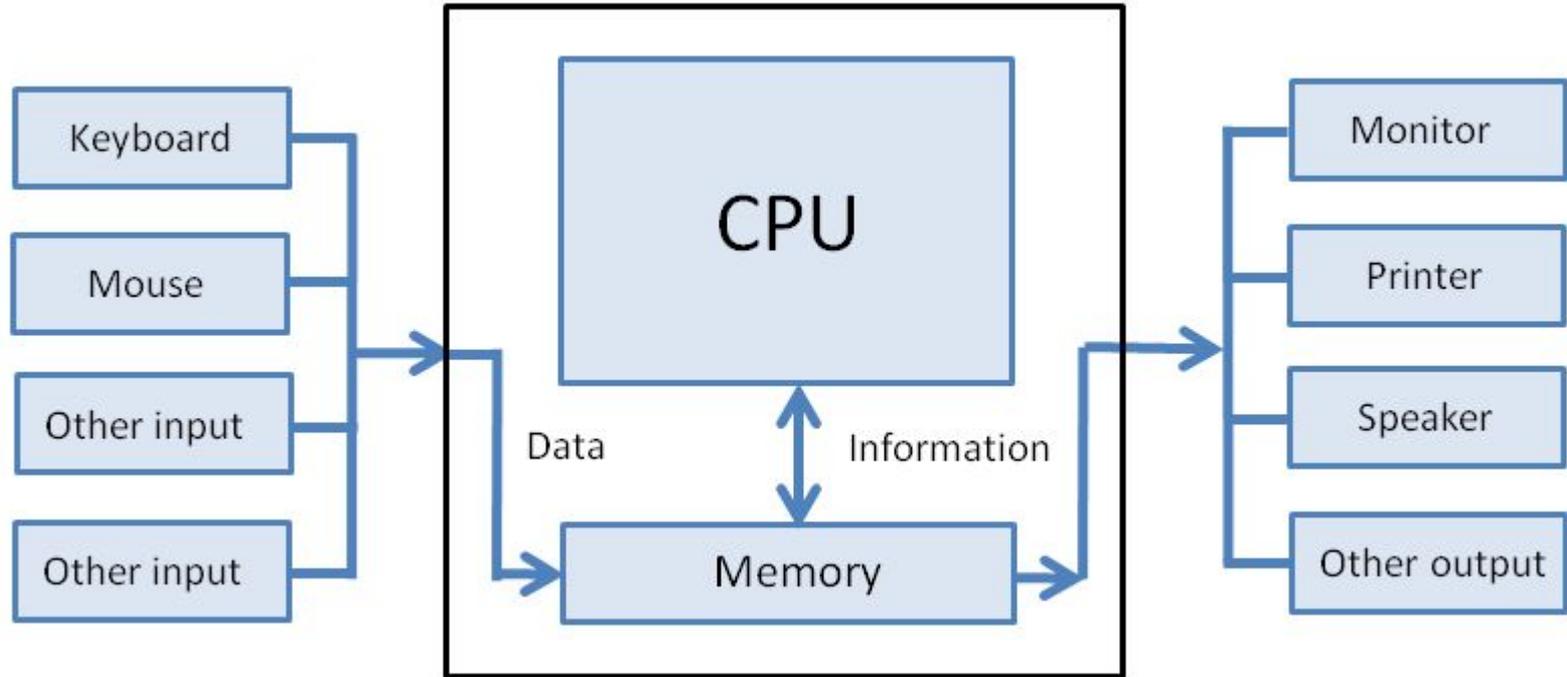


Hardware devices

iGCSE Computer Science

Hardware devices



Hardware devices

This unit we will consider:

- Input devices
 - Sensors
- Output devices

For a variety of different devices, you should be able to:

- Describe how each device works (at a simple level)
- How the devices are used in real-life scenarios

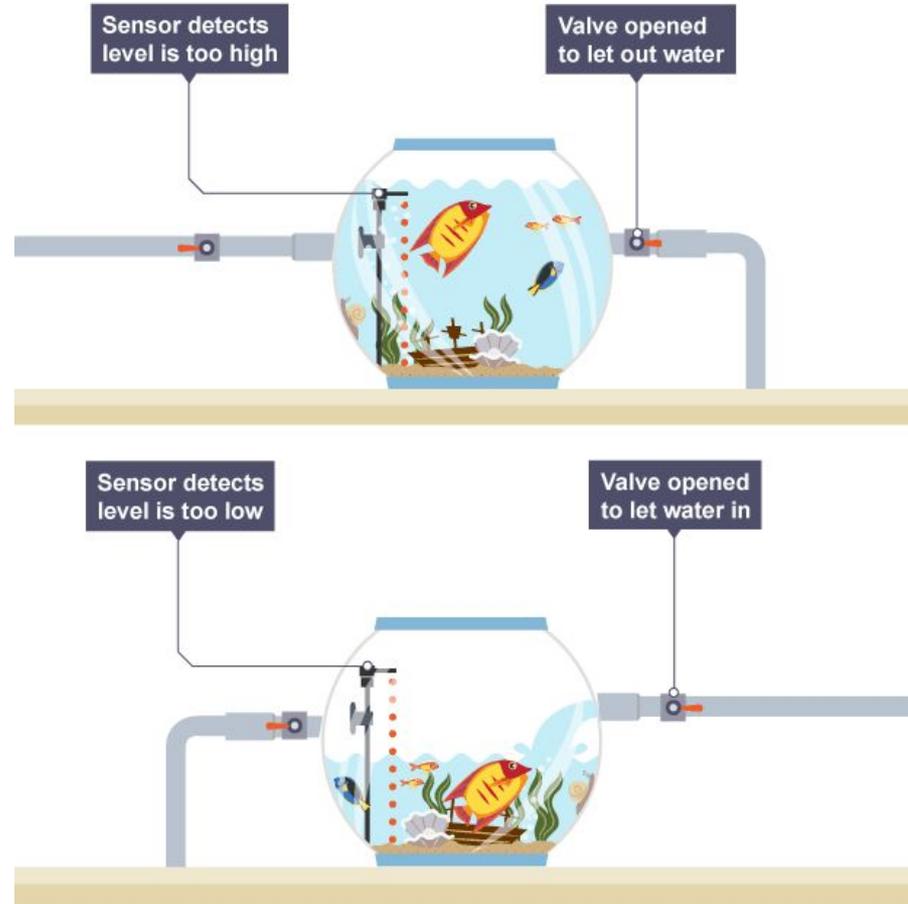
Components list

Input devices	Sensors	Output devices
2D & 3D scanner	Light	Inkjet printer
Barcode reader	Temperature	Laser printer
QR code reader	Magnetic field	3D printer
Digital camera	Gas	2D & 3D cutters
Keyboard	Pressure	Speakers & headphones
Mouse	Moisture	Actuators
Touch screens (resistive, capacitive & infrared)	Humidity	Flat panel displays (LCD, LED)
Interactive whiteboards	ph	LCD projectors
Microphones	Motion	DLP projectors

Some background

Feedback cycle

Sensor based programs generally work on a feedback cycle.

