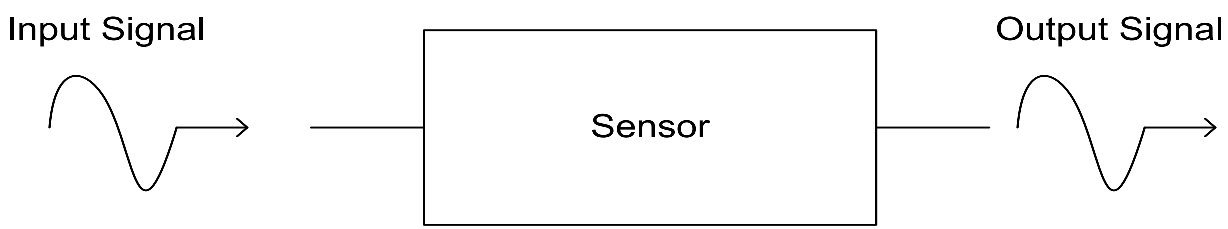
Sensors & Interfaces

IT3779 Smart Object Technologies

Sensors

- What are Sensors?
  - A device which provides a usable output in response to a specified measurand



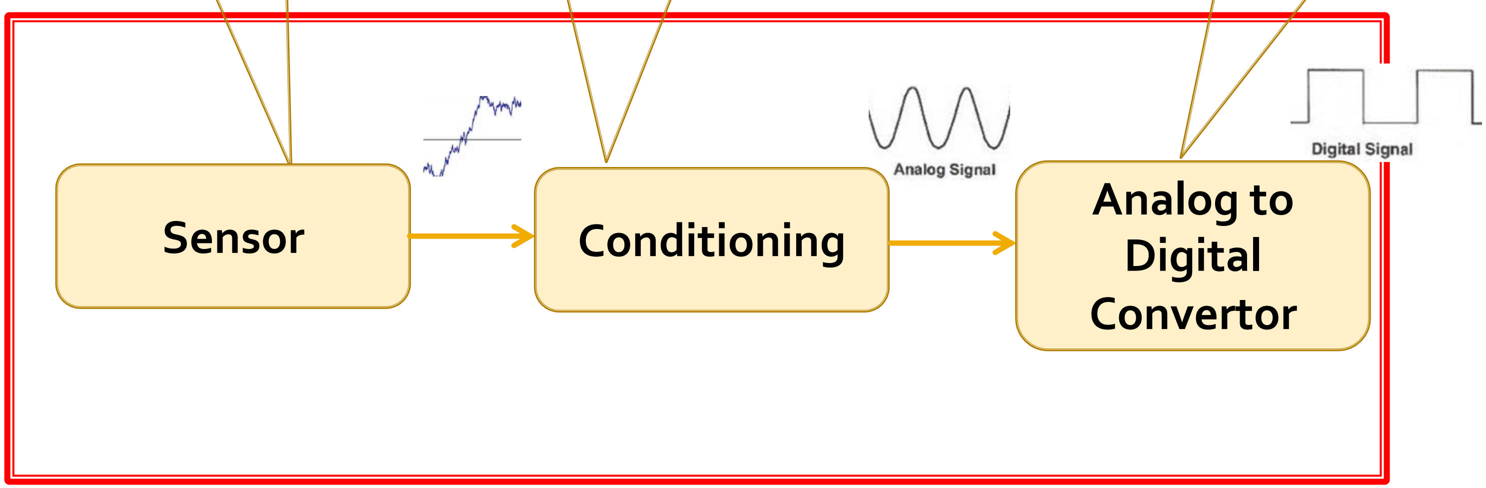
  - A sensor acquires a **physical parameter** (e.g. temperature) and converts it into a signal suitable for processing (e.g. optical, electrical, mechanical)

Sensing subsystem

Sensors gather info about physical objects or areas

Conditioning prepare captured signals for further use e.g. amplification, filtering of unwanted frequencies etc.

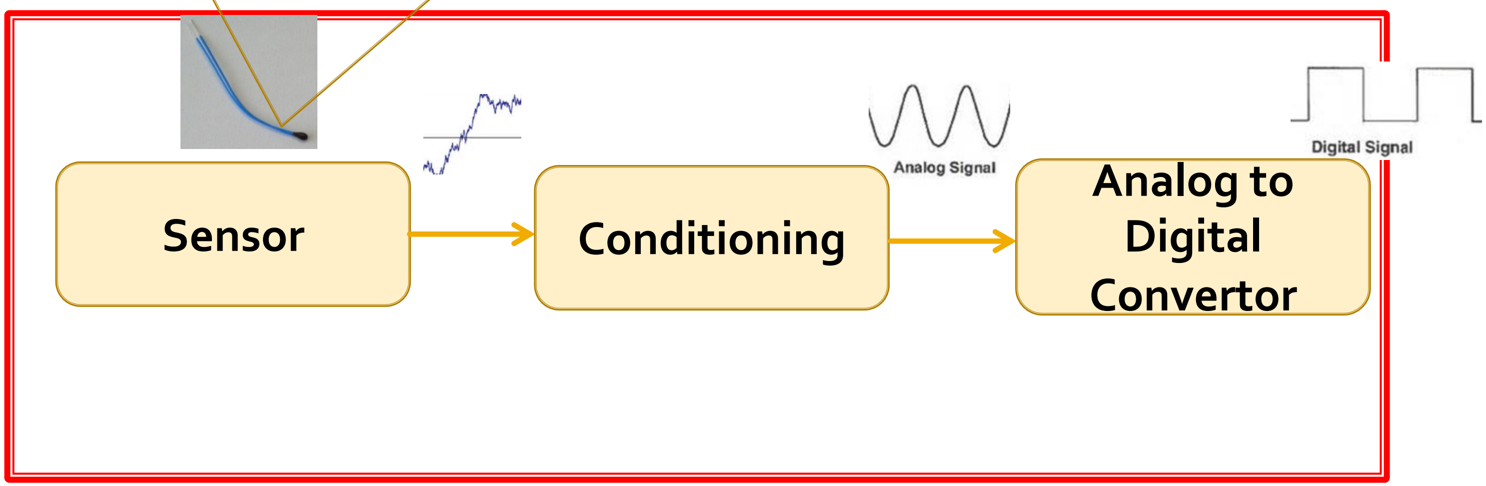
Analog to digital conversion translates analog signal into digital signal which is read by the controller



