University of Nottingham

Electromechanical devices MM2EMD

Lecture 1 - Counting to 1024 on your fingers and getting robots to pour beer.

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Summer 2015

Outline of the lecture

- **About me and Electronic Engineering**

- What is electronic engineering and why do I need to learn it?

- Representing information in electronic circuits.

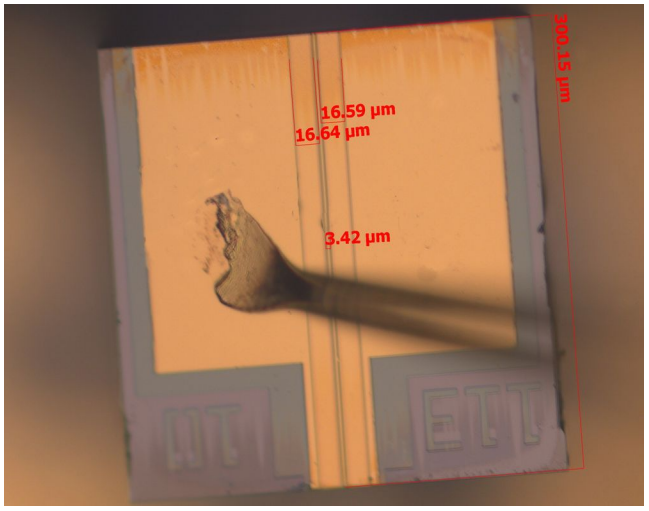
- Shaft encoders

- Making circuits smart – logic gates
  - AND gate
  - OR gate
  - NOT gate

Electronic Engineering and **me**

•Electronic Engineering is a subject I **love**.

•I have spent the last **15 years** of my life researching Electronic Engineering problems.

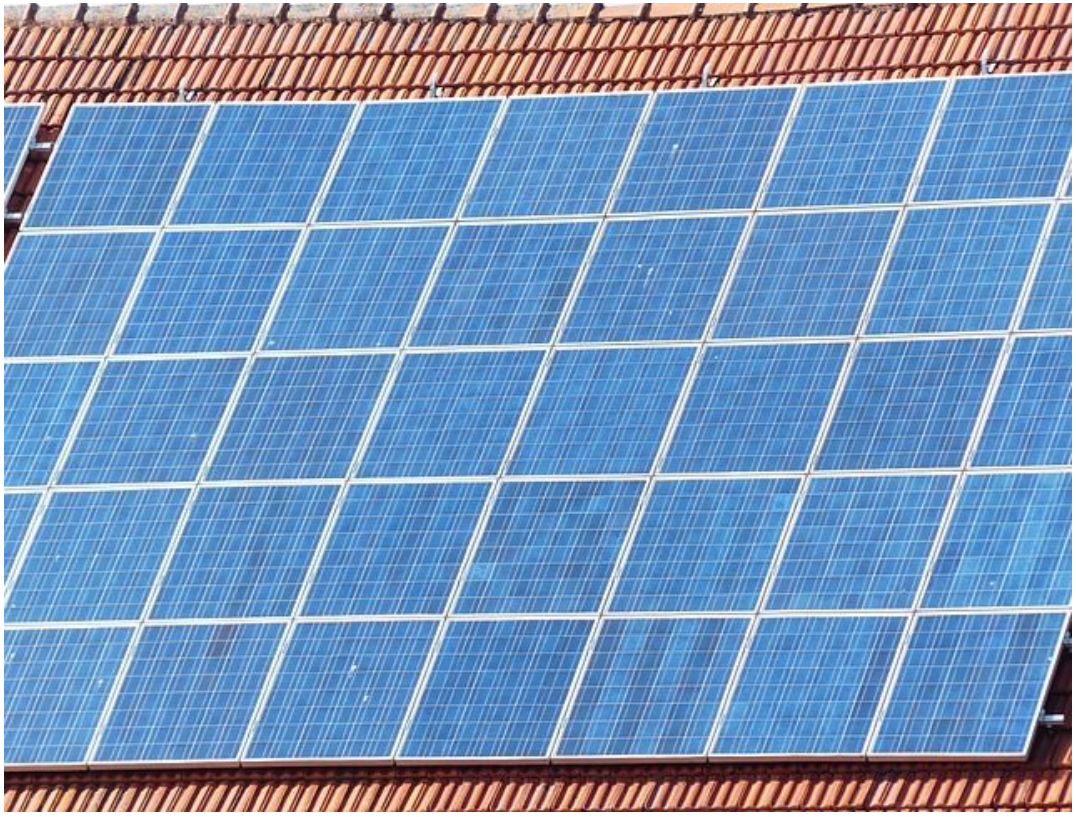


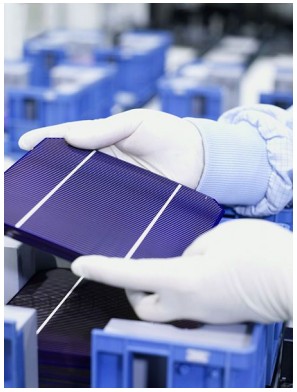
A laser I developed during my PhD

•I spent four years during my PhD developing **lasers** for:

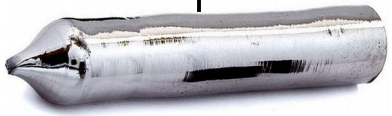
- **Inter-satellite communication**
- **Telecommunications**
- **Cancer surgery**

Replacing silicon solar cells

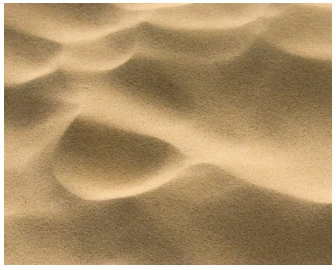




Silicon solar cell



Mono-crystalline silicon



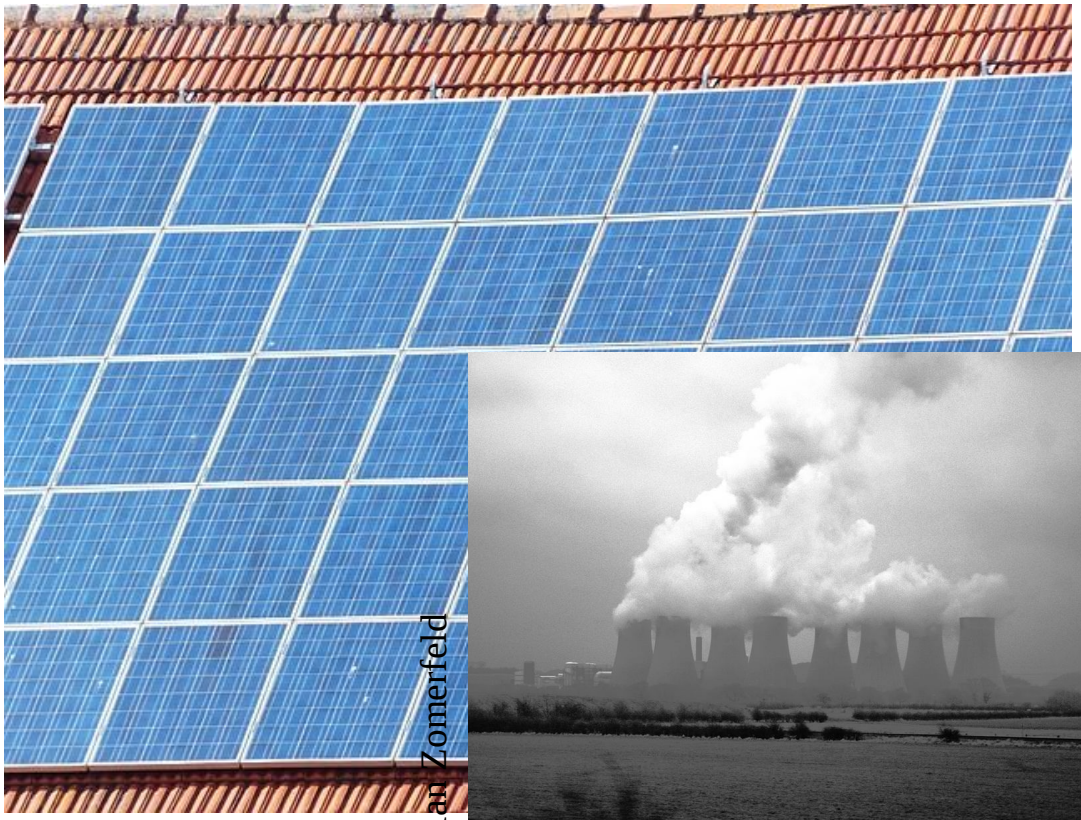
Naturally occurring silica

2 GJ per square meter!

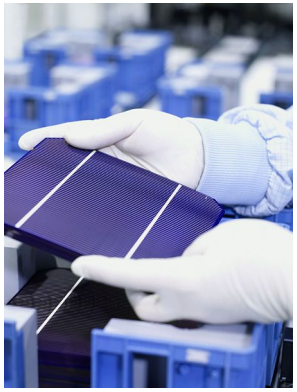
(553 kWh)

- We need a lot of energy to make silicon solar cells.

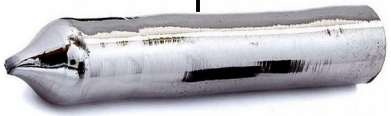
Replacing silicon solar cells



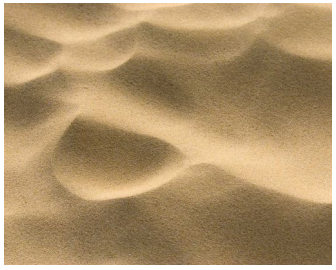
Alan Zomerfeld



Silicon solar cell



Mono-crystalline silicon



Naturally occurring silica

2 GJ per square meter!

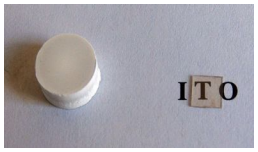
(553 kWh)

- We need a lot of energy to make silicon solar cells.

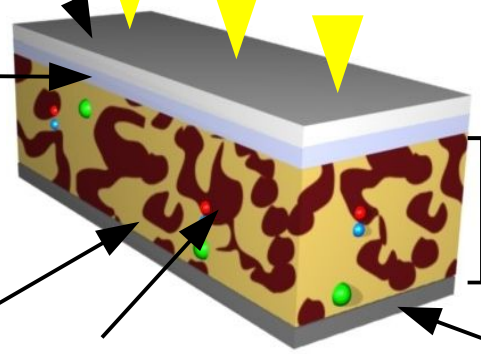
Recently, I have been working on plastic solar cells:

Transparent plastic substrate

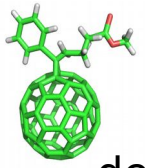
Sun light



Transparent oxide electrode



Light adsorbing polymer



C60 derivative

Metallic back contact

A example of a printed organic solar cell

Images from www.konarka.com

In summary

- I think electronic Engineering is a fantastic subject and I hope to convince you of this too!

What am I going to teach you about Electronic Engineering?

- Electronic Engineering is a **vast** and **wonderful** subject which effectively runs everything in our daily lives.

- Electronic Engineering spans everything from **quantum mechanics** to **electromagnetic waves** and from microwaves to cruise missiles.

- I **can't** teach you **everything** so I plan to teach you just the very essentials you will need during your career as a mechanical engineer.

What I will and what I won't teach you

- I will focus on **practical things**, **that you will need**.

- I am **not** going to teach you **a load of theory** you will not use.

- There will be **some theory**, but I will keep it to the absolute minimum.

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- Shaft encoders
- Making circuits smart – logic gates
  - AND gate
  - OR gate
  - NOT gate

Electrical Engineering (not electronic Engineering)

Alureiter from wikipedia

•Arthur Jones has been teaching you about electrical engineering

•Electrical engineering, is about **using** and **transmitting** big **voltages** and **big currents** to do useful work.