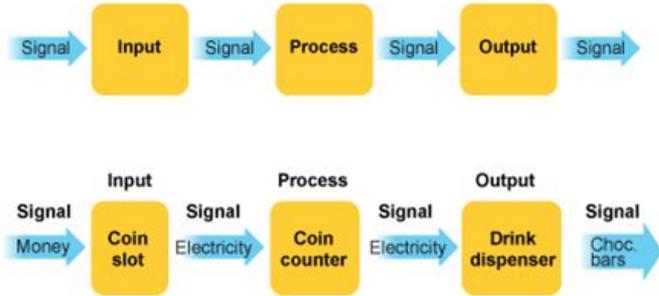


Open v closed loop feedback cycle

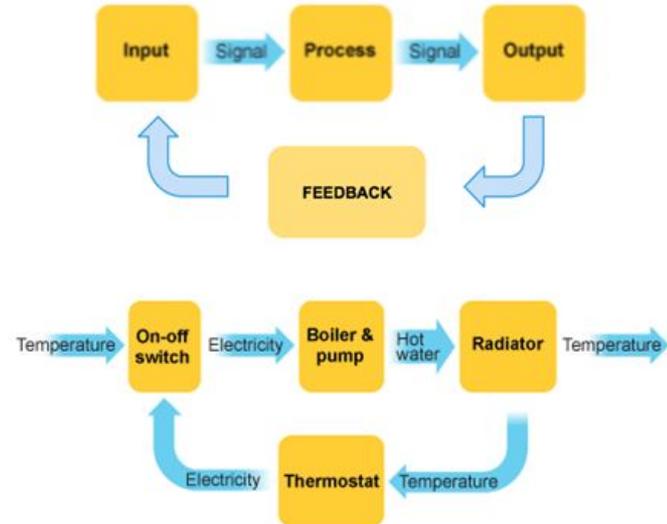
Does the output have a direct impact on future inputs?

- If no, it is open loop
- If yes, it is closed loop

OPEN LOOP SYSTEM



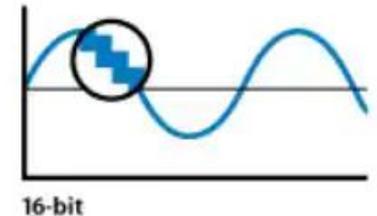
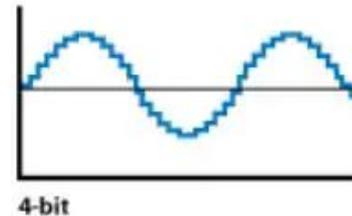
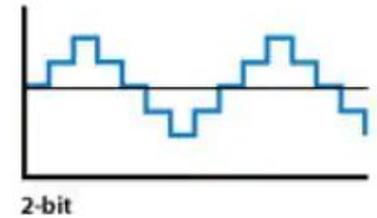
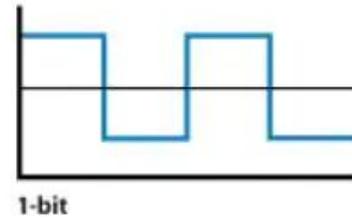
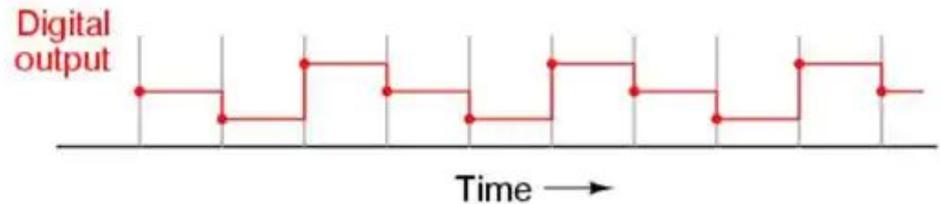
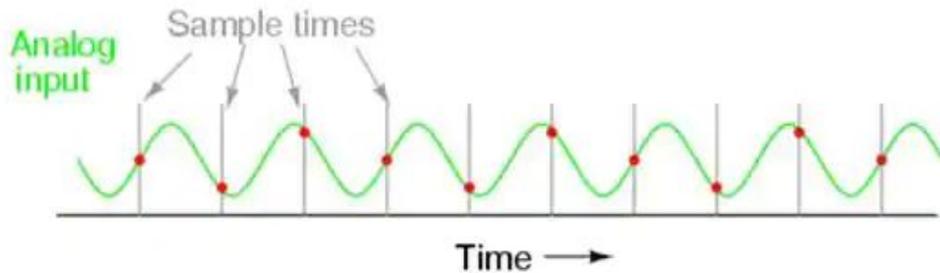
CLOSED LOOP SYSTEM



Analog to digital converter

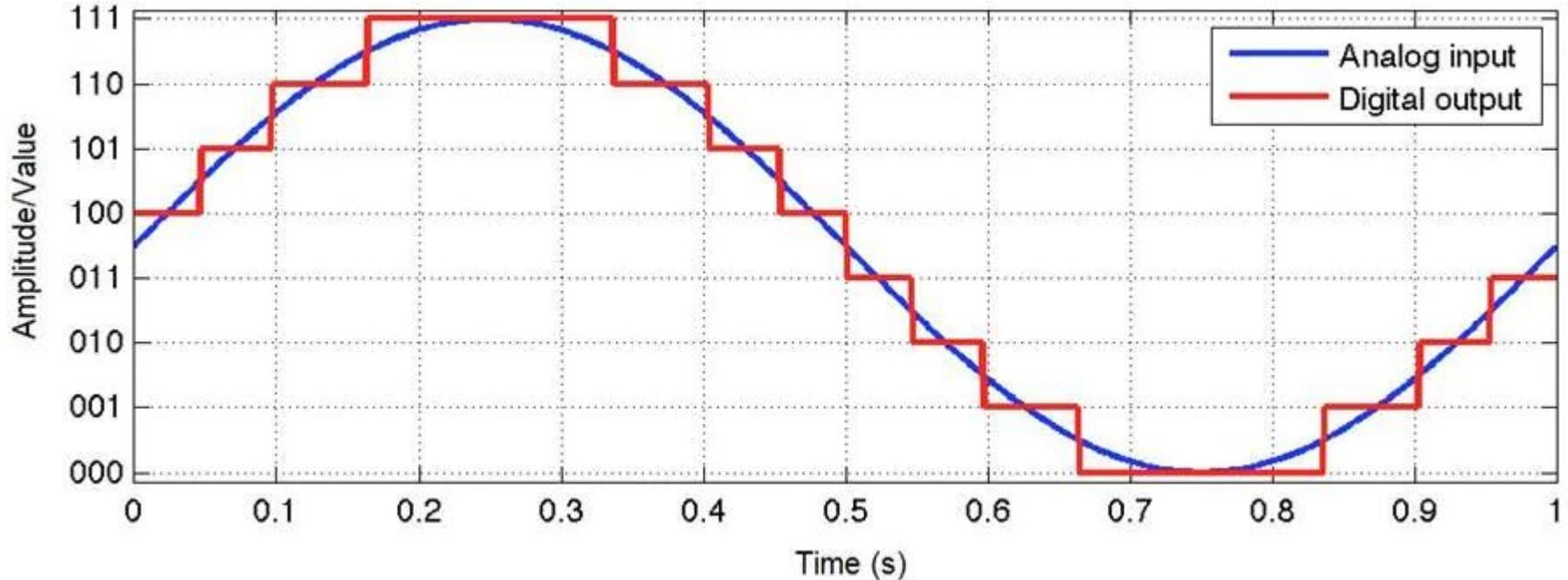
An analog to digital converter will sample the power supplied at a set frequency, and use those snapshots to determine the resulting digital signal.

The accuracy of the process will vary greatly depending on how many bits are being dedicated to the process. If a simple on/off is all that is required, then 1 bit is all that is needed.



Analog to digital converter

Here is an example with 3 bits allocated to read a value.