Sensing Subsystem

Case Study : Reading Temperature

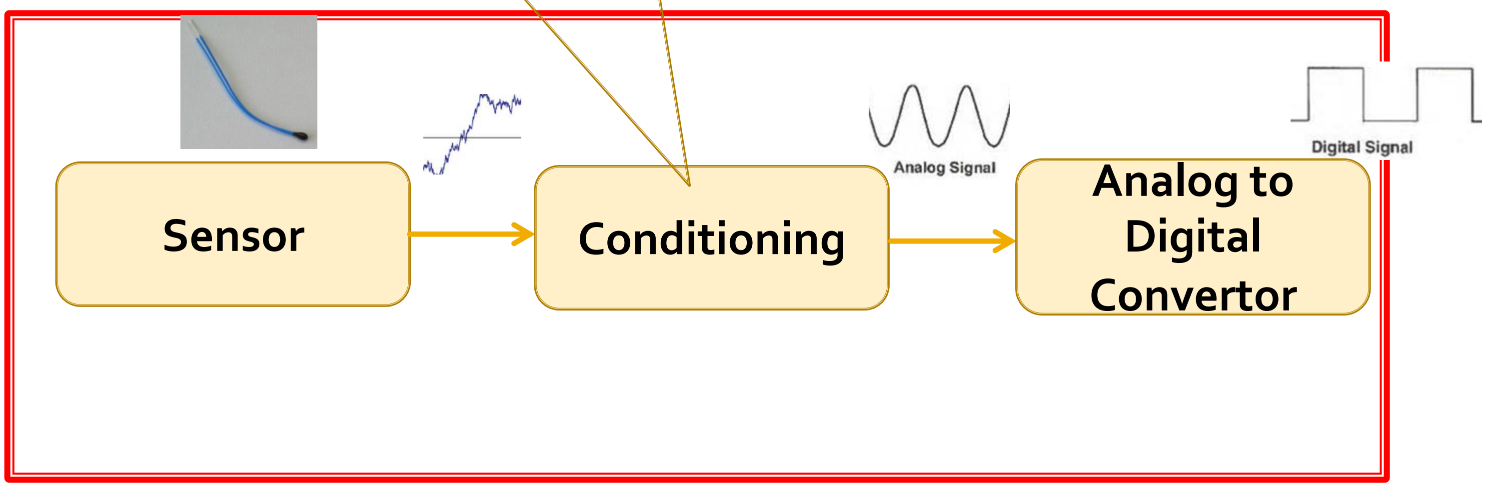
- A thermistor is used to measure temperature
- It is a resistor whose resistance varies significantly with temperature.
- Convert physical quantity (**Temperature**) to analog form (**Voltage**) using circuit



Sensing Subsystem

Case Study : Reading Temperature

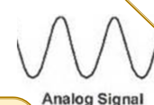
Conditioning hardware prepare captured signals for further use e.g. amplification, filtering of unwanted frequencies etc.

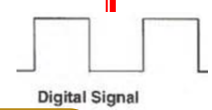


Sensing Subsystem

Case Study : Reading Temperature

Analog to digital conversion translates analog signal into digital data (1's and 0's) through ADC Convertor
Data usually stored as integer



