Sensors: Analog & Digital

Jonathan Brewer
Network Startup Resource Center
jon@nsrc.org

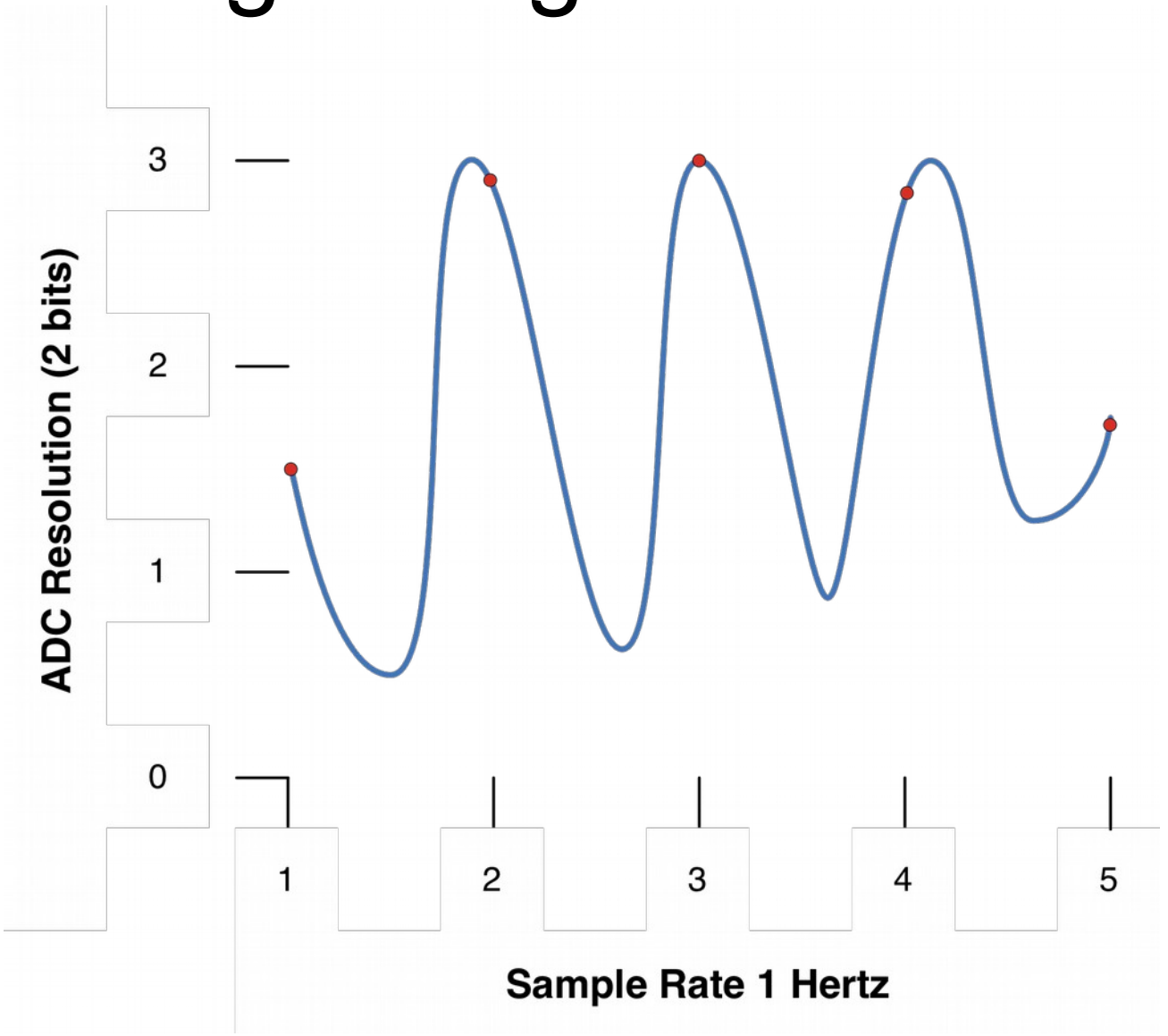
Sensors: Considerations

- Analog or Digital
- Digital Connectivity Method
- Some warm-up, others need calibration
- Power requirements vary widely
- Accuracy typically varies with price
- Remember the Wisdom of the Crowd

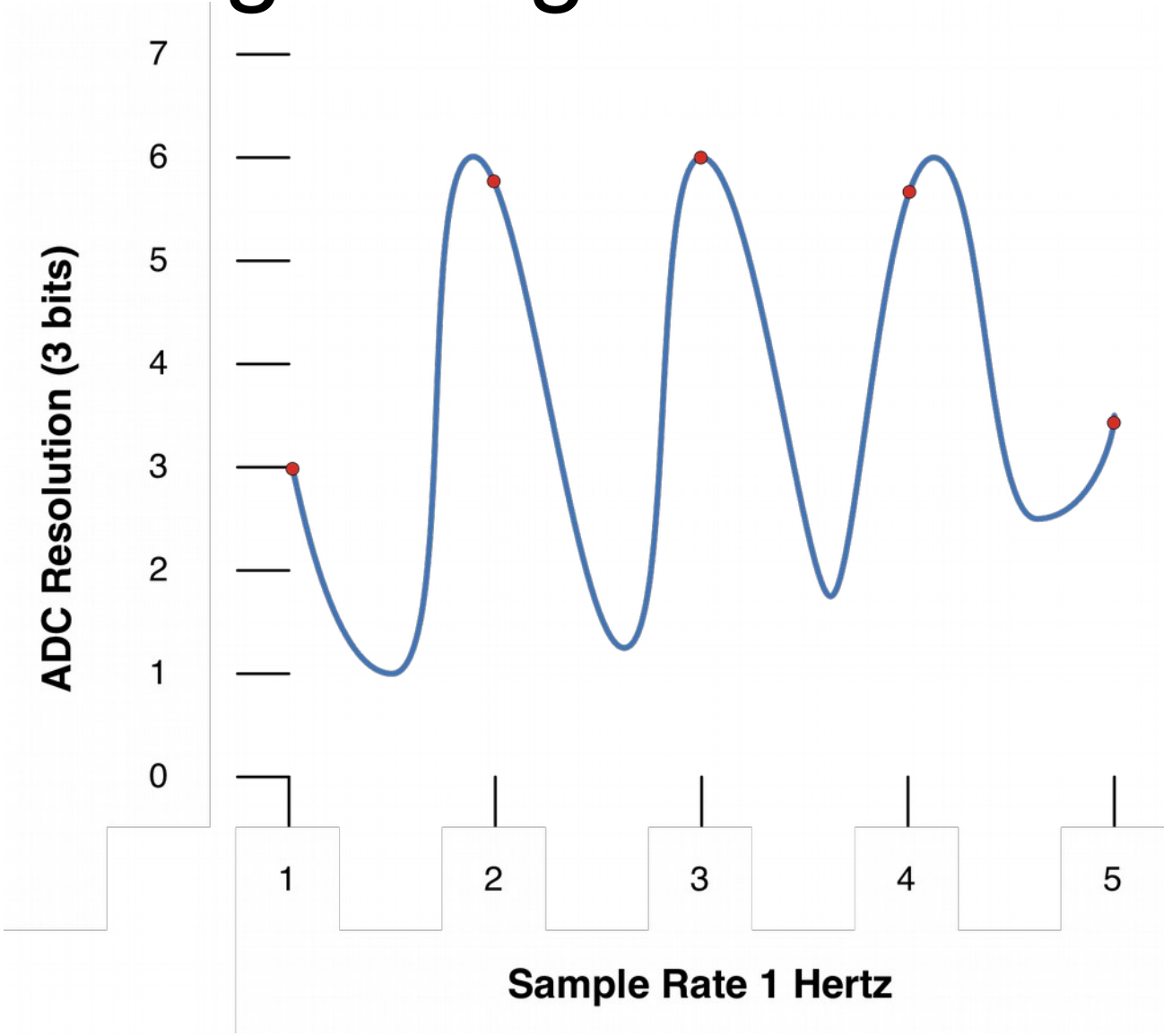
Analog Sensors

- Provide a continuous reading in millivolts
- Connect via ADC – Analog Digital Converter
- ADCs have resolution (z1 = 12 bits)
- ADCs have sample rates
- Need a reference voltage