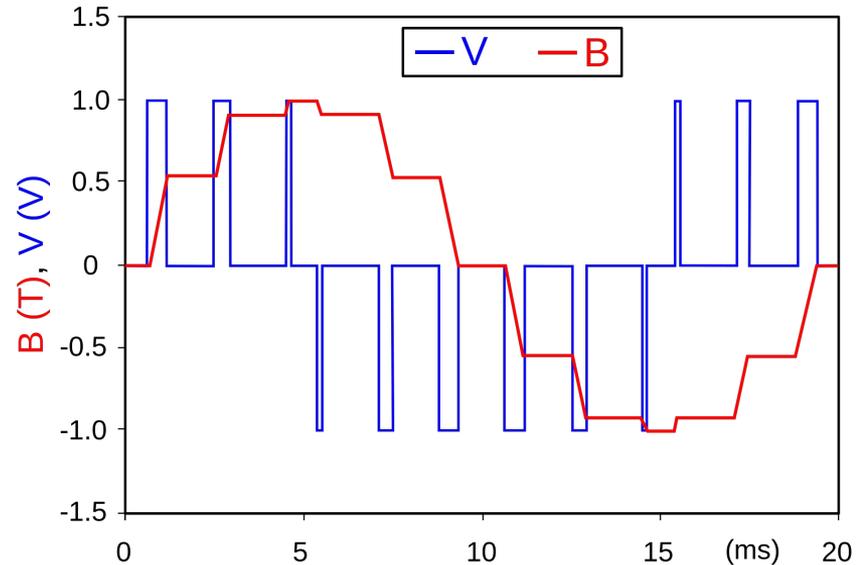


Digital to analog converter

One of the cheapest and most common methods of converting digital to analog is pulse width modulation.

Pulse width modulation (PWM) is a method of changing the length of on/off pulses of a digital signal such as to produce an analog-like sine-wave output.

Other methods are used where more accuracy is required, but these come at greater expense.



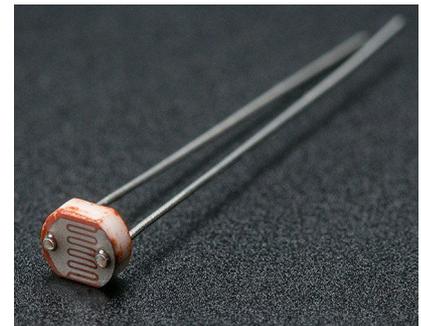
Active vs passive

Active sensor - require separate electrical power in order to measure environment signals.

Passive sensor - don't require separate electrical power for measuring environment signals.

Examples:

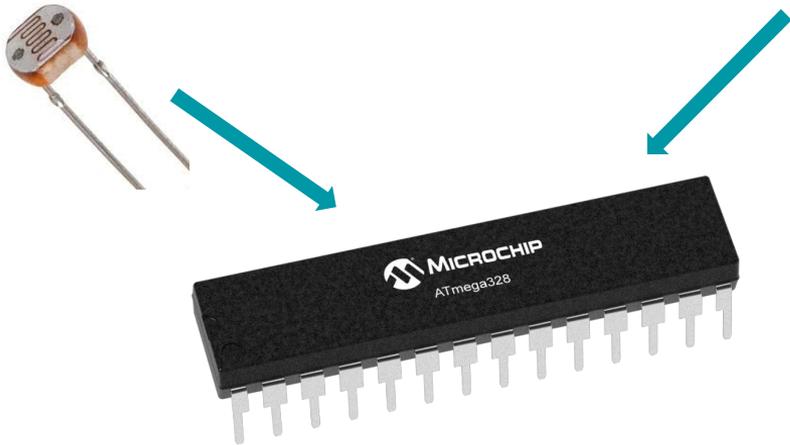
- The ultrasonic range finder is active as it requires you to supply power to it via the VCC and GND pins.
- The light sensitive resistor is passive. It will chemically vary it's resistance naturally based on the light around it and doesn't require a power supply to function.



Connection with microprocessor and your program

The sensor does not “detect an object” and then send the signal to the processor. Rather, the sensor is always sensing and sending data to the processor. It is the program you run on the processor that determines the significance of that data.

This is the single most common test mistake!



```
int threshold = 500;           // Light/dark value to trigger action

void setup() {
  Serial.begin(9600);
  pinMode( 10, OUTPUT );      // Initialise output pin
}

void loop() {
  int LDRValue = analogRead(A0); // read the value from the LDR
  Serial.println(LDRValue);      // print the value to the serial port
  if (LDRValue < threshold) {
    digitalWrite(10, HIGH);     // turn something on
  } else {
    digitalWrite(10, LOW);     // turn something off
  }
  delay(100);                  // wait a little
}
```

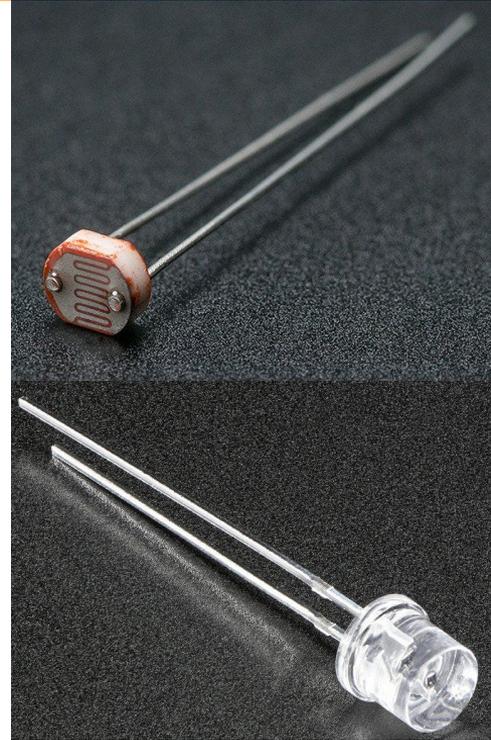
Sensors

Light sensor

There are two commonly used types:

Photosensitive resistor - CdS cells are little light sensors. As the squiggly face is exposed to more light, the resistance goes down. When its light, the resistance is about $\sim 1\text{K}\Omega$, when dark it goes up to $\sim 10\text{K}\Omega$.

Transistor Light Sensor - is a simple sensor that detects ambient light. It's kind of the opposite of an LED - when light hits the little chip inside, it induces current to flow from the long pin to the short pin.



Temperature sensor (thermistors)

Active sensor that returns a temperature value in degrees celsius.

There are two metals in a thermostat that will close and open depending on the current temperature. An electrical current will flow to heat up or cool down the atmosphere.

Find it in your refrigerator, air conditioner or security system.

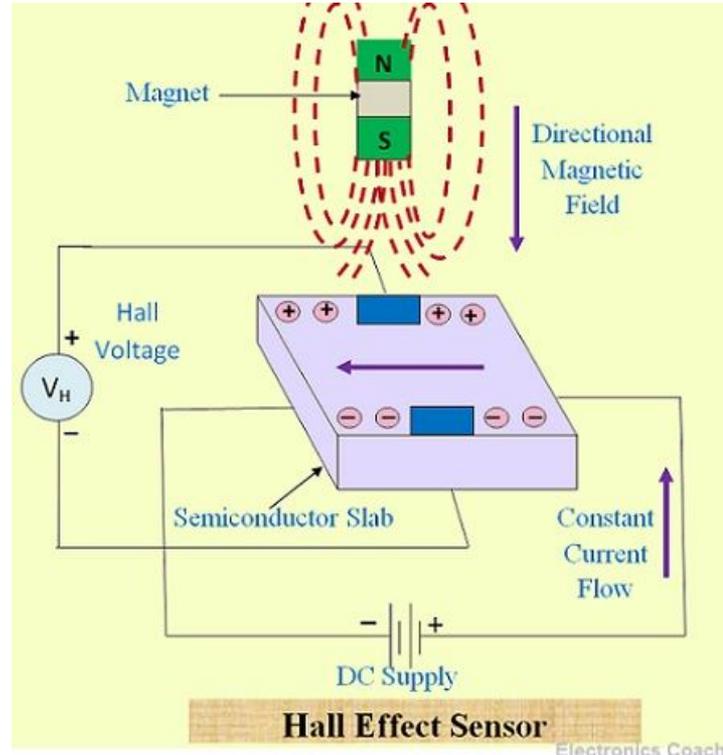


Magnetic field (hall effect)

An active sensor that detects the presence of a magnet

- used for scientific measuring
- used for the GPS in your cell phone

(pins: power, ground, data)



Gas sensor

The MQ-2 smoke sensor is sensitive to smoke and to the following flammable gases:

LPG

Butane

Propane

Methane

Alcohol

Hydrogen

The resistance of the sensor is different depending on the type of the gas.