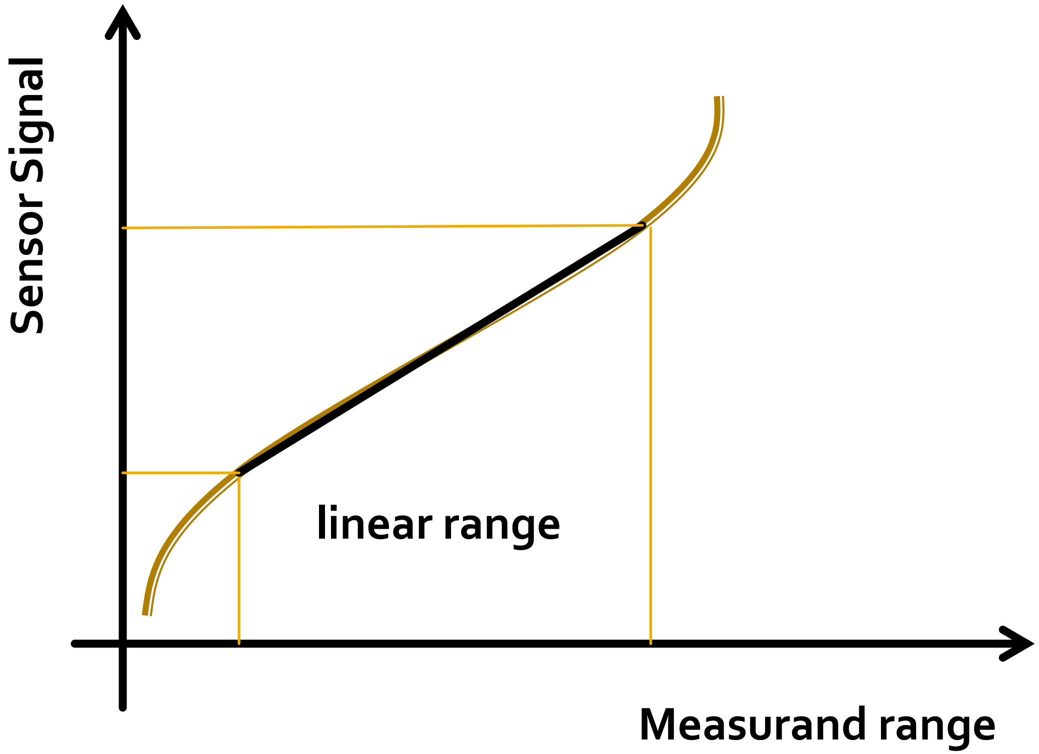


Sensor → Conditioning → Analog to Digital Convertor

Sensing Subsystem

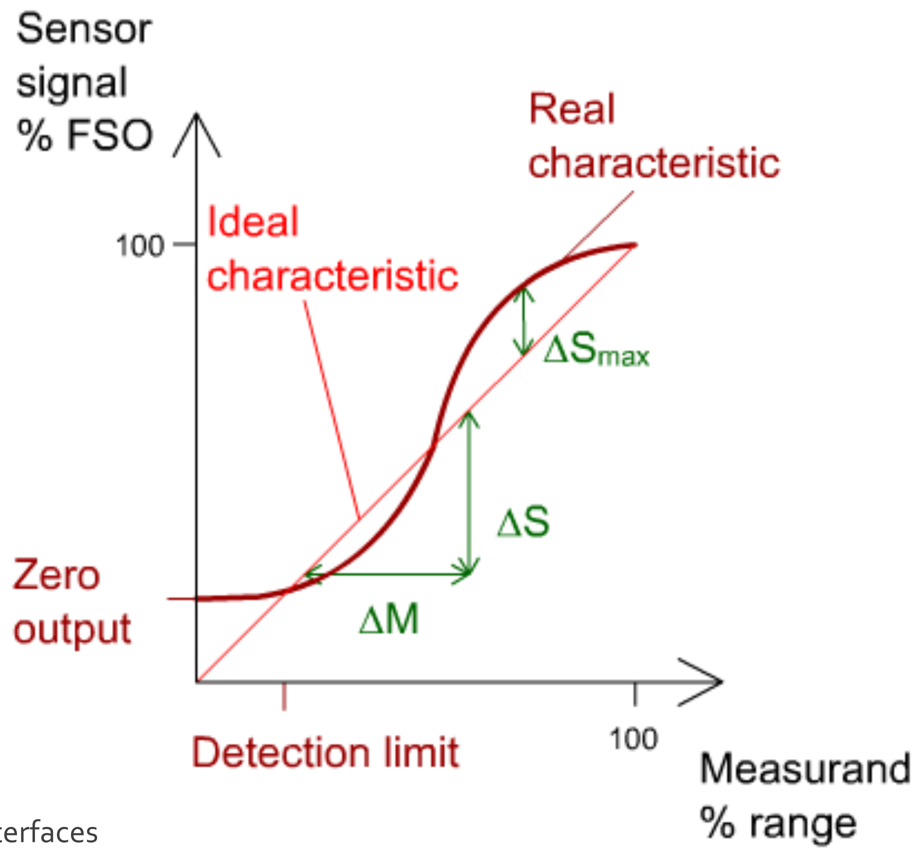
Sensor Characteristics

- Ideal sensor characteristics is linear



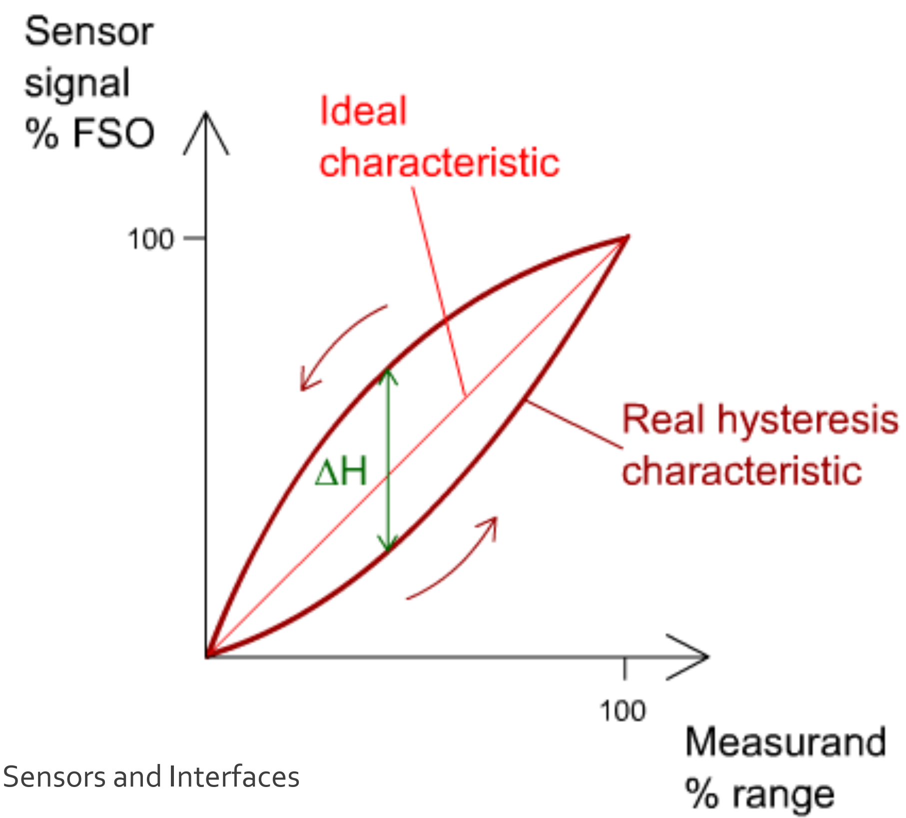
Sensor Characteristics

- Static sensor characteristics
- Sensor signal is equivalent to the measurand value



Sensor Characteristics

- Hysteresis is characteristics of sensor
- Sensor signal correspond to **different** values.



