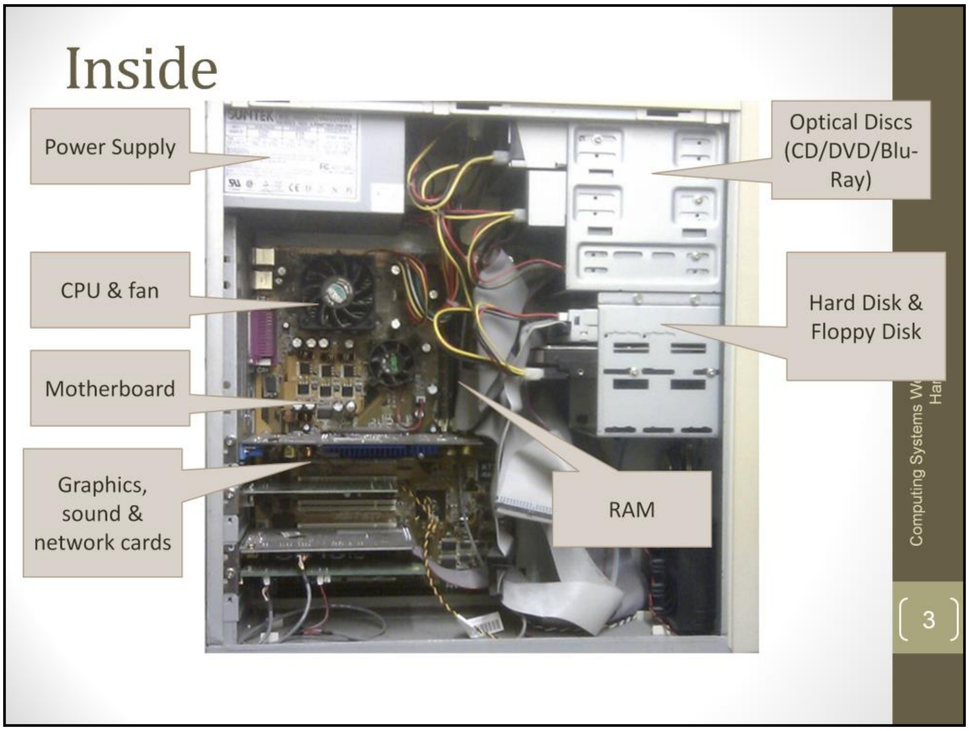
Computing Systems

Lecture 2
Computer Hardware

Inside the Desktop PC



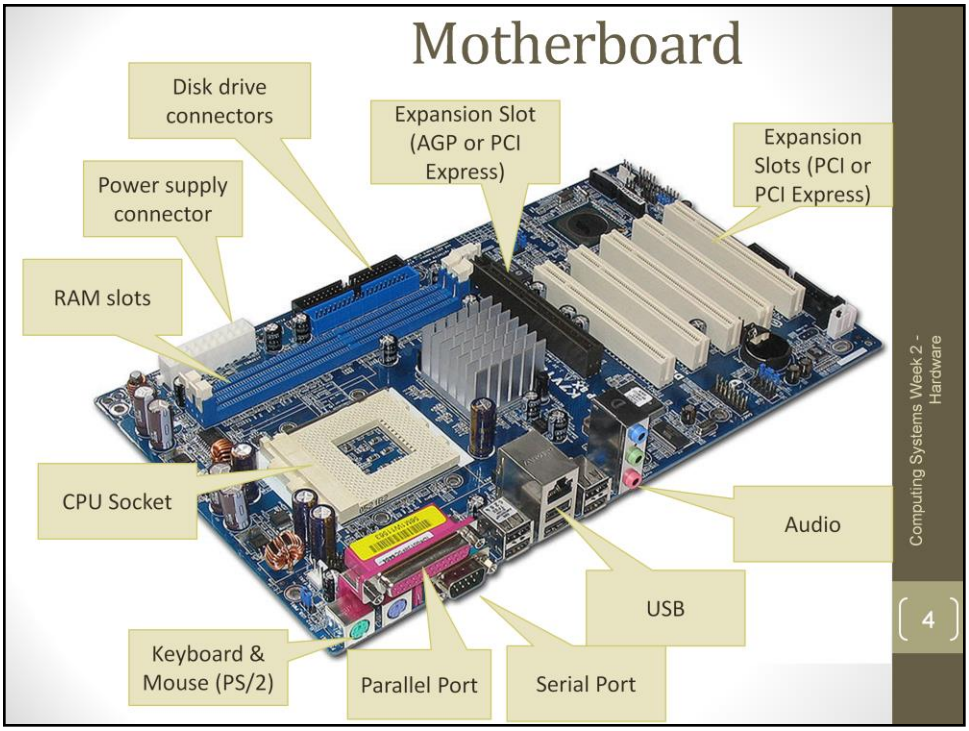
PC which is relatively new 10/11 years old.

Fan – prevent overheating of the CPU which generates a lot if heat when it operates. Cooling system which prevents the system melting itself.

RAM – behind cables.

Plug in boards for Graphics / sound / network cards. In modern PCs some of these may be integrated into the Motherboard, at the back, it has lots of components soldered / plugged into it.

Optical disks CD / DVD / Blu-Ray



Motherboard has a range of components with lots of different connectors.

CPU socket – where main processor will go, it is a square shape with lots and lots of pins, so there are lots of holes in the socket where the CPU pins will connect.

RAM – this machine has TWO RAM slots, which is quite common on a lot of modern motherboards, the RAM which plugs in may have quite large capacities.

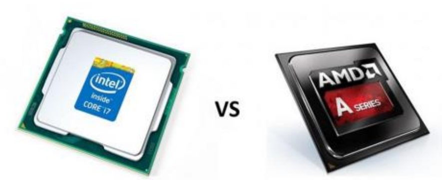
Slots for connecting disk drives. Expansion slots for PCI card and PCI Express cards, modern motherboards may have more PCI express slots. An older motherboard as it has the out-dated PS2 sockets for the keyboard and mouse.

Motherboard

- As its name implies, the motherboard is the uniting element among all the chips and circuitry that make up a computer.
- Devices communicate with each other through the motherboard's circuits, from which they also draw their power.
- Motherboards come in different **form factors** that align the board with different sizes and styles of computer cases.
- They also come with different sockets that determine what types of chips and **expansion boards** they can accept.

