INTERNET OF THINGS (IoT)

Interact

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NEON
Network of Competence on Internet of Things
Co-funded by the Erasmus+ Programme of the European Union
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FCEFyN
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Interaction in IoT

“Things” interact with their environment: from a data-scientist perspective they can read from (inputs) and write to (output) the environment

Interaction is done through **transducers**: *a transducer is a device that converts energy from one form to another*. Usually a transducer converts a signal in one form of energy to a signal in another.

Transducers are often employed at the boundaries of automation, measurement, and control systems, where electrical signals are converted to and from other physical quantities (energy, force, torque, light, motion, position, etc.).

Type of Transducers

Transducers can be categorized in two types based on the direction the information passes through.

A **sensor** is an *input device* which converts a state condition or quantity from a physical system into an information signal. States can be continuous (temperature, speed) or discrete (open/closed)

Instead, an **actuator** is an *output device* that converts an information signal into some kind of action that aims at changing some state or quantity of a physical system. Typically this is used to control some external system.

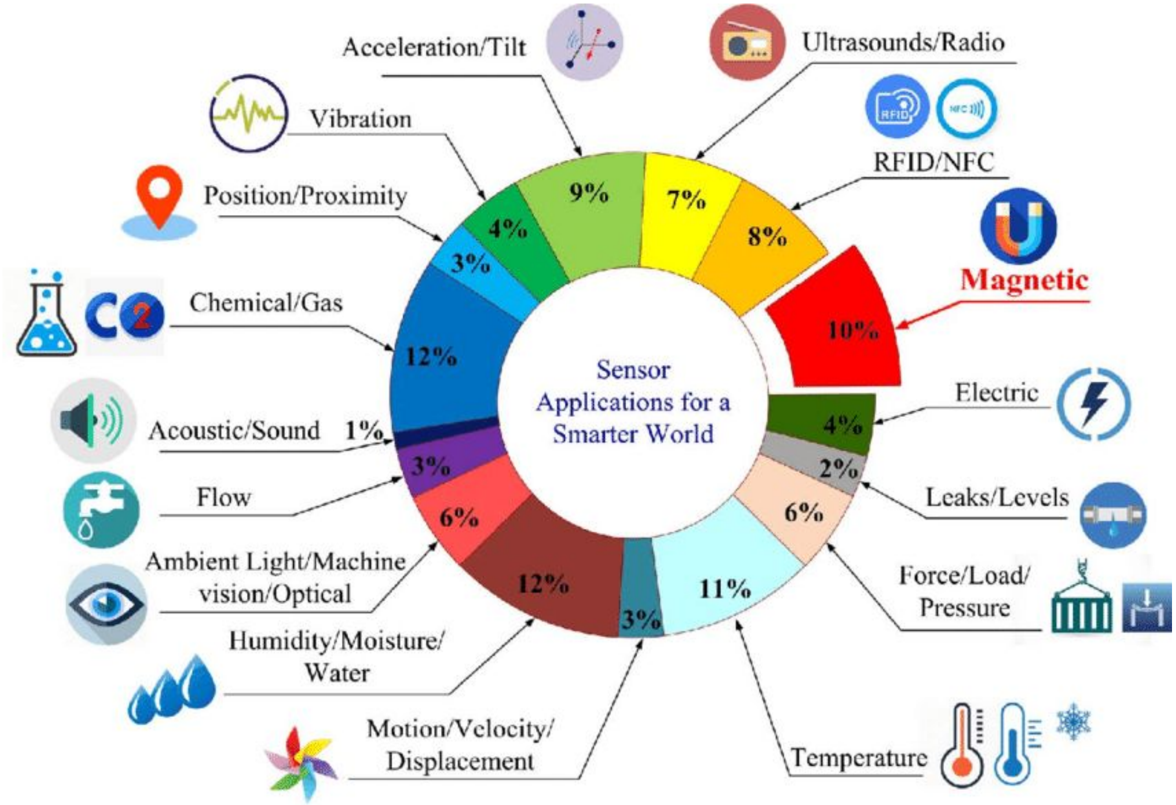
Examples: a microphone (input) converts sound waves into electrical signals and a loudspeaker (output) converts these electrical signals into sound waves

Sensors

Typical Sensors

- Temperature: air temperature or temperature of what they are immersed in. Often combined with air pressure and humidity in a single sensor.
- Buttons/Switches: indicate if they have been pressed or its position.
- Light: detect light levels and can be for specific colors, UV light, IR light, or general visible light.
- Scanners (RFID/NFC, FP, BC): identify surrounding objects
- Cameras: visual representation of the world by taking a photograph or streaming video to identify events (motion) or extract information (QR, text).
- Accelerometers: sense movement in multiple directions.
- Microphones: sense sound, either general sound levels or directional sound.
- Location (GPS): report location (latitude, longitude) of the device

Sensors for IoT Applications



[Review IoT Commercial Products with sensors]()

[Pycom boards]():
[Pysense]()
[Pyscan]()
[Pytrack]()

Analogue Sensors

Produce a continuous output signal or voltage which is generally proportional to a quantity that is *changing smoothly and continuously over time*.

These signals tend to be very small in value from a few microvolts (uV) to several millivolts (mV), so some form of amplification is required. Then circuits which measure analogue signals usually have a slow response and/or low accuracy.

Physical quantities such as Temperature, Speed, Pressure, Displacement, etc. are all analogue quantities as they tend to be continuous in nature.

Temperature

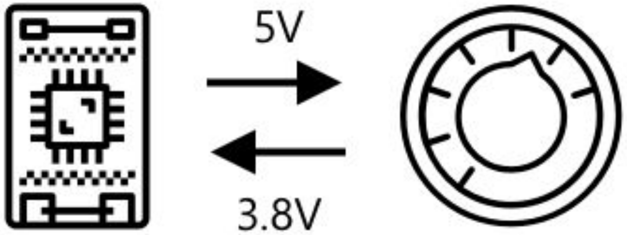
Speed

Pressure

DIsplacement

Analog to digital conversion

Analog sensor values need to be converted to a digital signal before they can be processed.



Most IoT devices have analog-to-digital converters (ADCs) to convert analog inputs to digital values

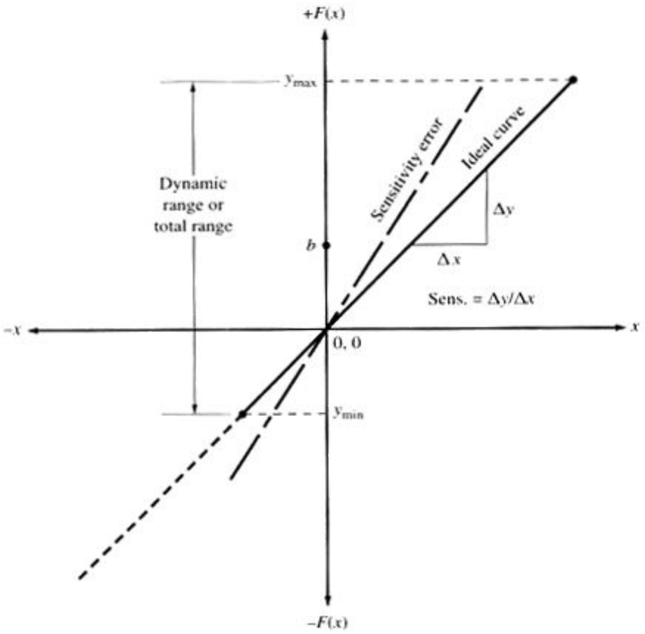
The voltage that comes out of the sensor is read in electrical units (typically, voltage) but by calculations inside the code ran in the IoT device be converted to physical quantities such temperature (C), distance (meter), etc

Sensor Sensitivity

Sensitivity is defined as the input parameter change (Δx) required to produce a standardized output change (Δy), hence as Δy/Δx

In typical temperature sensor with a sensitivity of 1 mV/K there will a 1 mV output voltage for each Kelvin of temperature. Then, 25℃ (298K) will output 0.298V

The *sensitivity error* (dotted curve) is a departure from the ideal slope. For example, the temperature sensor may have an actual sensitivity of 0.9 mV/K, hence a 0.1 mV/K sensitivity error.

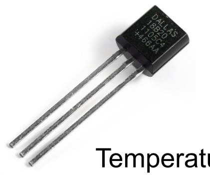


Digital Sensors

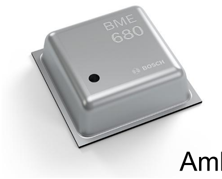
Produce a discrete digital output signals or voltages that are a digital representation of the quantity or state being measured.

Digital sensors produce a binary output signal in the form of a logic “1” or a logic “0”, (“ON” or “OFF”). Discrete (non-continuous) values may be outputted as a single “bit”, (serial transmission) or by combining the bits to produce a single “byte” output (parallel transmission).