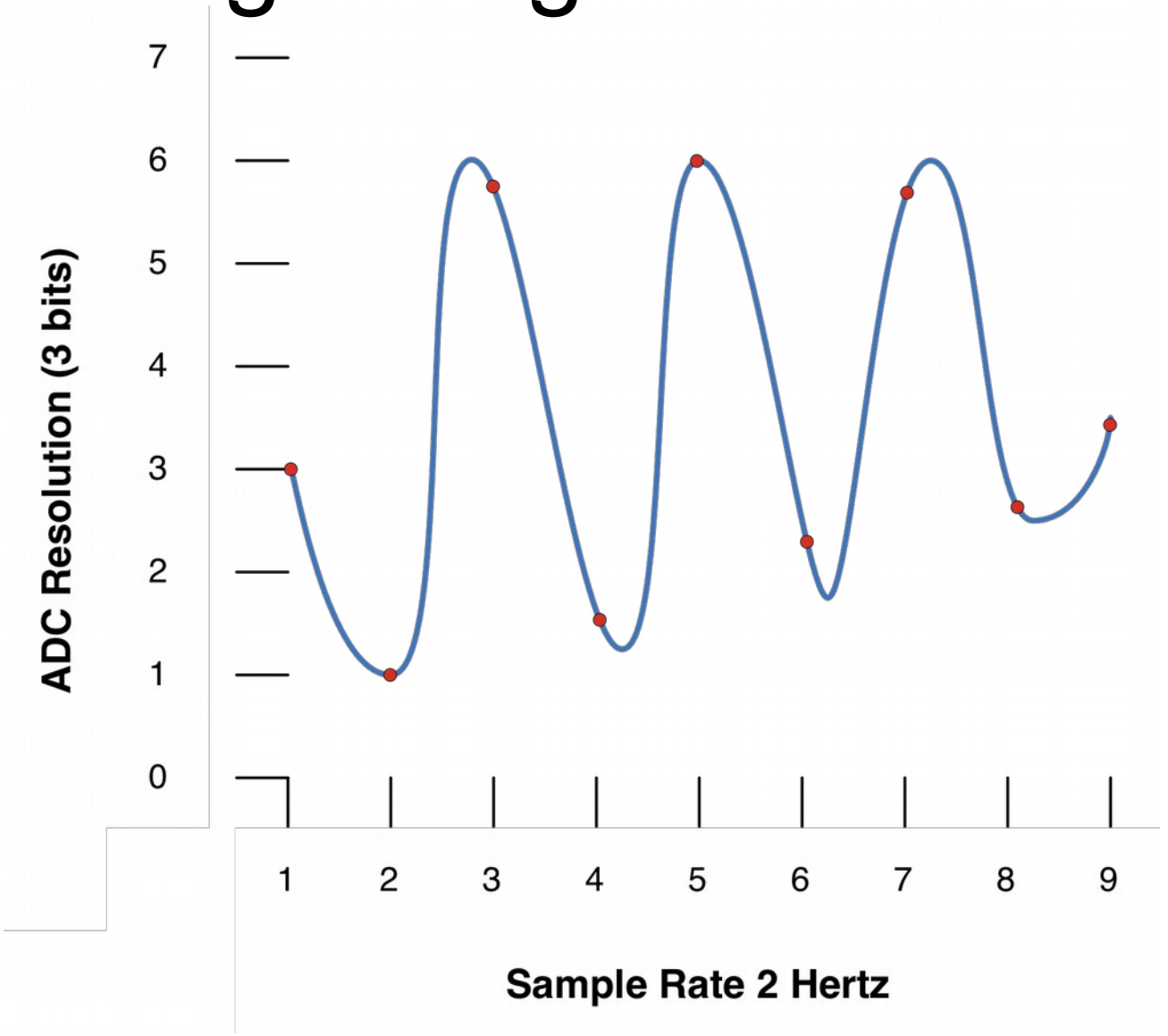
Analog to Digital Converters



Analog to Digital Converters



Analog to Digital Converters



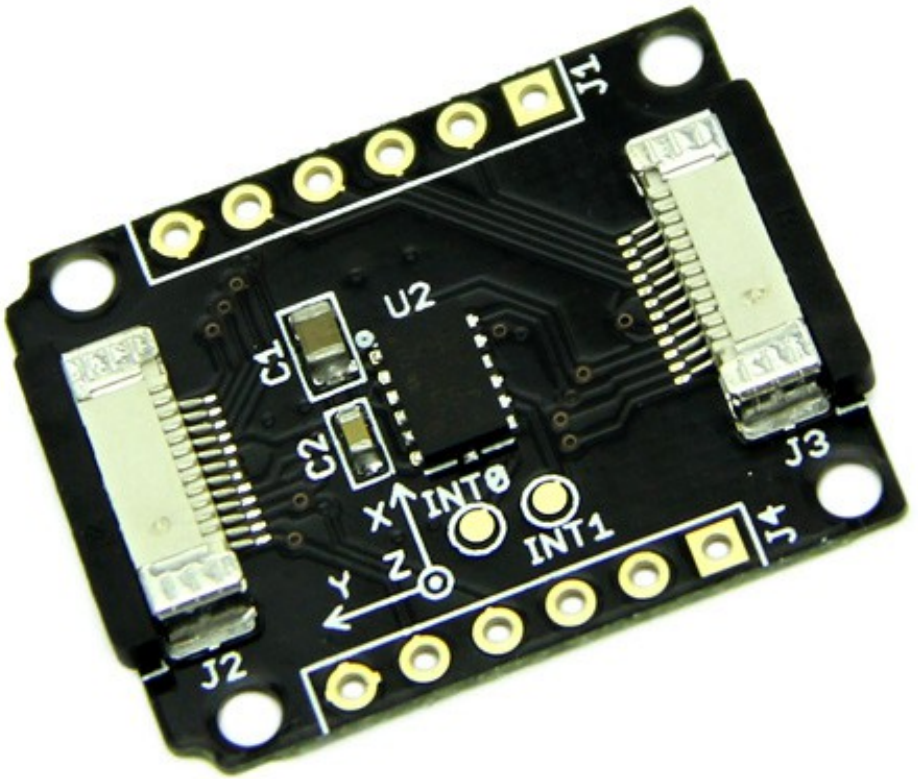
Digital Sensors

- Can be as simple as voltage or no voltage
- Normally use a protocol, including:
- 1-wire: half-duplex, 127 devices per wire
- I2C: two wires, 7-10 bit addressing
- SPI: 4 wires, full-duplex, low power, no unique addresses required, high data rates
- USB: high data rate, high power. “Universal”

Common IoT Sensors

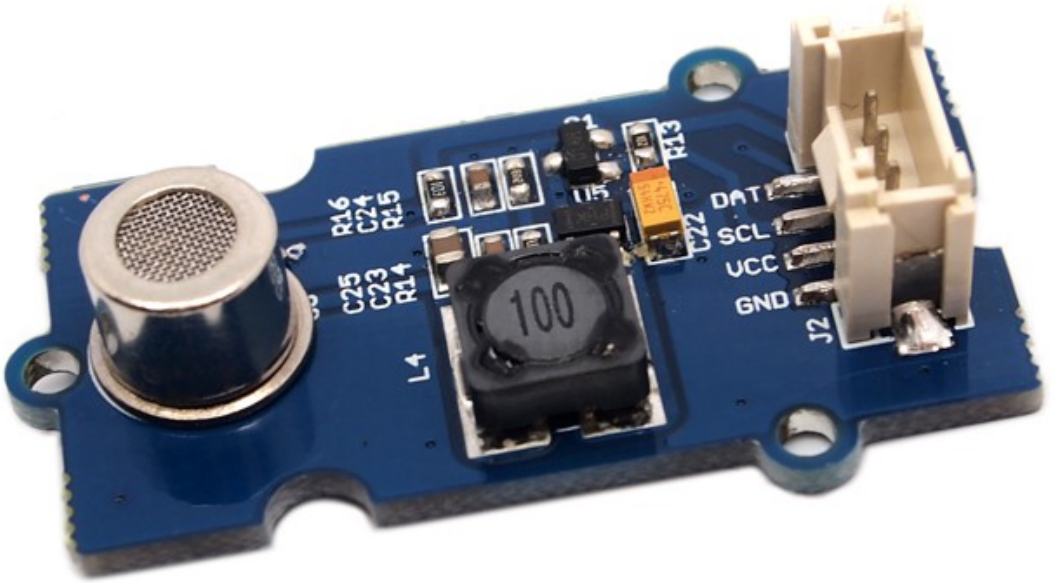
- Following all easy to purchase online
- Most between 5-20 euros each
- Large variation in power requirements
- Many good for prototyping, not production

