.

Common vector graphic attributes include:

Fill Colour, Line Colour, Co-ordinates, Shape, Position, Size, Rotation, Radius

Storing Instructions

Instructions are stored in binary are known as **Machine Code**

Instructions are written by humans using a **High Level Language** such as Visual Basic or Scratch.

These instructions must be translated into machine code before the computer can understand and execute them.

Reading Review 2

Having read pages 10 – 17, answer the questions below in preparation.

1. Describe how a real number is stored in a computer's memory.

____

____

____

2. How many bits would be required to represent a work with four characters in it?

____

3. Explain the difference between a bitmap and vector graphic.

____

____

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4. Explain the effect of increasing the resolution of a bit mapped image.

____

____

____

5. Explain how vector graphics are stored.

____

____

____

6. Give an example of a numeric definition used to create a blue rectangle.

____

____

Media Types

Standard File Formats

A standard file format is a type of file that can be recognised by **all computers**.

They don't need any special software in order to open them which makes them very **portable**.

Portable files can be easily transferred from one computer to another.

Text

This is a
document
about the
history of
computers

Text (txt) files store only the characters contained in the document.

Any formatting is **ignored** and not saved.

This is a *document* about the **history** of computers.

Rich Text Format (RTF) stores the characters as well as **some formatting** information.

This makes the file size of RTF larger than plain text files.

Standard File Format	Use	File Size
TXT (Text)	Plain Text Only	Very small (1 byte per character)
RTF (Rich Text Format)	Formatted Text	Larger than Txt (due to formatting)

Audio

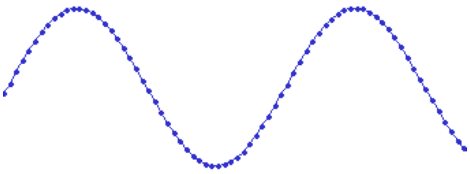
WAV is a standard for storing uncompressed sound that has been sampled by a computer. This makes wav files very large in size.

MP3 is a sound format that compresses sound files by removing parts of the sound that our ears cannot hear.

MP3 files have a much smaller file size than wav with very little reduction in sound quality

Sampling Rate

The sampling rate is **how often** a sound is "listened to", converted into digital and stored **each second**.



Each dot here represents a sample (and must be stored).

The more times per second a sound is sampled, the greater the quality will be (and the larger the file size).

Standard File Format	Use	File Size
WAV	Uncompressed Sound	Very Large (depending on sample rate)
MP3	Compressed Sound	Very Small

Increased Sample Rate = Increased File Size

Decreased Sample Rate = Decreased File Size

Compression = Reduced File Size

Video

AVI is a standard for storing video that has been captured by a computer. AVI uses little compression making file sizes very large.

MP4 is a video format that compresses video files by encoding only the **changes** between frames.

MP4 files have a much smaller file size than AVI with very little reduction in quality.

Standard File Format	Use	File Size
AVI	Video (with some compression)	Very Large
MP4	Compressed Video	Small

Greater Compression = Reduced File Size

Graphics

JPEG (Joint Photographic Experts Group)

JPEG is a graphic file format that uses **compression** to reduce file size.

JPEG compression involves removing parts of the image that our eyes normally ignore.

JPEG files have a much **smaller file size** than BMP with very little reduction in quality.

This is why JPEG files are commonly used for digital cameras, websites and when emailing images.

GIF (Graphics Interchange Format)

GIF is a graphic file format that also uses **compression** to reduce file size.

GIF images only allow 256 colours so are unsuitable for high quality photographs.

GIF images are commonly used for cartoons, logos and especially **animations.**

PNG (Portable Network Graphics)

PNG is another graphic file format that uses **compression** to reduce file size.

PNG files achieve better compression than GIF but allow many more colours so file sizes will still be larger.

PNG allows control over **transparency** in images.

Summary

Standard File Format	Use	File Size
JPEG	Compressed. High Quality Photographs	Small
GIF	Compressed. Animations, cartoons	Small
PNG	Compressed. Transparency	Small

Compression

Compression is the method of reducing the file size of any text, graphic, audio or sound files.

Compressing allows for more files to be stored on a computer/portable storage device because file sizes are reduced therefore taking up less storage space.

It also reduces the upload, download or transfer time of files as they are smaller in size.

However, compressing larger files can take time and if compression is used repeatedly on a file the quality of the file may become damaged.