The smoke sensor has a built-in potentiometer that allows you to adjust the sensor sensitivity according to how accurate you want to detect gas.

Demo project here

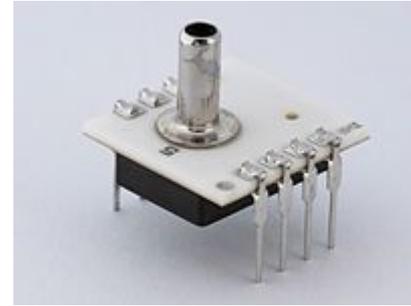
<https://create.arduino.cc/projecthub/Aritro/smoke-detection-using-mq-2-gas-sensor-79c54a>



Pressure sensor

A pressure sensor is a device for pressure measurement of gases or liquids. Pressure is an expression of the force required to stop a fluid from expanding, and is usually stated in terms of force per unit area.

Pressure sensors can be used to indirectly measure other variables such as fluid/gas flow, speed, water level, and altitude.



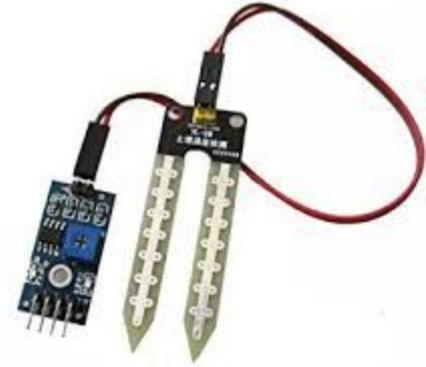
Moisture sensor

The soil moisture sensor consists of two probes that are used to measure the volumetric content of water. The two probes allow the current to pass through the soil, which gives the resistance value to measure the moisture value.

When there is water, the soil will conduct more electricity, which means that there will be less resistance. Dry soil conducts electricity poorly, so when there is less water, then the soil will conduct less electricity, which means that there will be more resistance.

This sensor can be connected in analog and digital modes.

Should we get a self watering plant for 333?



```
int sensor_pin = A0;
int output_value ;

void setup() {
  Serial.begin(9600);
  Serial.println("Reading From the Sensor ...");
  delay(2000);
}

void loop() {
  output_value= analogRead(sensor_pin);
  output_value = map(output_value,550,0,0,100);
  Serial.print("Mositure : ");
  Serial.print(output_value);
  Serial.println("%");
  delay(1000);
}
```

Humidity sensor

Provides a floating point number that can be used to approximate humidity in the surrounding air.

Where can humidity sensors be used:

- used in greenhouses to control heat
- air conditioning system
- for recording weather



pH sensor

Measures the acidity/basic pH of a solution.

Where can pH sensors be used:

- chemical laboratories
- chemical manufacturing
- aquariums, the pH level must be set at specific point for different fish and it should be consistent.



Motion sensors

Accelerometer - measures orientation in the X, Y and Z plane (looks like a microchip but it actually has tiny moving parts within it). Compare current orientation to past orientation and you can determine movement.



Tilt ball sensor - measures True/False for if the ball bearing inside is making a connection across the pins.



Ultrasonic range finder - Will transmit an ultrasonic sound frequency pulse when the trigger pin is activated. The echo pin will activate when it hears an ultrasonic pulse. Your software can use the time delay based on the speed of sound, to calculate the distance to an object.



Infrared - Using an IR LED and an IR detector, your program can detect if something is blocking the path between the two elements or not



Applications: Automated doors, security, Nintendo Wii, motion lights.

Input devices

Scanners

It will scan surface of paper document using light sensors.

Scanners can digitise a document or photograph at a higher resolution than digital cameras.

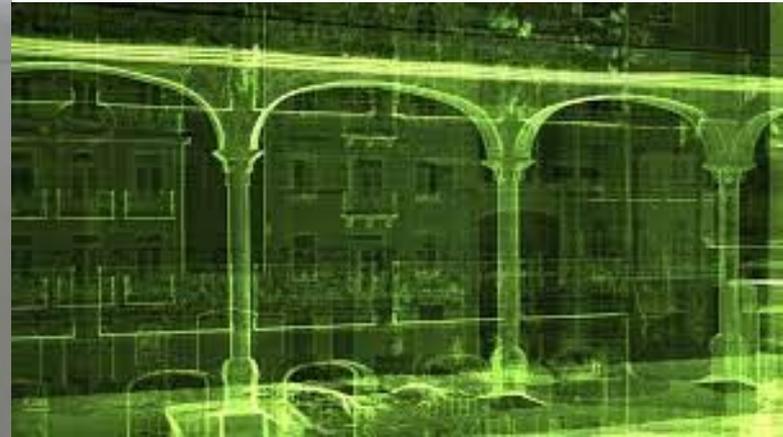
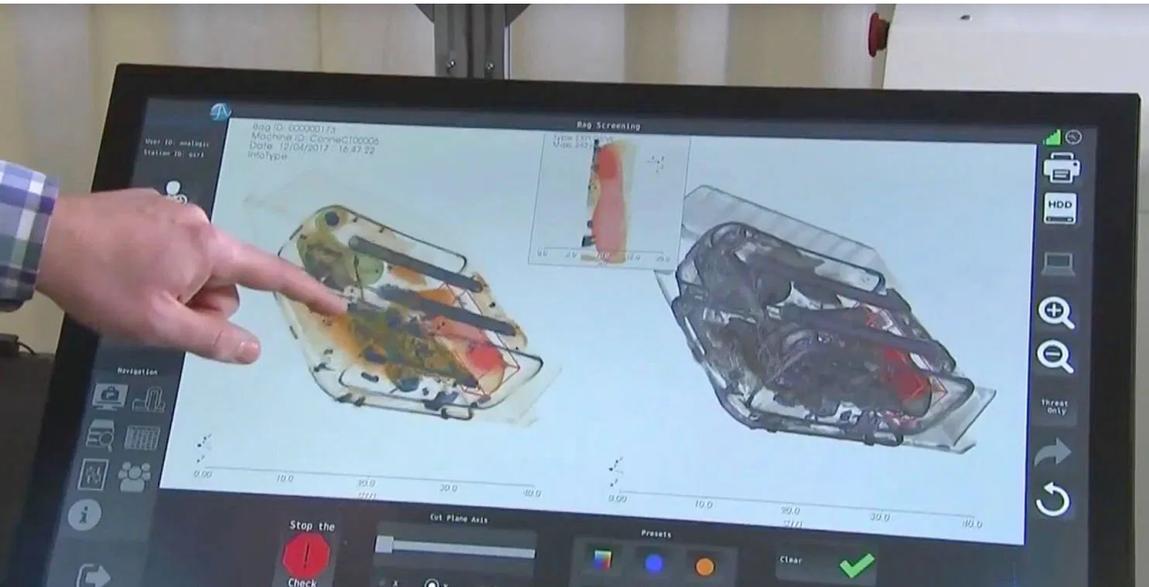
Scanners are commonly used with:

- OCR - Optical character recognition (text recognition)
- OMR - Optical mark recognition (scanned marks are converted to inputs such as the bubbles on a multi choice exam)



3D scanners

3D scanners: used to produce a 3D model and it uses laser and radiation or a light source. You can find this in airports to check for hidden weapons. Can also be used to scan architecture models.