CPU

- Often called the brains of a computer, the microprocessor or central processing unit (CPU) is a tight, complex collection of transistors arranged so that they can be used to manipulate data.
- The processor handles most operations of your computer, the design of which dictates how software must be written to work correctly.



CPU Socket

- This determines what kind of **microprocessor, or CPU,** the motherboard uses.
- Boards are designed to work with processors made by either **Intel or AMD.**
- Motherboards do not work with all CPUs from the same company.
- The socket and board must be designed for specific lines of microprocessors and must have the right shape and number of holes for the chip's pins to fit.

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RAM

- Random Access Memory is a collection of microchips aligned on small circuit boards that fit into slots with a couple of hundred or more connectors.
- RAM is where the computer stores programs and data while it uses them.
- When the computer is turned off, the contents of RAM are lost.

ROM

- **Read-only memory** (**ROM**) is a class of storage medium used in computers and other electronic devices.
- Data stored in ROM can only be modified slowly or with difficulty, or not at all, so it is mainly used to distribute firmware(software that is very closely tied to specific hardware, and unlikely to need frequent updates).

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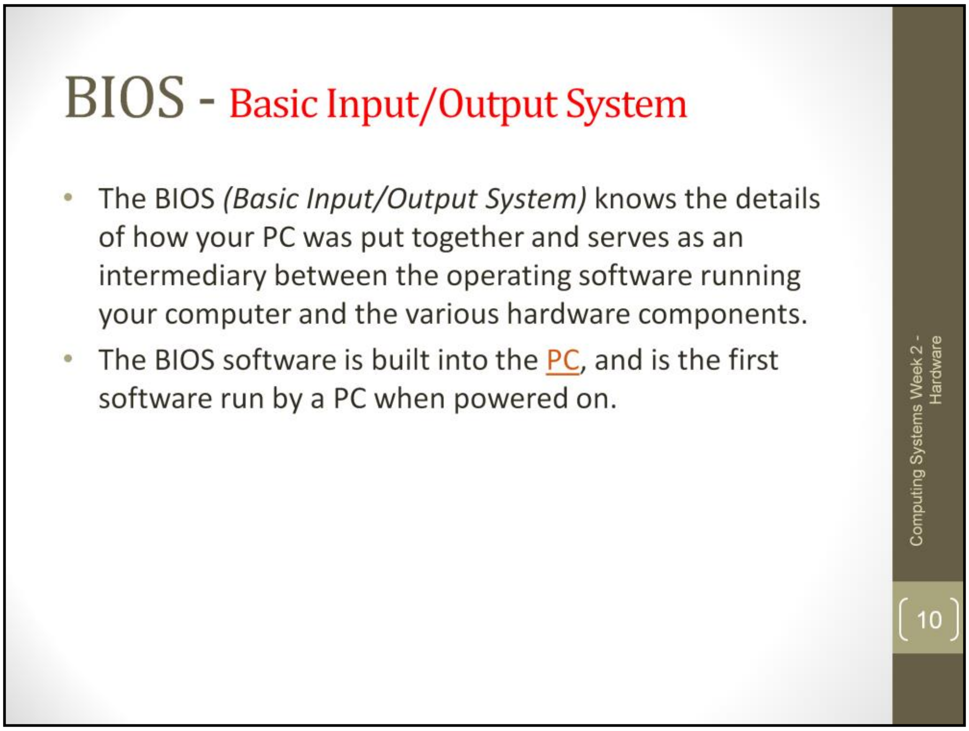


BIOS – basic start up software for when the machine is first switched on. It enables it to load programs from disk and do other operations.

BUS – there are a lot of different buses in a modern PC.

BIOS

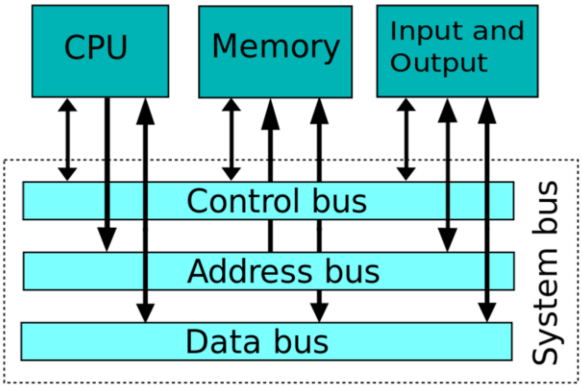
- When you turn on your computer, this is the first component to come to life, providing enough code to wake up the rest of the hardware. It also contains code to support specific types of processors, drives, and other functions that might need updating occasionally.
- BIOS software is stored on a non-volatile ROM chip on the motherboard.
- It is specifically designed to work with each particular model of computer, interfacing with various devices that make up the complementary chipset of the system.
- In modern computer systems, the BIOS contents are stored on a flash memory chip so that the contents can be rewritten without removing the chip from the motherboard. This allows BIOS software to be easily upgraded to add new features or fix bugs, but can make the computer vulnerable to BIOS issues.

Flash Memory Chip

- **Flash memory** is an electronic non-volatile computer storage medium that can be electrically erased and reprogrammed.
- Example applications of both types of flash memory include personal computers, PDAs, digital audio players, digital cameras, mobile phones, synthesizers, video games, scientific instrumentation, industrial robotics, medical electronics, and so on. In addition to being non-volatile, flash memory offers fast read access times.

