University of Nottingham

Computer Programming with MATLAB

MM1CPM - Lecture 4

Computer hardware, Screen output, strings and keyboard input

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Overview of this lecture

- **Computer fundamentals**
  - **What's in a computer?**
  - **Types of computers**
  - ASCII code
- Writing to the screen
- Reading text from the keyboard
- Strings in depth

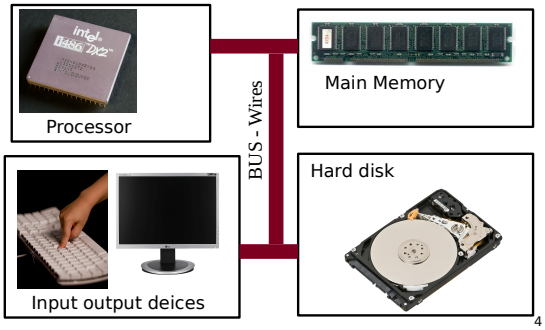
What is inside a a typical computer?

- In the next few slides you are going to learn what the **key components** of a computer are and **how they work**.

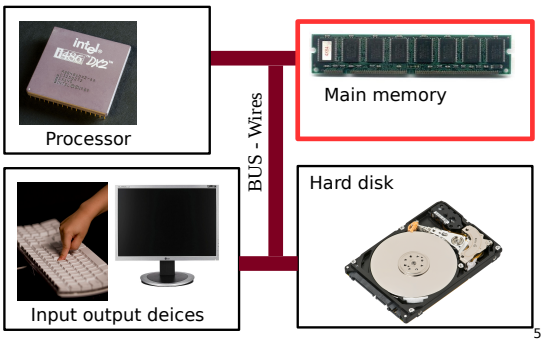
- My aim is to give you enough background knowledge so you can interact with Electrical Engineers when designing machines.
- We will be using the **typical PC** as an example because the **components are big but all computers have these basic components**.

The components of a computer

- Let's look at the components one by one.



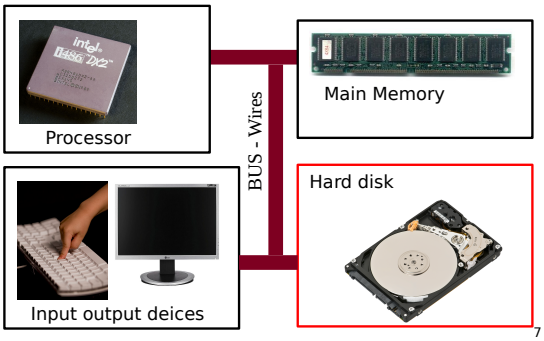
The components of a computer:



Main memory chips

- Store all information the computer **is currently using**.
- The **computers memory is very fast (1 ns)** but very expensive per Mb of stored information
- The **computer's memory** will only store information whilst the power is on – if you switch off the power it looses all information.
- Any **arrays** or **variables** you define will be stored in the memory.
- The memory also stores your programs/scripts whilst they are running.

The components of a computer:

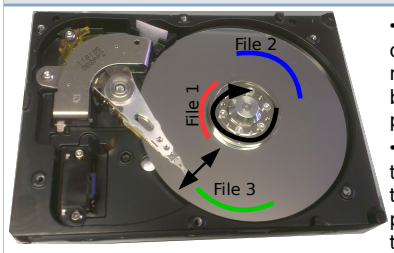


Hard disk

- This can hold a lot of information information while the computer is switched off – programs, word documents etc...
- Hard disks offer very low cost per Mb stored but **very very slow**
- 1 ms access time - $1x10^6$ times slower than main memory).

- But why are hard disks so slow?

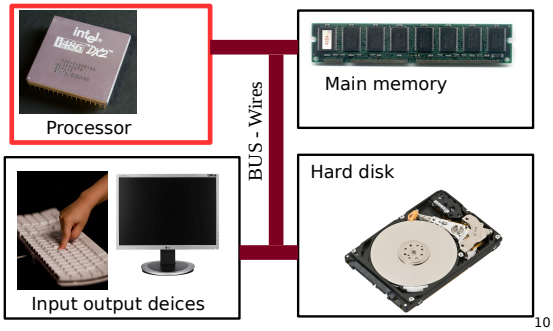
Why is a hard disk slow?