•This ship uses **very big induction motors** running at **500 V** and **100 Amps**.

50kW = 500V * 100 Amps

•Electrical engineering is clearly a useful thing for mechanical engineers to understand.

Other examples of Electrical Engineering

• This 3,500 horsepower (2,600 kW) dump truck uses a diesel motor to drive an electric generator which in turn drives four 500V / 5A electric motors attached to each wheel.

Shal Farley (shalf)

•Tesla model S P85D electric car, 0-60 in 3.2 Seconds using a 416 hp (310 kW) motor, runs at ~360V, >40A

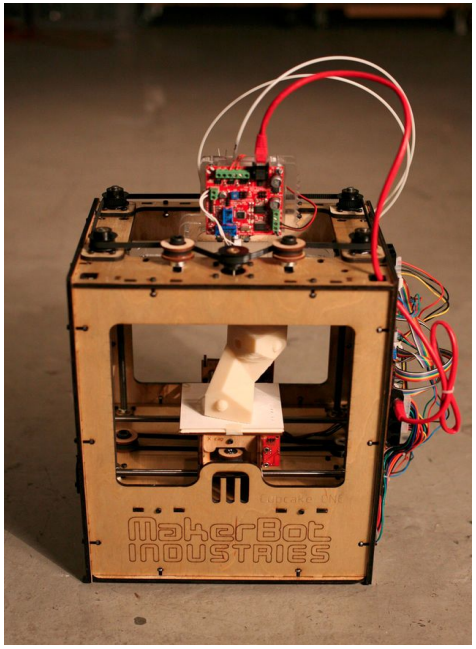
Understanding about big voltages and big currents is clearly useful for mechanical engineers.

So what is this electr**onic** engineering thing then?

- Electr**onic** engineering, is the use of **small currents (50 mA) and small voltages** (<5V) to make **clever decision making circuits....**

- Examples of electronic engineering are:

Jet engine control circuits, which decide how/when fuel is injected - **5V/50 mA**



http://www.flickr.com/photos/bre/3458247336/

Control circuitry for a maker bot **5V/ 50 mA**.

Using low voltages to control high voltages

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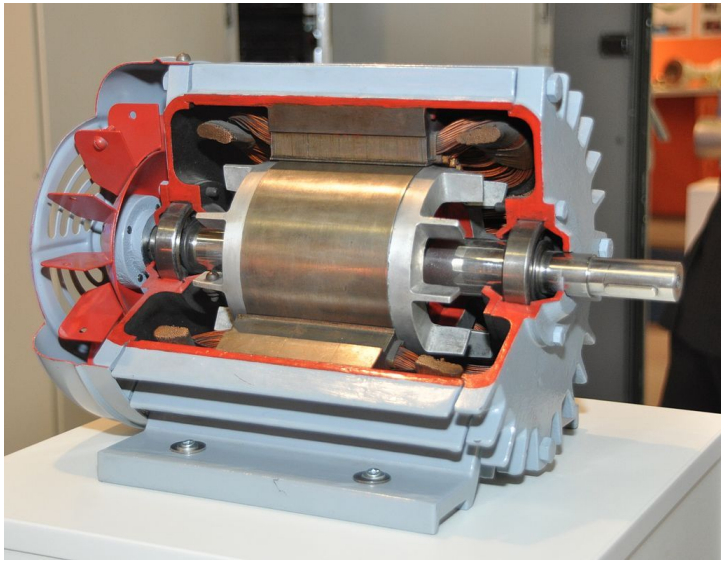
Smart Electronic Circuits (low voltage)

Dave Jones

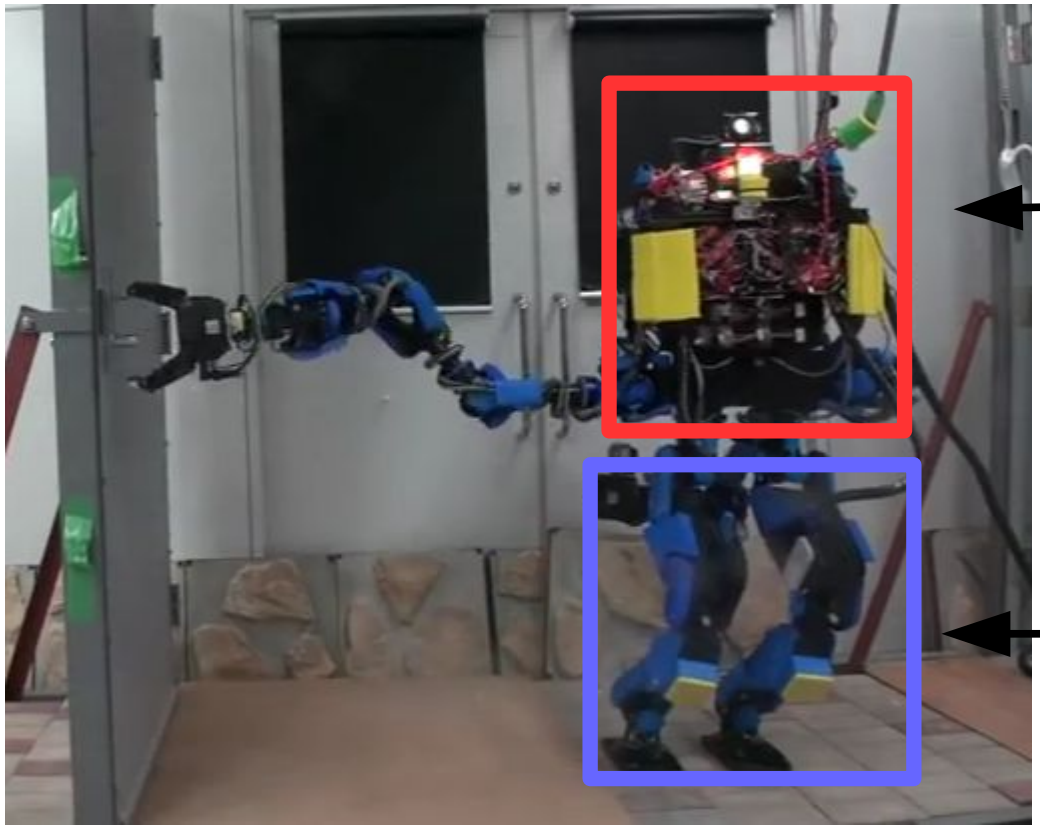
Simple Electrical Circuits (high voltage)



S.J. de Waard

- The smart electronic circuits always tell the simple electrical circuits what to do. Video.

So what is this electronic engineering thing?



Smart low voltage electronic Circuits (low voltage)

driving

Simple high voltage/current electrical Circuits

- In the next ~ten lectures I will be teaching you how to design the smart electronics you will need to drive your robots and smart machines.

So what is electr**onic** engineering?

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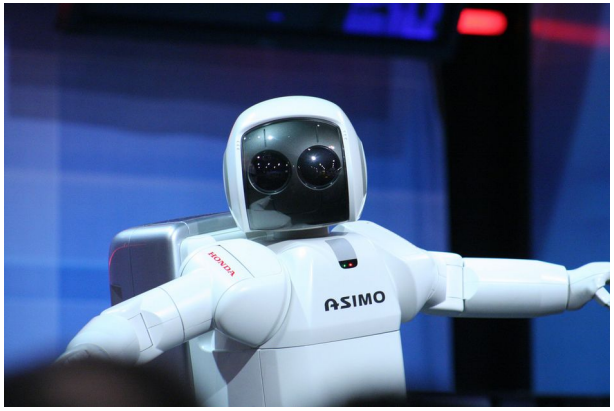
- Knowing how to design smart electronics will help you a lot in your 3rd and 4th year projects.

- Before we can design complex robot control systems we need to know some basic electronics.....



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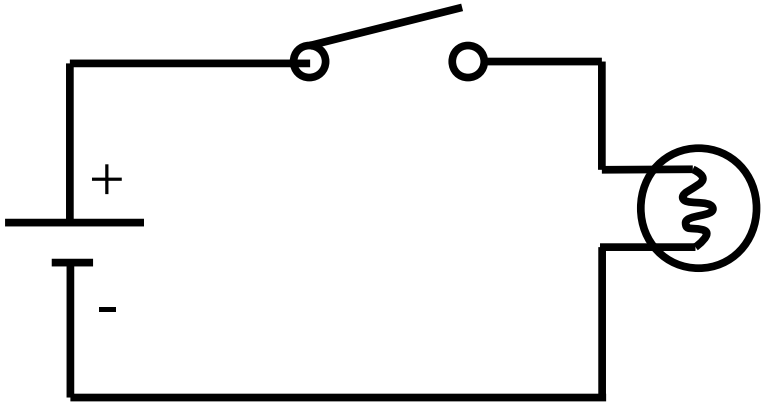
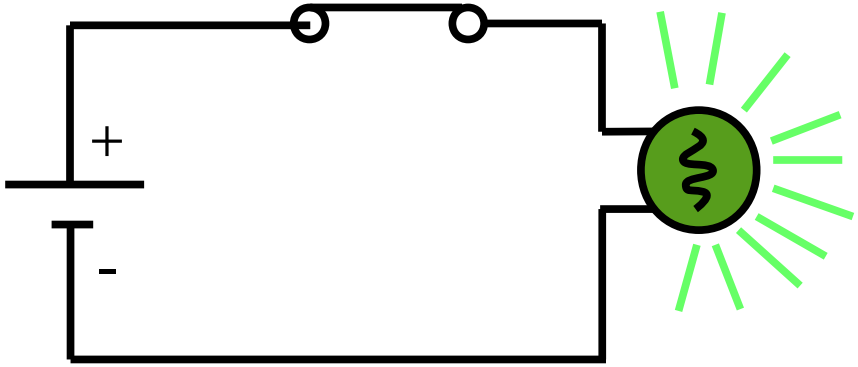
Making electronics smart.

- Before we can make electronic circuits smart, we need to make them store information.

- The simplest way to store information in electronic circuits is to define the number 1 as 'on' and the number 0 as 'off'

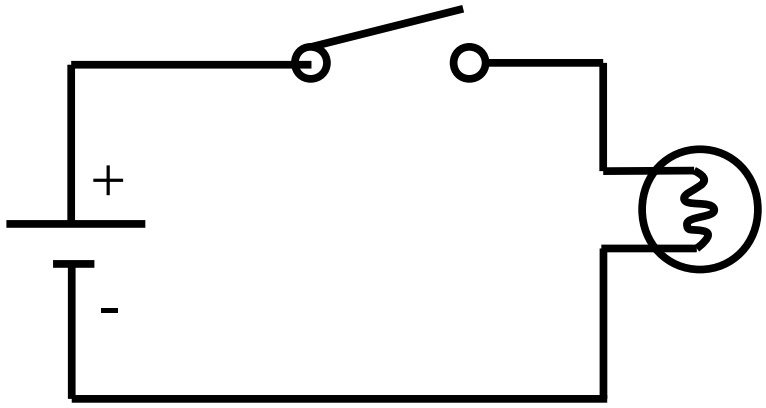


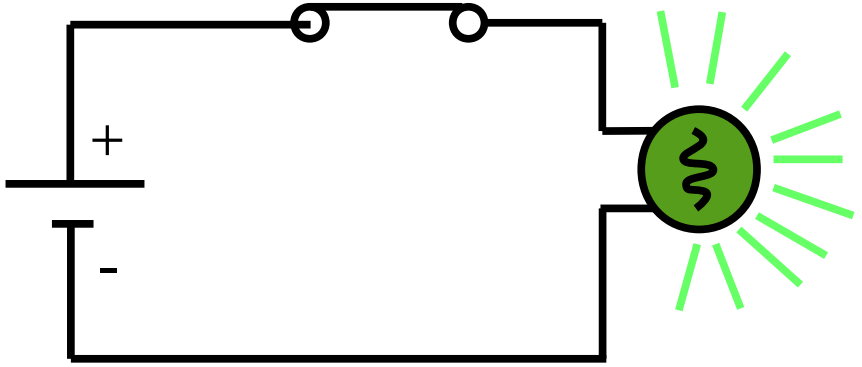
Off = 0



On = 1

Making electronics smart.