Bus

- Computer architecture term for subsystem that transfers data between computer components



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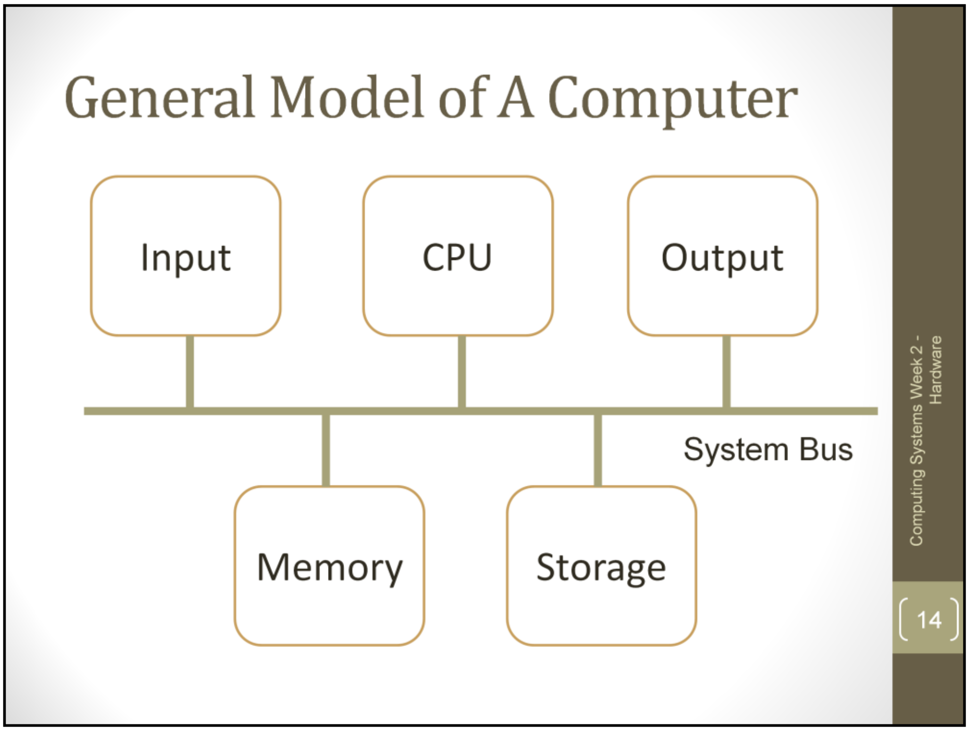
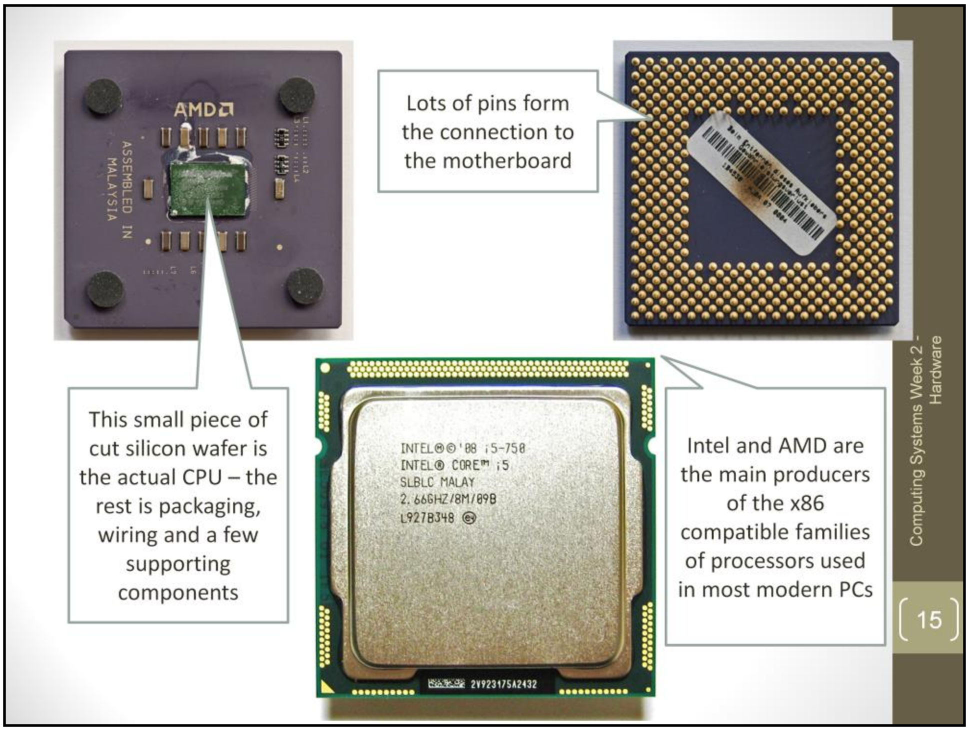


Storage - a memory for the computer when it is switched off.

System Bus – connects all components



Actual CPU is a small silicon wafer,

Most modern Windows PCs and Macs will be using an x86 processor. Chips like the Pentium for example.

Chip Set

- The PC has become so complex that even the most recent, powerful processors can 't do the entire job of managing the flow of data by themselves.
- The CPU has been given help in the form of the **chip set,** located nearby on the motherboard.
- The chip set consists of two microchips, often referred to as the **North Bridge** and the **South Bridge,** that act as the administrators to the CPU, or chief executive.
- The chip set bridges logical and physical gaps between the CPU and other chips, all the time watching and controlling the input and output of specific components.

Chip Set

- The exact function of the chip set is constantly changing. But in all cases, the bridges determine what kinds of memory, processors, and other components can work with that particular motherboard.
- There is an unfortunate trend to replace the names North Bridge and South Bridge with less elegant terms such as **Graphics Memory Controller Hub (GMCH)** and the **I/O Controller Hub (ICH),** even though their basic purpose is the same.
- For our purposes here, we' ll stick to the more seemly bridge nomenclature.

North Bridge cont.