Digital sensor report values directly in the physical magnitude units (C, meters)



Temperature



Ambient

Accelerometer

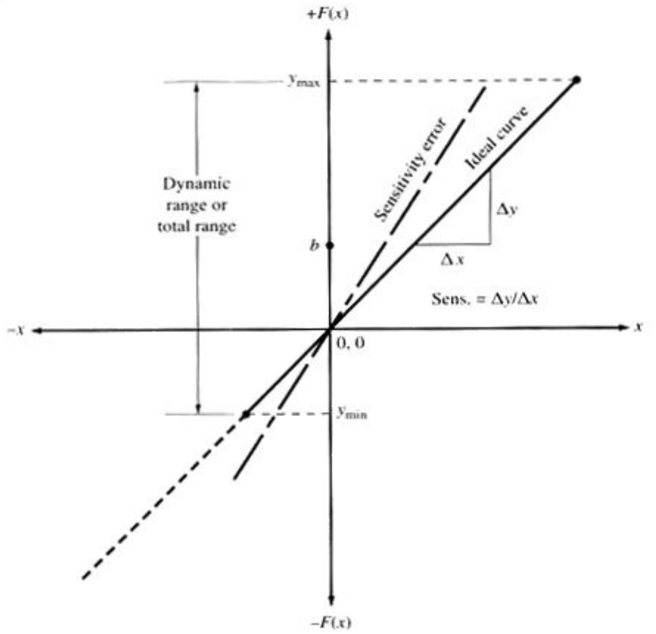
Magnetometer

Sensor Range

Range is the maximum and minimum values that can be measured.

A given temperature sensor may have a range of -50℃ (223K) to +100℃ (373K). Positive and negative ranges often are unequal.

The *dynamic range* is the total range of the sensor from minimum to maximum. For the example above, the dynamic range is then 150℃ (150K),



Sensor Resolution

Resolution is the smallest change it can detect in the quantity that it is measuring.

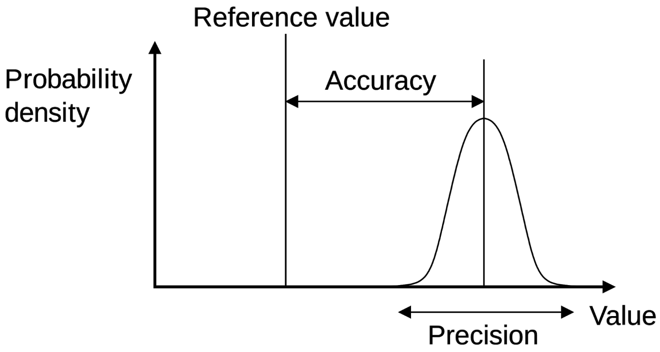
The resolution of a sensor with a digital output is usually the resolution of its digital output.

For example, assuming a dynamic range of 150℃ using a 16-bits digital output (ADC), we can determine the smallest possible increment we can detect. That is, $2^{16} = 65536$, or 1 part in 65,536, so 150 / 65536 ≃ 0.0023℃ per A/D count. Therefore, the smallest theoretical change we can detect is 0.0023℃.

Sensor Precision

Precision refers to the degree of reproducibility of a measurement due to random errors.

If exactly the same value were measured a number of times, an ideal sensor would output exactly the same value every time. But real sensors output a range of values distributed in some manner relative to the actual correct value.

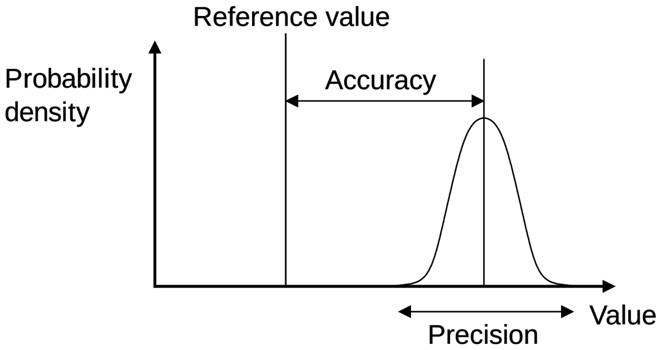


For simplicity, precision can be expressed as the maximum error of with respect to the *same measurement*. For example, a temperature sensor may have a precision of (an error up to) 0.5°C (0.5K)

Sensor Accuracy

Accuracy is amount of uncertainty in a measurement with respect to an absolute standard. It is the maximum difference that will exist between the actual value and the indicated value at the output of the sensor.

High accuracy requires high precision as accuracy considers not only a statistical bias but also additive errors (precision) resulting from the measurement process.

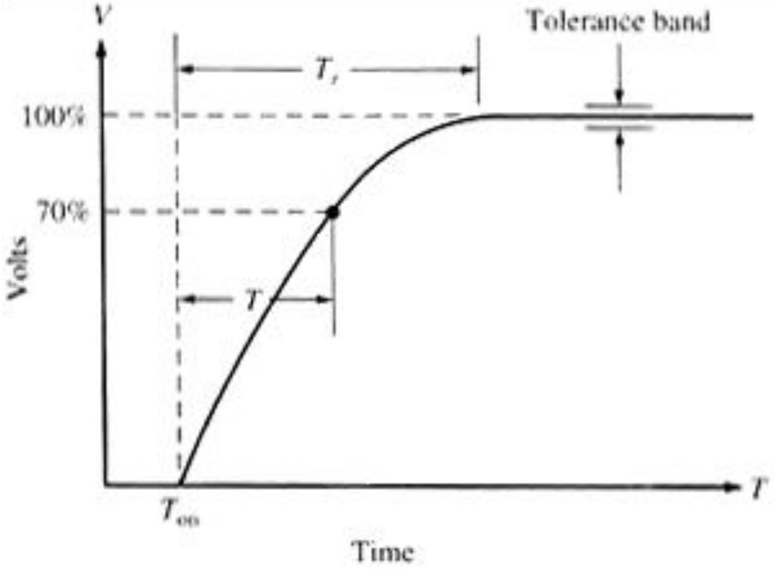


Accuracy can be expressed either as a percentage of full scale or in absolute terms.

Sensor Response Time

Sensors do not change output state immediately when an input change occurs. Rather, it will change to the new state over a period of time, called the *response time* (T_r).

This time can be defined as the time required for a sensor output to change from its previous state to a final settled value (100%) within a *tolerance band* of the correct new value.



Mobile Phone Sensors

Mobile phones typical supports three major categories of sensors:

- Environmental sensors, to measure various environmental conditions, such as ambient air temperature and pressure, illumination, and humidity. These sensors include barometers, photometers (light sensors), and thermometers.
- Motion sensors, to measure device motion. These sensors include accelerometers, gravity sensors, gyroscopes, and rotational vector sensors.
- Position sensors, to measure the physical position of a device. This category includes magnetometers (geomagnetic field sensors) and proximity sensors.

Other sensors include device camera, fingerprint sensor, microphone, GPS (location) sensors as well as communications interfaces (WiFi, Bluetooth, BLE)

Environmental Sensors

Light Sensor

A light sensor is a photoelectric device that converts light energy (photons) detected to electrical energy (electrons)

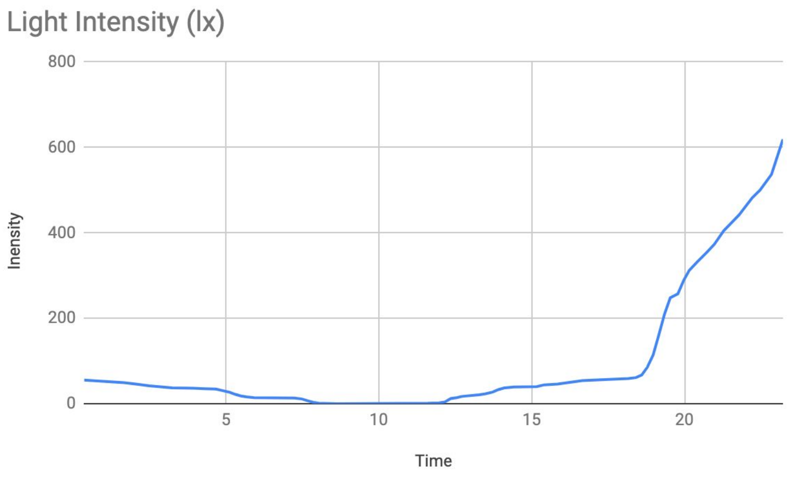
A Lumen (lm) measures the total amount of visible light from a light source (total amount of light emitted in all directions).