Properties of Good Sensors

- Good linearity
- Small hysteresis
- Low temperature drift
  - Characteristics changes with temperature
- Low interference effects e.g. electromagnetic interference
- Long term stability and reliability

Sensors Classification

- Sensors can be classified according to the measured quantity
  - Mechanical quantities : Position, displacement, force, acceleration, pressure, flow rate, etc.
  - Electrostatic & Magnetic: Magnetic field, magnetic flux, current, voltage, electric field, etc.
  - Thermal quantities : Temperature, heat flow, etc.
  - Chemical quantities : Concentration of humidity, gas components, etc.
  - Biological quantities : Concentration of enzyme substrates, antigens, antibodies, etc.

Sensor: Mechanical Quantity

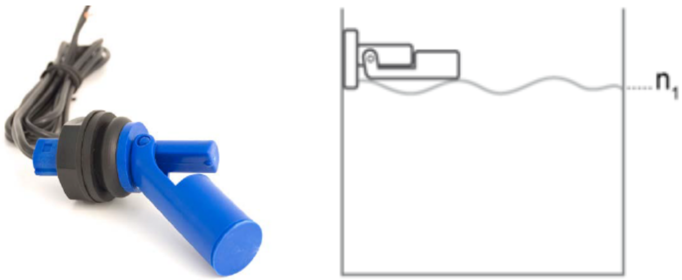
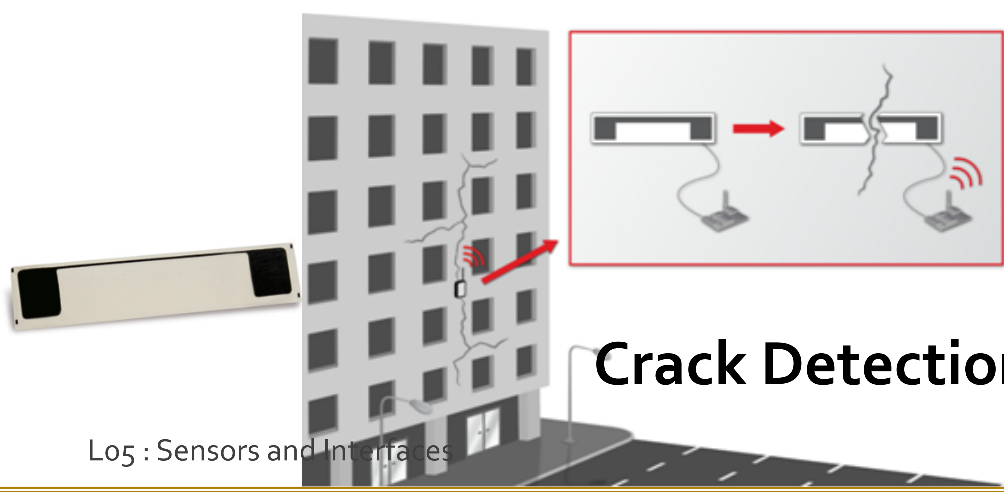