Off = 0

On = 1

g4ll4is

- Have you ever wondered why there is a 1 and a 0 on off on buttons? Well this is why!

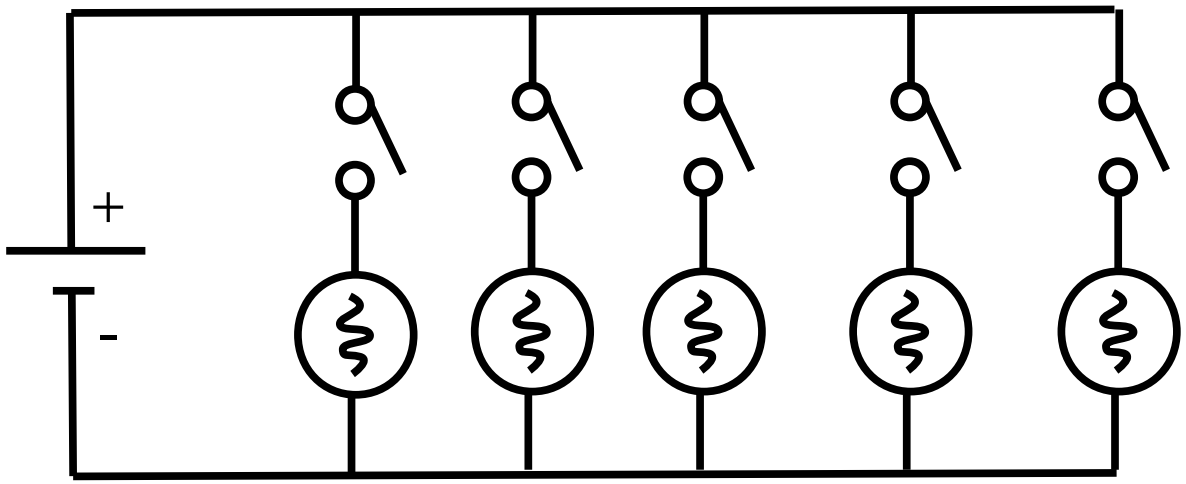
- So now we can store the numbers 1 and 0 in an electronic form.

So we can now make an electronic circuit count from 0 to 1.

- But what if I want to count to **2** or **3** or **4** ??
- How would I do that?
- Can anybody guess?

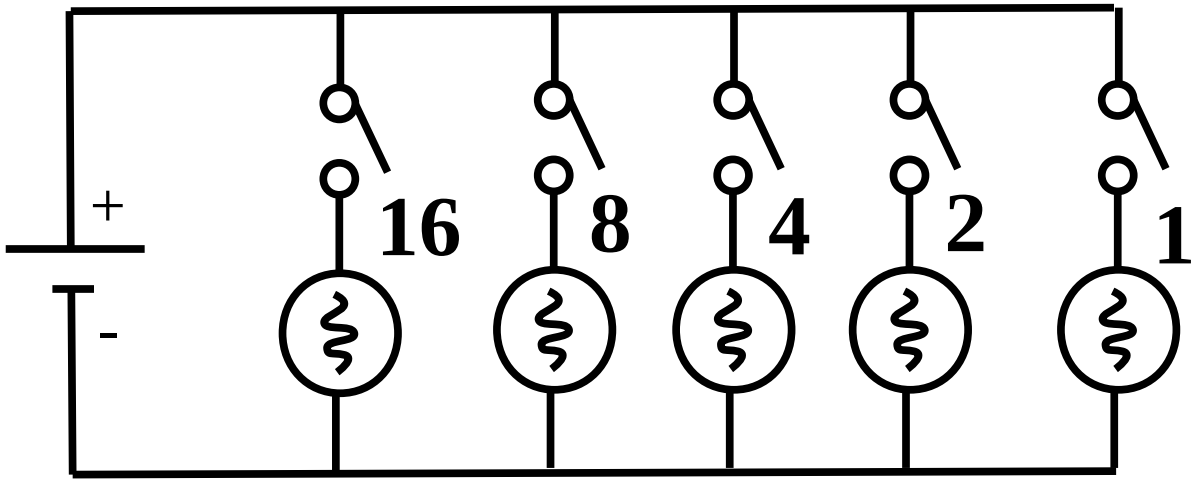
So we can now make an electronic circuit count from 0 to 1.

- But what if I want to count to **2** or **3** or **4** ??
- How would I do that?
- What we do is use lots of light bulbs.....

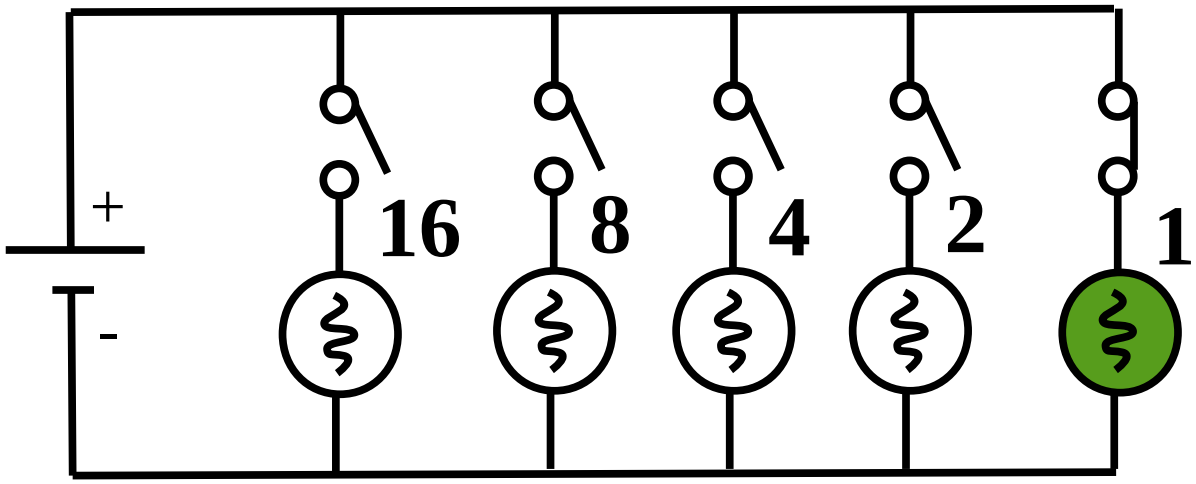


Numbers in electronics

- And we label each light bulb with a number, each double the size of the last number....