Bar code readers

A barcode reader is used to scan barcodes and convert it into a number. There is a sensor inside the device, it converts the analogue signal into a digital signal. A barcode reader would be found in a supermarket, their barcode would be stored in the computer system and match up with the product detail and the computer will be able to input the price.

Most modern smartphones are able to decode barcode using their built-in camera.



QR code readers

QR codes: represented with lots of black and white squares. Each square is called a module. QR codes are two dimensional and can store up to 7000 numbers. A QR reader is needed to read the QR code, that can be found in the camera of your smartphone. A QR code can be used to advertise a product and can be found on billboard.

Advantage:

- efficient method of storing a variety of data such as images
- even if some parts of the QR code is missing, the code can still be read

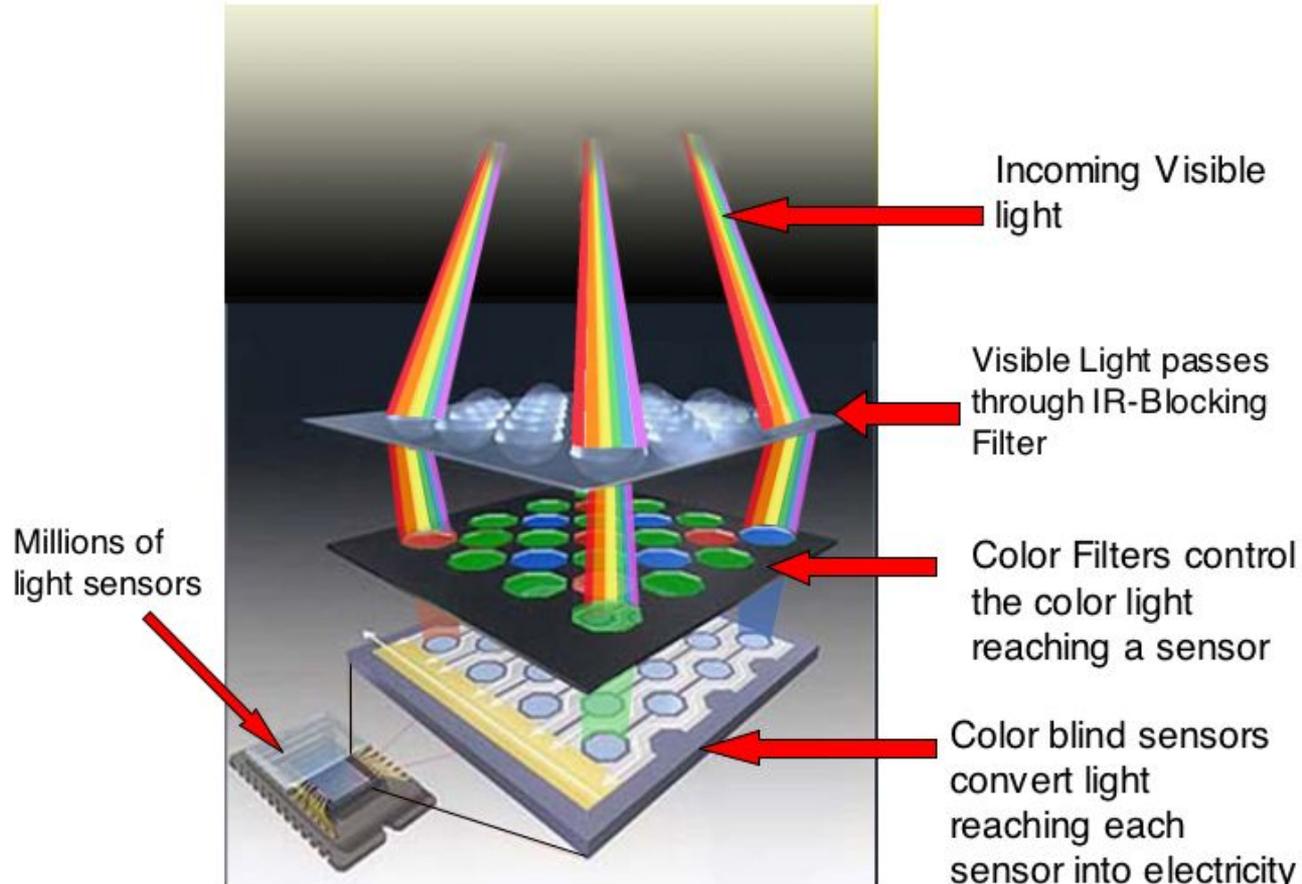
Disadvantage:

- People need a device that can read the QR code



Digital cameras

The sensor in a digital camera is called a charge-coupled device.



Digital cameras

Captured images to digital photo files

- Light is focused through a lens onto a charged couple device
- The photons hit the CCD according to intensity of the image
- The intensity striking the individual CCD determines the voltage for that pixel
- The analogue voltage is converted to a digital signal using an ADC
- Image is turned into a grid of pixels
- Each pixel is given binary values to represent the color
- Pixels are stored in sequence (in a file)
- Metadata is stored to describe the dimensions/resolution of the image

Keyboard

The keyboard helps in inputting the data to the computer. The layout of the keyboard is like that of traditional typewriter, although there are some additional keys provided for performing some additional functions.



May 2021 paper 12

Choose six correct terms from this list

- Binary
- Breaks
- Calculated
- Character
- Circuit
- Current
- Information
- Network
- Press
- Processor
- Signal
- Switch

A keyboard has a key matrix underneath the keys. When a key is pressed, it presses a _____ that completes a _____.

This allows _____ to flow. The location of the key pressed is _____.

The location of the key pressed is compared to a _____ map to find the _____ value for that key that has been pressed.

Mouse

Older style of mouse uses a roller ball to move the pointer while nowadays they use an optical laser.

Advantages

Easy to use

Not very expensive

Moves the cursor faster than the arrow keys of keyboard.



Touch screens

There are 3 types of touch screens you need to deal with:

- Capacitive
- Resistive
- Infrared

There is almost always a question asking how a touch screen works!



Touch sensors: Capacitive

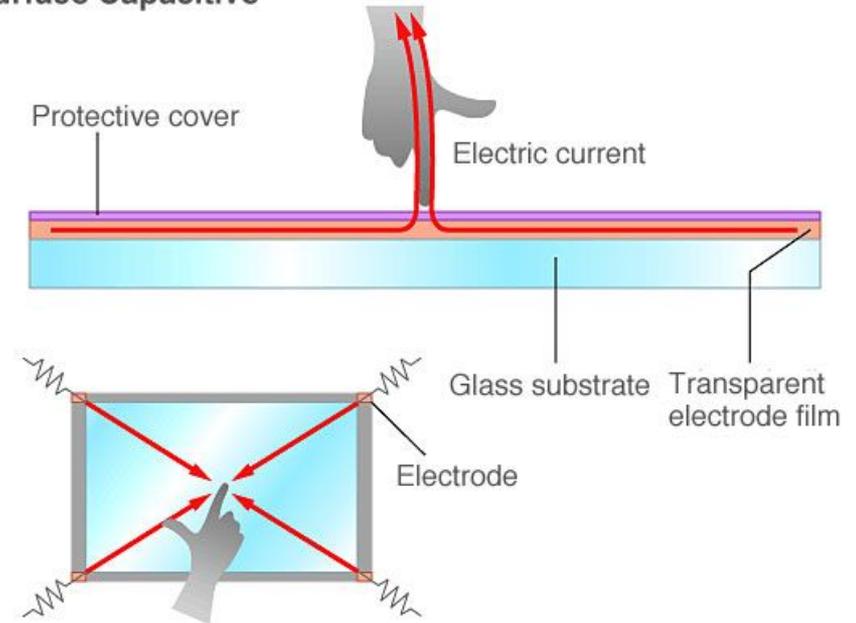
A capacitive (charge holding) coating is applied to a (usually) glass panel.