Figure 18: Image of the PTFA3415 sensor

Water level Sensor

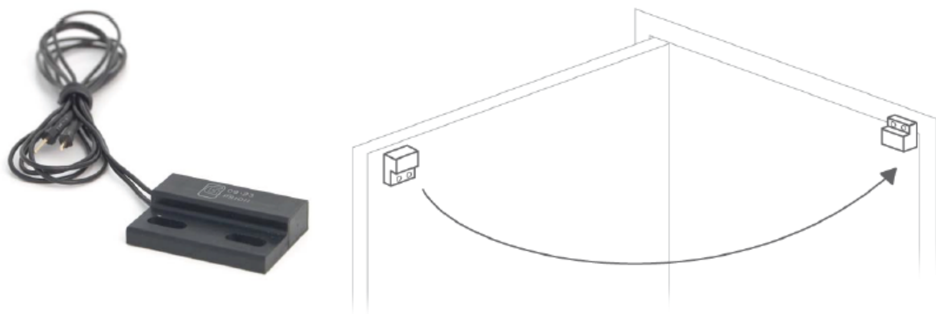
Figure 8: Image of the PZ-

Vibration Sensor

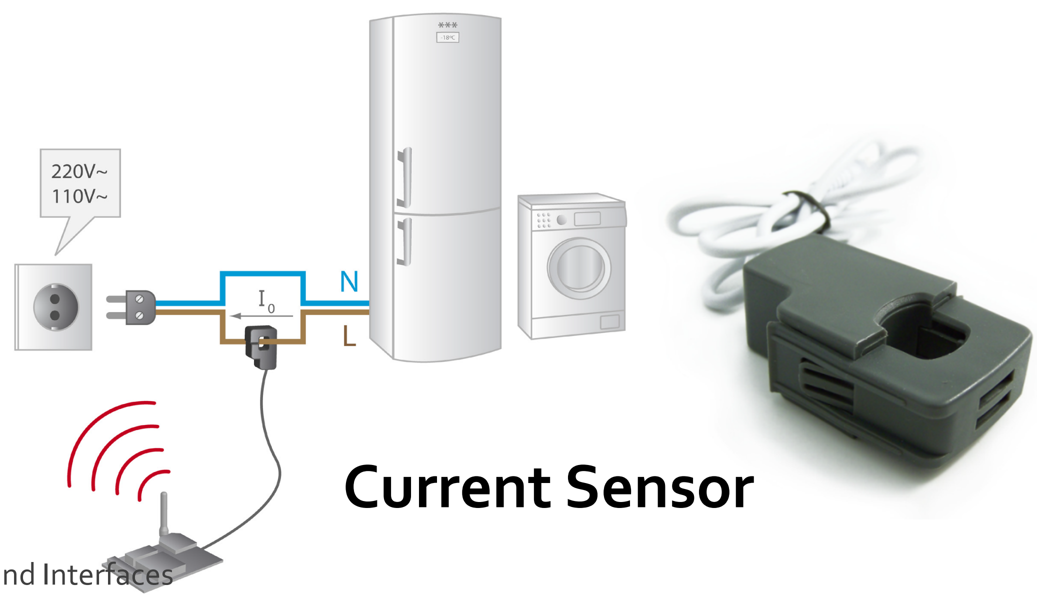


Crack Detection Sensor

Sensor: Electrostatic & Magnetic

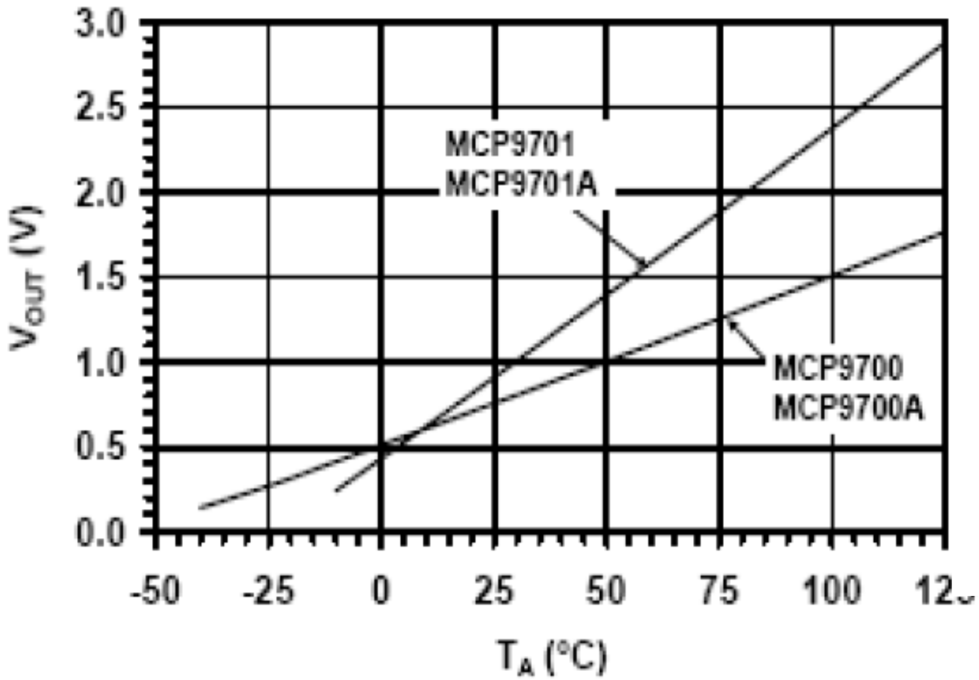


Hall Effect Sensor



Current Sensor

Sensor: Thermal Quantity

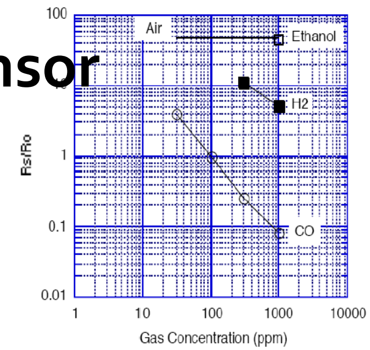


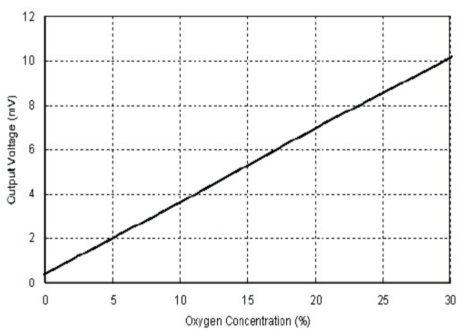
Temperature Sensor

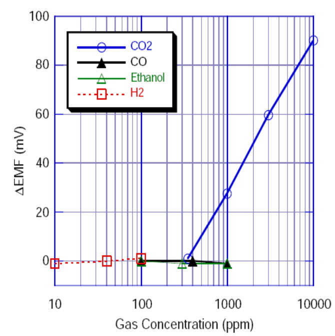
Sensor: Chemical Quantity

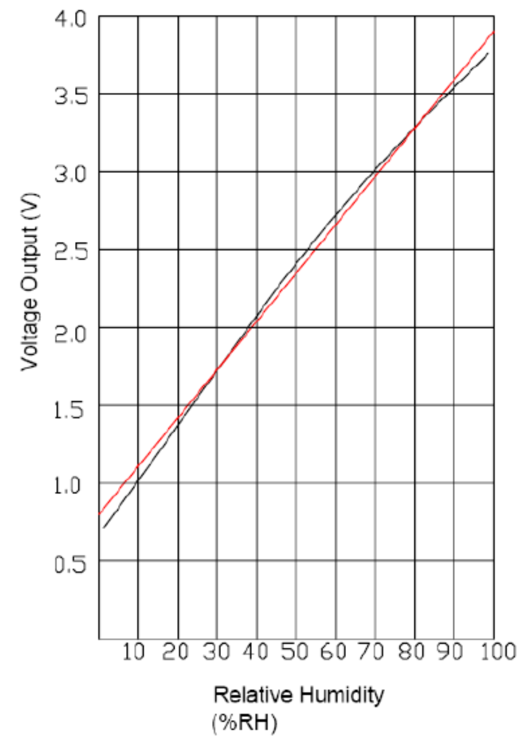
Typical Gas Sensor

Figure 10: Image of the TGS2442 sensor