Accelerometer

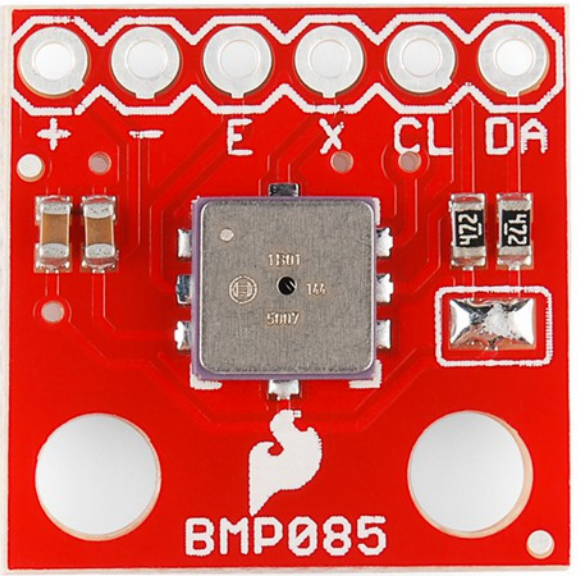


Air Quality Sensor

Alcohol Sensor



Barometric Pressure



Camera

Collision Sensor

Colour Sensor

Compass: Digital

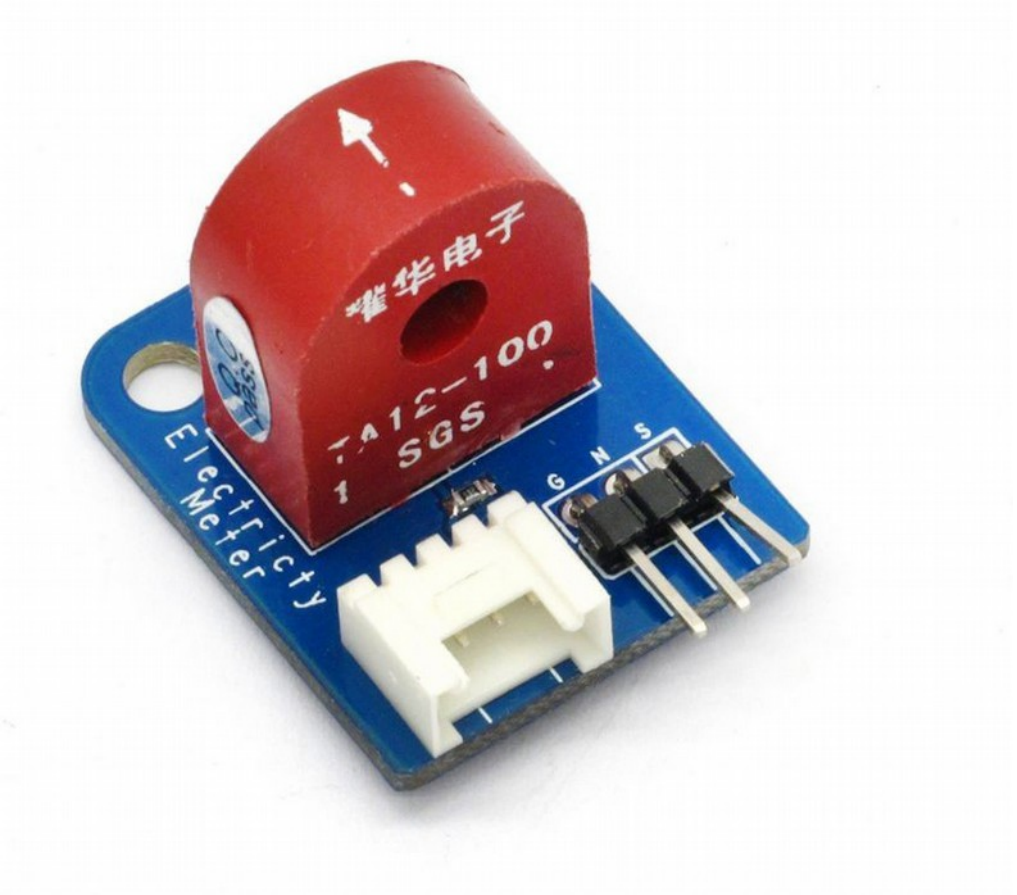
Formaldehyde Sensor

Galvanic Skin Response

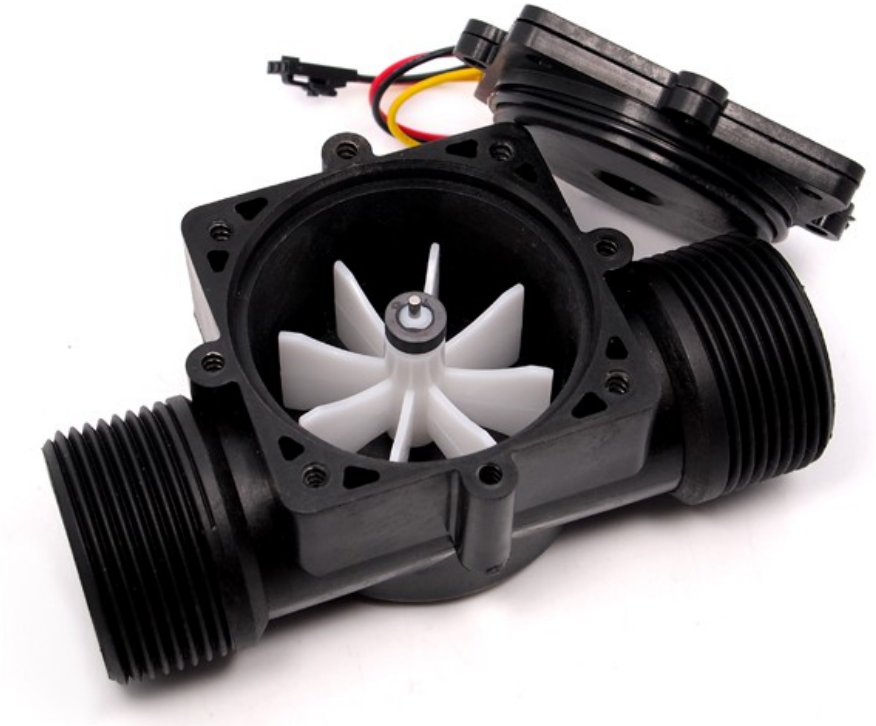
Gas Sensor

Global Positioning System

Electrical Current Sensor

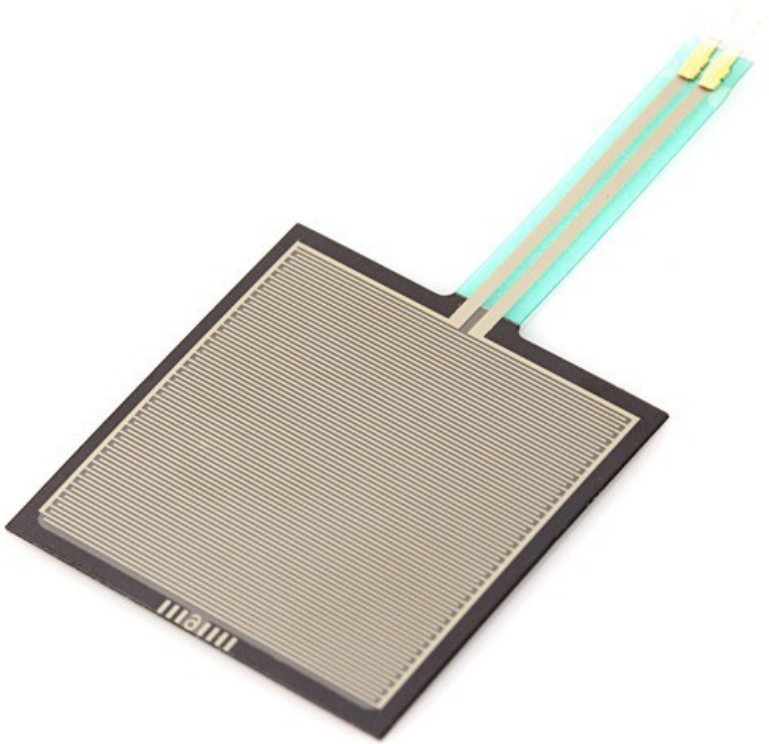


Flow Sensor