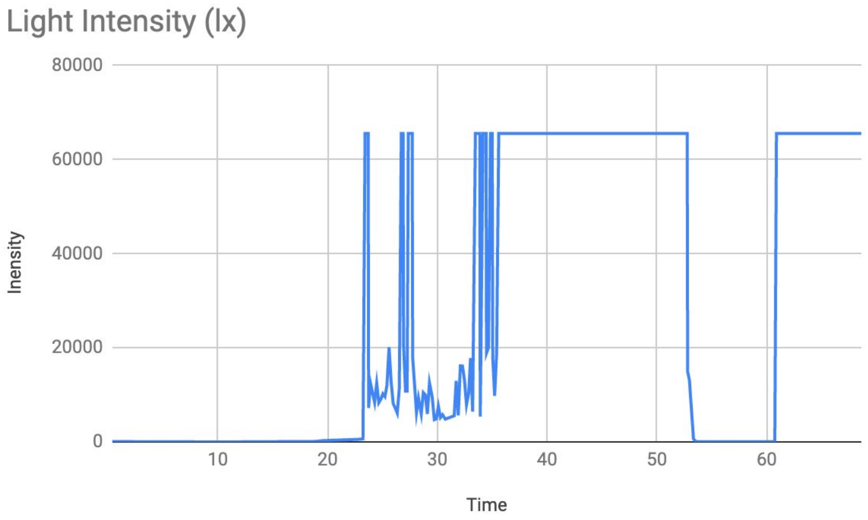
A Lux (lx) measures the total amount of light that falls on a particular surface. It is equal to one lumen per square metre.

How many bits of resolution has this sensor?

[DevCheck Android App]

Phone Light Sensor (Indoor >> Outdoor)





Barometric Pressure Sensor

A barometric pressure sensor is a sensor that detects atmospheric pressure.

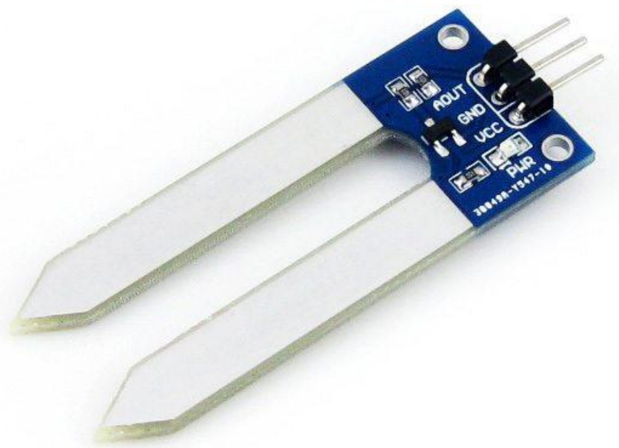
The most frequently used pressure units are pascal (Pa), kilopascal (kPa), megapascal (MPa), psi (pound per square inch), torr (mmHg), atm (atmospheric pressure) and bar.

Humidity Sensor

A humidity sensor (or hygrometer) senses, measures and reports both moisture and air temperature.

The ratio of moisture in the air to the highest amount of moisture at a particular air temperature is called relative humidity. This is expressed as a percentage value (0-100%).

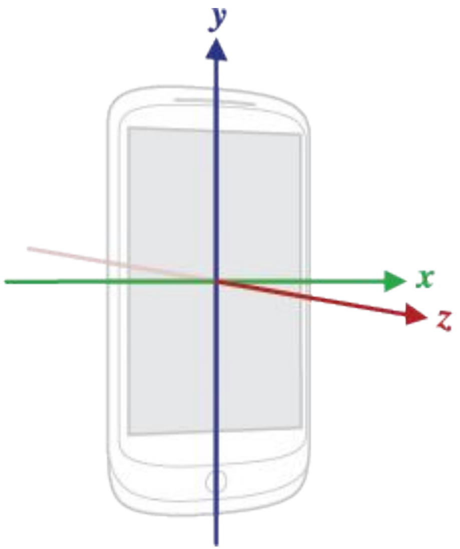
Humidity sensors work by measuring the capacitance or resistance of air samples.



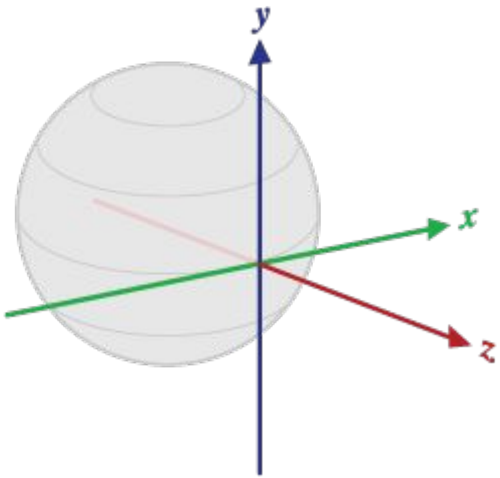
Motion Sensors

Reference Coordinates

Device Coordinates

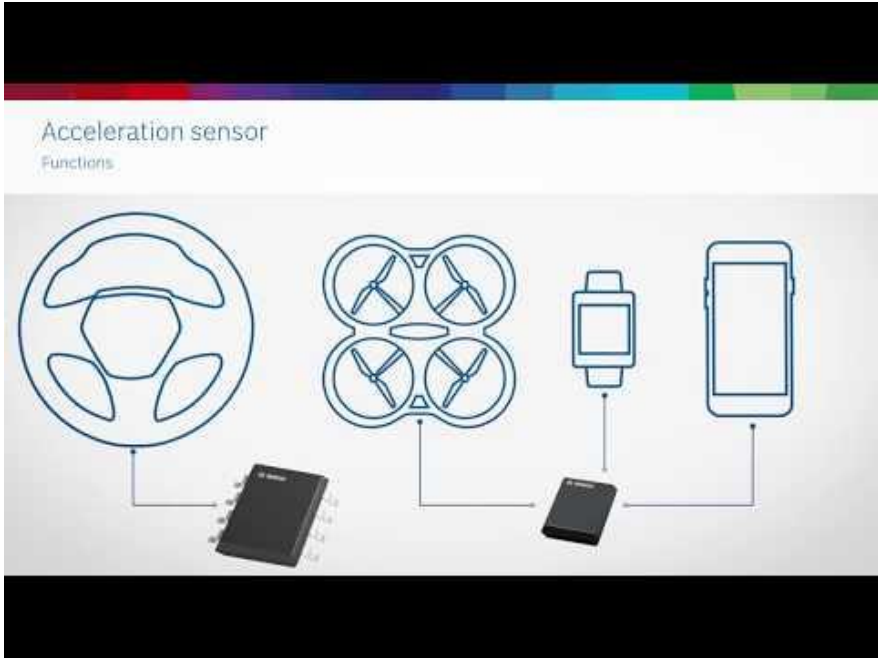


Earth’s Coordinates



Accelerometer Sensor

An electromechanical device used to measure acceleration forces. Such forces may be static, like gravity or, dynamic to sense movement or vibrations.



Acceleration is the measurement of the change in velocity, or speed divided by time.

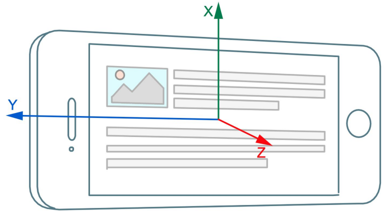
For example, a car accelerating from a standstill to 60 km/h in 6 seconds is determined to have an acceleration of 10 km per second (60 divided by 6).

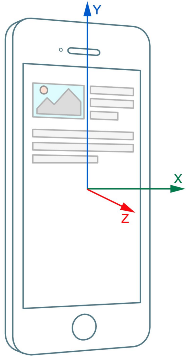
Gravity Sensor

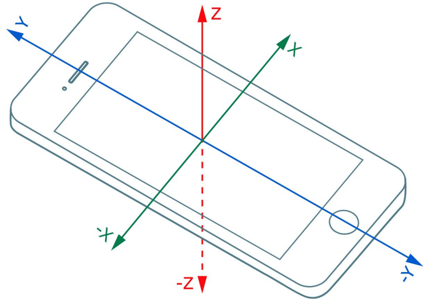
The gravity is a force that attracts an object to the center of the earth, or towards any other physical object having mass.

Gravity sensor (software sensor) is only available if the device has a gyroscope. By combining accelerometer data with gyroscope data, the acceleration due to moving the device can be filtered out to leave the pure gravity signal.

The gravity sensor provides a three dimensional vector indicating the direction and magnitude of gravity. Typically, this sensor is used to determine the device's relative orientation in space.