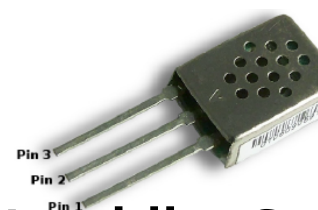






Temperature:25℃

Power Supply:5.00V DC



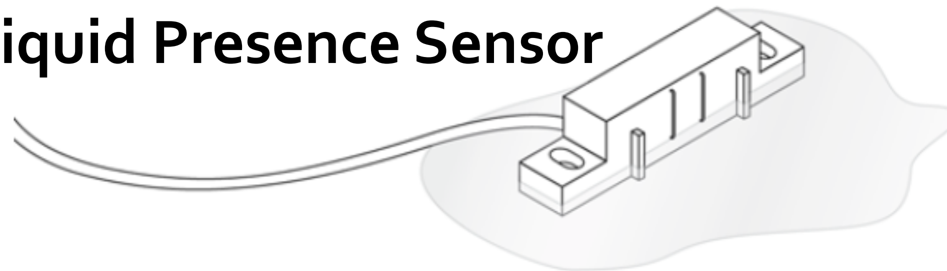
Humidity Sensor

Figure 2: Image of the 808H5V5 sensor

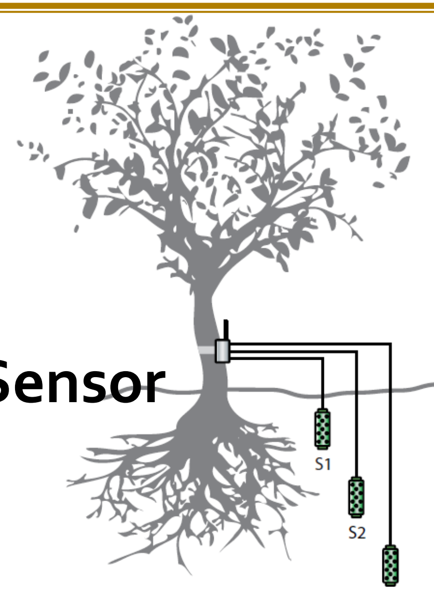
Sensor: Chemical Quantity

Figure 26: Image of the Liquid Presence sensor

Liquid Presence Sensor



Soil Wetness Sensor



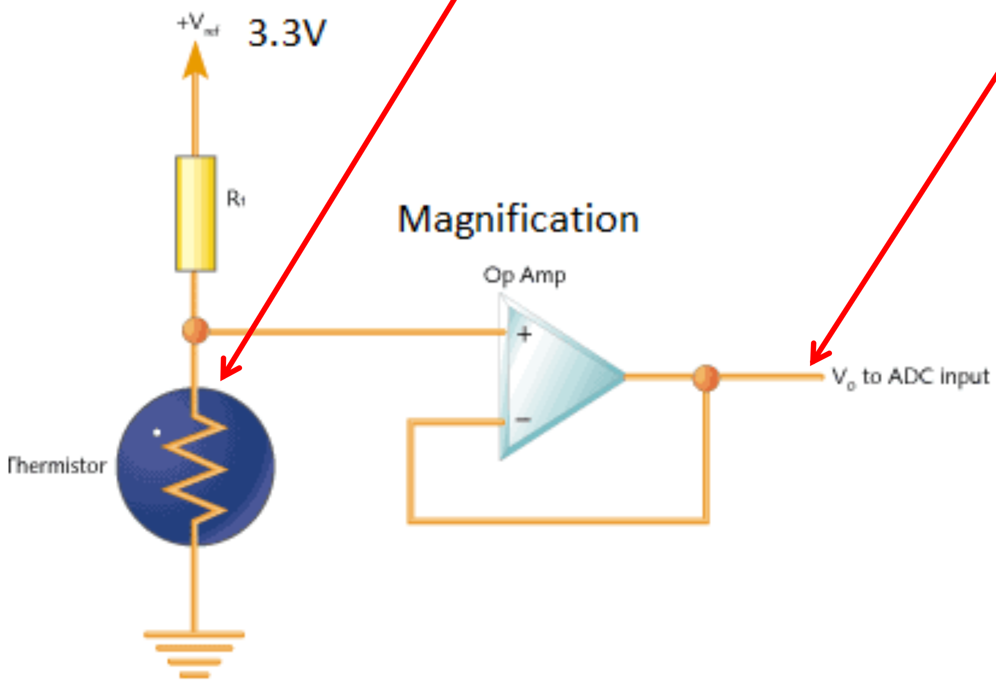
Example : MeasuringTemperature

- STEP 1 : Measure environment temperature
  - Select appropriate sensor.
  - Thermister: a type of resistor whose resistance varies significantly with temperature.
  - Infrared: Reflection of infrared signal from body.