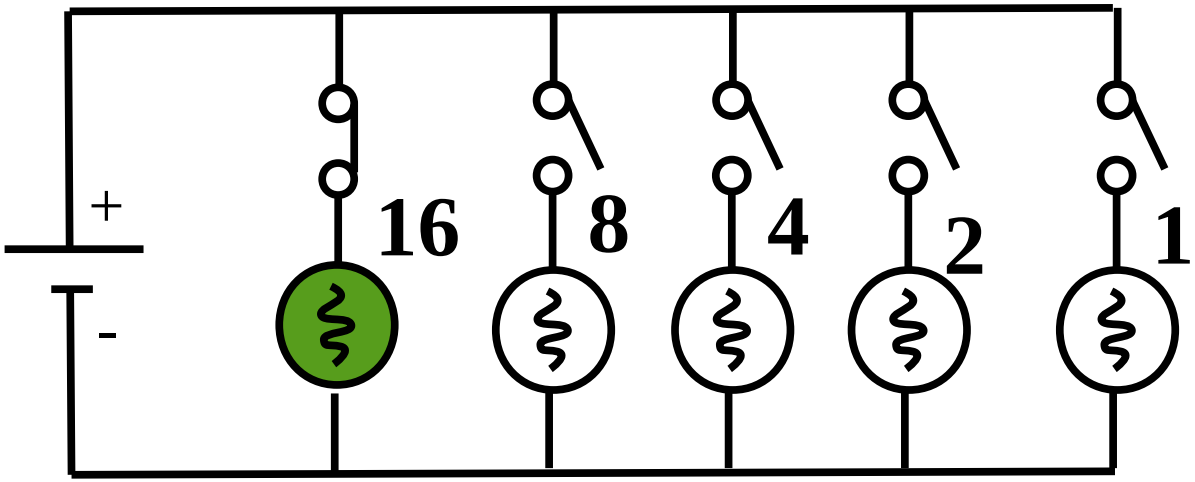


Representing the number 1



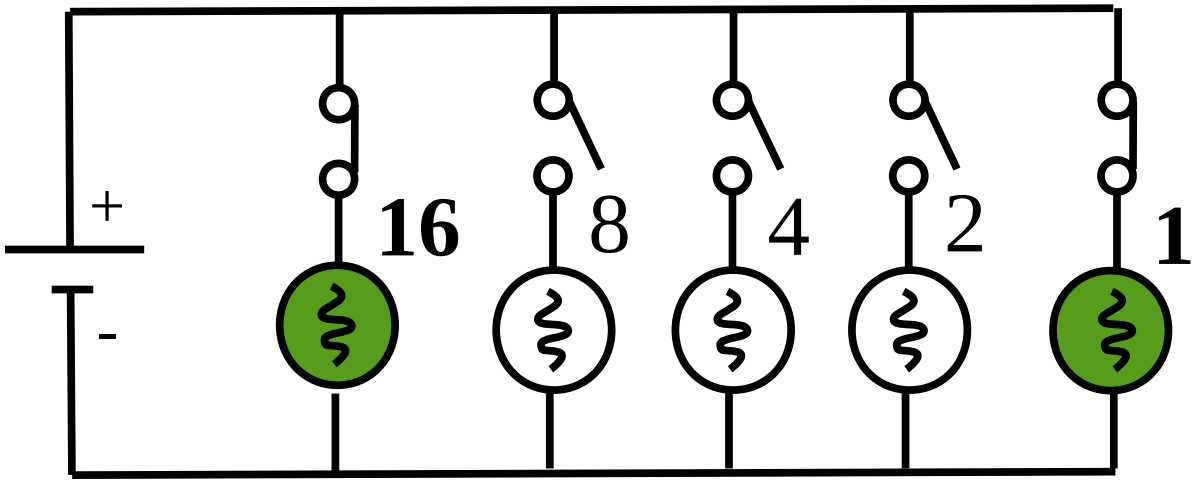
1

Representing the number 16



16

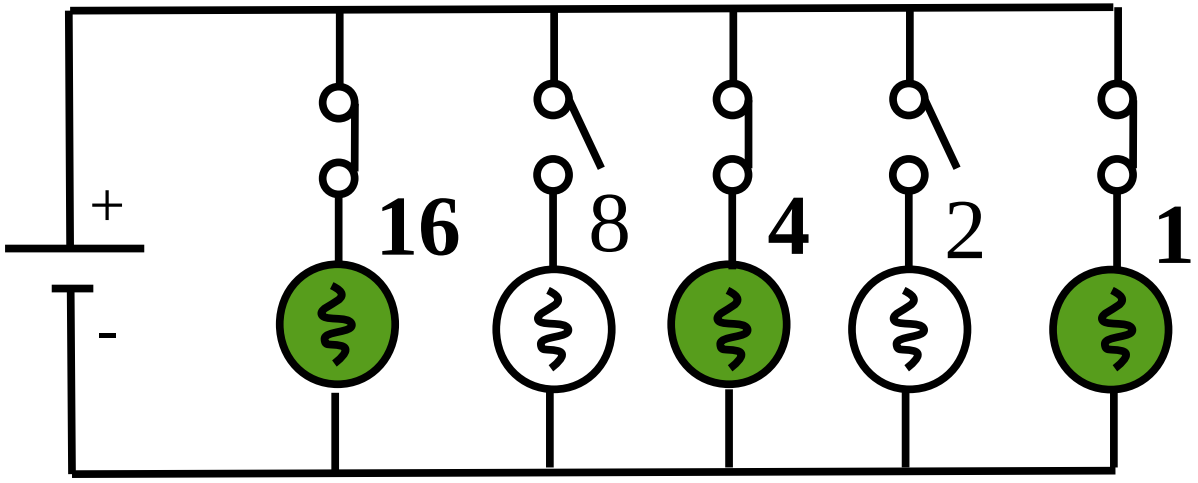
Numbers in electronics



16+1=17

Numbers in electronics

- If we want to store the number **21** we turn on **16**, **4** and **1**



16+4+1=21

Representing electronic numbers on paper

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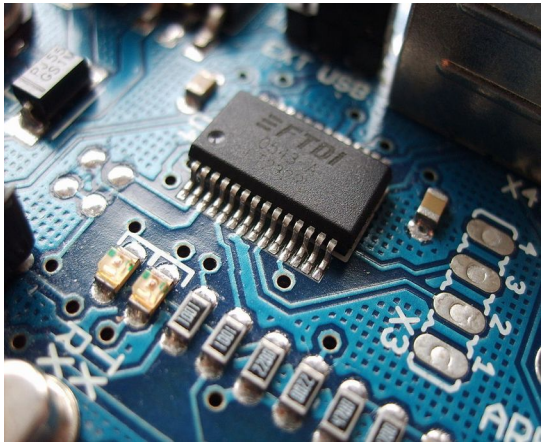
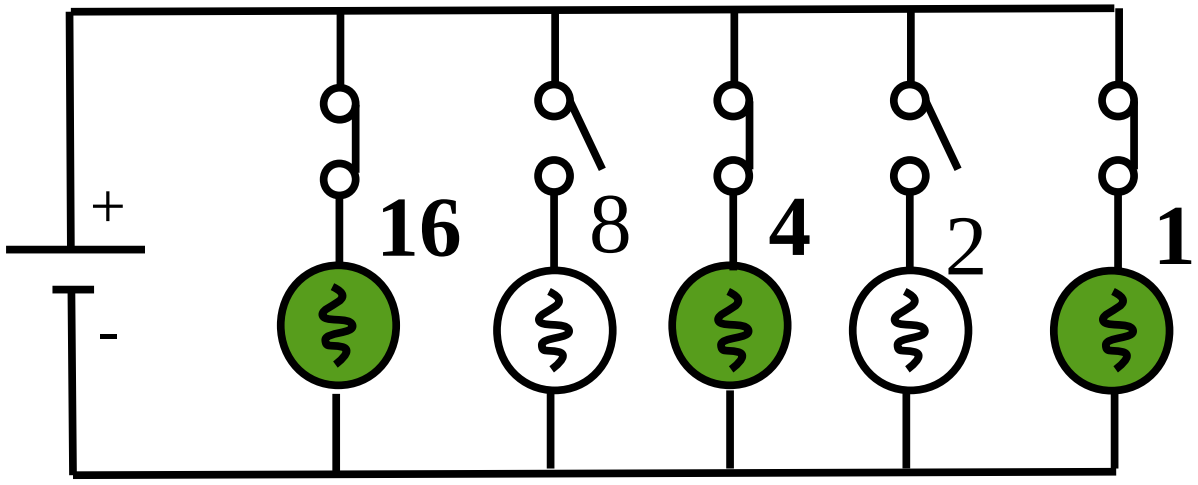
•When designing an electronic circuit it is often handy to be able to write down an electronic number without having to draw this circuit:

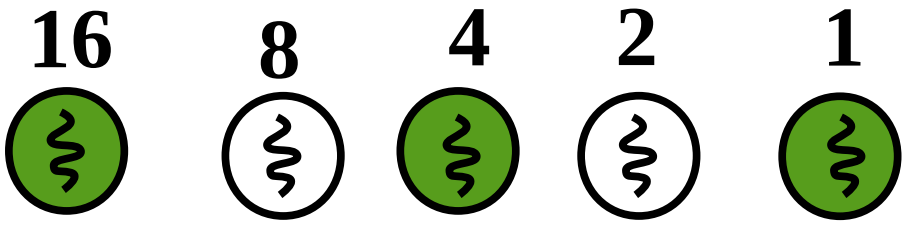




•So let's get rid of the circuit diagram and just keep the light bulbs.....

Simplifying our circuit...

- That's better...

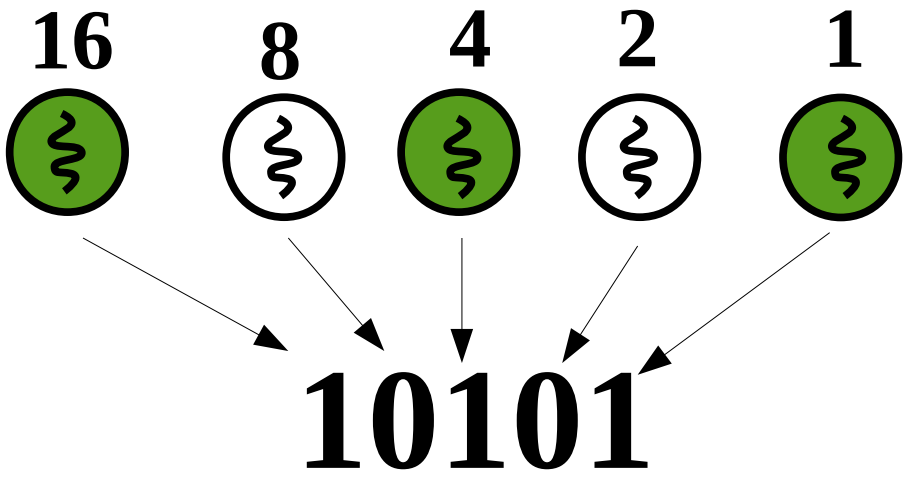


- However, it still takes quite a lot of effort to draw light bulbs.

- So let's replace the light bulbs with a **1** representing that the light bulb is **on** and a **0** representing that the light bulb is **off**.

g4ll4is

Binary numbers....



•This type of a number is called a **binary number**. It only contains 1's and 0's. (think of a **bi**cycle)

•So we can now represent any number by a series of 1's and 0's – or ON/OFF signals.

g4ll4is

How to count in binary.....

Number	Electronic (binary) number (16 8 4 2 1)	
0	0 0 0 0 0	=0+0+0+0+0
1	0 0 0 0 1	=0+0+0+0+1
2	0 0 0 1 0	=0+0+0+2+0
3	0 0 0 1 1	=0+0+0+2+1
4	0 0 1 0 0	=0+0+4+0+0
5	0 0 1 0 1	=0+0+4+0+1
6	0 0 1 1 0	=0+0+4+2+0

Binary number

Number	16	8	4	2	1	
0	0	0	0	0	0	=0+0+0+0+0
1	0	0	0	0	1	=0+0+0+0+1
2	0	0	0	1	0	=0+0+0+2+0
3	0	0	0	1	1	=0+0+0+2+1
4	0	0	1	0	0	=0+0+4+0+0
5	0	0	1	0	1	=0+0+4+0+1
6	0	0	1	1	0	=0+0+4+2+0
7	?	?	?	?	?	=?+?+?+?+?
8	?	?	?	?	?	=?+?+?+?+?
9	?	?	?	?	?	=?+?+?+?+?
10	?	?	?	?	?	=?+?+?+?+?
11	?	?	?	?	?	=?+?+?+?+?
12	?	?	?	?	?	=?+?+?+?+?

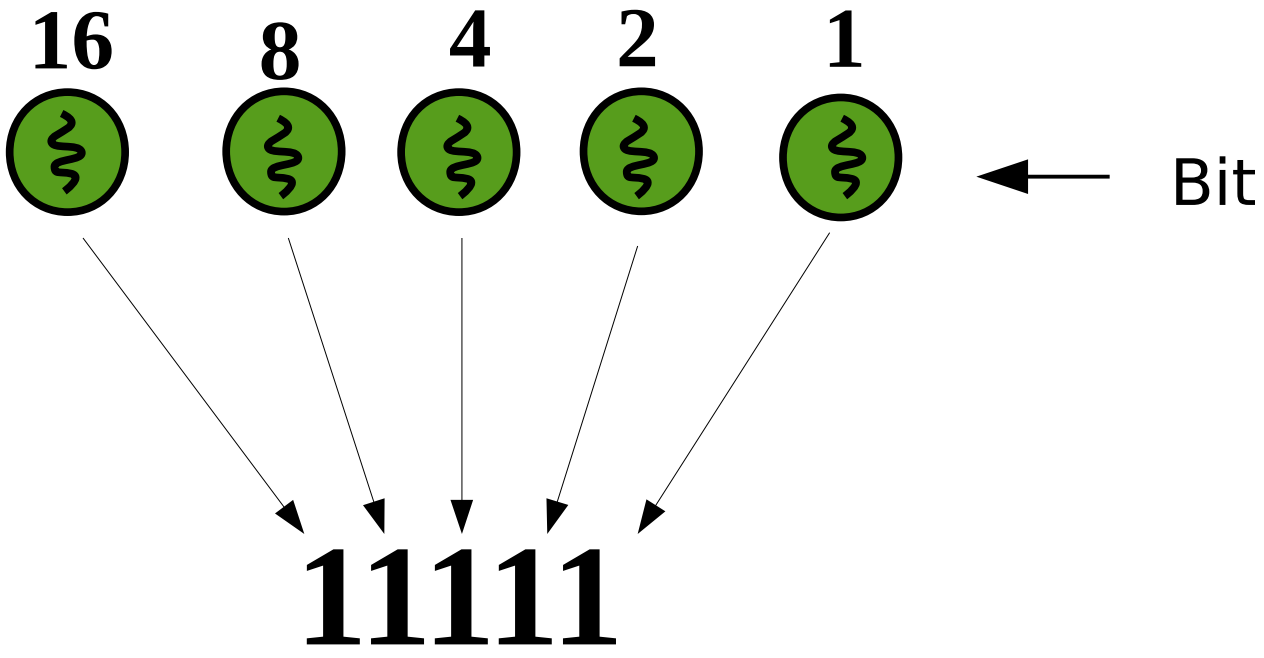
Your go, fill in the rest of the table....

The answer..

Number	16	8	4	2	1
0	0	0	0	0	0
1	0	0	0	0	1
2	0	0	0	1	0
3	0	0	0	1	1
4	0	0	1	0	0
5	0	0	1	0	1
6	0	0	1	1	0
7	0	0	1	1	1
8	0	1	0	0	0
9	0	1	0	0	1
10	0	1	0	1	0
11	0	1	0	1	1
12	0	1	1	0	0

Electronic (binary) number

Question?