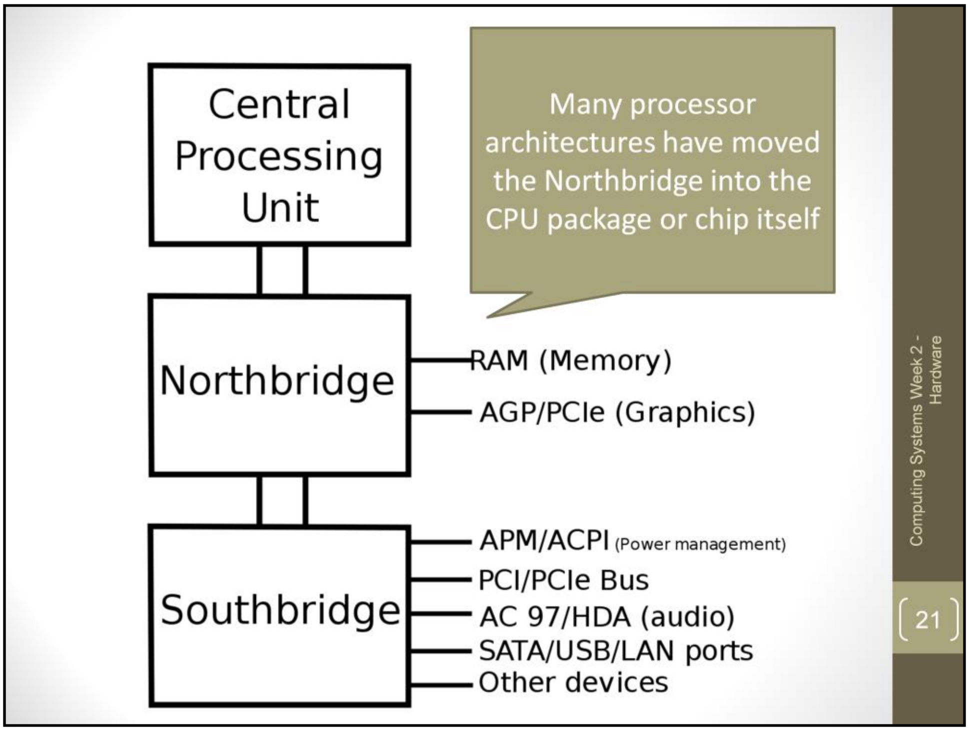
- The North Bridge and South Bridge together form the computer's **chip set,** secondary only to the processor in determining the performance and capabilities of a Pc.
- The North Bridge chip either provides or controls the computer's graphics, RAM, and the **front side bus,** the main highway for data connecting graphics and memory to the CPU.
- A crucial mechanism in the North Bridge is the memory controller, which constantly renews the memory modules (RAM). Each memory cell with an electrical charge represents a 1 bit. Because the charge begins to dissipate as soon as it's created, the bridge's memory controller endlessly, thousands of times a second, reads each of the millions of cells and writes back the values it read.

North Bridge

- When the CPU needs data from RAM, it sends a request to the North Bridge memory controller. The controller, in turn, sends the request along to memory and tells the CPU how long the processor must wait to read the memory over a speedy connection called the **front side bus (FSB).**
- The North Bridge is also the liaison with the other component for which speed is crucial: the video card. (Some chip sets have video, sound, or other functions built into them, but onchip video is not as fast as a dedicated expansion card).

South Bridge

- The other half of the PC **chip set,** the South Bridge is in charge of input/output with the disk drives, audio, networking and universal serial port.
- The South Bridge primarily handles the routing of traffic between the various input/output (I/O) devices on the system for which speed is not vital to the total performance, such as the disk drives, optical drives, PCI-Express devices, the older PCI bus, and the USB, Ethernet, and audio ports.
  - It is also responsible for less prominent input/output, such as the real-time clock, interrupt controller, and power management.
  - Some South Bridge chips incorporate audio capabilities good enough to support Dolby Digital and THX multimedia audio.



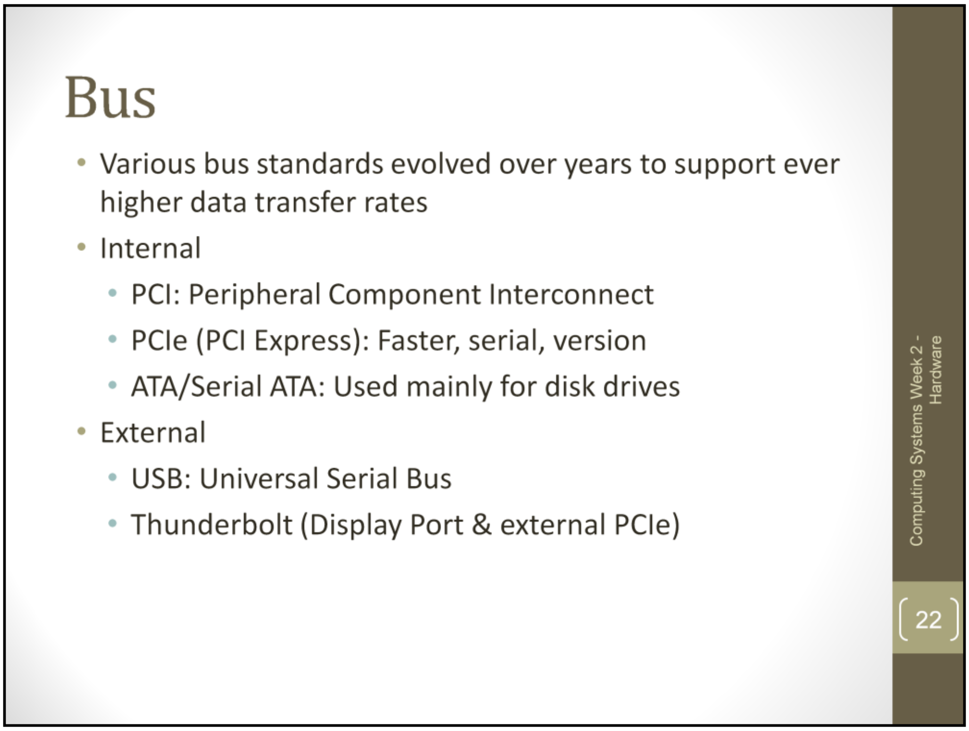
Common in modern PCs especially Windows, the CPU is connected to a couple of other chips, the Northbridge and the Southbridge, which in turn connect to a range of different buses and different devices.

Many of the slower peripherals are connected to the Southbridge, whereas RAM and the Graphics system