Thermistor

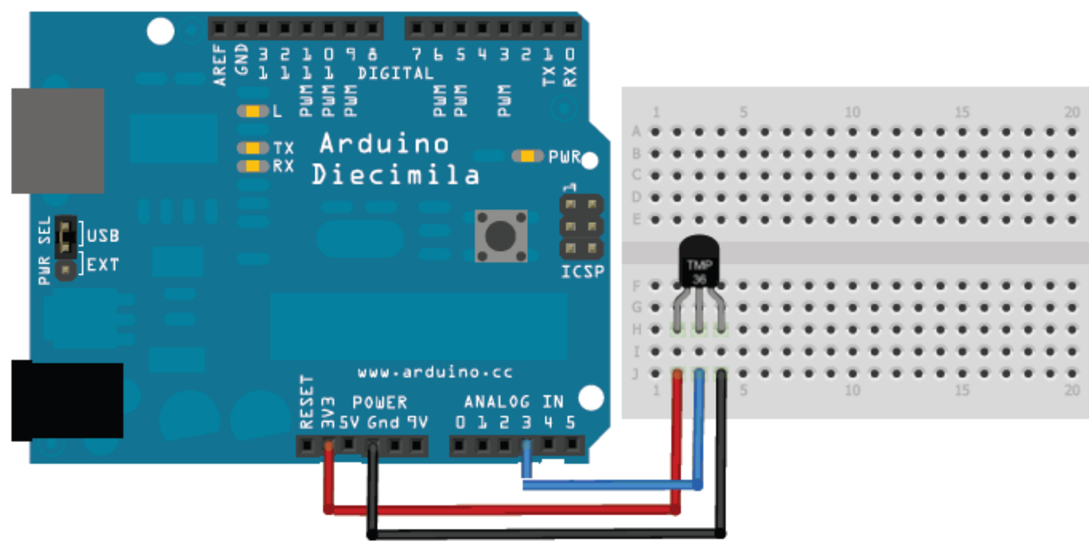
Example : MeasuringTemperature

- STEP 2: Convert resistive value to analog voltage



Example : Measuring Temperature

- **STEP 3:** Measure and convert Voltage to digital data using Analog to Digital Conversion (ADC)
  - 10 bits ADC calibrated to be as follows.
    - 0 V => 0
    - 3.3 V => 1023



Example : MeasuringTemperature

- **STEP 4:** Software to determine the voltage (digital representation) based on ADC digital value
- Software to based on the voltage digital representation to determine the temperature in ^{0}C based on the graph (provided by thermistor supplier)

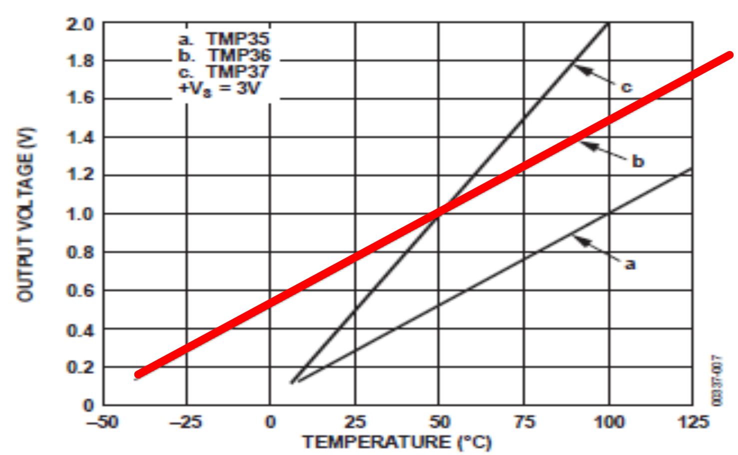
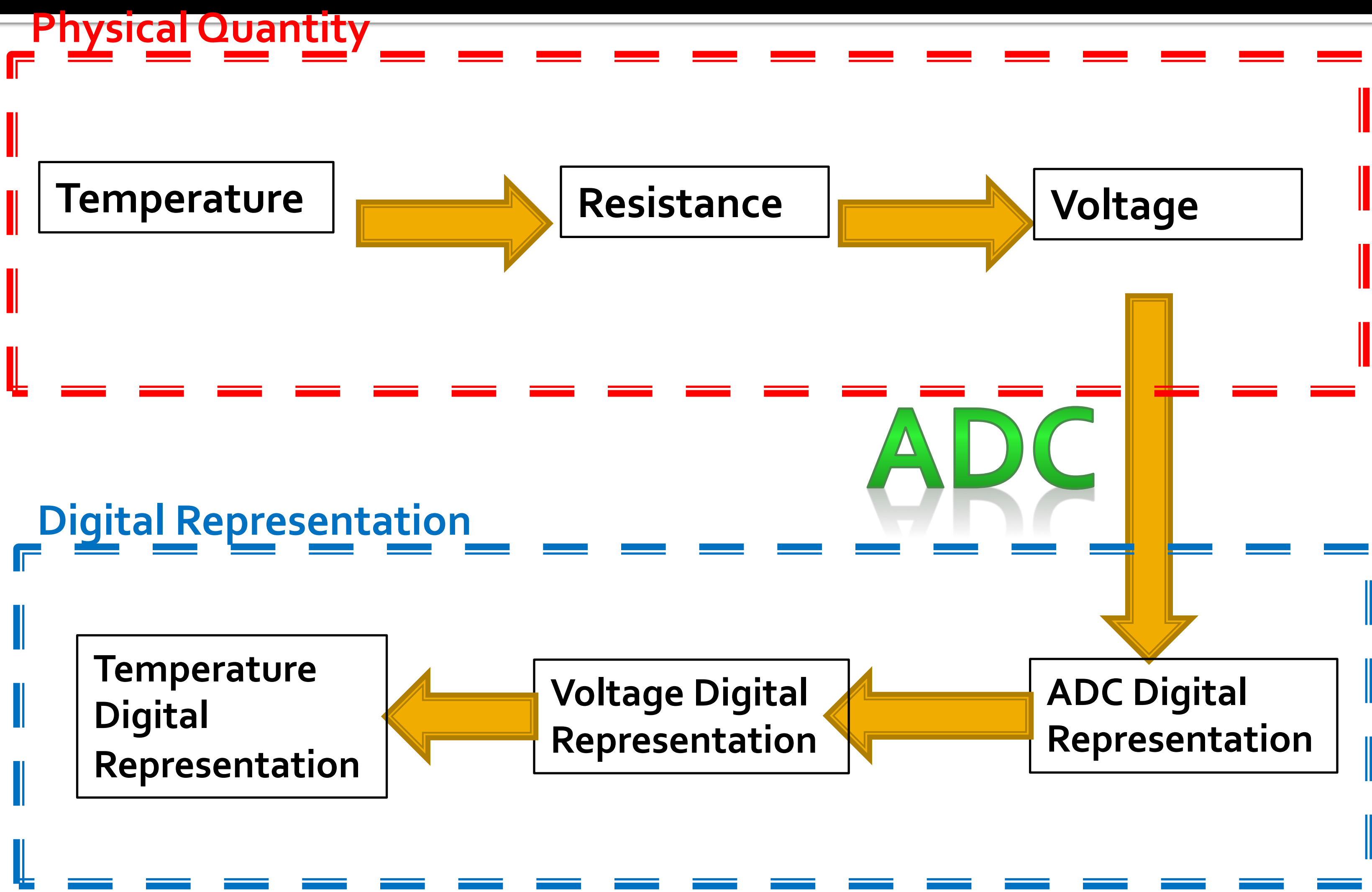


Figure 6. Output Voltage vs. Temperature

Summary: MeasuringTemperature



Case Study : Ten Foot Container Security

- International logistics operations involving cargo freight move upwards of 5 or 6 million containers every day.
- According to *Bruce Simpson, from the European Parliament Committee on Transport and Tourism*, 10,000 containers are lost at sea each year, with 2,000 containers lost in European waters alone.
- Containers are sometimes opened without authorisation and goods stolen.