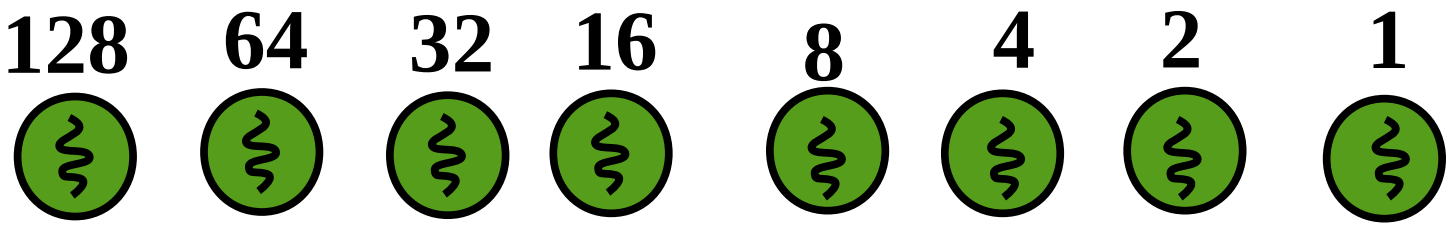


- What is the maximum value we can represent with a five digit binary number?

- What could we do to count higher?

Answer

•Make it longer....



128+64+32+16+8+4+2+1=255

•Now we can represent any number with on and off signals in an electronic circuit....

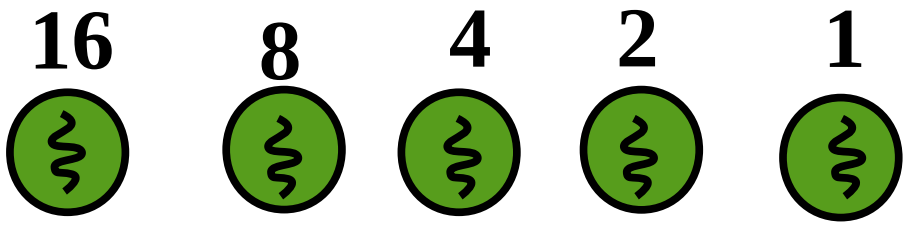
•Incidentally modern computers use, 32 or 64 bits to represent information.

Answer

- Generally, the maximum number we can count to with a binary number is given by

$$2^n - 1$$

- Where n is the number of bits



2^5-1=16+8+4+2+1=31

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Knowing what your machine is doing

- The beer challenge - I would like a volunteer. :)

Knowing what your machine is doing

- The beer challenge - I would like a volunteer. :)
  - The task is not hard...

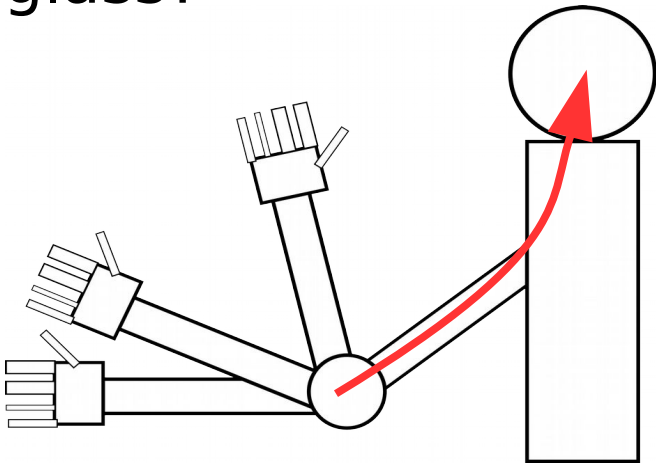
Knowing what your machine is doing

- Close your eyes.
- And poor the beer into the glass.

Knowing where your beer is...

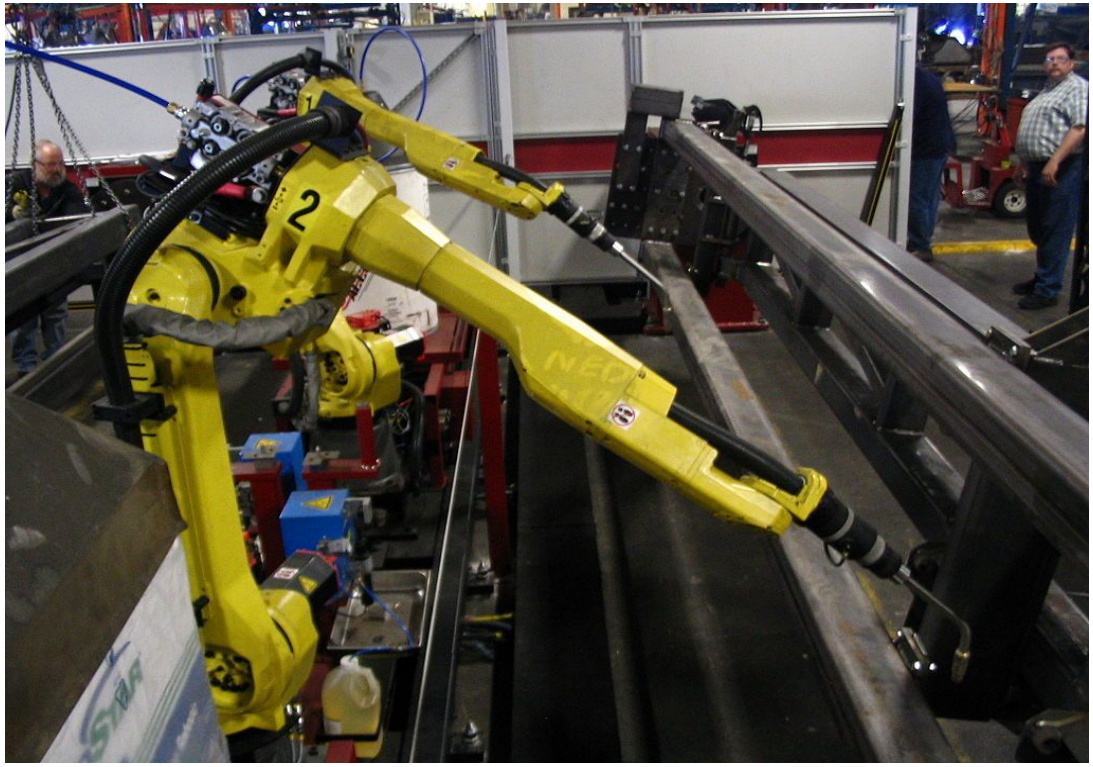
•How did our volunteer do this task even though **he did not see** the can of beer or the glass?

•He has **nerves** in his arm which act as **sensors** telling his **brain** exactly where his arm is.



•Robots need the same type of sensor.....

Well robots need the same types of sensors to do useful work...

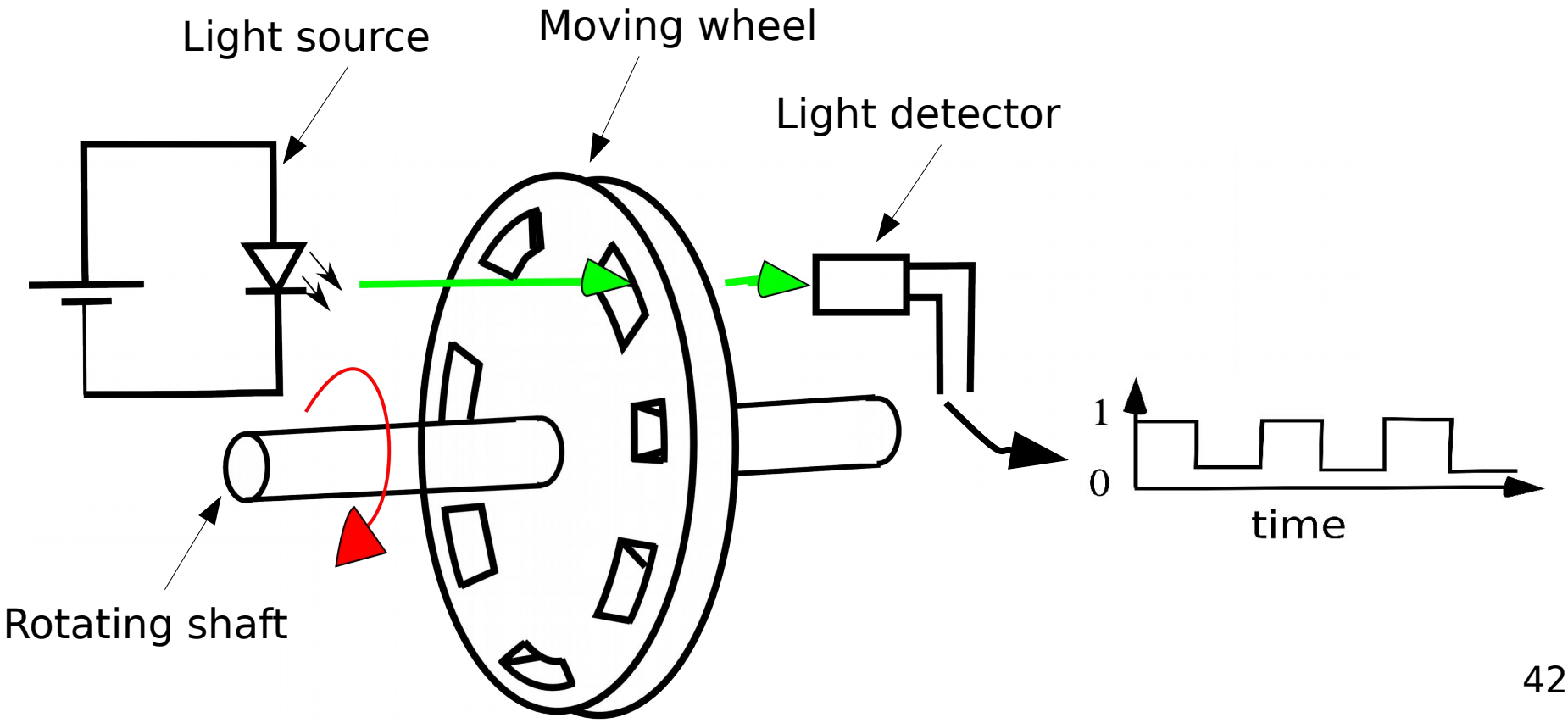


Phasmatisnox

•For our robots to be smart they need the same type of sensors telling them what they are doing.