- The files are stored on a rotating magnetic disk – a bit like a record player
- For the computer to read the files, the head must physically move, this takes time.

- **Top programming tip:** If your program is running slowly you are probably using the hard disk to much.

The components of a computer

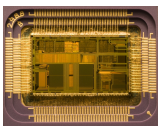


The Processor

- This is the chip that:
  - Performs all **mathematical operations**
  - **Runs** and understands your **programs line-by-line**.

- When you type anything into the MATLAB:

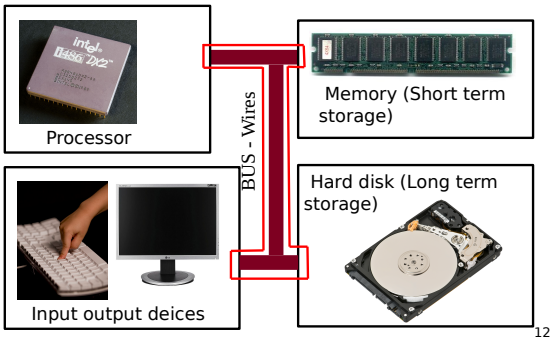
```
> (1+2)*(3+4)/7
```



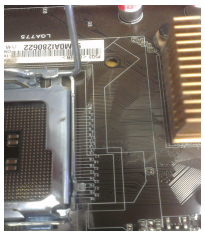
- The processor **is the chip that works out the answer.**

- Processor speed is measured in **Operations per second**.

The components of a computer:



The bus



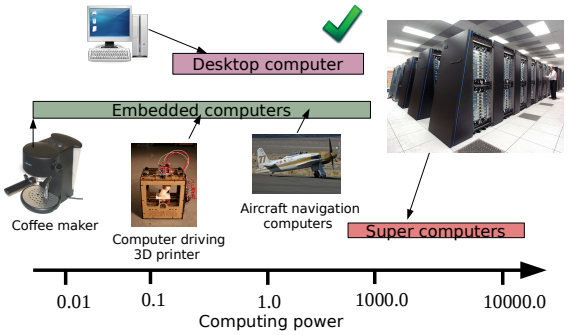
•The bus is a set of wires which connects the **processor**, **memory** and **storage devices together**.

•The bus is used to transfer information between components in the computer.

•It's a bit like an information highway.

•In the computer circuit board I am handing around you can see it as a brown set of wires – these are the bus.

Types of computer and their computing power



1.0= the power of a standard desktop PC

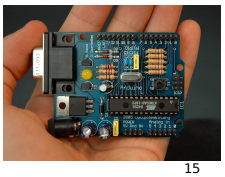
Embedded computers

•**Embedded computers** are:

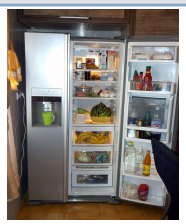
- •computers embedded in an object – like computers embedded in a robot.
- •These are the most likely sort of computer you will come across.

•**Computers on a chip**

- •All components (memory, processor and some storage) are integrated onto a single chip.

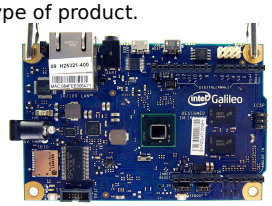


Internet of things – more embedded devices



•We will soon be living in a world where everything is online – even your fridge.

•This is Intel's kit for developing this type of product.

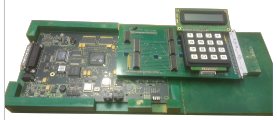


•It has everything that a normal computer would have.

Embedded computers

•**Digital Signal Processors (DSP)**

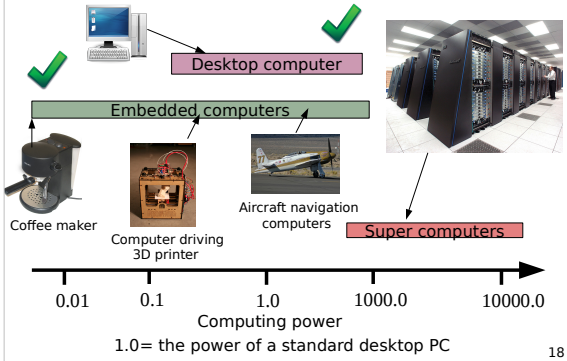
- •This type of computer is specially optimized to process real time data streams



•They widely used to optimize fuel/air mixtures in car engines in response to changing engine conditions.