Factors Affecting File Size / Quality

Resolution (graphics)

Increase = Increased quality = Increased file size

Colour Depth (graphics)

Increase = More colours = Increased file size

Sampling Rate (audio)

Increase = Increased quality = Increased file size

Compression(all)

Increase = Reduced Quality= Decreased file size

Decreasing all of the above has the opposite effect

Reading Review 3

Having read pages 20 – 25, answer the questions below in preparation.

1. Explain what a standard file format is.

____

____

____

2. Name and describe **two** text standard file formats.

____

____

____

3. Name and describe **two** video standard file formats.

____

____

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4. Name and describe **two** image standard file formats.

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5. Explain the term compression.

____

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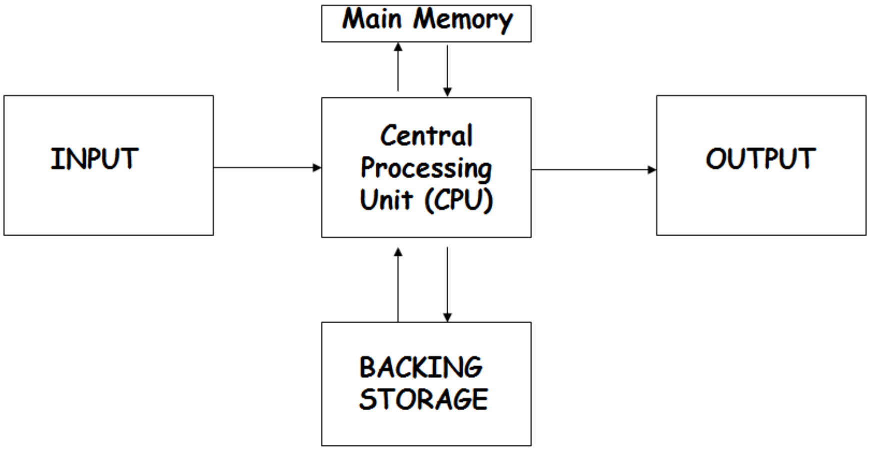
Computer Structure

Basic Computer System



The CPU

The CPU is the main component within a computer where instructions are processed and computations carried out.

CPU consists of 3 main parts:

- **Arithmetic Logic Unit (ALU)**
- **Control Unit**
- **Registers**

Arithmetic Logic Unit (ALU)

- Carries out calculations
- Performs logical operations
- Deals with comparisons

Control Unit

- Makes sure program instructions are carried out in the correct order.
- Makes sure all operations are carried out at the correct time.
- Sends out Control Signals

Registers

Small and fast, temporary storage locations within the processor.

Used to store:

- **Data** being processed
- **Instructions** to be executed
- **Addresses** to be accessed

Instructions to be executed by the CPU are held in memory (RAM). Before executing an instruction, the CPU must first **fetch** it from memory.

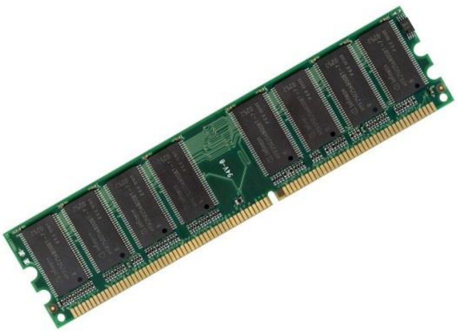
After being transferred from memory, instructions are held in registers.

Main Memory

Random Access Memory (RAM)

- RAM is used to store a program **while it is running**.

- Data and instructions in RAM are held in **storage locations**



- Each storage location has a **unique address** number to identify it.

All data in RAM is lost when the computer is switched off.

Transferring Data

Q. How does data travel around a computer system?

A. On a **Bus**

There are three main buses in a computer system:

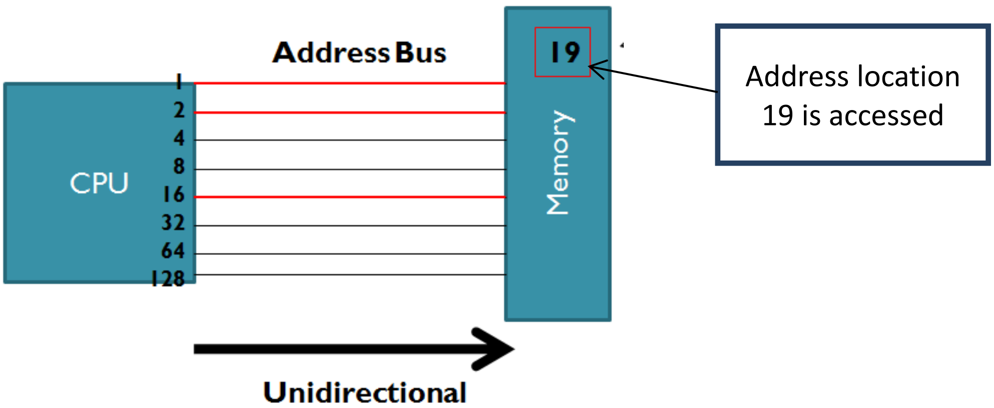
- **ADDRESS BUS**
- **DATA BUS**

Address Bus

The address bus is used to carry memory **address** information **from the CPU to main memory**.

The address bus is **unidirectional** (Addresses only travel from CPU to Memory)

The lines on the address bus work together to produce a binary number.



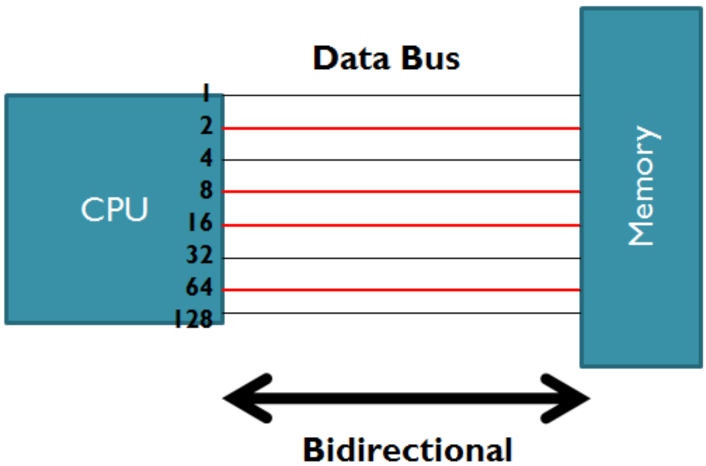
The CPU uses the address bus to **specify a location in main memory** to **read data** from or **write data** to.

Data Bus

The data bus is used to **transfer** data **to main memory from the CPU.** The data bus is also used to carry instructions and data **to the CPU from main memory.**

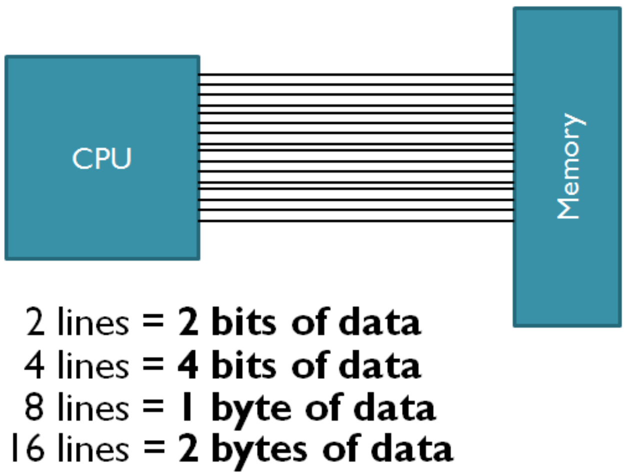
The data bus is **bidirectional** (Data travels in both directions)

The CPU uses the data bus to transfer data and instructions **to and from** memory.



The number of lines on the data bus dictates the amount of data that can be transferred at once.

This also dictates the maximum **amount of data in each storage location** in memory **(Word Size)**



Reading Review 4

Having read pages 28 – 31, answer the questions below in preparation.

1. Explain the purpose of the **ALU**.

2. Explain the purpose of the **registers**.

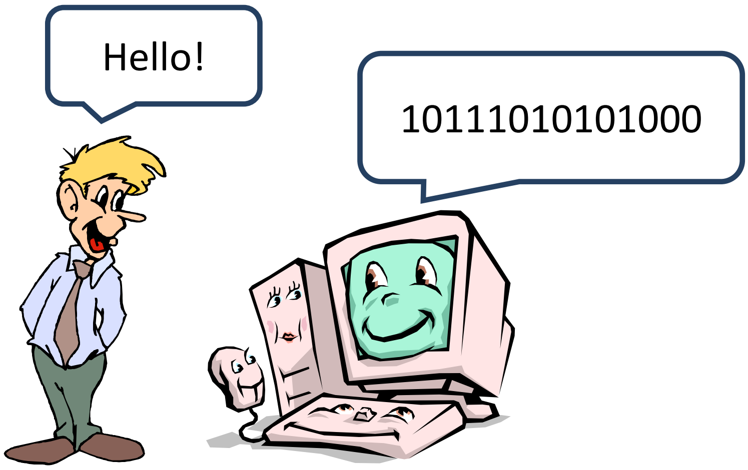
3. Explain the purpose of the **control unit**.