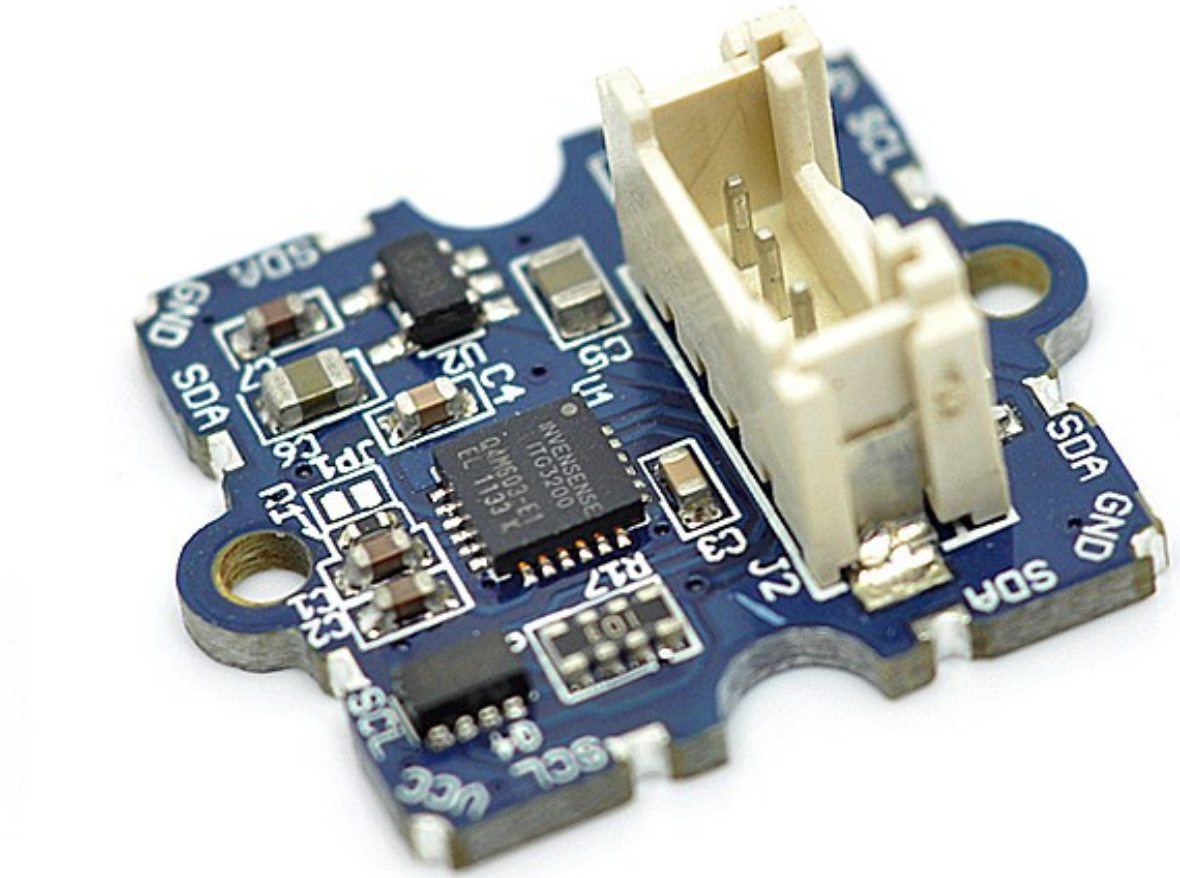


Flow Switch

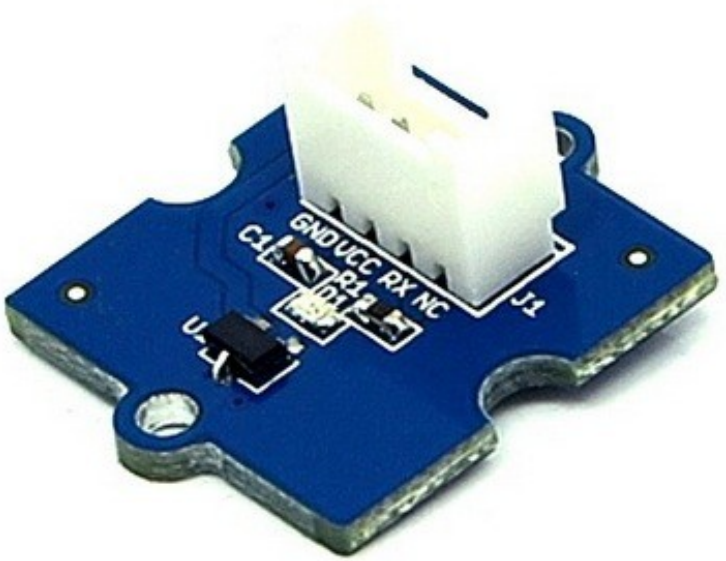
Force Sensitive Resistor



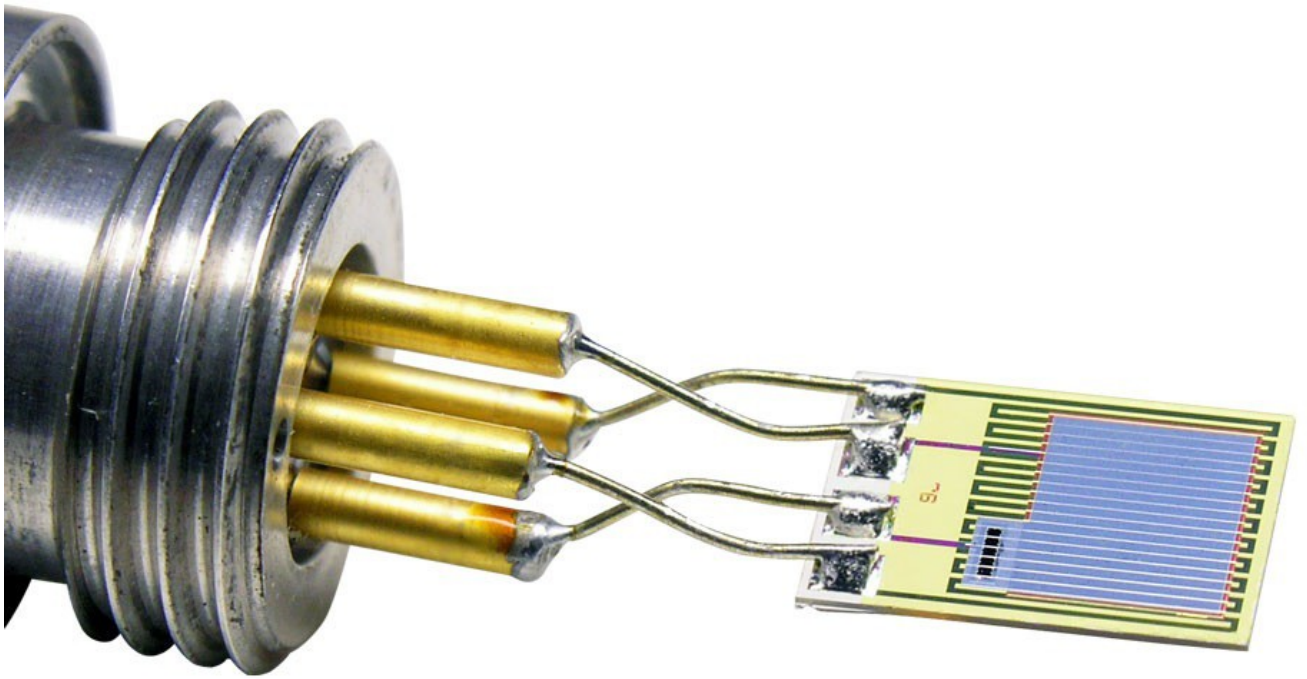
Gyroscope


GND
SDA
SDA
SCL
SDA
GND
SDA
GND
SCL
VCC
SCL
INVENSENSE
ITG3200
C4
C5
C6
C3
C2
R17
J2
JP1

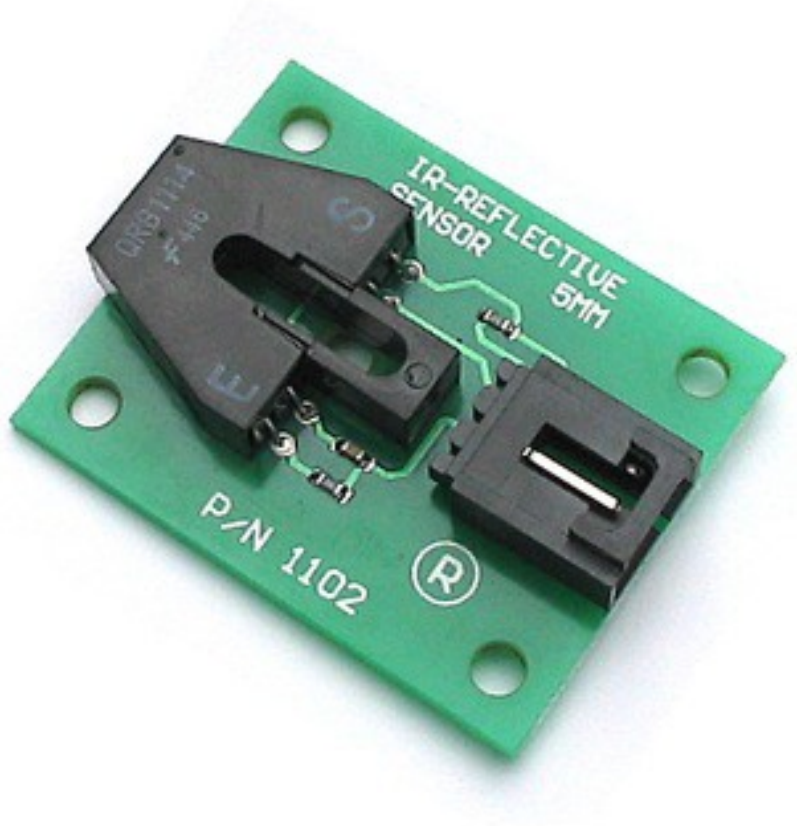
Hall Sensor



Humidity Sensor

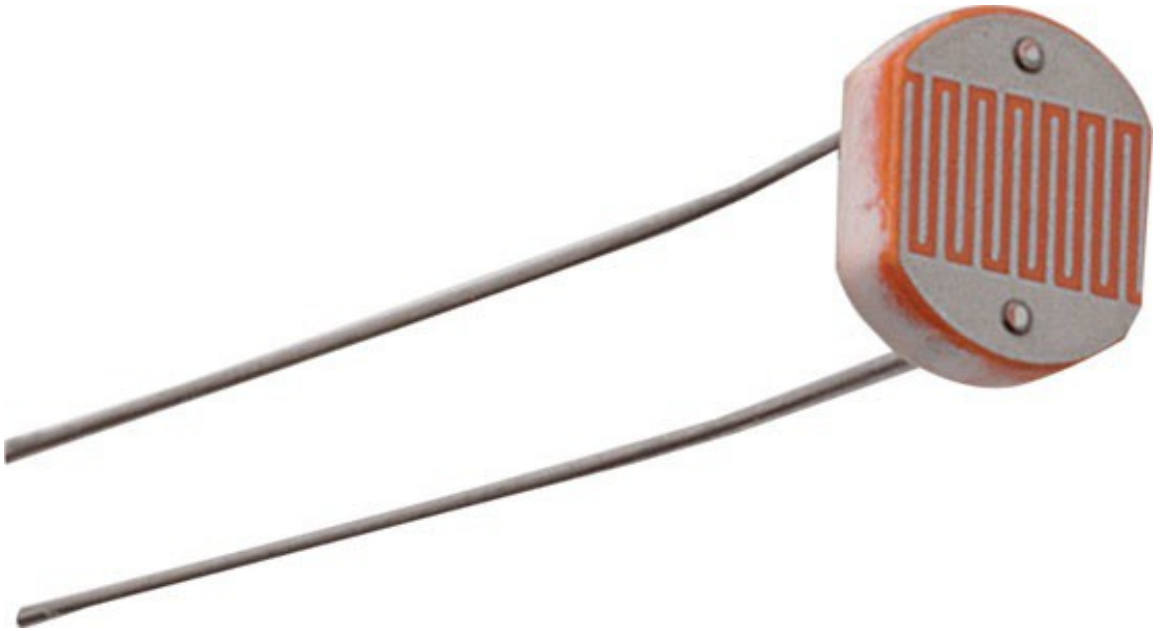


Infrared Reflection



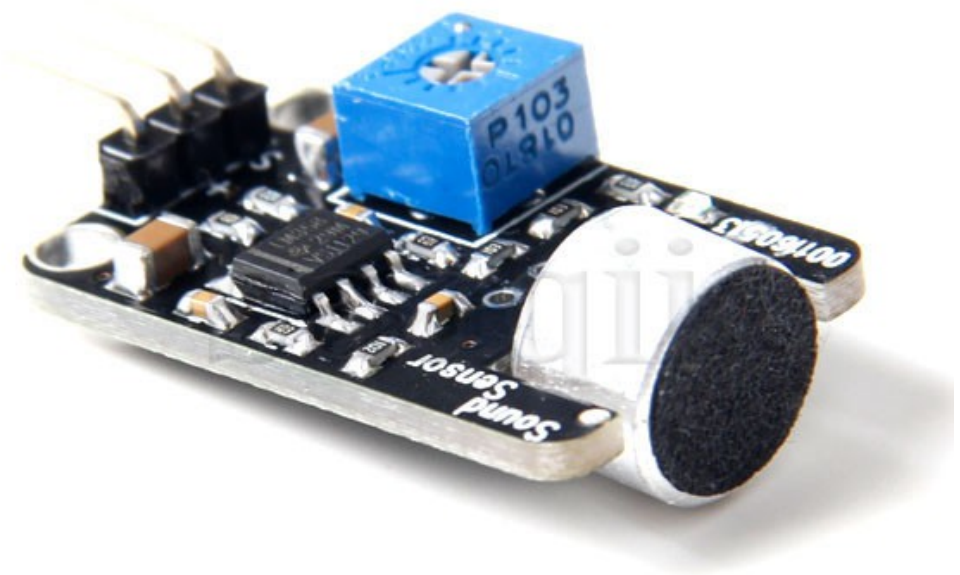