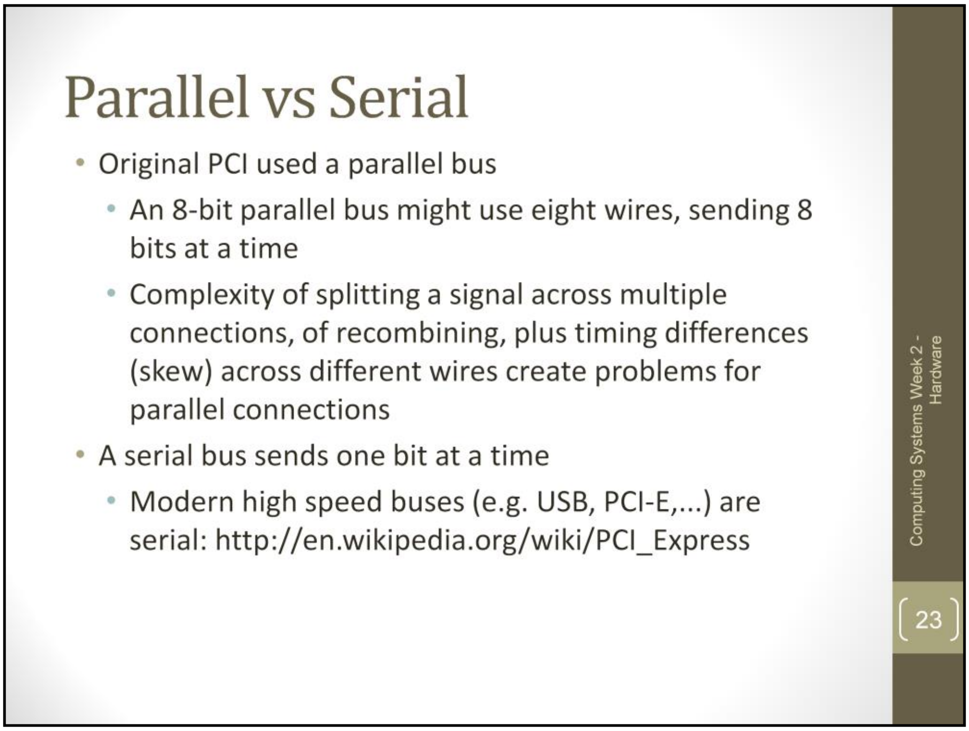
need very fast access and are connected to the Southbridge. Though some processor architectures have the CPU and the Northbridge architecture inside the one package or integrated circuit nowadays.

The **Accelerated Graphics Port** (often shortened to **AGP**) is a high-speed point-to-point channel for attaching a video card to a computer's motherboard.

Conventional PCI (formed from **Peripheral Component Interconnect**,[1] part of the **PCI Local Bus** standard and often shortened to **PCI**) is a computer bus for attaching hardware devices in a computer.



Computer bus can be internal a component of the motherboard, or a link to something which is external e.g. USB



The Original PCI must receives 8 bits at the one time and they have to be recombined resulting in timing differences due to the length of the wires connecting both end of the parallel bus, the differences are tiny but they create a skew as they have to wait for all the bits to arrive before they can recombine the bits or parallel signals into one byte.

Serial buses have been found to be able to work at much higher speeds. The PCI Express has multiple serial connections and can operate each lane independently. Therefore they do not have to wait for each other to catch up before they process the data.

Almost all modern high speed buses have serial connections

Breaking the Bus Barrier

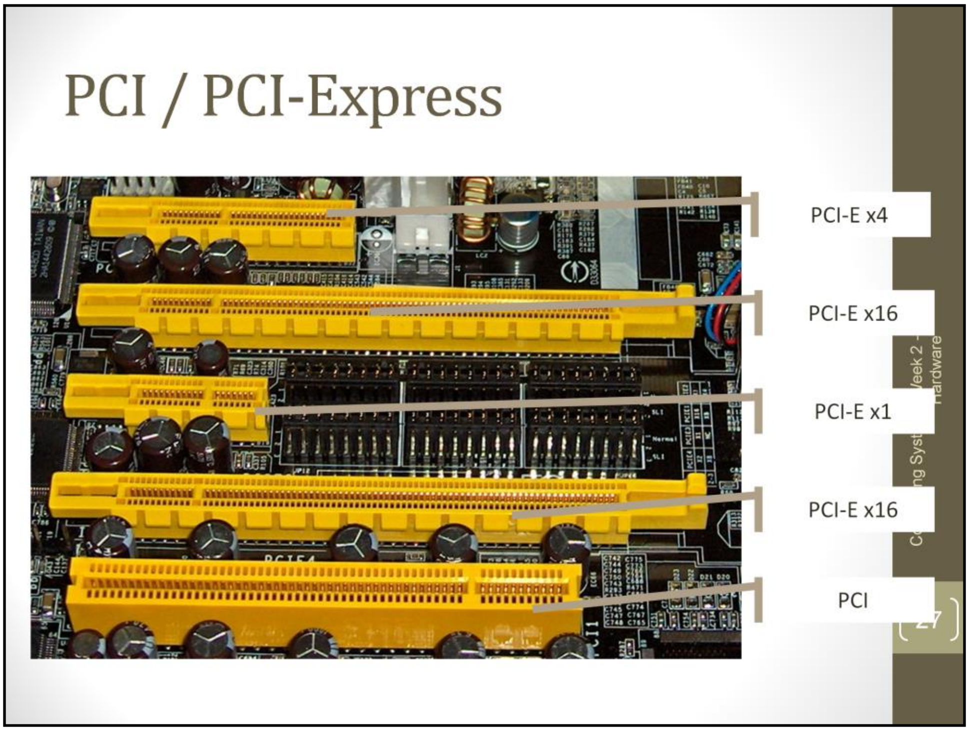
- New computer applications, such as streaming video and photo editing, put new demands on PCs to move vast amounts of data ever quicker.
- Until recently, PCs were bogged down as data was trundled among components by outdated buses-the peripheral components interconnect (PCI) and the accelerated graphics port (AGP) .
- Even the fastest of them , AGP, which send out 2.134 gigabytes a second, can't keep up with the demands of real-time-photorealistic animation that needs values for the colours of millions of pixels pushed through the circuits 60 times or more each second.

Breaking the Bus Barrier

- The solution is a bus architecture that uses both parallel and serial transfers. It's called PCI-Express, or PCI-E .
- In the older PCI bus, all the devices share the same parallel circuits and receive the same data.
- The data includes an identifier that says which device the signals are destined for. All other devices simply ignore them. But like telephone users on a party line, the components can't receive data while some other device monopolizes the connection.
- The links in PCI-E are **point-to-point.** Data goes to several components at the same time. It's like talking on a private, single-line phone.

PCI-E

- To handle graphics and sound data faster, the PCI-E slot can be expanded to **x4, x8,** or, shown on the next slide, **x16** slots, where the numbers represent multiples of the speed of an xl PCI-E slot.
- Their ability to move data is indicated by the multiplier factor in their designations.



Close-up of a Motherboard. Some have a range of sockets.

PCI Express x16 sockets would normally be used for Graphics cards, therefore the example could support two graphics cards which may be interconnected to get a very high graphical performance.