4. Explain the purpose of the **address bus**.

5. Explain the purpose of the **data bus**.

Translation

Translator programs are required because humans and computers speak a different language.



High level languages are written using English-like words such as **PRINT, FOR, IF, NEXT, LOOP, THEN.**

Computers only understand **machine code** (1s and 0s)

Can you imagine writing or editing the following program?

```
100010111010100010101010001010101011101010
100100010101001011101010010010101010111101
100010101010101001111111100010001010101010
```

Translator Programs

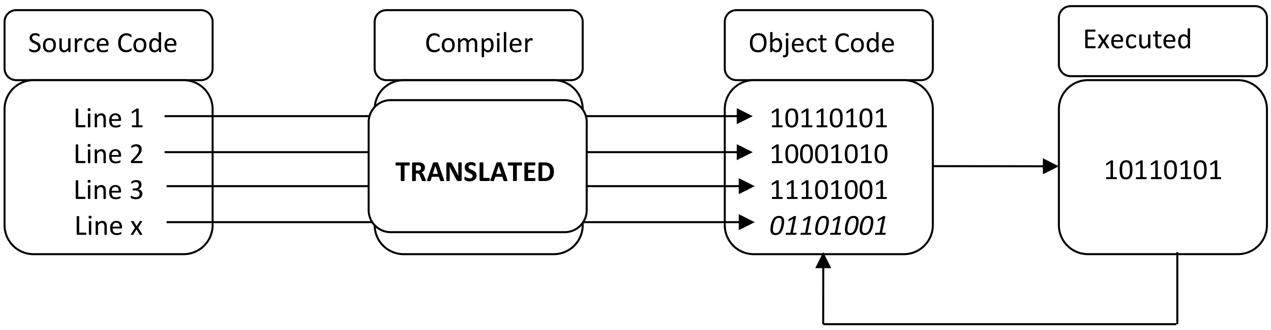
The programs that convert high level programming instructions into machine code are called **Translators**

Two types of translator program:

- **Compiler**
- **Interpreter**

Compiler

A **Compiler** translates the program (**source code)** into a machine code version (**object code**) which is stored in a executable file.



- Reads and translates each line of code in turn
- Stores translated code as object code in a separate file
- Object code is then executed one line at a time

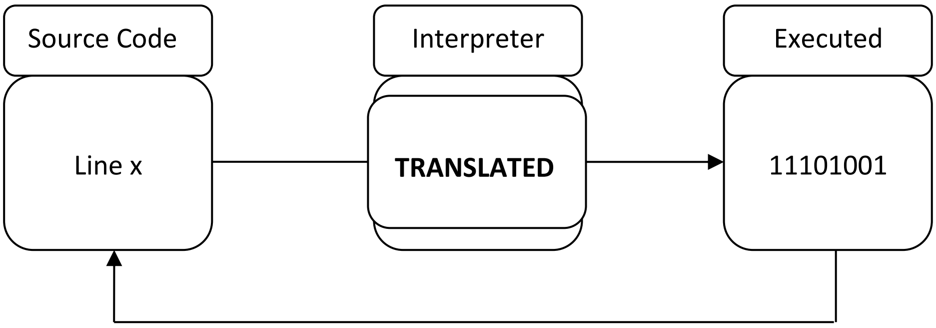
The object code can be run **without** the compiler being present because it already contains translated code.

Advantages	Disadvantages
Translator software only needed at time of compiling.	More difficult fix errors. All error messages appear at once.
Executes faster as object code has been created (not translated every time it is executed)	Slow to compile as whole program is translated at once.
Commands within a loop are translated once only improving efficiency.	

Interpreter

An **Interpreter** program translates and executes HLL code **one line at a time**.

No object code is produced so the interpreter is needed every time the program runs.