When touched, the capacitance of the person is detected (ie: small electrical charge transfers from the device to the person - this loss is detectable).

Sensors at the corners measure the relative difference in capacitance so the processor can calculate coordinates of the touch.

Only works when touched by electrically conductive items (such as people!).

Surface Capacitive

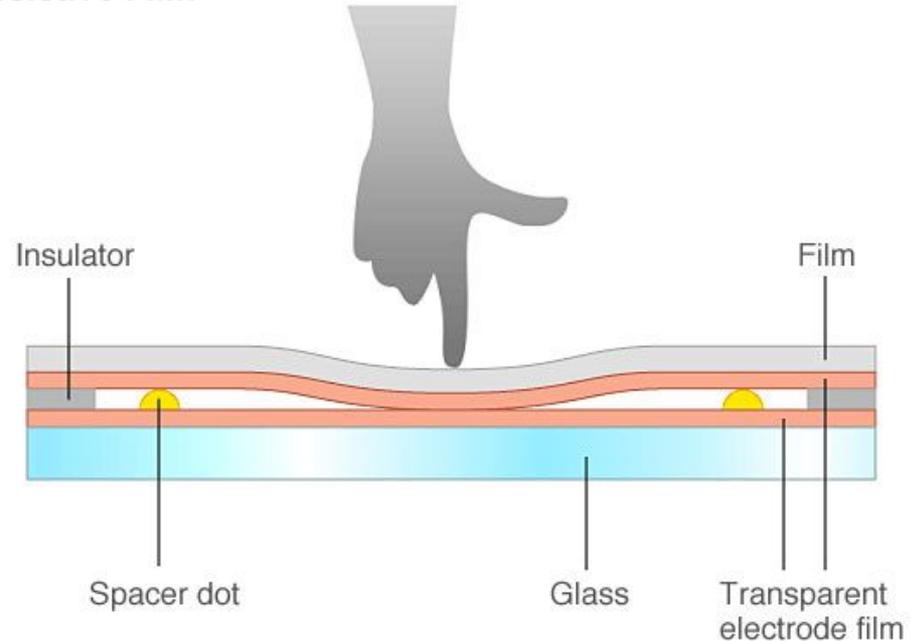


Touch sensors: Resistive

Resistive touch screens use at least two layers. When the top layer is touched, the two layers will make contact and the point of contact can be calculated.

Works when touched by anything (so gloves are ok). Can't detect multi-touch gestures though.

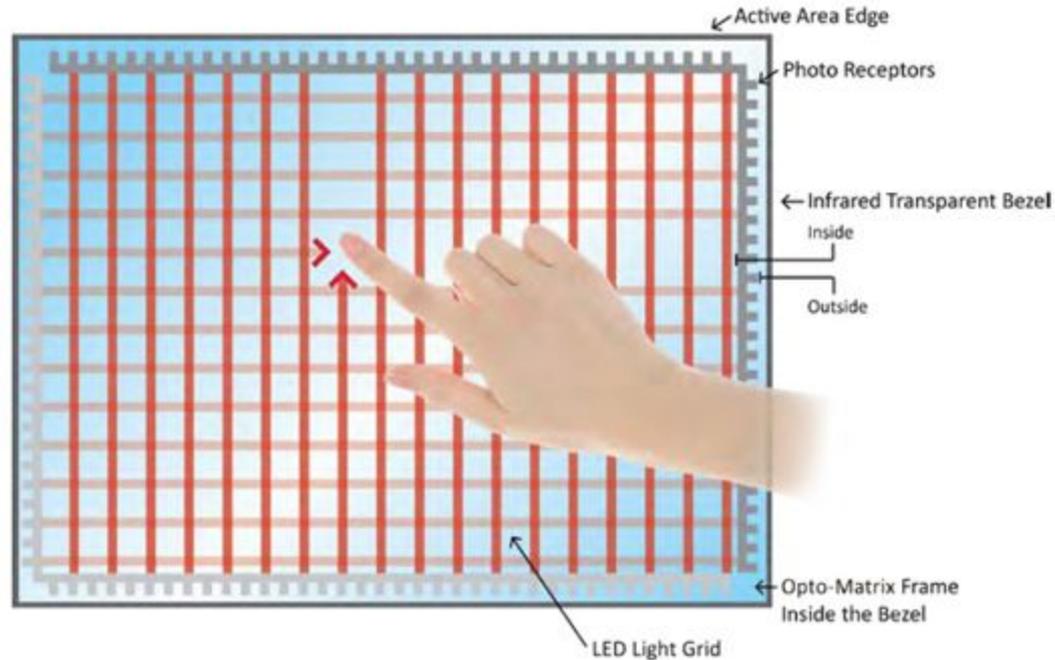
Resistive Film



Touch sensors: Infrared

Infrared rays are sent across screen to sensors at the other end.

The rays form a grid across the screen. When a ray is broken, the coordinates can be used to locate the touch.



IWBs (Interactive white boards)

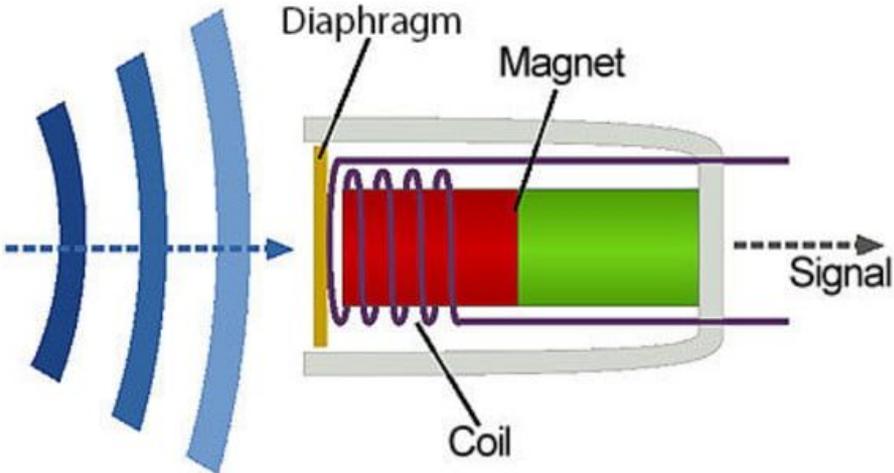
Sensors detect which part of the board has been touched and translate it. An interactive whiteboard allows user to handwrite text, PC control where applications can be controlled and text input. It can be used in schools, sports or in businesses.

They allow a user to write on a surface using a pen, the text and drawings can then be captured and stored for later use. (key point)



Microphones

analogue input device that records sound, analogue sound wave must be converted into digital form before the computer is able to process it. The microphone's signal is connected to the computer sound card with a cable. Microphone's diaphragm can vibrate and move a magnet or coil and makes current flow in wire. Microphones are used for voice recognition in speech-to-text softwares, or speech input in games or televisions and in biometric security.



Output devices

Laser printer

Advantages

Very high speed.

Very high quality output.

Gives good graphics quality.

Supports many fonts and different character sizes.

Disadvantage

Expensive.