Infrared Sensor: Passive

Light Sensor



Load Sensor

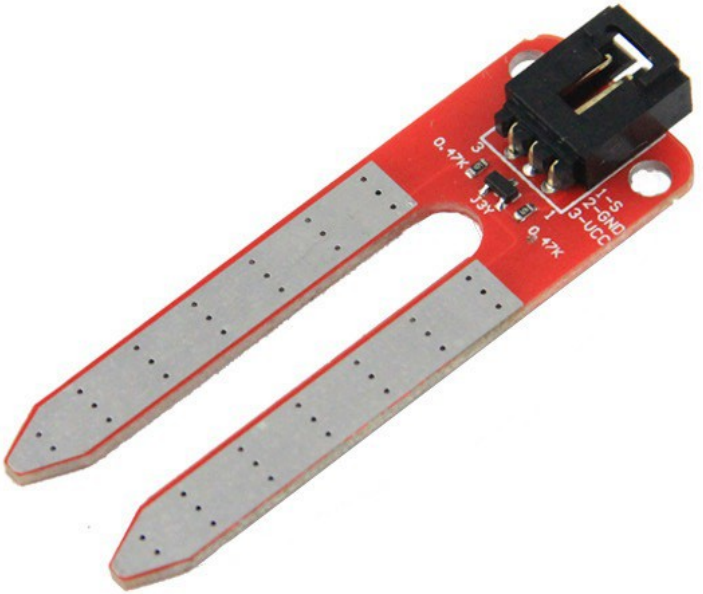
Loudness Sensor



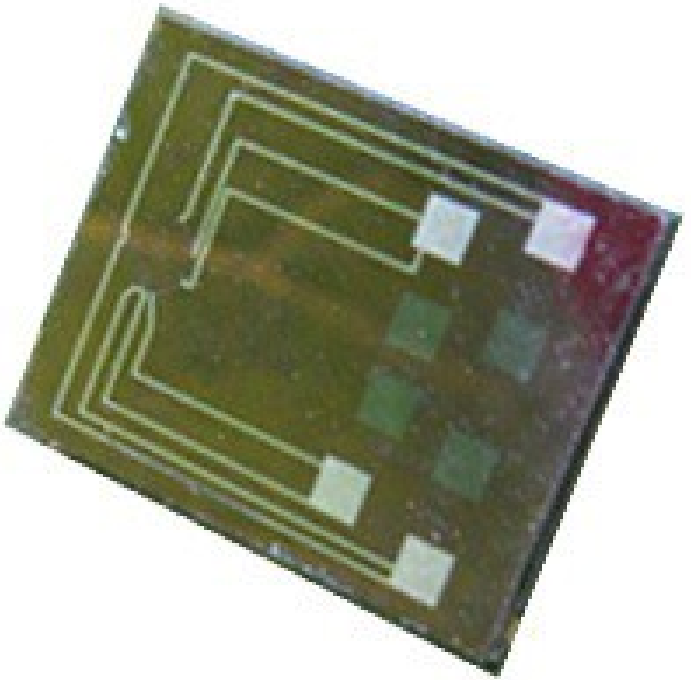
Microphone


AO
POWER
GND
VCC
DO
SENSOR
2578-SC
19809WH2
102
102
104
103
101
104

Moisture Sensor



Moisture Sensor Chip (Cornell)



Optical Dust Sensor

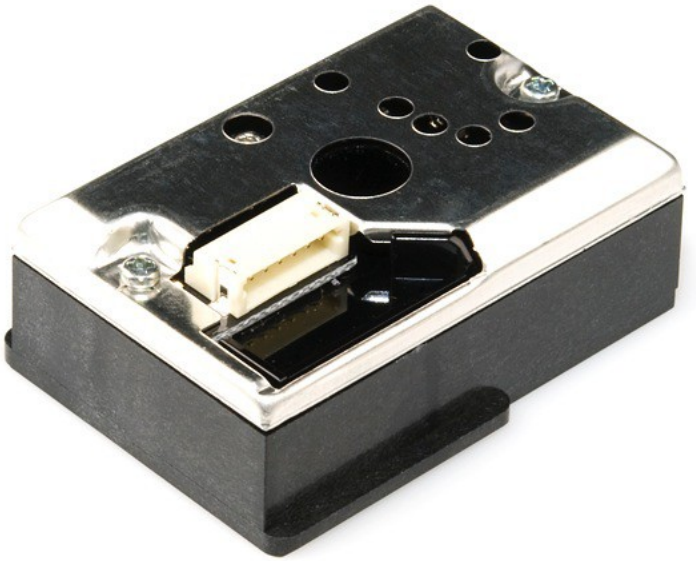
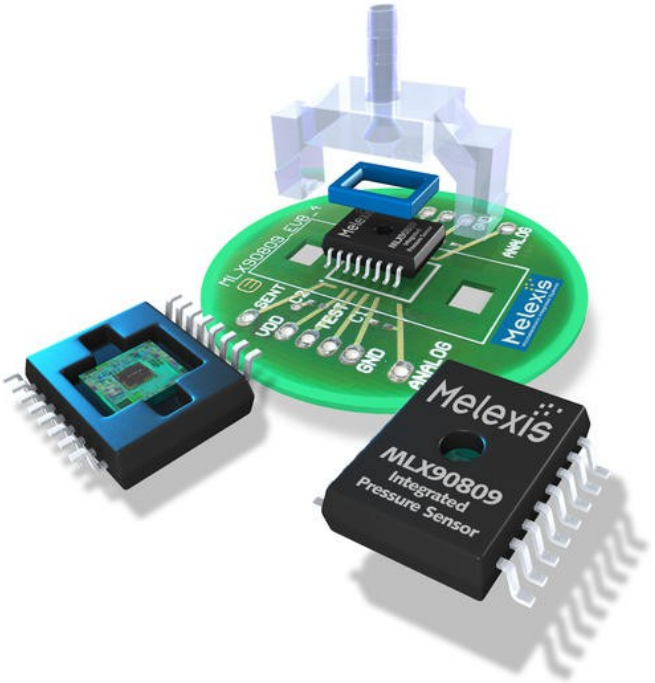


Photo Interruptor

Pressure Sensor (MEMS)