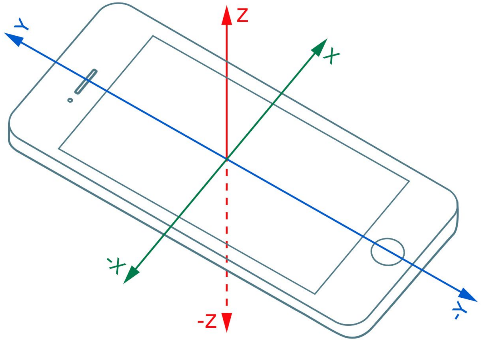


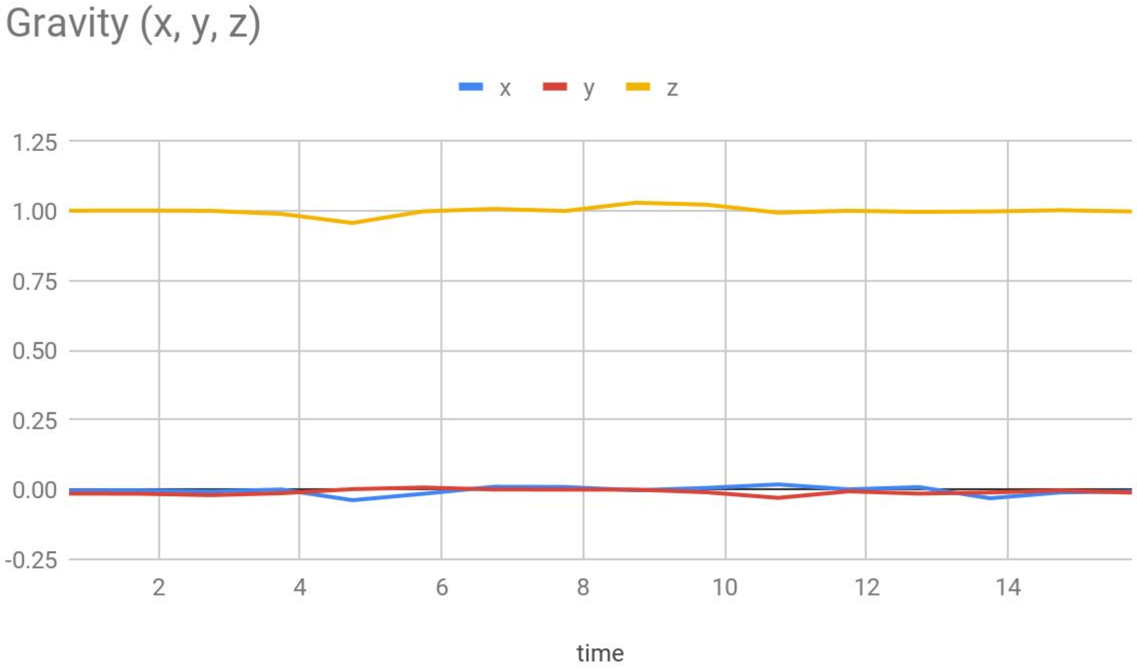




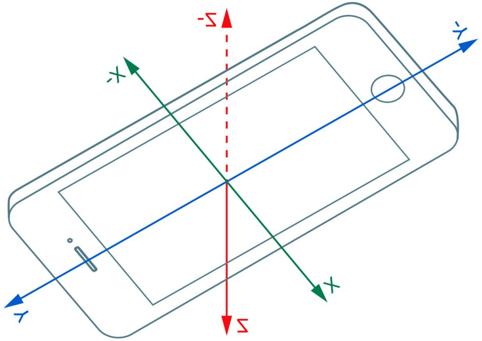
Gravity Z~+1

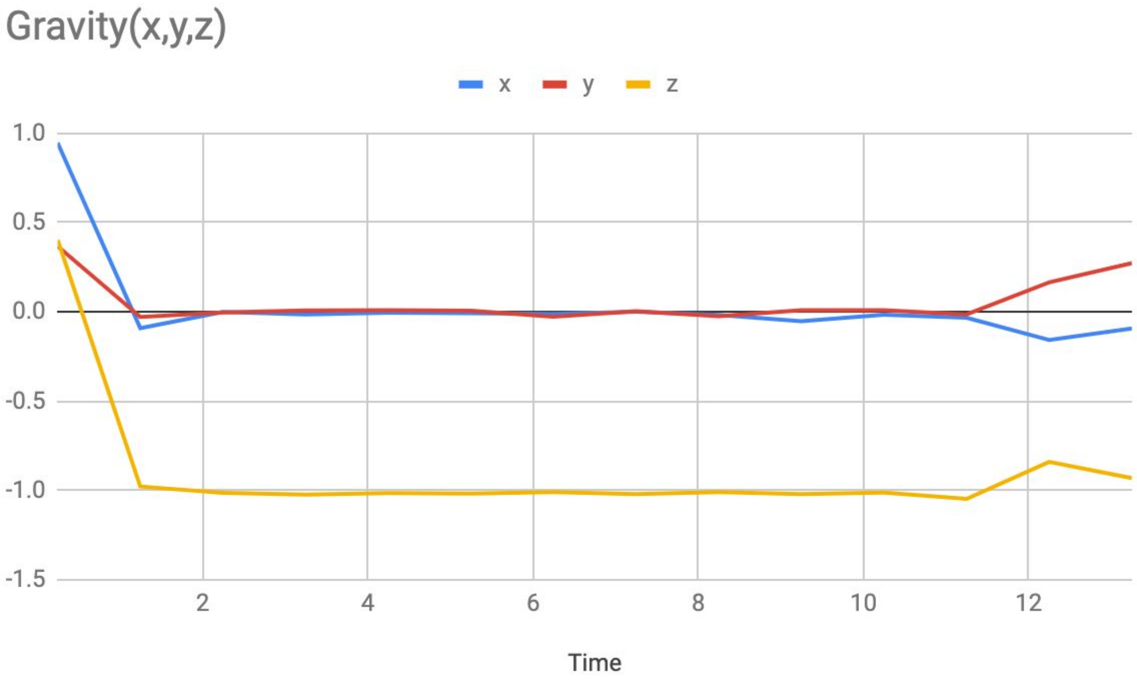
The gravity sensor provides a three dimensional vector indicating the direction and magnitude of gravity. Typically, this sensor is