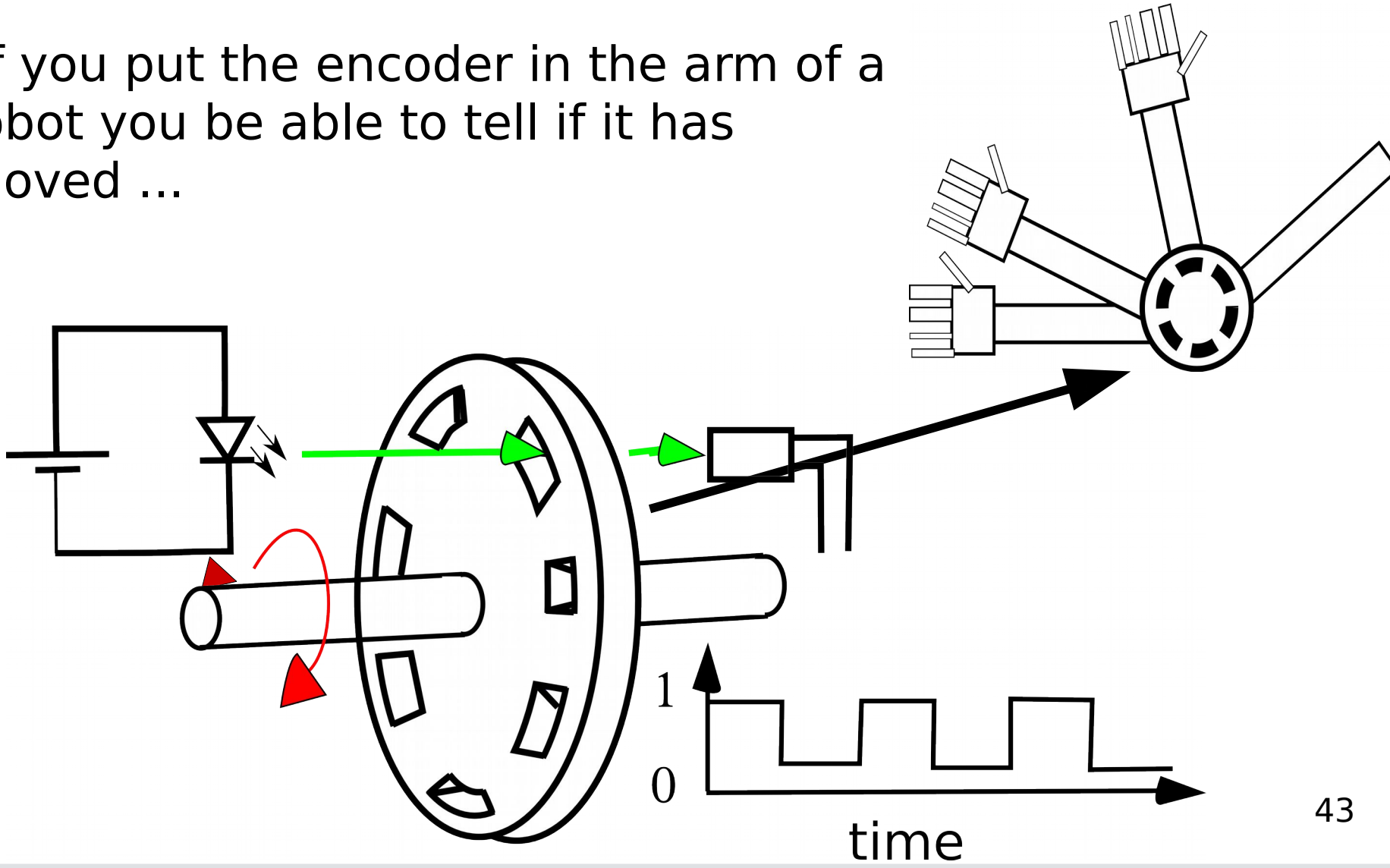
Shaft encoders

- The way we detect movement in mechanical devices is using a shaft encoder and it looks like this....



Shaft encoders in robots

- If you put the encoder in the arm of a robot you be able to tell if it has moved ...



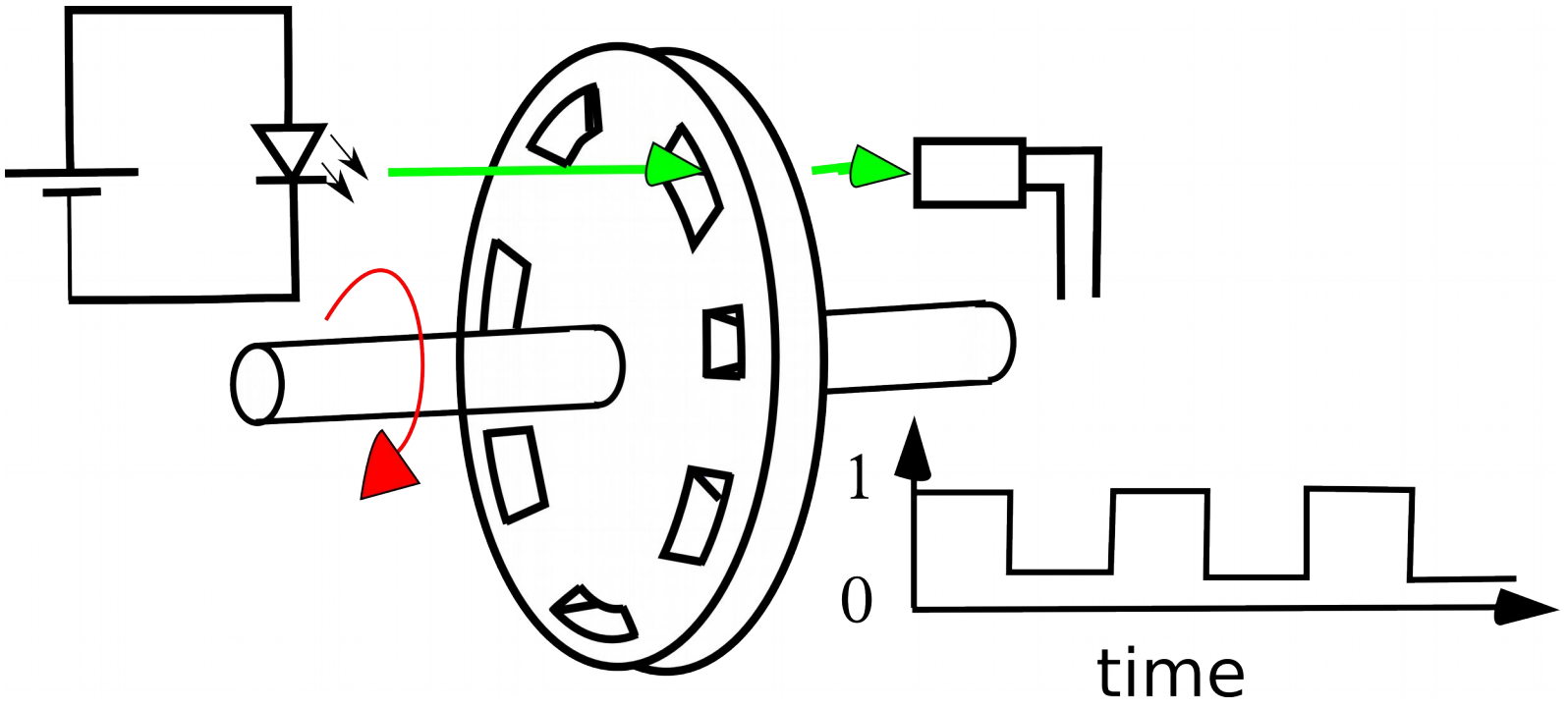
A real shaft encoder

- Here is a real shaft encoder.
- It's in a nice hardened package ready for use.
- What could a problem with this type of shaft encoder be?

Victor Korniyenko

The problem with shaft encoders

•The problem with this type of shaft encoder is that they can tell us that our motor is moving and how fast it is moving but not it's exact position..



Better shaft encoders

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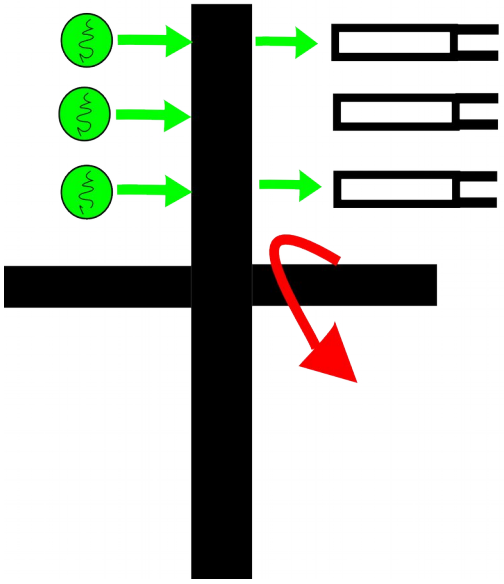
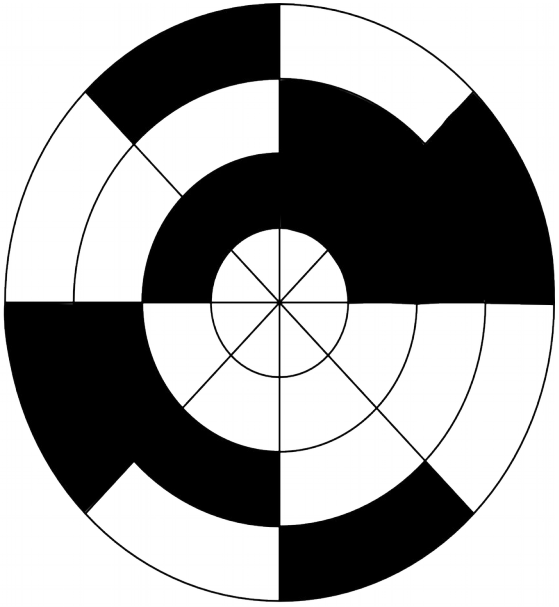
•To solve this problem we use multiple lights and multiple slots in a wheel.





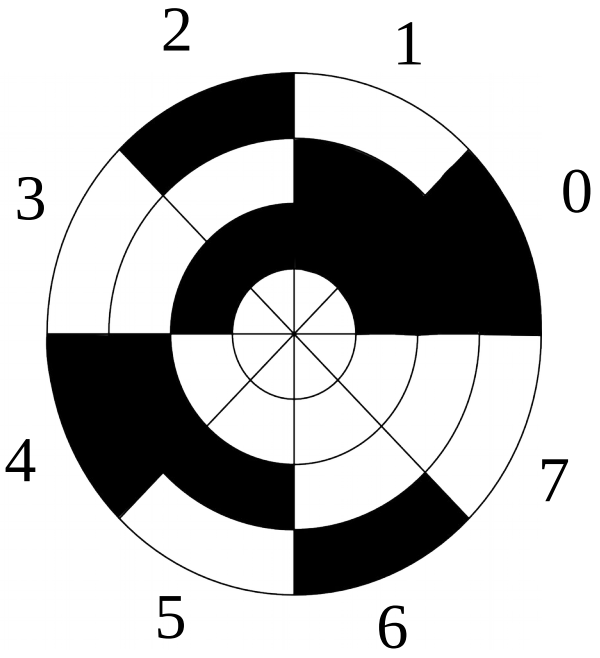
•We then cut a series of slots into the wheel and we will know exactly where the wheel is.

•Do you recognize the pattern on the disk?

Better shaft encoders

- Exactly, it's binary code...

Sensor 1	Sensor 2	Sensor 3	Number	Angle
off	off	off	0	0-45
off	off	on	1	45-90
off	on	off	2	90-135
off	on	on	3	135-180
on	off	off	4	180-225
on	off	on	5	225-270
on	on	off	6	270-315
on	on	on	7	315-360



Accuracy of shaft encoders

- We had three sensors so we could count to 1+2+4=7
- Including 0 we had 8 positions
- Therefore we had an accuracy of 360/8=~45 degrees
- If we wanted a more accurate sensor we would simply add more sensors so we could get a higher resolution
- i.e. four sensors, 1+2+4+8=15, 16 positions including 0
- Resolution of 360/16=22 degrees.

Shaft encoders in action

KUKA Roboter GmbH,

•Have a look at this video:

Video

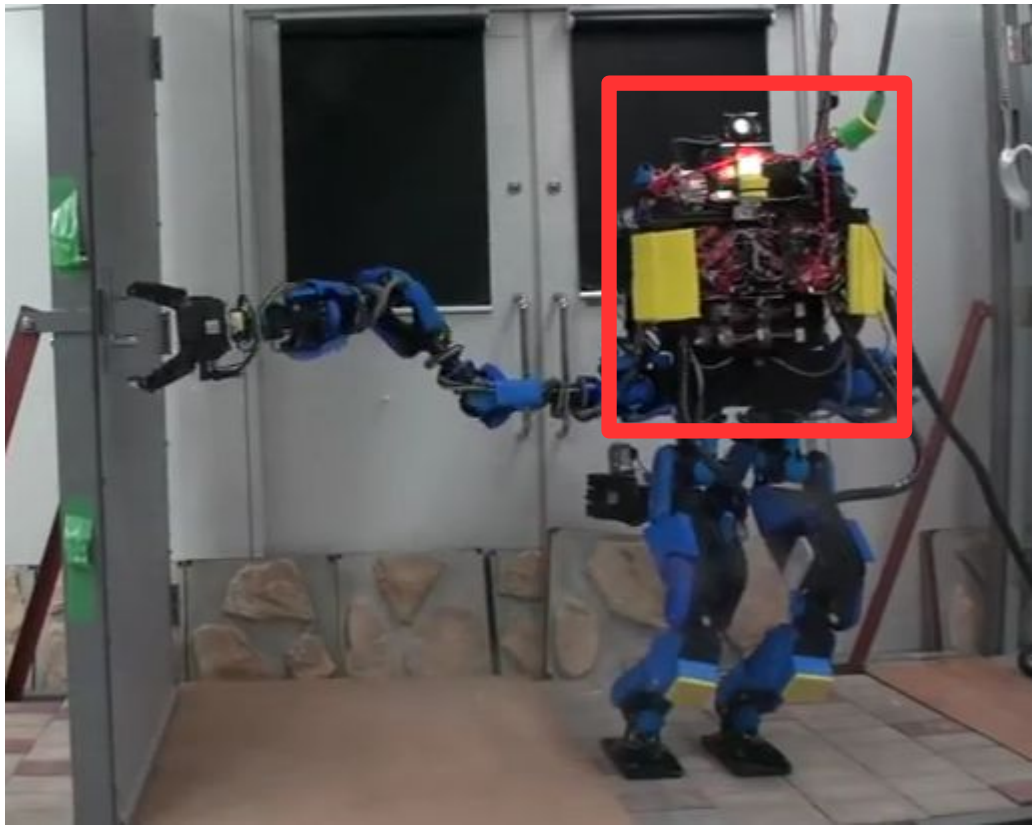
•Whilst you are watching this I want you to notice how accurate and precise the movements of the robot arms are.