- Reads, translates and executes each line of code in turn
- Executed line of code is then forgotten so translation required for every execution
- No object code file is created so interpreter is always required to execute program

Advantages	Disadvantages
Easy to find errors. Syntax errors reported as each line is typed.	Program must be translated every time it is executed – this makes execution slow.
Easy for learners to use.	Interpreter is always resident in memory
	Commands within a loop must be translated for every repetition of the loop, making it less efficient

Reading Review 5

Having read pages 33 – 35, answer the questions below in preparation.

1. Explain why translators are required to convert code from high level language to machine code.

2. Explain the difference between an interpreter and compiler.

3. Explain **two** advantages and **two** disadvantages of a compiler.

4. Explain **two** advantages and **two** disadvantages of an interpreter.

Environmental Impact

Energy Use

Office equipment is the fastest growing energy user in the business world, consuming 15% of the total electricity used in offices.

Around 66% of the energy consumed by office equipment is attributed to computers (PCs and monitors) however; all office equipment is a potential source of energy waste.

30% of energy in buildings used inefficiently or unnecessarily

Reducing Energy Use

The energy use of computer systems can be reduced by:

- Buying green computers and peripherals - “Green” devices are devices which use low levels of electricity
- Switching off computers/monitors/electronic devices when they are not in use, don’t leave them on standby (the easiest for us in the classroom!)
- Setting computers, monitors, hard disk drives and peripherals to energy saving modes (hibernate)
- Reduce screen brightness to save energy
- Do not print out unnecessarily or print using both sides of the paper
- Correctly recycle printer ink and toner cartridges

Reading Review 6

Having read page 38, answer the questions below in preparation.

1. Describe **four** ways in which the energy use of computer systems can be reduced.

Security Precautions

Firewall

A firewall is used to protect a computer network from intruders.

It does this by controlling what data can pass through the firewall. Firewalls check the packets of data as they are received by a computer system or network. If the packet of data is not considered acceptable then it is not allowed to pass through the firewall. A firewall can block access from specific ports or external computers or networks.

Most routers contain software that allows firewall rules to be set up.

In summary, a firewall can:

- Block ports for services so they cannot be accessed from outside the network
- Block IP addresses of specific computers (suspected hackers from accessing the network)
- Analyse for suspicious activity

Encryption

Encryption is the process of changing data so that it cannot be understood by a third party. **Decryption** is the reverse.

Data is **scrambled** using a mathematical process which turns it into something that looks like nonsense.

This means that if anyone steals the information it will be meaningless to them. It will look like gobbledygook.

Encrypted data is known as **ciphertext**. Ciphertext cannot be read without first being decrypted.

How encryption works

Data (plain text) is encrypted using a secret key and encryption algorithm. Both parties must have a copy of the secret key which must also be kept secure.

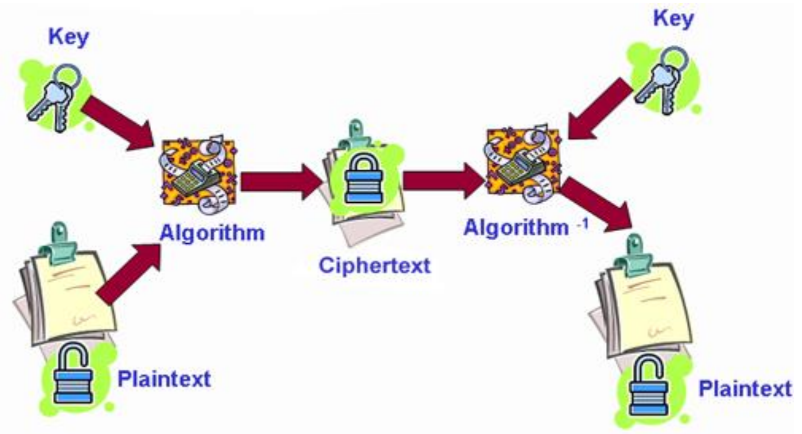
Encryption Key

A **key** is a long sequence of bits used by encryption / decryption algorithms.

To crack some ciphertext encrypted with a 64-bit key by trying every combination of keys possible means you have 2^64 possible combinations (18 followed by 18 naughts).

If you have a computer that can carry out one encryption operation every millisecond, it will take about 292 million years to find the correct value.

Plain text is combined with the secret key and encryption algorithm to produce ciphertext.



Ciphertext is then combined with the secret key and the decryption algorithm to produce plain text.

Reading Review 7

Having read pages 41 – 42, answer the questions below in preparation.

1. Describe the purpose of encryption.

2. Explain how encryption works?

3. Explain the purpose of a firewall.

4. Describe two ways a firewall can protect a network.