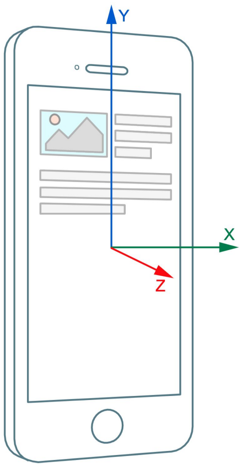


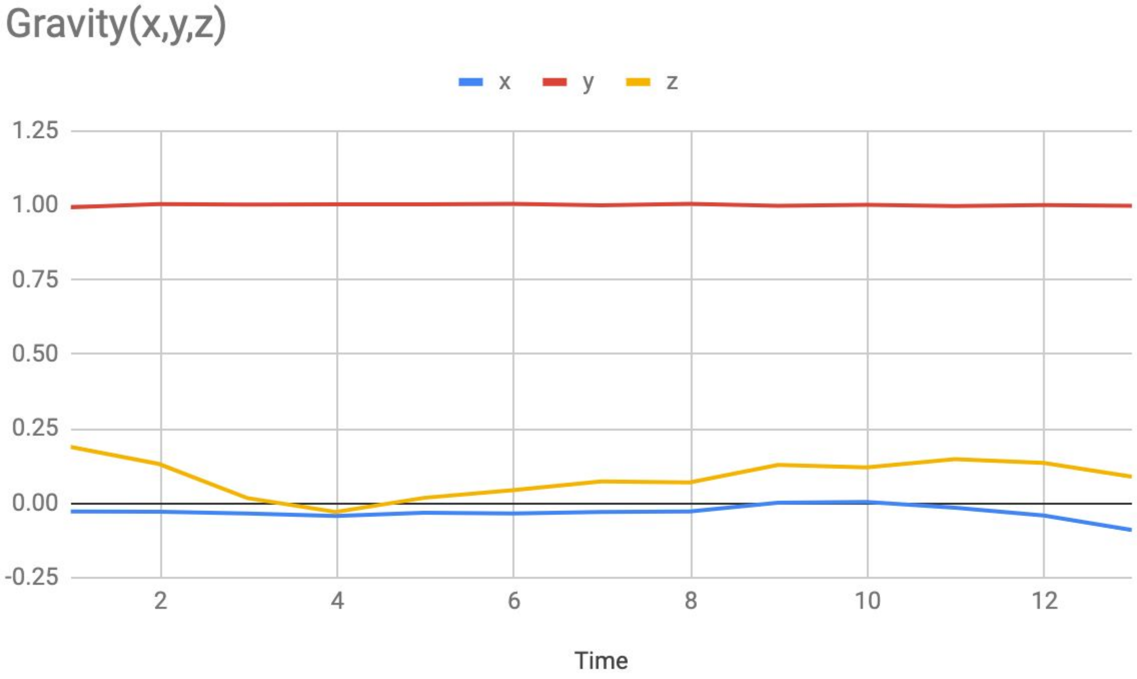
Gravity Z ~ -1



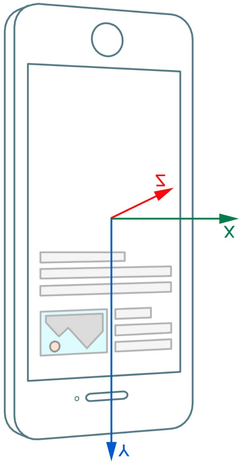


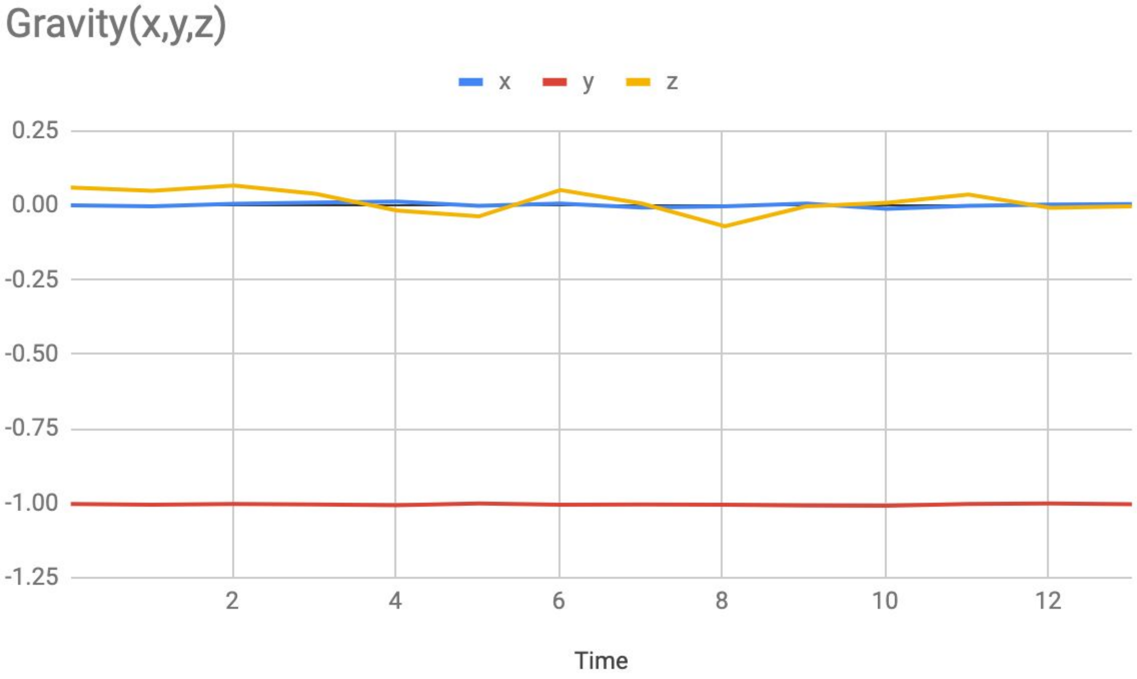
Gravity Y ~ +1



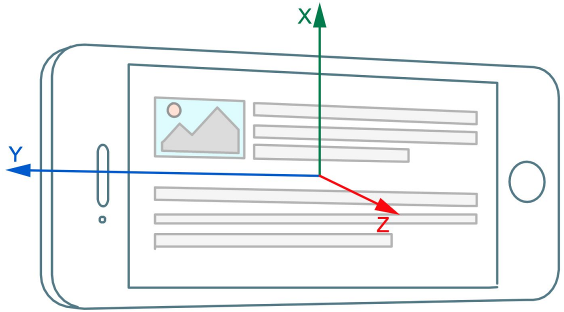


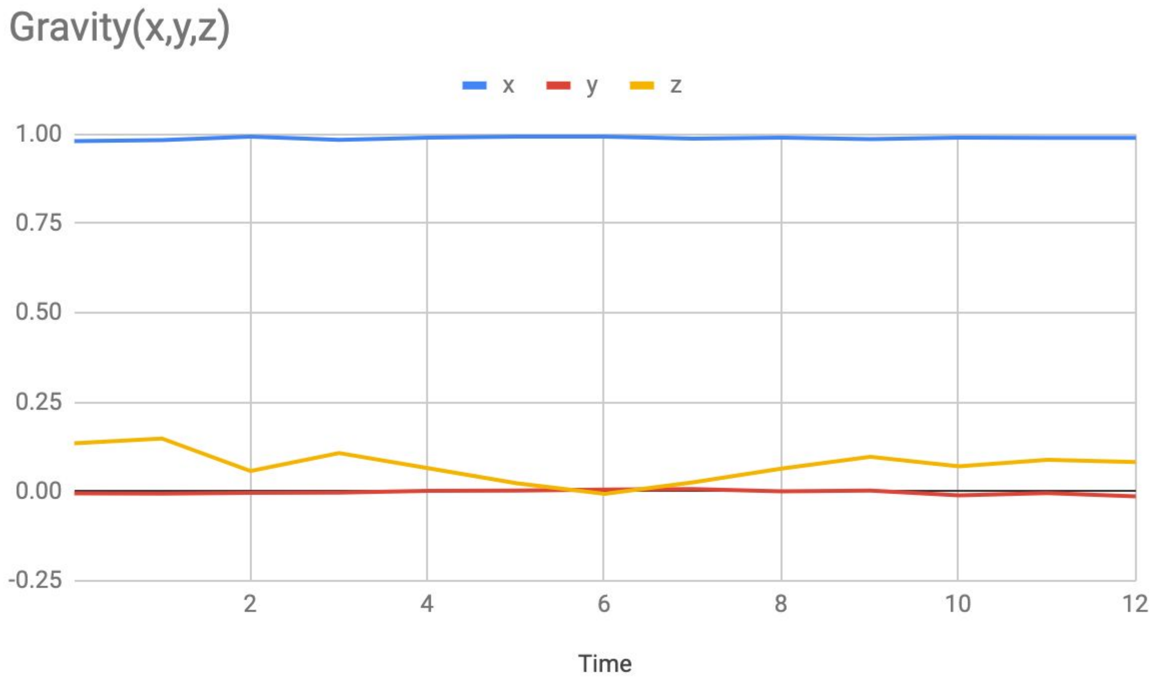
Gravity Y ~ -1



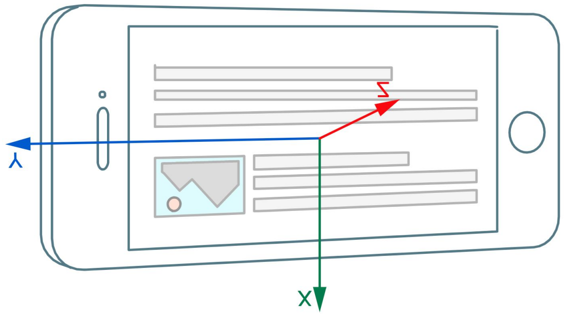


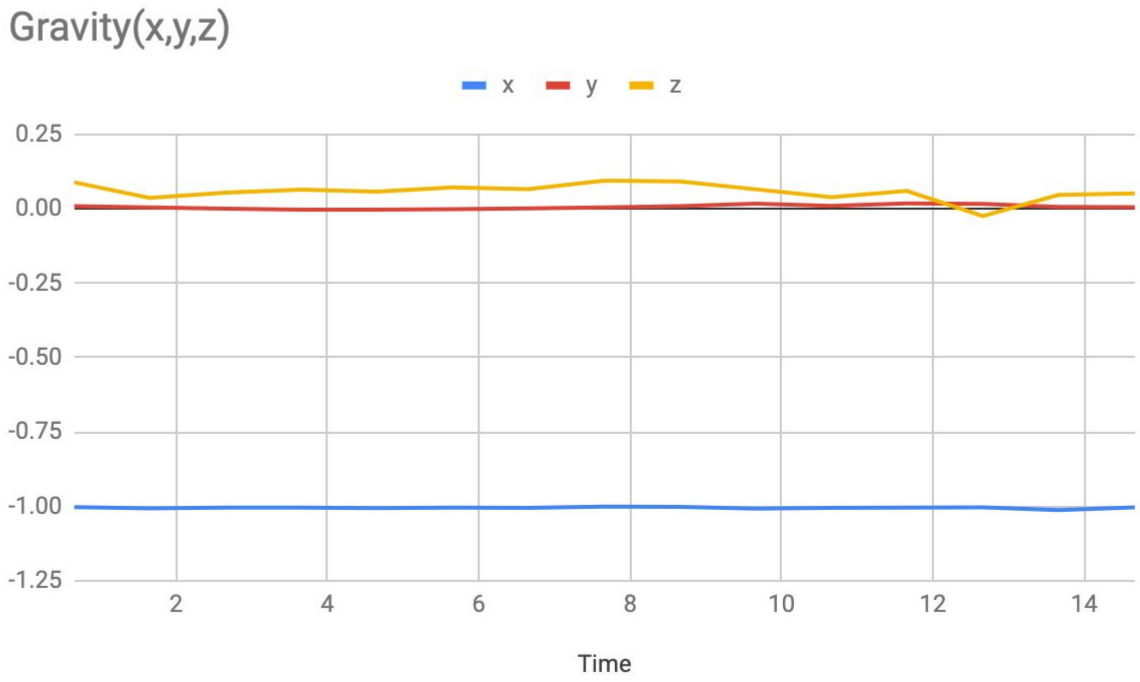
Gravity X ~ +1





Gravity X ~ -1


Z
Y
X

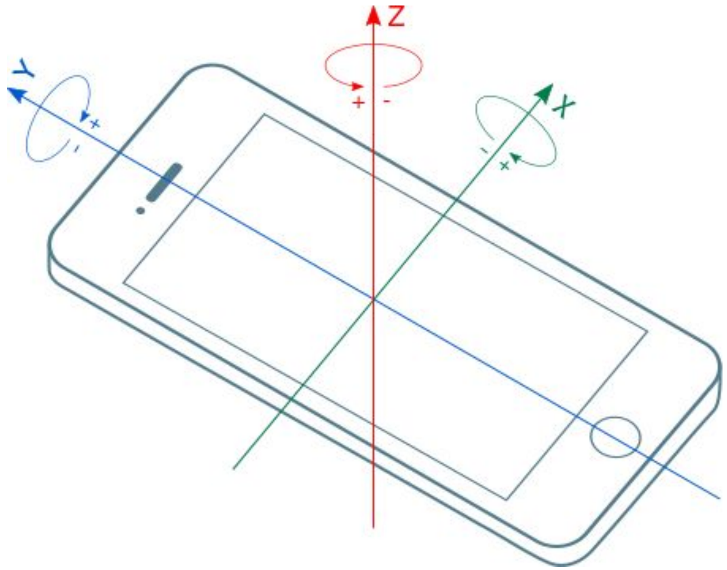

Gravity(x,y,z)
x
y
z
0.25
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
2
4
6
8
10
12
14
Time

Gyroscope sensor

Measures the rate of rotation around the three device axes (x , y , z).

All values are in radians/second.

The concept of Coriolis force is used in these sensors. To measure the angular rate, the rotation rate (and resulting force) of the sensor is converted into an electrical signal.



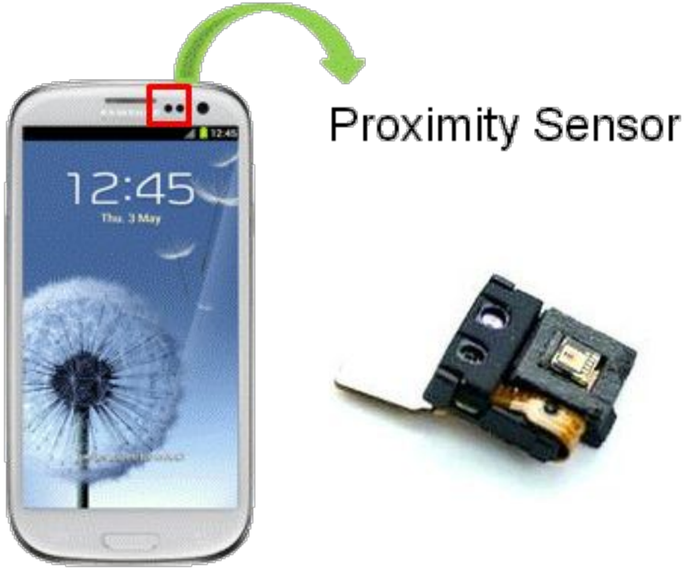
Position Sensors

Proximity Sensor

Detects the presence of nearby objects without any physical contact.

Consists of an infrared LED light and an infrared radiation (IR) detector, and is generally located at the top of the phone screen and near the receiver. It detects the distance between an object and the phone by calculating changes in infrared light signals it receives.

The working range is about 10 cm.

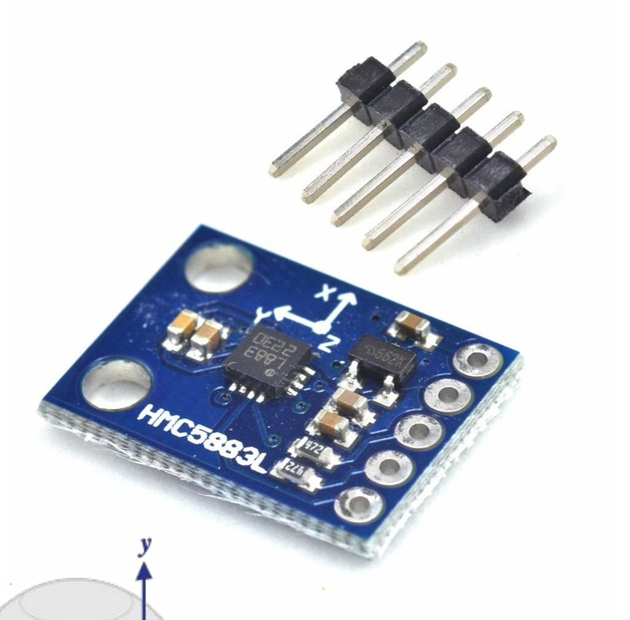


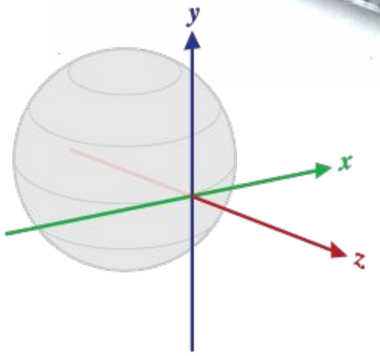
Magnetometer Sensor

Detects the relative orientation of your device relative to the Earth's magnetic north (rotation vector)

A Hall-effect sensor produces voltage which is proportional to the strength and polarity of the magnetic field along the axis each sensor is directed. Values are in µT (micro Tesla)

Enables applications like compass (2D).

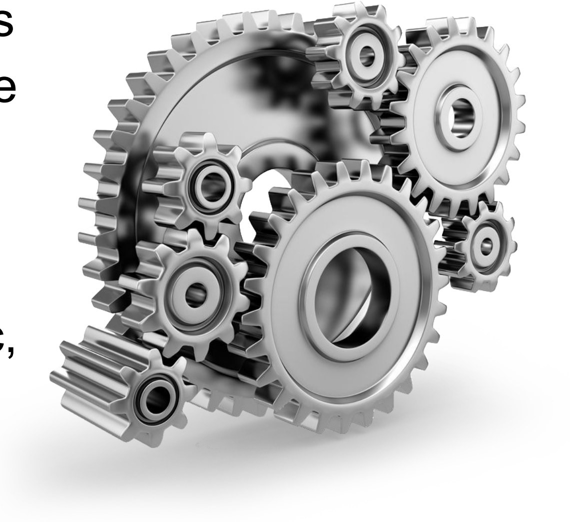




Actuators

Definition

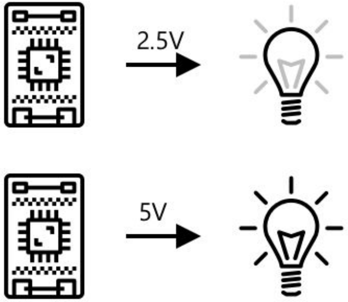