PCI Express slots can be of different sizes, corresponding to how many data lanes they have.

They all have a set number of lanes for power and for basic connectivity then a varying number of data lanes.

PCI Express 16 would have 16 data lanes, are the longest slots there.

The older PCI at the bottom has a different design from the others, this is a slower interface, a slower bus,

Inside the CPU

- More basic CPUs have:
  - Control unit(s)
  - Arithmetic logic unit(s)
  - Internal data buses
  - Input/output interfaces
  - Registers & memory cache
- But how do these represent instructions and data?

What is the world’s most successful CPU range?

Join ‘Room 642124’ Socrative and add your answer.

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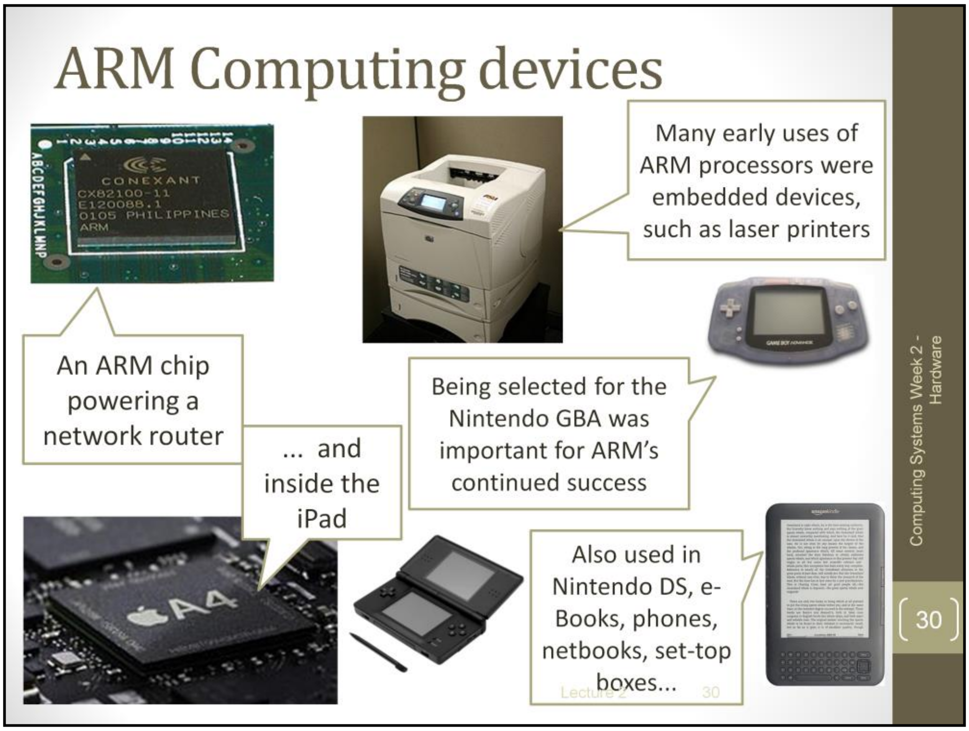

In terms of Unit Sales the ARM chip is the most successful.

Advanced Risk Machine.

The early uses were in Network Routers and laser printers.

Over time it was adopted increasingly for a wider range of computer devices. The Nintendo Game Boy Advance was very important for it's continued success.

ARM used a lot in mobile phones especially SMART phones. Because of the wide range of uses it has continued to make a lot of sales.

The Chip Company That Doesn't Make Chips

- ARM doesn't actually produce chips – instead they license chip designs to other companies who make them
  - Perhaps after adding additional components to the design, e.g. Nvidia Tegra
- Over 15 Billion ARM based chips shipped... several billion more to ship this year

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ARM create the designs that are licensed to other companies who make the chips. ARM also sell services where they adapt the chips for other companies. Nvidia have a Tegra chip for mobile computing, it combines an ARM processor core with inVidia graphics technology.

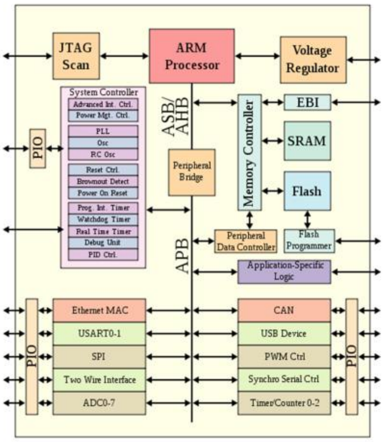
Over time they may be selling more chips than there are people.

System-On-a-Chip (SoC)

- All the components needed for a computer or other system included on a single chip
- Design can be complex and costly, & building disparate components on a single piece of silicon may compromise efficiency of elements
- Drawbacks offset by lower manufacturing and assembly costs and much less power is required for running the chip

ARM chips are often used to create a system on a chip. All the components needed for a computer or other system included on a single chip , not keyboard or monitor.

System-On-a-Chip (SoC)



CPU
Memory
Storage
Input
Output

Connected via a Bus

All on the same chip

Quick Quiz

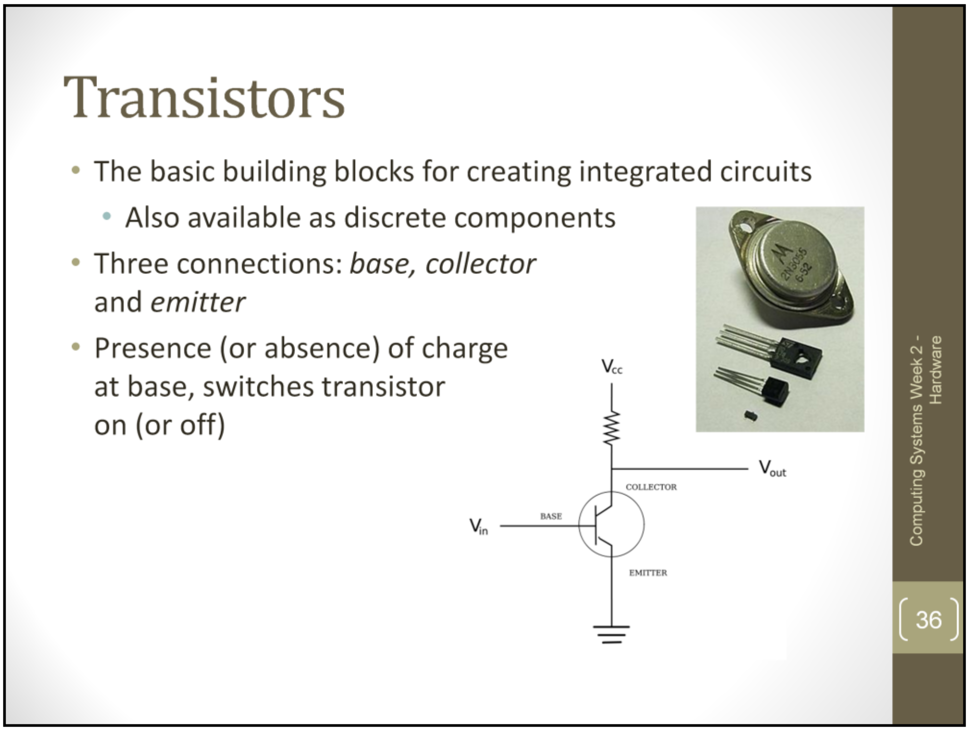
- Join 'Room 642124' Socrative and complete the quick quiz.