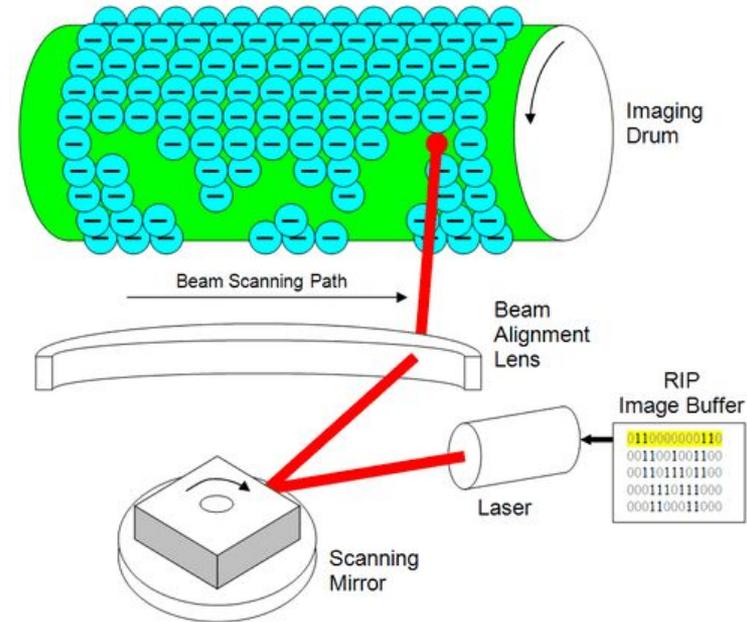


Laser printer

A drum is spun inside the printer. A laser is shone at parts of the drum that will require ink for the printing process. Positively charged powder (toner) is applied to the drum, this toner will only stick to the charged parts created by the laser.

The paper is rolled past the drum and the toner will stick to the page creating an exact copy of the image.

The paper will now pass a heated fuser which will melt the ink onto the paper, and then it will exit the printer.



Inkjet printer

They print characters by spraying small drops of ink onto paper. Inkjet printers produce high quality output with presentable features.

They make less noise because no hammering is done and these have many styles of printing modes available. Colour printing is also possible. Some models of Inkjet printers can produce multiple copies of printing also.

Advantages

- High quality printing
- More reliable

Disadvantages

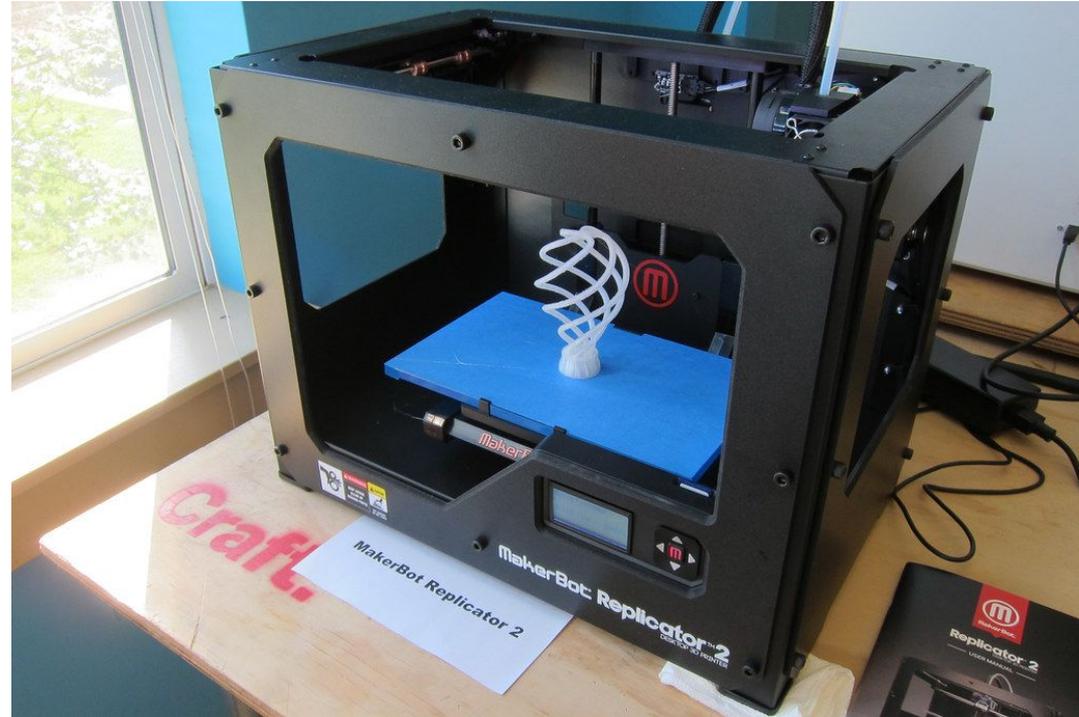
- Expensive as cost per page is high
- Slow as compared to laser printer



3D printers

Using a method called additive manufacturing, 3D objects are created by layering a material, layer by layer, from the ground up until the object is completed.

[3D printed buildings!](#)



3D cutters (CAM)

aka Computer aided manufacturing. Computer Aided Manufacturing (CAM) is the use of software and computer-controlled machinery to automate a manufacturing process.

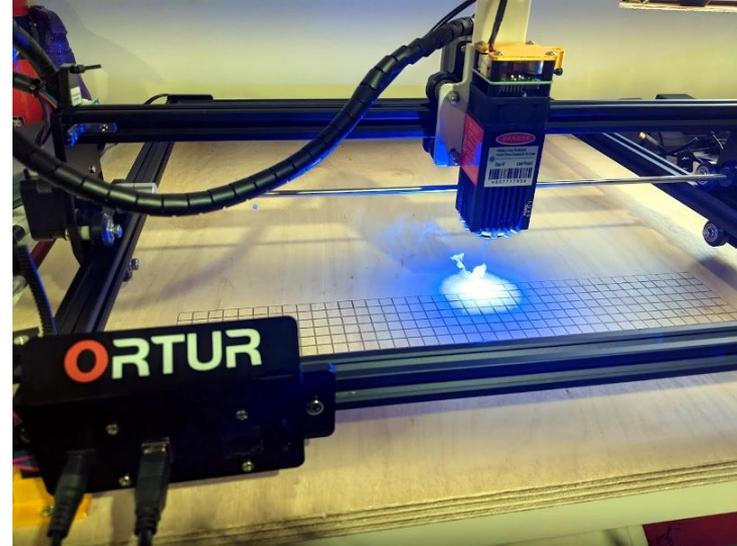
3D CAM machines: these are 3D cutters. They use millers or routers which have tools that can rotate on six axes. They can cut into wood, wax, plastics etc. As well as bespoke products that are used to test. This helps reduce errors and it saves time.



2D cutters (CAM)

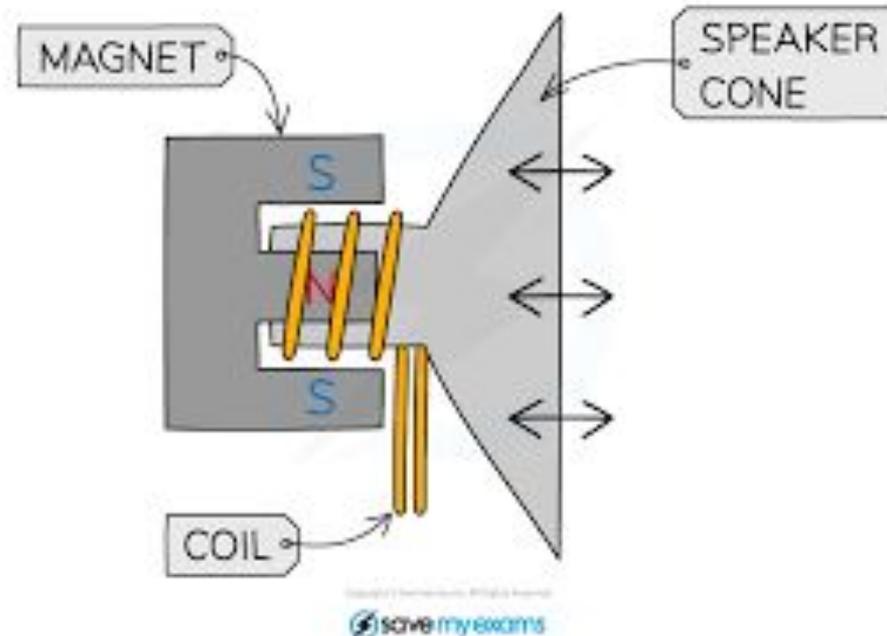
Water, Plasma & Laser Cutters

These machines use precise lasers, high-pressure water, or a plasma torch to perform a controlled cut or engraved finish. Manual engraving techniques can take months to complete by hand, but one of these machines can complete the same work in hours or days. Plasma cutters are handy for cutting through electrically conductive materials like metals.