•This is all done with shaft encoders, no complex computer vision.

Outline of the lecture

- About me and Electronic Engineering
- What is electronics and why do I need to learn it?
- Representing information in electronic circuits.
- Shaft encoders
- **Making circuits smart – logic gates**
  - AND gate
  - OR gate
  - NOT gate

Electronics is about making our devices smart



- I am now going to teach you the fundamentals electronic components which are used to make devices smart.

- These components can be used to make decisions.

- The first and most important logic element is called the AND gate.

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The most basic logic component of any circuit is the AND gate.

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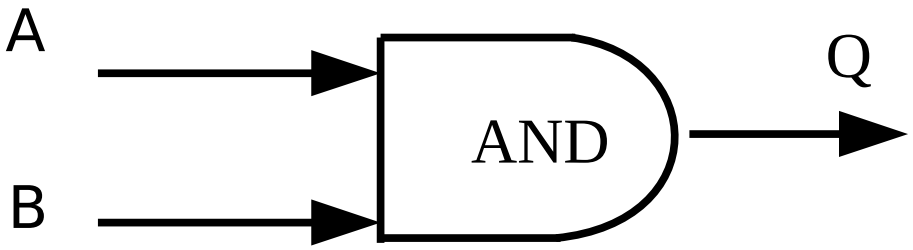
- An AND gate is a circuit that gives a 1 when **one input AND** the **other input** are 1.

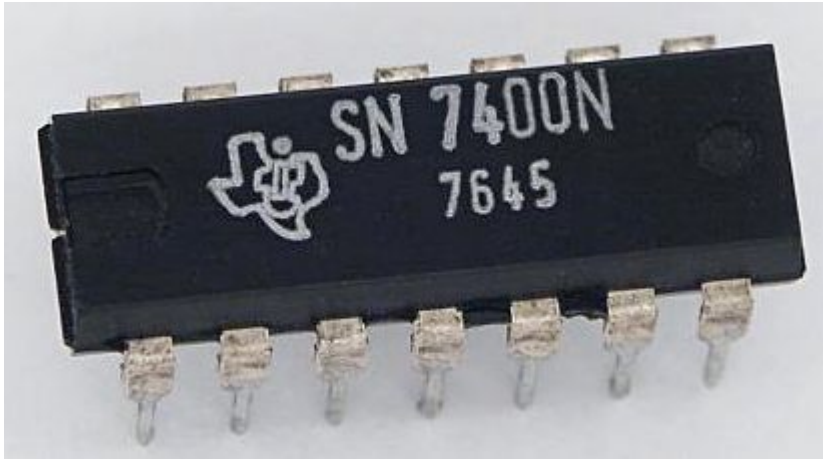


A	B	Q
0	0	0
0	1	0
1	0	0
1	1	1

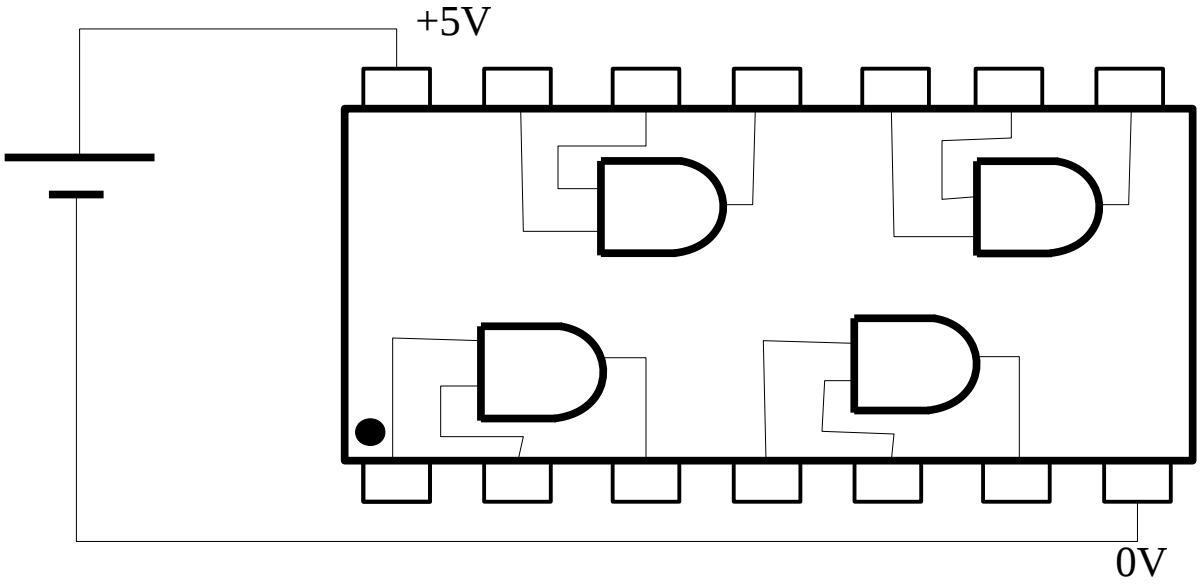
Truth table

- An **AND** gate is not some theoretical concept...

A real AND gate, they are extremely useful if you want to build simple logic



They cost about 50 p



Let's use the AND gate to make a burglar alarm circuit with this chip.

Electronic logic – the AND gate

- You want the alarm to sound when:
  - **The alarm has been set**

g4ll4is

  - AND
  - **Someone steps on the pressure sensor**


HAF 932

The AND gate

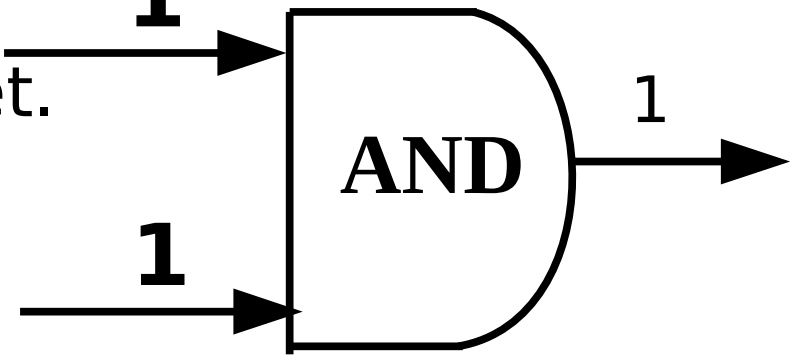
- So we want the alarm to sound when **one condition** is met **AND** another **condition is met**.

The alarm has been set.

1

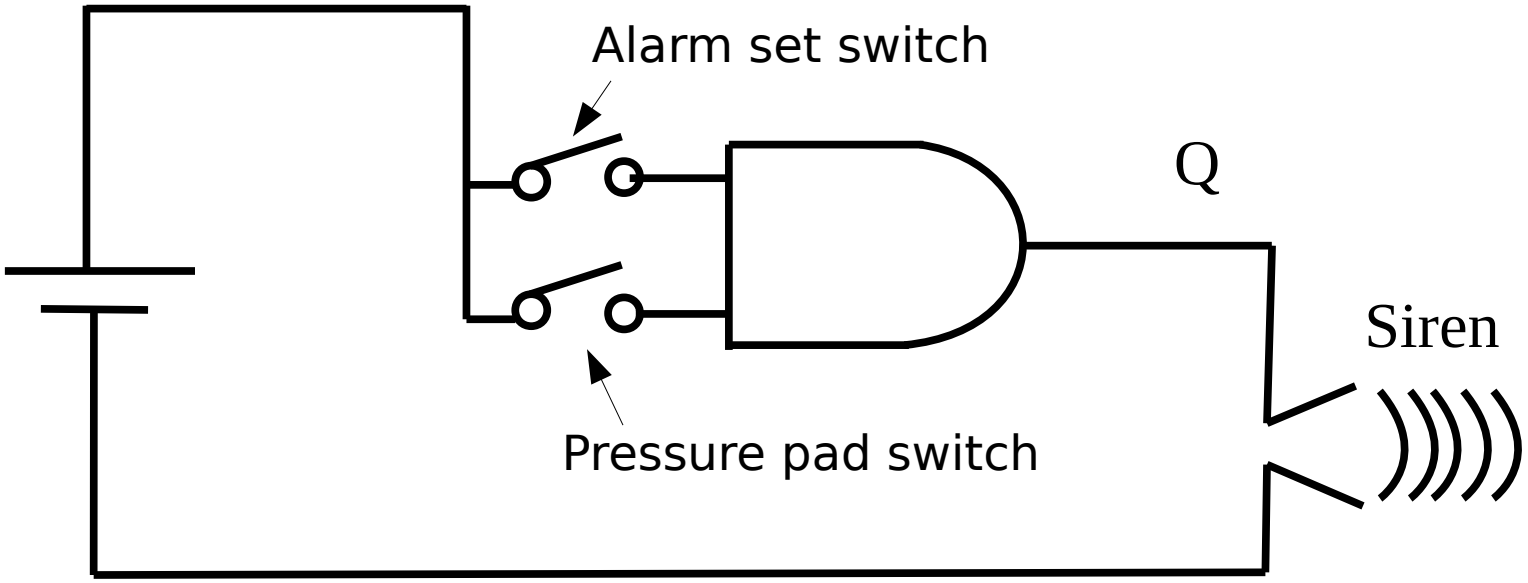
Someone steps on the pressure sensor

1



Our finished circuit

Our final burglar alarm circuit would look like this:



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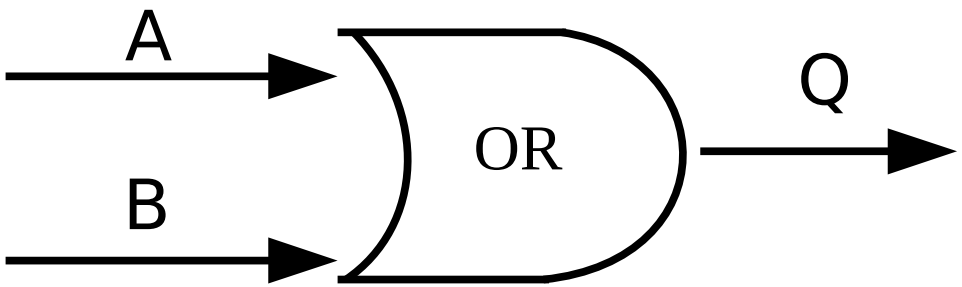
The OR gate truth table



A	B	Q
0	0	0
0	1	1
1	0	1
1	1	1

The OR gate

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- Imagine this time we were designing an alarm to detect a fire in an aircraft engines.