•They are also used to process audio, and video streams.

Types of computer



1.0= the power of a standard desktop PC

Supercomputers

- These computers are very powerful computers typically 1000-100000 more powerful than your desktop computer.
- Engineers use them all the time to solve very complex problems.
- Design of **airplane wings**, **optimizing rocket engines**, in general solving very **difficult problems**.

Supercomputers

- In your professional life there is a good chance you will use a supercomputer.
- Supercomputers could fill a whole lecture. I have therefore organized a special lecture on Supercomputers on **Wednesday 29th October at 2pm** in this room.
- **Dr. Colin Bannister** who runs the university of Nottingham supercomputer facility will be the guest lecturer.
- This is optional and the content will not be in the exam, but it should be interesting (and fun!).

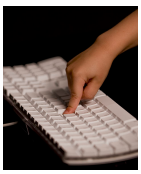
Overview of this lecture

- **Computer fundamentals**
  - What's in a computer?
  - Types of computers
  - **ASCII code**
- Writing to the screen
- Reading text from the keyboard
- Strings in depth

How do computers store information?

- Did you know that computers store and transmit ***all*** text as numbers from 0 to 255?
- For example:

a 97 A 65 b 98



- This code is called ASCII code (American Standard Code for Information Interchange)

Here is the full character list (ASCII code)

Number	Char	Number	Char	Number	Char	Number	Char
0	[NULL]	32	[SPACE]	64	@	96	`
1	[START OF HEADING]	33	!	65	A	97	a
2	[START OF TEXT]	34	"	66	B	98	b
3	[END OF TEXT]	35	#	67	C	99	c
4	[END OF TRANSMISSION]	36	$	68	D	100	d
5	[ENQUIRY]	37	%	69	E	101	e
6	[ACKNOWLEDGE]	38	&	70	F	102	f
7	[BELL]	39	'	71	G	103	g
8	[BACKSPACE]	40	(	72	H	104	h
9	[HORIZONTAL TAB]	41	)	73	I	105	i
10	[LINE FEED]	42	*	74	J	106	j
11	[VERTICAL TAB]	43	+	75	K	107	k
12	[FORM FEED]	44	,	76	L	108	l
13	[CARRIAGE RETURN]	45	-	77	M	109	m
14	[SHIFT OUT]	46	.	78	N	110	n
15	[SHIFT IN]	47	/	79	O	111	o
16	[DATA LINK ESCAPE]	48	0	80	P	112	p
17	[DEVICE CONTROL 1]	49	1	81	Q	113	q
18	[DEVICE CONTROL 2]	50	2	82	R	114	r
19	[DEVICE CONTROL 3]	51	3	83	S	115	s
20	[DEVICE CONTROL 4]	52	4	84	T	116	t
21	[NEGATIVE ACKNOWLEDGE]	53	5	85	U	117	u
22	[SYNCHRONOUS IDLE]	54	6	86	V	118	v
23	[END OF TRANS. BLOCK]	55	7	87	W	119	w
24	[CANCEL]	56	8	88	X	120	x
25	[END OF MEDIUM]	57	9	89	Y	121	y
26	[SUBSTITUTE]	58	:	90	Z	122	z
27	[ESCAPE]	59	;	91	[	123	{
28	[FILE SEPARATOR]	60	<	92	\	124	|
29	[GROUP SEPARATOR]	61	=	93	]	125	}
30	[RECORD SEPARATOR]	62	>	94	^	126	~
31	[UNIT SEPARATOR]	63	?	95	_	127	[DEL]

ASCII numbers to text example

This is how the computer stores my name:

Dr. MacKenzie

Name = [68 114 46 32 77 97 99 75 101 110 122 105 101]

But why should I care about this?

- **All computers store/transmit/read all information using this code.**
- When you later (in mechatronics) try to make your computer talk to a **3D printer**, **data capture card** or **robot** it will **expect** commands composed of **ASCII** numbers from you.

- For example if you send this robot the command ***PowerOn*** you would actually send [80 111 119 101 114 79 110] in ASCII code.