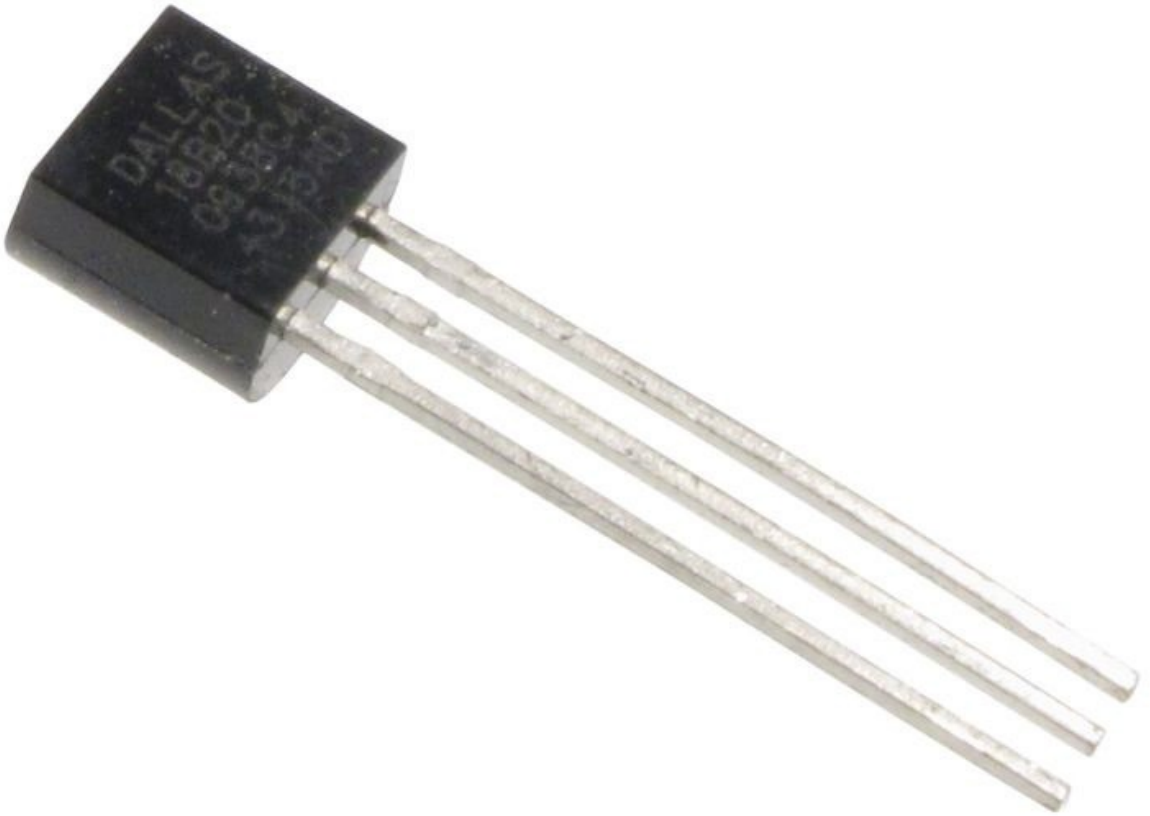


Real Time Clock

Reed Switch

Solar Radiation Sensor

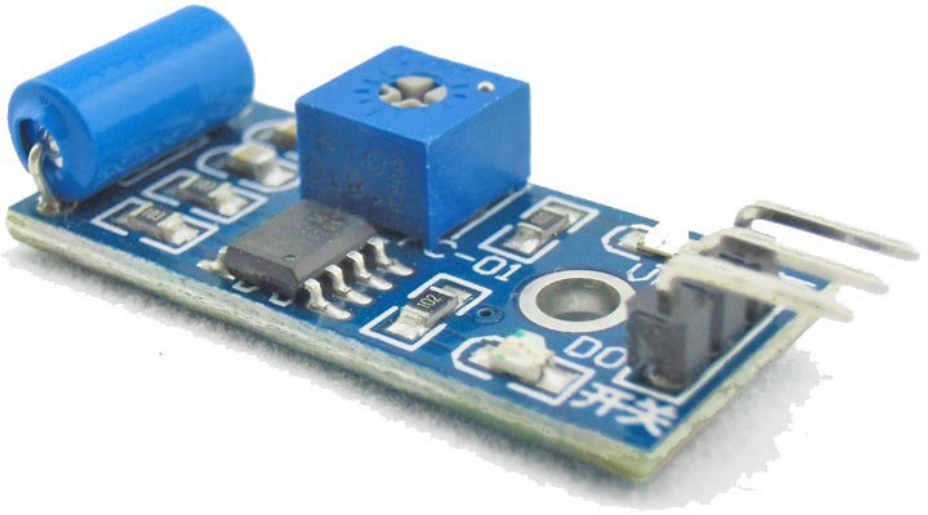
Temperature Sensor



Thermistor

Touch Sensor: Capacitive

Vibration Sensor



Ultrasonic Range Finder

Ultraviolet Radiation Sensor

Sensors: Analog & Digital

Jonathan Brewer
Network Startup Resource Center
jon@nsrc.org

UNIVERSITY OF OREGON

NSRC

Sensors are the most interesting part of the Internet of Things. They translate the world into digital signals that can be understood and acted on by computers. They're the basis of everything we'll talk about in relation to the Internet of Things.

Sensors: Considerations

- Analog or Digital
- Digital Connectivity Method
- Some warm-up, others need calibration
- Power requirements vary widely
- Accuracy typically varies with price
- Remember the Wisdom of the Crowd

Analog Sensors

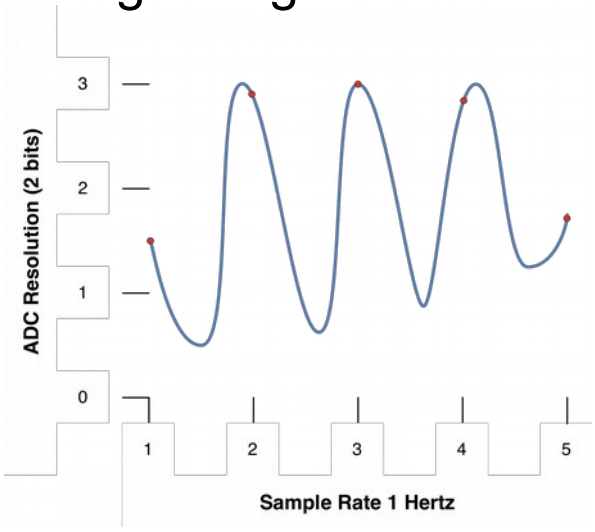
- Provide a continuous reading in millivolts
- Connect via ADC – Analog Digital Converter
- ADCs have resolution (z1 = 12 bits)
- ADCs have sample rates
- Need a reference voltage

UNIVERSITY OF OREGON

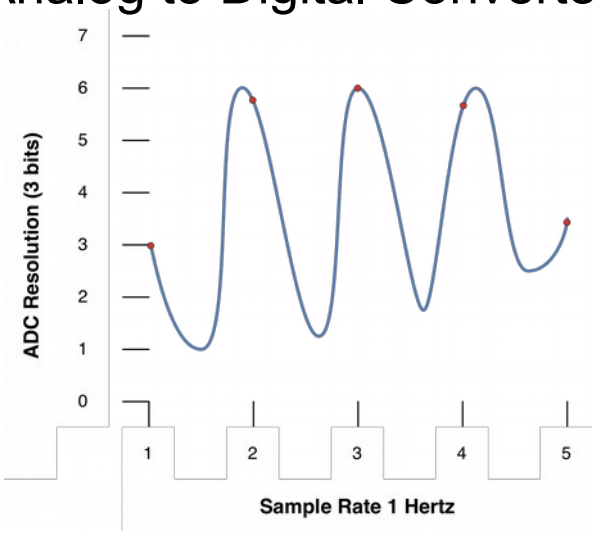
NSRC

As a rule, sample rate should be 2x the phenomena you are trying to measure. Human speech requires 8kHz to reproduce accurately, but should be sampled at 16Khz for measurement.

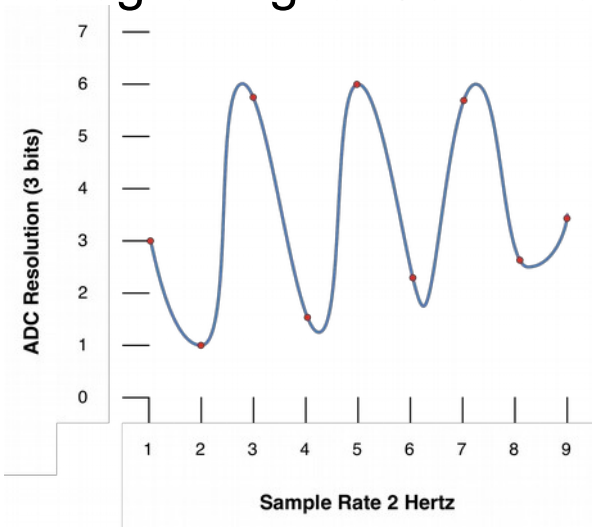
Analog to Digital Converters



Analog to Digital Converters



Analog to Digital Converters



Digital Sensors

- Can be as simple as voltage or no voltage
- Normally use a protocol, including:
- 1-wire: half-duplex, 127 devices per wire
- I2C: two wires, 7-10 bit addressing
- SPI: 4 wires, full-duplex, low power, no unique addresses required, high data rates
- USB: high data rate, high power. “Universal”

Common IoT Sensors

- Following all easy to purchase online
- Most between 5-20 euros each
- Large variation in power requirements
- Many good for prototyping, not production

Accelerometer

UNIVERSITY OF OREGON

NSRC

Measures acceleration in multiple axis.

On a person or animal, an accelerometer can help to track motion for health.

I actually wear an armband that has an accelerometer, along with a few other sensors. It helps to remind me to get enough exercise.