- When you have completed the quiz it is a good time for a quick break.

Zeroes and Ones

- Low voltage values (e.g. 0-0.4 V) represent *off* or Zero
- High voltage values (e.g. 2.8-5 V) represent *on* or One
- Transistors (and valves) can act as electrical switches
  - Large numbers of transistors can be combined in a single *integrated circuit*

Valves were used in the olden-days. Power comes from millions of transistors integrated into a single circuit.



Three different types of individual transistors.

Some voltage in can switch the circuit on or off and that will affect the voltage out. A very simple form of transistor invertor is shown. If voltage IN is ON then voltage OUT is OFF. Emitter we have a low voltage at the collector is HIGH voltage.

When V_{in} is OFF the circuit is broken, and we don't have a connection from the emitter through to V_{out} so the voltage at V_{out} is V_{cc}.

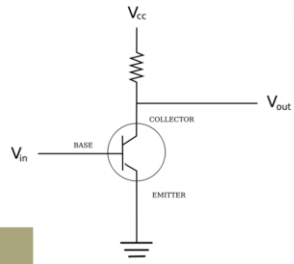
When V_{in} is ON the circuit is complete, and we do have a connection from the emitter through to V_{out} so the voltage at V_{out} is the Voltage from the emitter. The presence of the resistor will ensure this.

Also called a NOT gate as the output is the inverse of the input value. The table is a truth table.

Different circuits of transistors and resistors can make up different logic gate.

A Simple Transistor Inverter

- Simple inverter circuit
- If Vin is on, Vout will be off
- Vin off, Vout on
- A *NOT* gate



Input	Output
0	1
1	0

Transistors to Logic Gates

- Using different circuits of transistors & resistors, a range of basic *logic gates* can be built up
- Inverter is a NOT gate
  - 0 input becomes 1 output and vice versa
- Other gates take two (or more) inputs
  - E.g. AND gate produces 1 output only if *both* inputs are 1
  - More next week

Binary Representations

Strings of zeroes and ones act as both *instructions* and *data*:

- Instructions for the CPU control unit
- Data as e.g. numerical inputs and outputs for the Arithmetic Logic Unit
- How do we represent numbers using only zeroes and ones?

Binary Integer Numbers

- Decimal: From right to left columns are
  ... *thousands, hundreds, tens, units*
- $2053 = 2*1000 + 0*100 + 5*10 + 3*1$
  $= 2*10^3 + 0*10^2 + 5*10^1 + 3*10^0$
- Binary: From right to left, columns are *eights, fours, twos, units, ...*
- $1101_2 = 1*2^3 + 1*2^2 + 0*2^1 + 1*2^0$
  $= 8 + 4 + 0 + 1$
  $= 13_{10}$

Binary to Decimal

128	64	32	16	8	4	2	1		
1	1	0	0	1	0	1	1	=	**203**

= 128 + 64 + 8 + 2 + 1

= 203

So, what is the decimal of 11111111_2?

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

More Binary To Decimal

- Work out the decimal value of the following binary numbers:
- 0011
- 1010
- 110011
- 11100111
- 11001100

Join ‘Room 642124’ Socrative and add your answers.

Decimal To Binary

- Convert 198_{10} to binary
- Start by creating a table of the powers of 2:

128	64	32	16	8	4	2	1	198
1								- 128

remainder = **70**

- From left to right, enter ones
  - Subtracting the power of two (column value) from our number
  - Repeat until we reach 0 (next slide)

Decimal To Binary

128	64	32	16	8	4	2	1	198
1	1							- 192

remainder = 6

128	64	32	16	8	4	2	1	198
1	1	0	0	0	1			- 196

= 2

128	64	32	16	8	4	2	1	198
1	1	0	0	0	1	1	0	- 198

= 0

More Decimal To Binary

- Work out the binary equivalent of the following decimal values:
- 77
- 63
- 121
- 202

Bits and Bytes

- A single binary value (zero or one) is a *bit*
- A group of 8 bits is a *byte*
- What is a group of 4 bits?

Range

- Join 'Room 642124' Socrative and complete the quick quiz.

- With 8 binary digits, how many values can be represented?
- With 16?
- With 32?

Binary Arithmetic

- Addition & Subtraction

	1	0	1
	+	1	1
= 1	0	0	0

	1	0	1
	-	1	1
=		1	0

- Multiplication
  - Multiply 1010_2 by two?
  - **10100** – *shift left*
- Division
  - Divide 1010_2 by two?
  - **101** – *shift right*