Converting from numbers to characters using char

In MATLAB if we wanted to tell the computer to convert this list of numbers back to a human readable string we would type:

```
>name = [68 114 46 32 77 97 99 75 101 110 122 105 101]

>char(name)

    Dr. MacKenzie
```


Your go!

- This set of numbers is sent to a robot:

  [80 79 87 69 82 79 78 0 82 111 116 97 116 101 57 48 100 101 103]

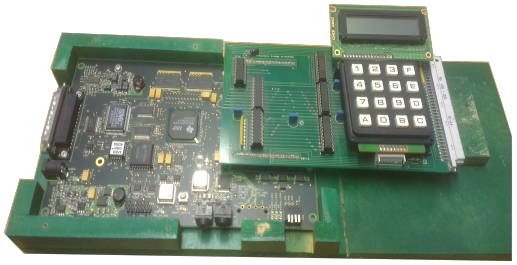
- Using the ASCII table on the previous slide convert this command into human readable text.
- What does this command tell the robot to do?
- Hint: The 0 is used by the robot to separate commands.

Question?

What did all the computers in today's lecture not have?

Answer:

Good displays.



Controlling output to the screen

- Most the computers you will work with be embedded in products like cars or jet engines.
- It is very important to be able to display text on these screens (graphs and pretty graphics are not an option!)

- We therefore need to know how to control text output accurately..... back to MATLAB

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- Computer fundamentals
  - What's in a computer?
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Controlling output to the screen in MATLAB

- So far, our only option for controlling output to the screen is has been putting a '**;**' at the end of the line.
- This stopped MATLAB printing to the screen:

```
>x=1+2
   x=3

>x=1+2;
>
```

- So we need a better method to control output if we want to control screens like this:

Displaying text using the *disp* command

- Two simple examples of the **disp** command:

```
>disp('Hello world!')

 Hello world!
```

Notice the single quotes.

or

```
>disp('Learning how to program a computer will make me rich!')

Learning how to program a computer will make me rich!
```

You can remember this command by thinking of a computer *disp*lay

Displaying numbers with the *disp* command

- ***disp*** command can display **numbers** OR **sentences**
  - But not both at the same time

```
%Program to print the speed of light

disp('The speed of light is ');
disp(3e8);
disp('m/s');
```

```
The speed of light is
3e8
m/s
```


Variables that can hold text

- Before we can get more control over the output we have to learn about '***strings***'
- **Strings** are a special type of variable that can hold text. Examples are:

```
message='The speed of light is '
name='Rod'
day_of_week='Monday'
name_of_university='Nottingham'
```

Single quote

disp can print variables .....

- The **disp** command also works with variables:

```
%Program to print the speed of light
message='The speed of light is ';
speed_of_light=3e8;
units='m/s';

disp(message);
disp(speed_of_light);
disp(units);
```

```
The speed of light is
3e8
m/s
```

- But notice we still don't have much control over how our text is printed.
- **What is wrong with this output?**
- For this we need another command.

More control over ***disp*** with ***sprintf***

•Imagine I wanted to print
"The speed of light is 300000000.0 m/s"

```
>sprintf('The speed of light is %f m/s',3e8)
ans='The speed of light is 300000000.0 m/s'
```

•**%f** is called a format specifier.

sprintf another example

•Imagine I wanted to print
"I have 100.0 pounds"

```
>sprintf('I have %f pounds',100.0)
      ans=I have 100.0 pounds
```


sprintf in depth

•Another example imagine we wanted to print:
speed=500 m/s fuel left= 5000 L altitude=10000 m

```
>sprintf('speed=%f m/s fuel left=%f L altitude=%f m ',500, 5000, 1e4);
      ans=speed=500 m/s fuel left= 5000 L altitude=10000 m
```

•**sprintf** replaces anything beginning with a '%' with the corresponding number.