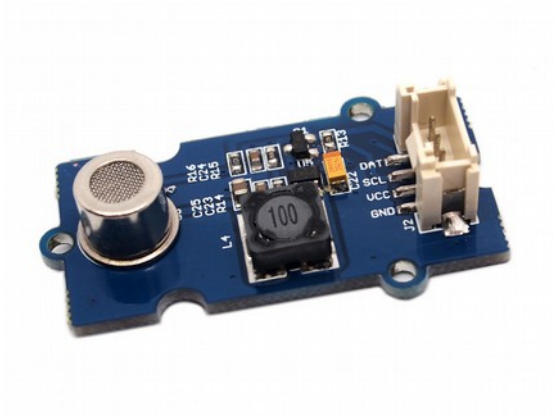
Air Quality Sensor

UNIVERSITY OF OREGON

NSRC

Air quality sensors typically look for a few different things: carbon monoxide, alcohol, acetone, formaldehyde. A generic, inexpensive device might give you a warning that something is wrong, but not necessarily what is wrong.

Alcohol Sensor



UNIVERSITY OF OREGON

NSRC

This five-euro sensor can be used to test breath alcohol. It could be used to provide an inexpensive interlock on a machine, a car or a tractor that shouldn't be operated by someone who has been drinking.

Barometric Pressure

UNIVERSITY OF OREGON

NSRC

The most obvious use for a barometer pressure sensor is for weather monitoring. A change in reading from a stationary barometer can mean that the weather is going to change.

I think the most common use for barometers today though is in smartphones. They use barometers in a mobile application to determine a device's height above sea level. Combined with details from a GPS and from a cellular network, a barometer can help a phone get very accurate positioning information.

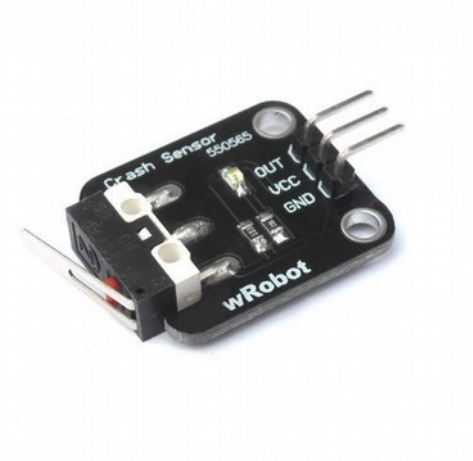
Camera

UNIVERSITY OF OREGON

NSRC

We all know what cameras are good for. I'll just use mine right now. (and now for a selfie). In the world of the Internet of things a camera can do more than just take selfies. Coupled with a Raspberry Pi and some free, open source software called OpenCV, a camera like this can be used for face recognition.

Collision Sensor



UNIVERSITY OF OREGON

NSRC

Much of the popularity of small microprocessors like the Arduino is a result of people's fascination with robots. This very rudimentary collision sensor allows a moving device (hopefully moving very slowly) to know when it's hit something else - maybe a wall, another robot, or a shoe.

Colour Sensor

UNIVERSITY OF OREGON

NSRC

Colour sensors are a bit more interesting to me than cameras. I think this one senses red, green, blue, and brightness, and reports back an intensity You could point one at a machine that has red and green lights, to easily know the state of the machine. You could also use one with a conveyer belt to check or record the ripeness of some fruit or vegetables.

Compass: Digital

UNIVERSITY OF OREGON

NSRC

Which way is North? This is a very easy to understand sensor that is important to anything mobile.

Formaldehyde Sensor

Formaldehyde is used in the manufacture of fabrics, wood products, tissue products, insulation, and thousands of other products. It can be used as a disinfectant as it kills fungus and bacteria. It can be emitted from many manufactured products when they're heated or burned. It's also toxic!

Detecting formaldehyde concentrations and other indoor air pollutants in a factory or workshop is a good way to ensure the health and safety of workers.

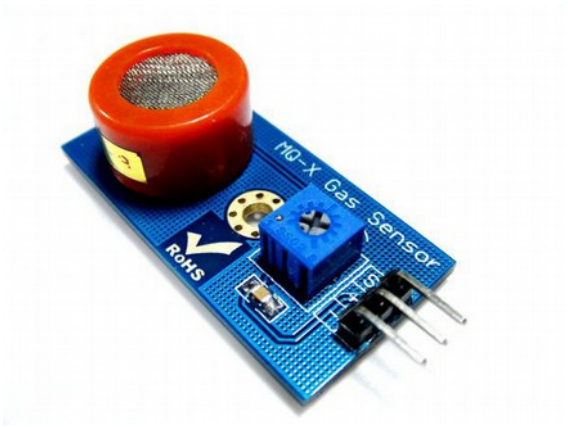
Galvanic Skin Response

UNIVERSITY OF OREGON

NSRC

Galvanic Skin Response measures the conductivity of skin, which can change depending on how active a person’s sweat glands are. Physical and Psychological stress makes glands more active and this lowers the skin’s electrical resistance. My armband - the one with the accelerometer in it, also tracks galvanic skin response.

Gas Sensor



UNIVERSITY OF OREGON

NSRC

Gas sensors come in a number of different versions, Methane, Butane, LPG, Alcohol, Ethanol, Carbon Monoxide, Hydrogen, Ozone, Benzene, Hydrogen Sulfide, Ammonia… the list goes on. Inexpensive sensors will output a voltage that varies with the concentration of the target gas. As with the formaldehyde sensor, these gas sensors can be important for indoor health and safety in labs, workshops, and manufacturing facilities.

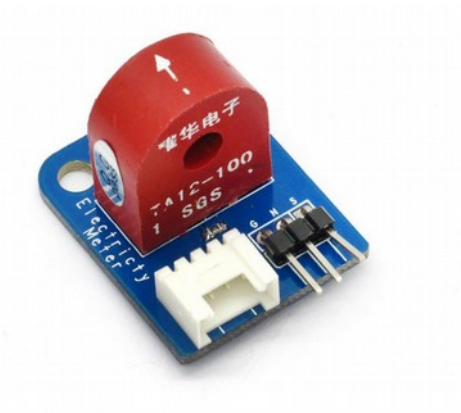
Global Positioning System

UNIVERSITY OF OREGON

NSRC

GPS can be used to find where we are on earth. Modern GPS receivers can pick up signals from the original US owned satellites, from Russia's GLONASS, and in the future from similar European, Chinese, and Indian systems. GPS is also useful in that it provides accurate time. Very, very accurate time, anywhere in the world. If you need to accurately synchronise devices in different places, like flashing safety lights, telecommunications transmissions, or logging of time sensitive data, a GPS based clock is the way to do it.

Electrical Current Sensor



UNIVERSITY OF OREGON

NSRC

This sensor allows you to pass a wire through it to monitor the current flowing through the wire. You might use it as an electricity meter, or you could use it to keep track of when an automated pump, fan, or light was running.

Flow Sensor

UNIVERSITY OF OREGON

NSRC

This flow sensor uses a hall effect to measure how fast a liquid or gas is moving through a pipe, and to record the volume of liquid or gas that has passed through in a particular time interval.

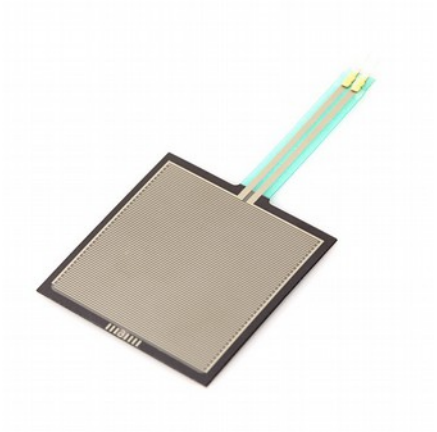
Flow Switch

UNIVERSITY OF OREGON

NSRC

A flow switch protrudes into the middle of a pipe. It can be set up to turn a device on or off depending on whether a liquid or gas is flowing or not.

Force Sensitive Resistor



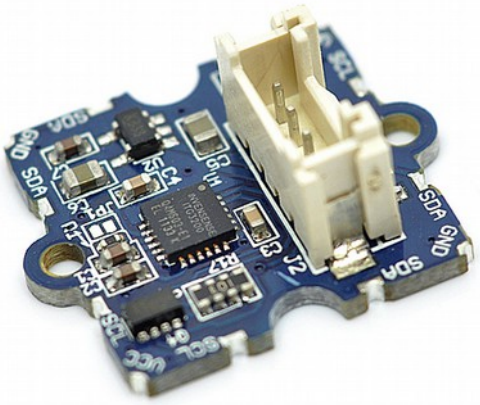
UNIVERSITY OF OREGON

NSRC

As you press on the surface of a force sensitive resistor, resistance through the circuit goes down.

It can be used as a robust, non-mechanical button or touch sensor, or as a very thin but not very accurate device for determining the weight of small load that has been placed on top of it, maybe up to half a kilo.

Gyroscope



UNIVERSITY OF OREGON

NSRC

A gyroscope measures orientation in multiple axis.

It helps you know which way is up, for example if a device has fallen over.