- An actuator **is a machine part** that initiates movements by receiving feedback from a control signal. Once it has power, the actuator creates specific motions depending on the purpose of the machine.
- An actuator, **causes an effect**.
- An actuator may be pneumatic, hydraulic, electric, thermal, or magnetic.

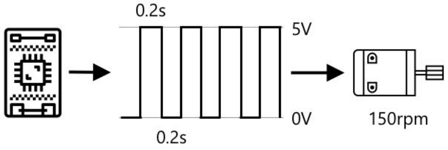


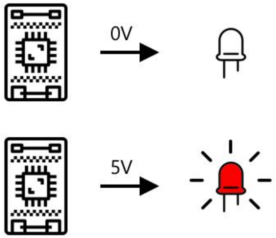
Actuators

Actuators are the opposite of sensors - they convert an electrical signal from your IoT device into an interaction with the physical world such as emitting light or sound, or moving a motor.

- Analog actuators: convert a signal level (voltage) or its duty cycle (PWM) to modify some interaction: light dimmer
- Digital actuators: convert a digital signal into multiple states (LED, screen)





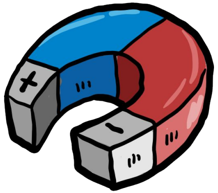


Typical Actuators

- LED - these emit light when turned on
- Speaker - these emit sound based on the signal sent to them, from a basic buzzer to an audio speaker that can play music
- Stepper motor - these convert a signal into a defined amount of rotation, such as turning a dial 90°
- Relay - these are switches that can be turned on or off by an electrical signal. They allow a small voltage from an IoT device to turn on larger voltages.
- Screens - these are more complex actuators and show information on a multi-segment display. Screens vary from simple LED displays to high-resolution video monitors.

Types of actuators

- **Electrics**: It uses an electric energy to generate an mechanical movement.
- **Pneumatics**: Devices that convert the energy of **compressed air or gas** into a mechanical motion.



- **Hydraulics**: Hydraulic actuator uses hydraulic (liquids) power to facilitate mechanical operation.

- **Magnetic**: This kind of actuator uses magnetic field to produce an effect.

Electric actuators

It uses an electric energy to generate an mechanical movement. Usually use a motor to convert electrical energy into mechanical torque.