More control over output of strings with ***sprintf***

•You can specify the number of decimal places a number should be printed to

```
a=sprintf('The value of pi is %.10f',pi);
disp(a);
>>The value of pi is 3.1415926536
```

%.10f

•Number of decimal places

```
a=sprintf('The value of pi is %.5f  %.10f',pi,pi);
disp(a);
>> The value of pi is 3.14159  3.1415926536
```


sprintf is not limited to decimal numbers

Type	Significance	Example
%f	Floating point (decimal place)	1.11111
%e	Scientific notation	1e-1
%d	decimal	100
%s	string	'hello'
%c	Single character	A

Mixing numbers and text with ***sprintf***

Imagine we wanted to print
•**'My name is Rod , I live at house number 9'** where Rod and 9 are stored in variables.
•We could do it like this.

```
>name='Rod'
>number=9
>a=sprintf('My name is %s , I live at house number %d',name,number);

>disp(a);
>My name is Rod , I live at house number 9
```

Special characters ***sprintf*** accepts

• ***sprintf*** also has some special sequences of characters which can be used to further format the string:

Character	Significance
\n	New line
\t	tab
\\	backslash
\"	Single '
\%	Percent

Note this is x2 single quotation marks →

•This is because ***sprintf*** understands % and ' as having a special meaning.

Special characters ***sprintf*** accepts

Oh this shiny new computer -
There just isn't nothin' cuter.
It knows everything the world ever knew.
And with this great computer I don't need no writin' tutor,
'Cause there ain't a single thing that it can't do.

by Shel Silverstein

```
%A computer poem
 a=sprintf('Oh this shiny new computer - \n There just isn\''t
nothin\'' cuter.\n It knows everything the world ever knew. \n And
with this great computer I don\''t need no writin\'' tutor, \n \''Cause
there ain\''t a single thing that it can\''t do.\n ');
 disp(a);
```


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•Writing to the screen

•**Reading text from the keyboard**

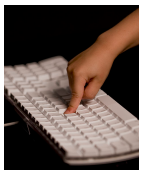
•Strings in depth

Input from the keyboard

•No matter which computer you spend your working day programming it will almost always have a keyboard.

•The next part of the lecture deals with getting text from the keyboard into MATLAB variables.

ATM



PC - keyboard

Flight management system from Boeing 737.

Keyboard ***input***

Often your program needs to ask the user a question which requires a numeric answer:

How much fuel is needed?

In MATLAB we would do this with the input command

```
answer=input ('How much fuel is needed?');
```


A simple example

```
% Program to evaluate a quadratic
x=input('What value of x do you want to solve the equation for?')
y=(2*x*x+3*x+1)*cos(x)*sin(x);
disp('The answer is:')
disp(y)
```

What value of x do you want to solve the equation for?

A simple example

```
% Program to evaluate a quadratic
x=input('What value of x do you want to solve the equation for?')
y=(2*x*x+3*x+1)*cos(x)*sin(x);
disp('The answer is:')
disp(y)
```

```
What value of x do you want to solve the equation for? 1.0
The answer is:
2.7279
```


Using *input* and *sprintf* together

Calculating how far the space ship will travel in ten seconds:

```
%program to calculate how far the space ship will
%travel in ten seconds
speed=input('How fast is the space ship traveling (m/s)?');
time=10.0;
distance=speed*time;
a=sprintf('It will travel %f m in %f seconds',distance,time);
disp(a)
```

```
How fast is the space ship traveling (m/s)?
```


Using *input* and *sprintf* together

Calculating how far the space ship will travel in ten seconds:

```
%program to calculate how far the space ship will
%travel in ten seconds
speed=input('How fast is the space ship traveling (m/s)?');
time=10.0;
distance=speed*time;
a=sprintf('It will travel %f m in %f seconds',distance,time);
disp(a)
```

```
How fast is the space ship traveling (m/s)? 1000.0
It will travel 10000.0 m in 10.0 seconds.
```


Keyboard *input*

It is also common to need to get text from the keyboard in response to a question:

```
Launch the rocket [yes/no]?
```

You need to append an 's' (for string) at the end of the input command....

```
answer=input ('Launch the rocket [yes/no]?','s');
```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Strings in depth

- In the first part of the lecture we learnt that strings of text can be stored in a variable.

```
% A string example
a='My name is Rod';
disp(a);
     My name is Rod
```

- But strings are ***really just arrays*** of letters and we can use all the tricks we learnt to deal with strings in the first three lectures to play with strings....

For example

- If we defined the string

```
a='My name is Rod'
```

- We could find out what the 2nd character is by doing

```
>a(2)
    ans='y'
```

- Or we could swap out the 14th character for a b

```
>a(14)='b';
>disp(a)
    My name is Rob
```

- Sometimes it's handy to think of strings as arrays.

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