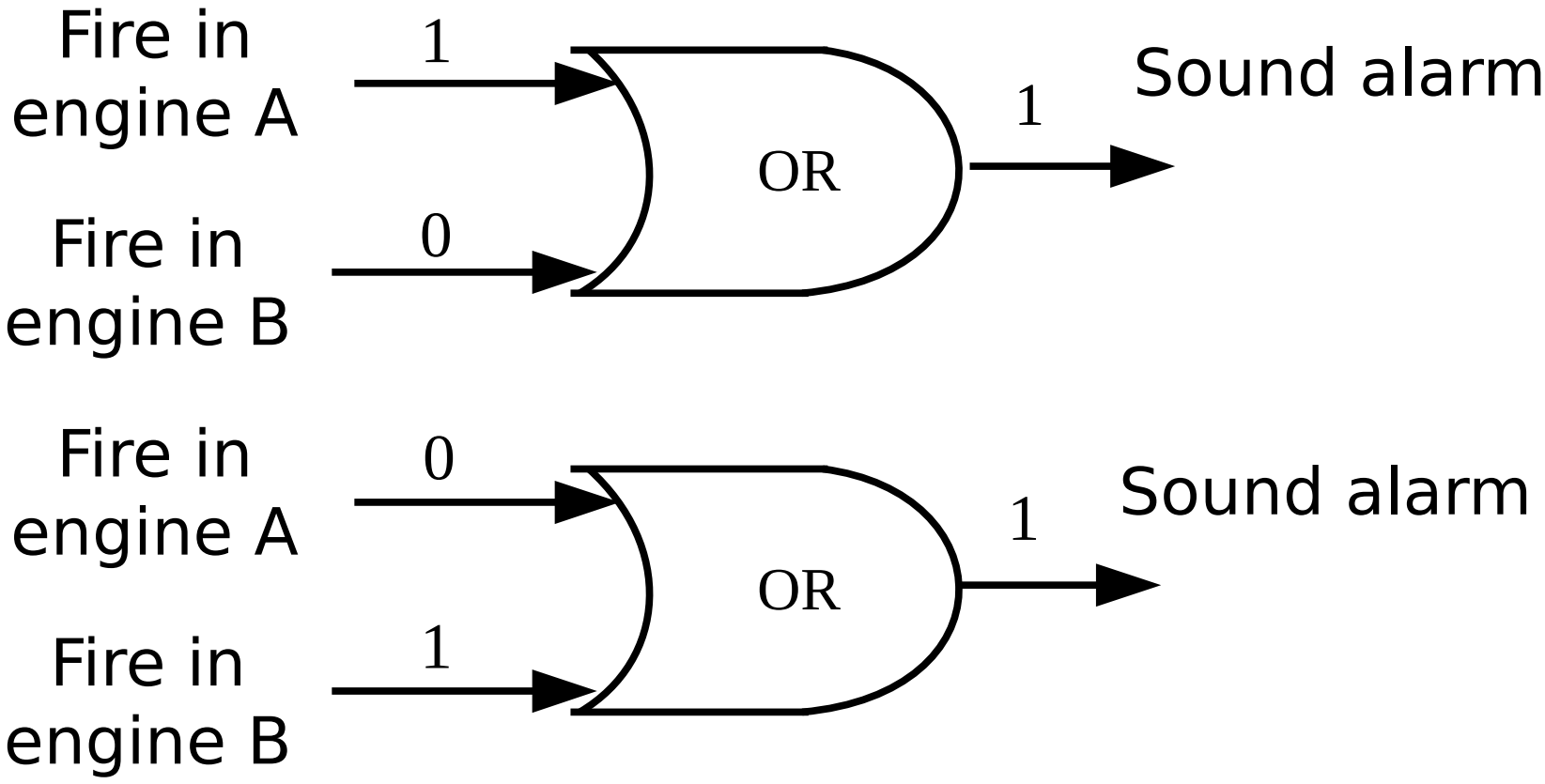
- The fire sensor produces a **1** when there is a fire and a **0** when there is no fire.

- The aircraft has **two engines** and we need to sound an alarm when there is a fire in one engine **OR** the other engine.

- To do this we would use an **OR** gate.

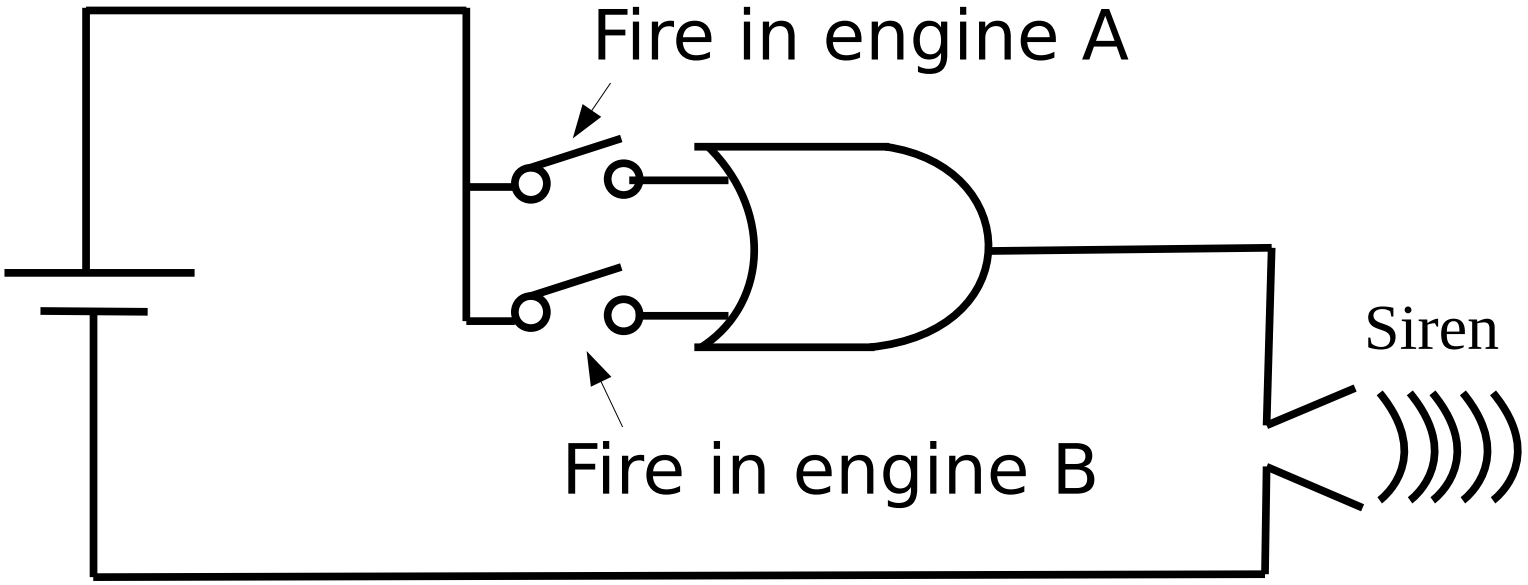
The OR gate

- An OR gate produces **1** on the output when **either** of the inputs are **1**.



The OR gate

Our final fire alarm circuit would look like this:



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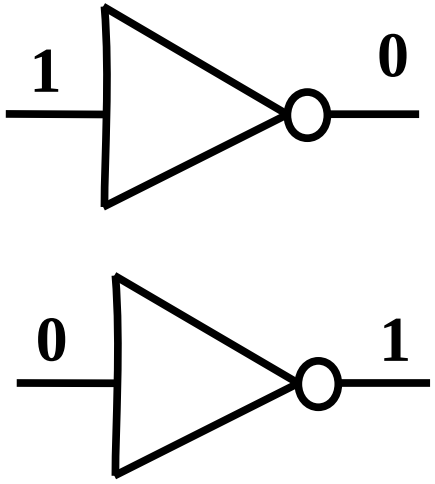
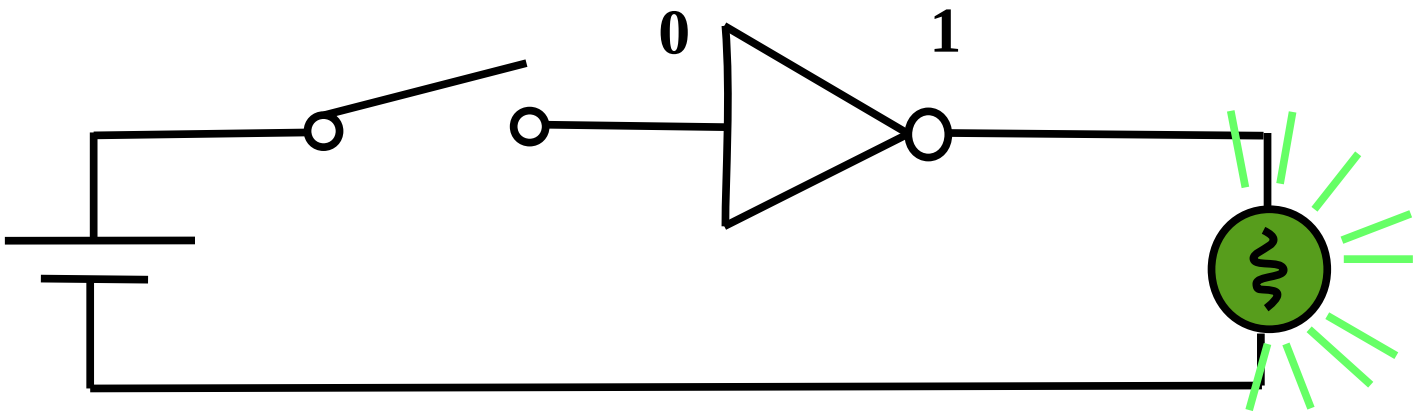
The NOT gate

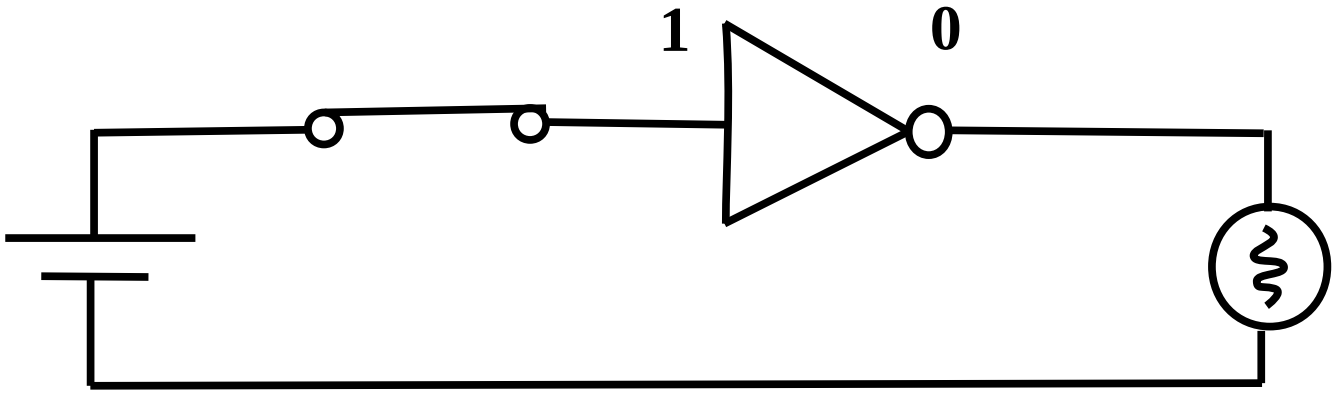
NOT gates invert the input signal:



A	Q
1	0
0	1

The NOT gate





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