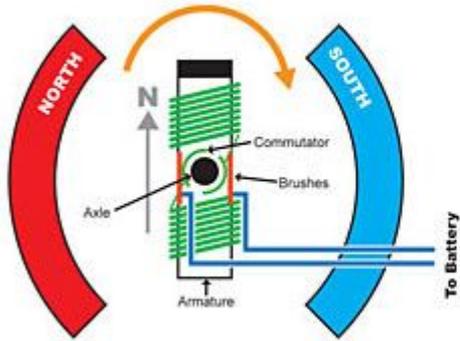
Speakers & headphones

Sound is produced in the speaker through a vibrating cone that works at different frequencies and amplitudes

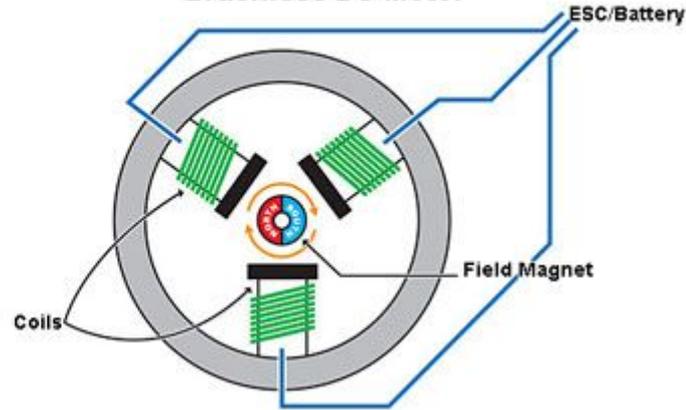


Actuators

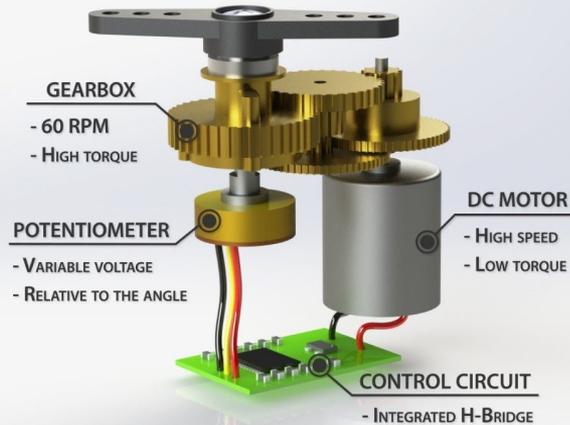
Brushed DC Motor



Brushless DC motor



Servo



An actuator is a component of a machine that is responsible for moving and controlling a mechanism or system, for example by opening a valve. In simple terms, it is a "mover". (wikipedia)

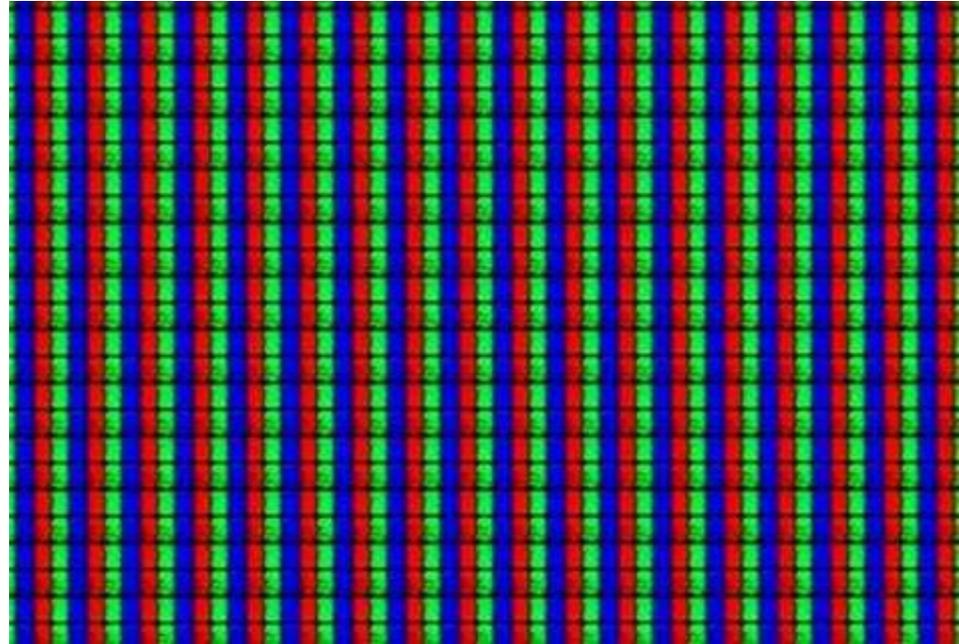
Flat panel screens (LCD, LED)

LCD stands for Liquid Crystal display. LED stands for light emitting diode.

These screens are made with thousands of individual pixels, each of these pixels contain a collection of red green and blue diodes. These diodes are lit in different combinations to make each pixel appear to be the correct color.

The difference between LCD and LED is the method used to provide light to the screen.

LCD used cold cathode fluorescent lamps instead instead of LEDs.



Projectors (LCD, DLP)

DLP projectors (digital light projector) uses digital micro-mirrors to reflect the light from the lamp and through the lens. They use LCD technology to create the image and just differ in how they send the image on to the screen or board.

LCD projectors use the same LCD technology as DLP projectors apart from that they use 3 layers of glass panel to reflect the light.

Closing comments

Common questions

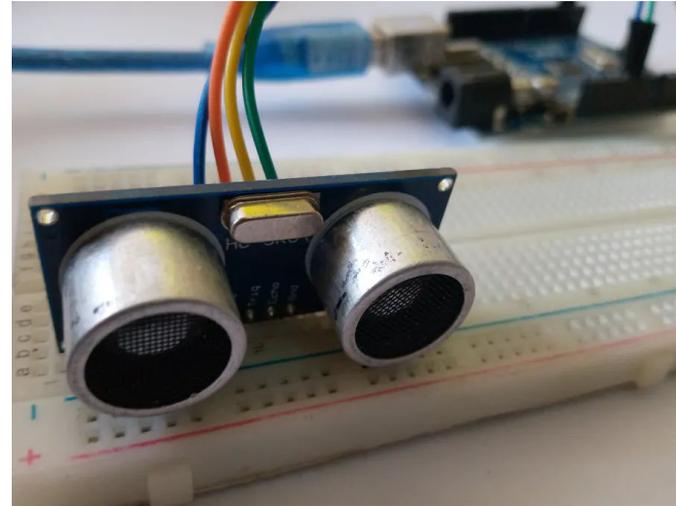
- There is almost always a barcode or QR code question
- There is almost always an image capturing question - camera, scanner etc
- There is almost always a touch screen question - resistance, capacitive, infrared

Detection vs measurement

After seeing your review questions, it bears repeating. **Sensors do not detect, they measure.** It might seem like semantics but you will not be awarded the mark if you say “the sensor detects a person etc”. It is the program running on the processor that decides how to interpret the data from the sensor.

Consider the ultrasonics sensor again...

```
Nearest object is 16 centimeters
Nearest object is 15 centimeters
Nearest object is 16 centimeters
Nearest object is 15 centimeters
Nearest object is 14 centimeters
Nearest object is 15 centimeters
Nearest object is 14 centimeters
Nearest object is 13 centimeters
Nearest object is 12 centimeters
Nearest object is 13 centimeters
```



We're done!