- Can produce a large magnitude of force with high speed. 😀
- Low noise operation.😀
- Expensive. 🙁
- Maintenance required. 🙁

Electric actuators

https://textiles-maranon.negocio.site/

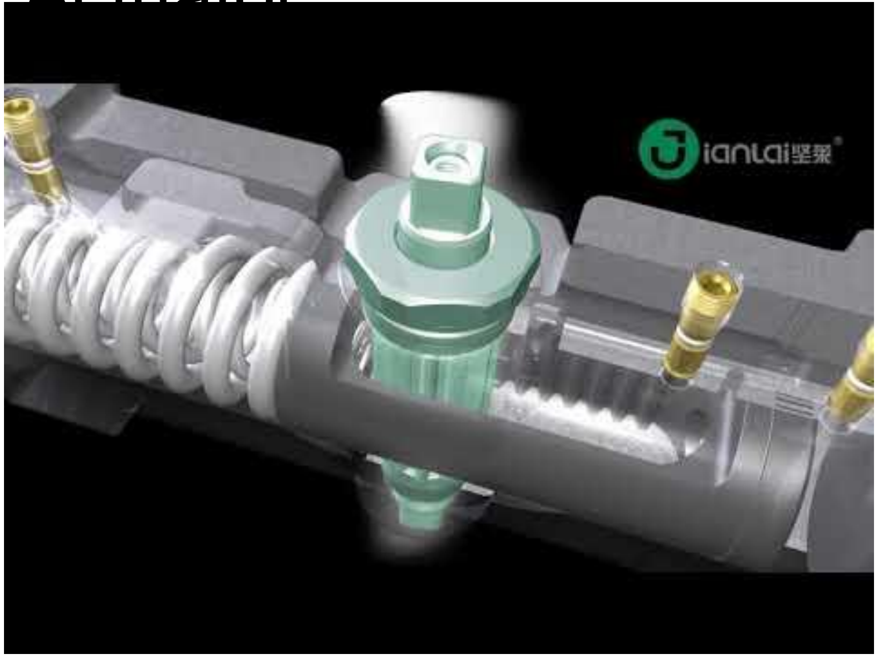
https://level.co/products/bolt

Hydraulic Actuator

Hydraulic actuator uses hydraulic (liquids) power to facilitate mechanical operation. The mechanical motion can be converted to rotary or linear motion.

- Can produce a large magnitude of force with high speed. 😀
- Expensive. 🙁
- High maintenance systems. 🙁

Hydraulic Linear Actuator

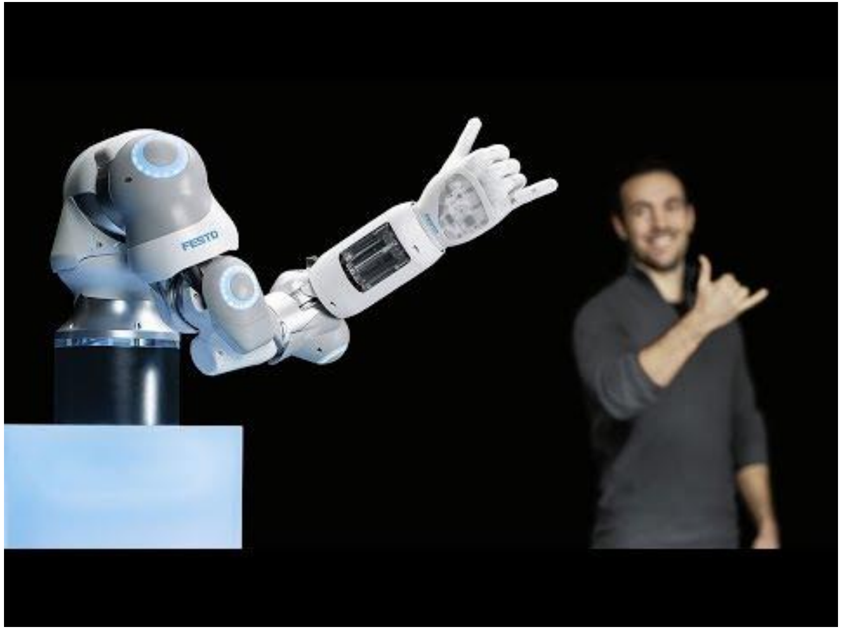


Hydraulic Rotary Actuator

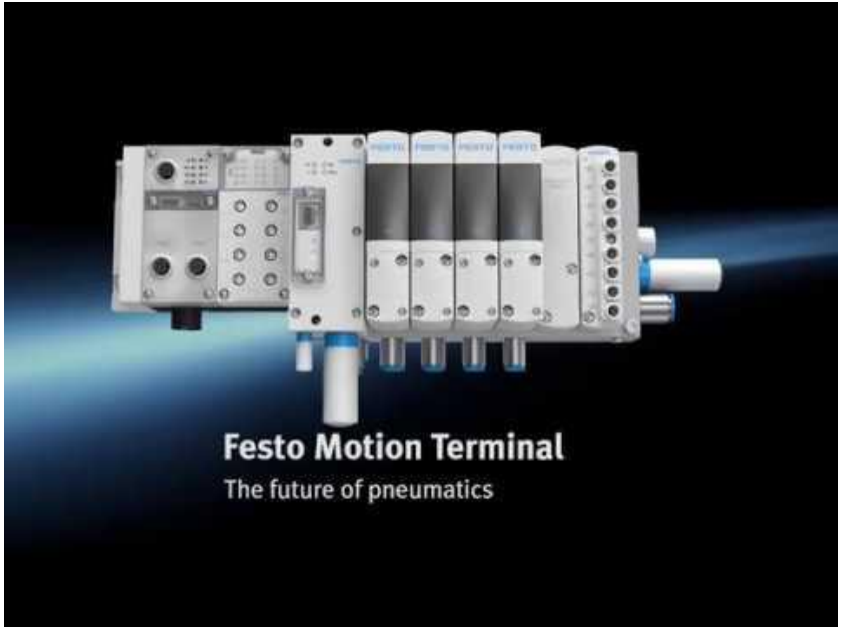
Pneumatic Actuator

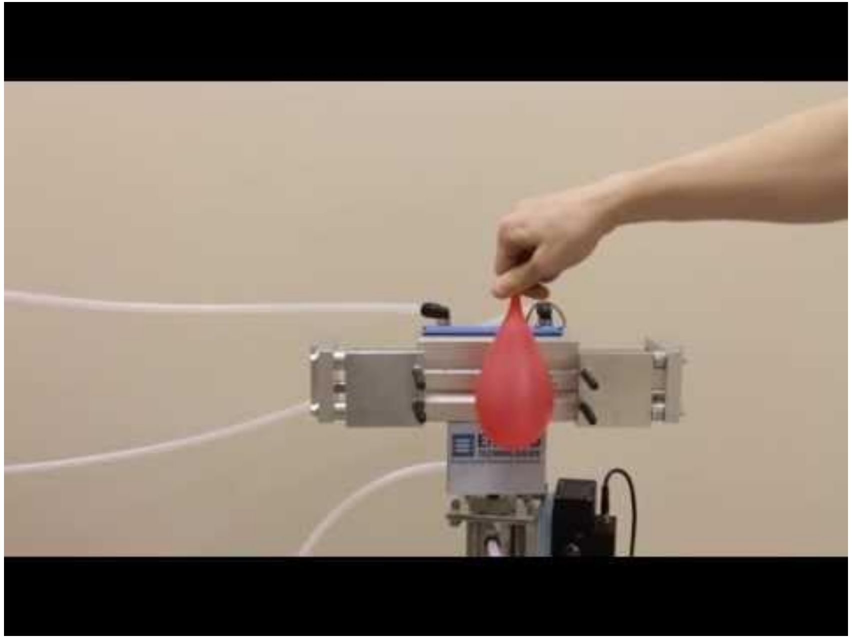
It converts the energy of **compressed air or gas** into a mechanical motion. The mechanical motion can be converted to rotary or linear motion.