Representing Text

- Need to represent text as well as numbers
- The ASCII standard is still widely used for text representation
  - American Standard Code for Information Interchange
  - 7 binary bits (0-127) giving 128 character codes
  - Each character code assigned to a printable or a control character (e.g. Newline)

b_7					0	0	0	0	1	1	1	1
b_6					0	0	1	1	0	0	1	1
b_5					0	1	0	1	0	1	0	1
Bits b_4 ↓	b_3 ↓	b_2 ↓	b_1 ↓	Column → Row ↓	0	1	2	3	4	5	6	7
0	0	0	0	0	NUL	DLE	SP	0	@	P	`	p
0	0	0	1	1	SOH	DC1	!	1	A	Q	a	q
0	0	1	0	2	STX	DC2	"	2	B	R	b	r
0	0	1	1	3	ETX	DC3	#	3	C	S	c	s
0	1	0	0	4	EOT	DC4	$	4	D	T	d	t
0	1	0	1	5	ENQ	NAK	%	5	E	U	e	u
0	1	1	0	6	ACK	SYN	&	6	F	V	f	v
0	1	1	1	7	BEL	ETB	'	7	G	W	g	w
1	0	0	0	8	BS	CAN	(	8	H	X	h	x
1	0	0	1	9	HT	EM	)	9	I	Y	i	y
1	0	1	0	10	LF	SUB	*	:	J	Z	j	z
1	0	1	1	11	VT	ESC	+	;	K	[	k	{
1	1	0	0	12	FF	FC	,	<	L	\	l	|
1	1	0	1	13	CR	GS	-	=	M	]	m	}
1	1	1	0	14	SO	RS	.	>	N	^	n	~
1	1	1	1	15	SI	US	/	?	O	_	o	DEL

E.g. $100\ 0001_2 = 65_{10}$ = 'A' $001\ 1011_2 = 27_{10}$ = Escape
$110\ 0001_2 = 97_{10}$ = 'a' $010\ 0000_2 = 32_{10}$ = ' ' (space)

What's wrong with ASCII?

- In recent years ASCII has increasingly been replaced with other character coding systems
- Why?

Replacing ASCII

- ASCII only supports the most common western Latin alphabet
- Many symbols used in other European languages missing
- What about Cyrillic, Semitic or Eastern languages and alphabets?
- 7 bits of ASCII only provides 128 symbols
- 16 bit or 32 bit systems can support vastly extended character sets

Unicode

- Current dominant standard for character encoding
- Over 100,000 characters
- Over 90 different scripts (alphabets)
- Full standard supports bi-directional text for right-to-left scripts (e.g. Hebrew, Arabic)
  - UTF-8 is a Unicode encoding that uses one byte for ASCII characters, up to four bytes for other characters

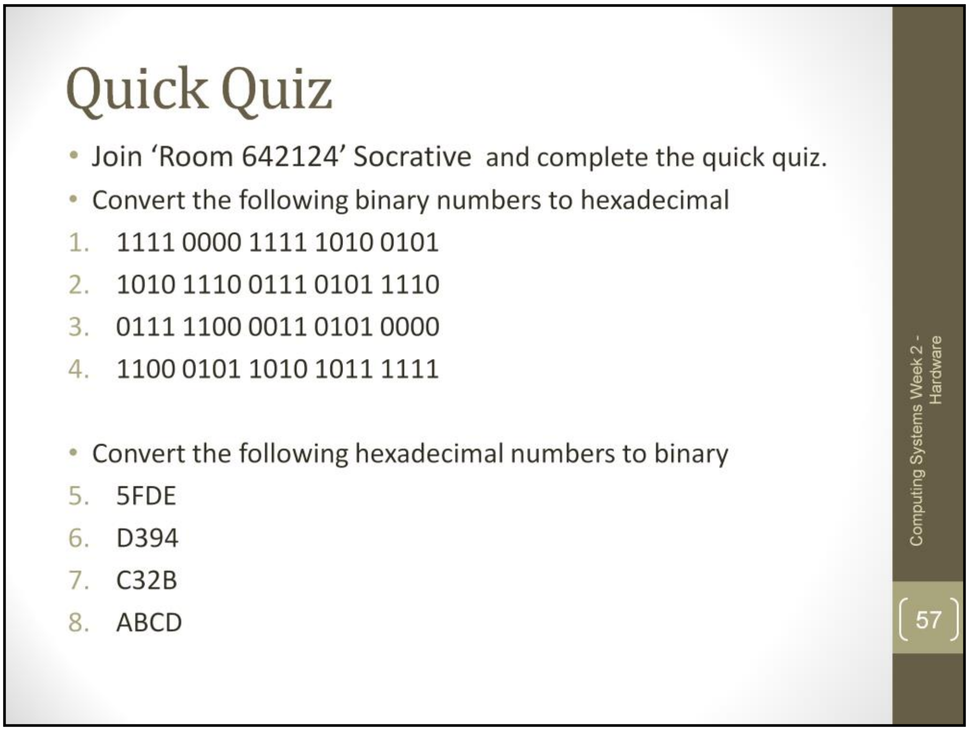
Hexadecimal

- Most computer architectures support operations on one, two, four or eight bytes
  - 8 bit computing, 16 bit, 32 bit and now 64 bit
- Useful to be able to write binary numbers in a convenient shorthand
  - E.g. From 10101110 01101001
- Decimal conversion not so simple!
- *Hexadecimal* is used...

Decimal	Hex	Binary		Decimal	Hex	Binary
0	0	0000		8	8	1000
1	1	0001		9	9	1001
2	2	0010		10	A	1010
3	3	0011		11	B	1011
4	4	0100		12	C	1100
5	5	0101		13	D	1101
6	6	0110		14	E	1110
7	7	0111		15	F	1111

Binary To Hex and Back

- Break up any binary number into chunks of 4 bits, and convert
  - $0101\ 1101_2 = 5D_{16}$
  - $1010\ 1110\ 0110\ 1001_2 =$
- Each digit of a hex number represents 4 bits:
  - $BD_{16} = 1011\ 1101$
  - $C0FA_{16} =$



1. 1111 0000 1111 1010 0101
2. AE75E
3. 7C350
4. C5ABF
5. 0101 1111 1101 1110
6. 1101 0011 1001 0100
7. 1100 0011 0010 1011
8. 1010 1011 1100 1101

Challenge Question

- Secret message test on Moodle
- 1. Can you decode the secret message?

53 52 49 20 74 6F 20 55 43 4C 41 3A 20 6C 6F

- 2. What does it mean?

Negative Numbers and Fractions?

- We've seen how binary values can be used to represent numbers and characters
- How can we represent fractions?
  - e.g. 10.5_{10} or 0.000533_{10}

Next Week

- ***Required*** *Reading*
  - HCW Chapter 6

- ***Further*** *Reading*
  - PCH, Chapter 2, 2.1-2.3,
    Chapter 4, 4.1-4.3, 4.7-4.9
  - ECS, Chapter 1