Hall Sensor

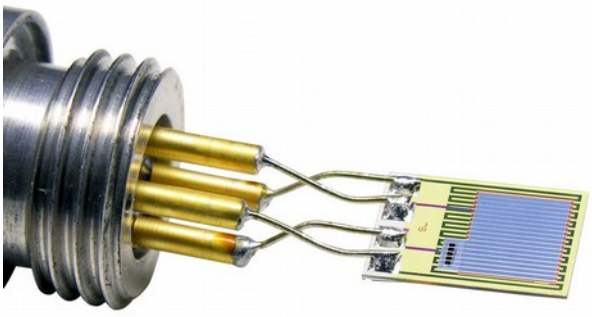
UNIVERSITY OF OREGON

NSRC

Measures magnetic field

Detect distance from a target

Humidity Sensor



UNIVERSITY OF OREGON

NSRC

Measures the relative humidity of the air.

Infrared Reflection

UNIVERSITY OF OREGON

NSRC

This sensor generates infrared light and measures its reflected strength. One of its applications is to determine distance. Infrared reflection sensing is also used to help robots follow lines, and in optical dust sensors.

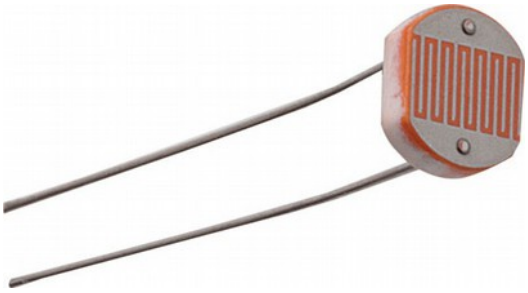
Infrared Sensor: Passive

UNIVERSITY OF OREGON

NSRC

A passive infrared sensor allows non-contact sensing of temperature. Point it at an object and you can take its temperature. When configured appropriately, it can be used as a motion sensor.

Light Sensor



UNIVERSITY OF OREGON

NSRC

A light sensor, or a light dependent resistor, is a very inexpensive but relatively inaccurate device that will tell you if it’s light or dark.

Load Sensor

UNIVERSITY OF OREGON

NSRC

A load sensor, or load cell, converts force into electrical output. This one is good for measuring weights up to 50 kilograms, but all sizes are available.

Loudness Sensor

UNIVERSITY OF OREGON

NSRC

A loudness sensor uses a microphone, an amplifier, and filters to output a digital signal that can be translated into a measurement of the decibel level of sound.

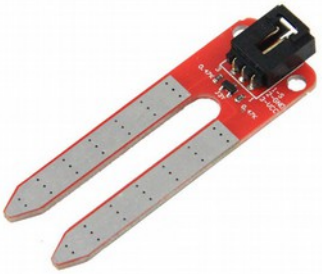
Microphone

UNIVERSITY OF OREGON

NSRC

While Internet of Things microprocessors aren't typically fast enough to process audio from a microphone, other small platforms like Raspberry Pi are, and can analyse sound from a microphone in real time.

Moisture Sensor

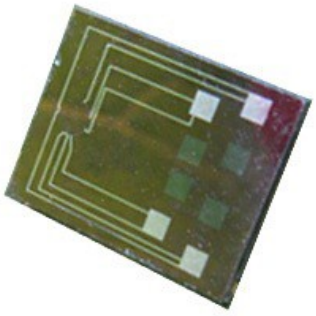


UNIVERSITY OF OREGON

NSRC

Moisture sensors measure the dielectric constant of soil, or its ability to transmit electricity, and derive an amount of moisture in a particular volume of soil. They can range from inexpensive and inaccurate for a cheap sensor stuck in a pot plant, to expensive and very accurate when properly installed and calibrated to the type of soil they're embedded in.

Moisture Sensor Chip (Cornell)



UNIVERSITY OF OREGON

NSRC

The moisture chip from Cornell, reported just in the last few months, promises to change soil moisture sensing for the better. Instead of measuring electrical conductivity, it measures the pressure on a semi-permeable membrane. It’s so small it can in inserted into the stem of a plant, and is expected to be far more accurate and far less expensive than traditional sensors.

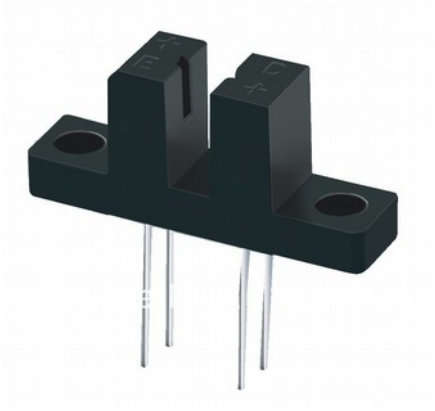
Optical Dust Sensor

UNIVERSITY OF OREGON

NSRC

An infrared transmitter and receiver that measures reflections from dust and particulate matter in the air inside a small chamber.

Photo Interruptor

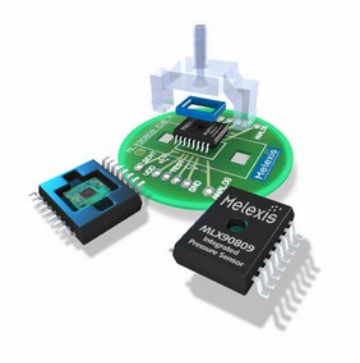


UNIVERSITY OF OREGON

NSRC

A photo interruptor has a light emitter and a light receiver in-line When something comes between them, a pulse is generated. It can be used to count things or switch things.

Pressure Sensor (MEMS)



Micro Electrical Mechanical Pressure Sensor - a little machine made of silicon for very precisely measuring pressure.

Real Time Clock

A real-time clock is an accurate clock that's not a part of the main system of a computer, but operates on its own, and has its own power supply. Some chips have programmable functionality, allowing you to not just keep time but turn things on and off per a calendar or schedule.

Reed Switch

UNIVERSITY OF OREGON

NSRC

A Reed switch is a glass tube with two wires. A magnet will bring the wires together, causing the circuit to be connected. Some applications that use Hall effect to count revolutions of a wheel could use a Reed switch instead.

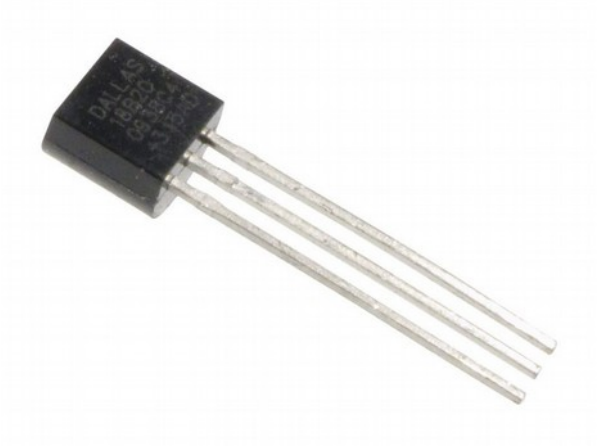
Solar Radiation Sensor

UNIVERSITY OF OREGON

NSRC

More than just a light dependent resistor, a solar radiation sensor provides intensity as a digital output. It can be used in agriculture to record the amount of sunlight that crops have had, or in solar power applications to check the efficiency of installed solar systems.

Temperature Sensor



UNIVERSITY OF OREGON

NSRC

Temperature sensors range in cost an accuracy, but are almost always inexpensive and easy to use. They’re so inexpensive, they are often integrated into other sensors and circuit boards. This model uses a 1-wire communications bus, with each device having a 64-bit serial number. Many sensors can be chained together to produce high resolution data.

Thermistor

UNIVERSITY OF OREGON

NSRC

The thermistor varies resistance depending on its temperature.

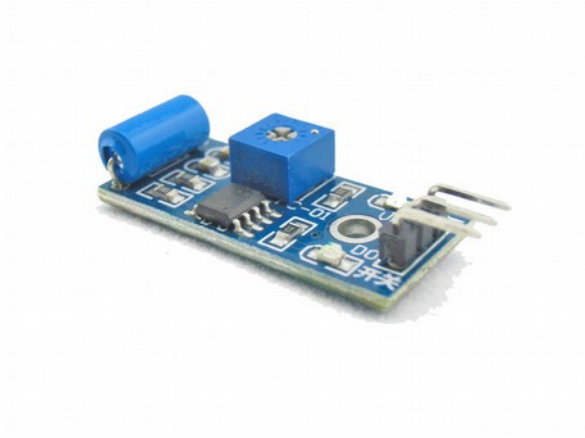
Touch Sensor: Capacitive

UNIVERSITY OF OREGON

NSRC

Capacitive Touch Sensors detect when they are touched by a conductive surface, such as a finger.

Vibration Sensor



UNIVERSITY OF OREGON

NSRC

Some vibration sensors are based on piezoelectric devices, and generate voltage in response to being vibrated. Any movement can activate a sensor, the signal from which could be used to wake up a microprocessor and other sensors or actuators.

Ultrasonic Range Finder

UNIVERSITY OF OREGON

NSRC

Ultrasonic Range Finders are used to measure distance. An ultrasonic ping is sent from the device, which then listens for the ping to come back, and uses the delay between sending and receiving to calculate the distance of an object. The company I'm working for now is using these ultrasonic sensors to measure the amount of water in water tanks.

Ultraviolet Radiation Sensor

UNIVERSITY OF OREGON

NSRC

Tracking ultraviolet radiation can be useful in evaluating inputs in agriculture. Ten years ago in New Zealand is was important to track UV for skin safety reasons - because of a hole in the ozone layers we had very high uv radiation and it was very easy to get a sunburn because of it.