- Can produce a large magnitude of force with high speed. 😀
- Low maintenance systems. 😀
- Needs air compressor running continuously. 🙁



Pneumatic Actuator



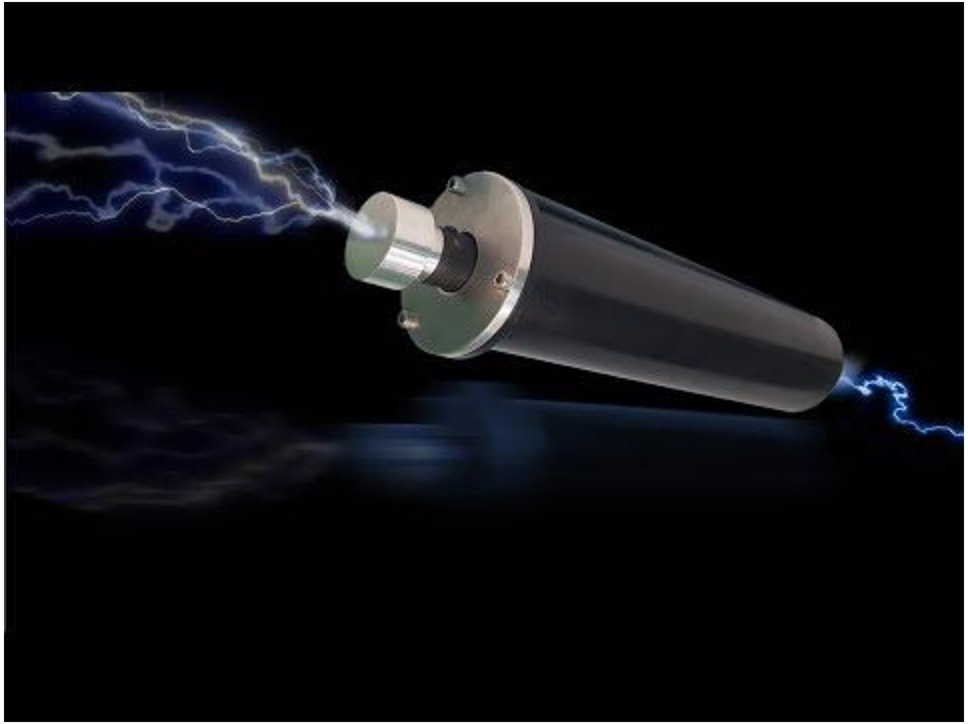


Magnetic Actuator

Magnetic: This kind of actuator uses magnetic field to produce an effect, usually combined with electric energy.

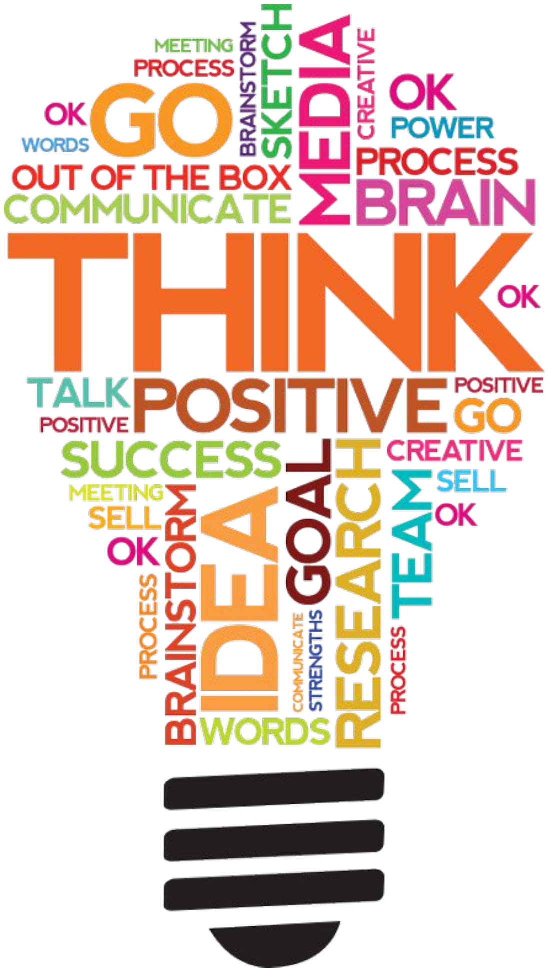
- Compact and economical. 😀
- Low maintenance systems. 😀

Magnetic Actuator

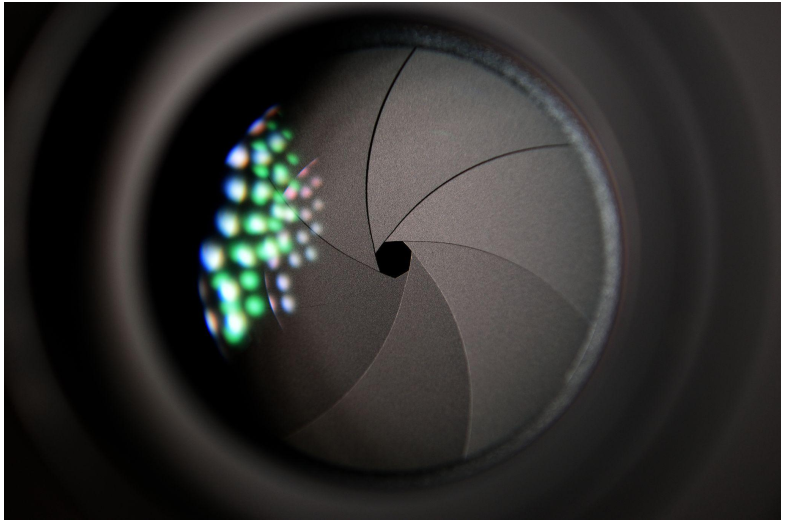


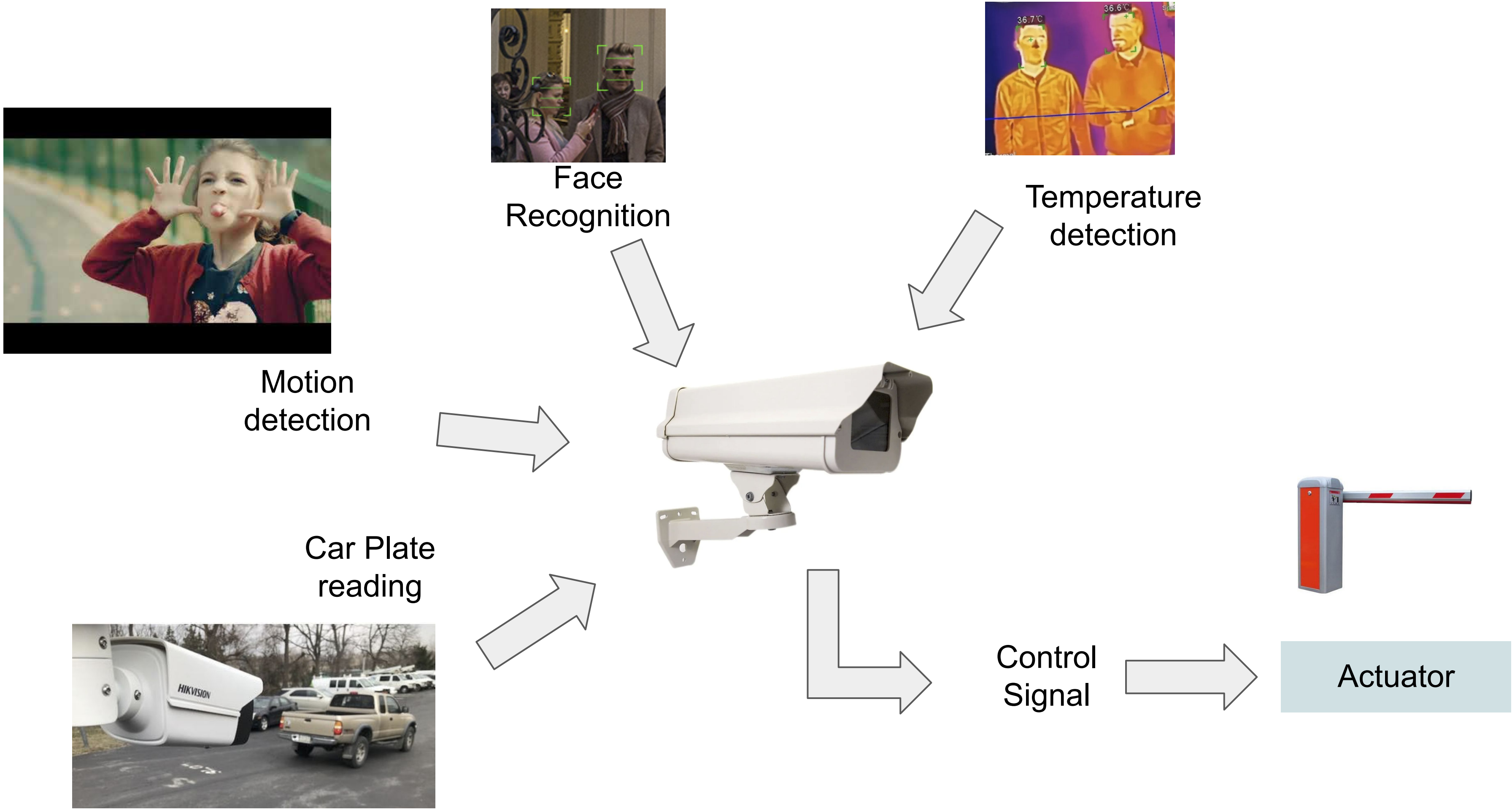
https://irisdynamics.com/

Ideas for the project?



Camera as an IoT sensor device





Face Recognition
Temperature detection
36.7℃
36.6℃
Motion detection
Car Plate reading
HIKVISION
Control Signal
Actuator

Applications

Color Meter App

Applications

[Easy Measure](#) App

Applications