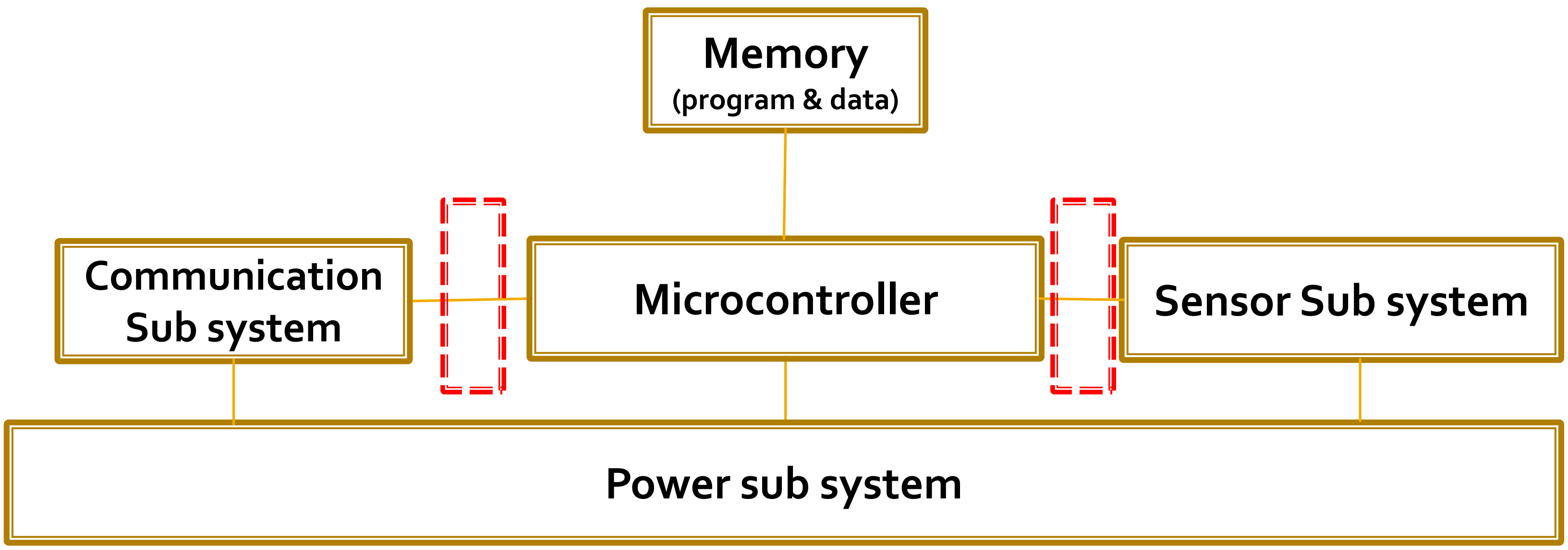
What sensors would you recommend to solve these problems : TFU loss & Unauthorised opening of TFU?

Case Study : Precision Farming

- Soil moisture monitoring is critical when attempting to increase wine grape quality or save water. It is essential for application of regulated deficit irrigation or partial root zone drying.
- **Soil water content** is a measure of the amount of water in the soil. Changes in soil water content help estimate the volume of water taken up by the vines and the amount of irrigation to apply.

What sensors would you recommend to monitor the content of water in soil?

Communication Interfaces



Communication Interfaces

- *Fast* and *energy efficient* data transfer between the subsystems of a smart object node is vital.
- Communication via a parallel bus is *faster* than a serial transmission
  - Parallel bus requires more space,
  - Parallel bus requires more electronic component
  - Parallel bus requires bigger power supply.

Serial Communication Interfaces

- The choice is often between *serial interfaces* :
  - Serial Peripheral Interface (SPI)
  - General Purpose Input/Output (GPIO)
  - Secure Data Input/Output (SDIO)
  - Inter-Integrated Circuit (I^2C)

- Among these, the most commonly used buses are *SPI* and *I^2C*

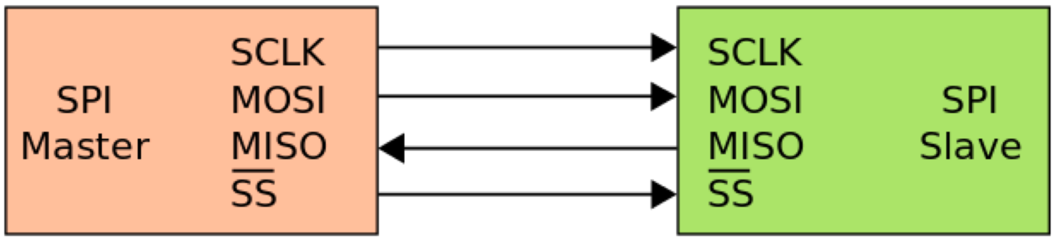
Serial Communication Interfaces

- Serial Peripheral Interface
  - *High-speed*, *full-duplex*, *synchronous* serial bus
  - Does *not* have an official standard

- Inter-Integrated Circuit (I^2C)
  - Every device type that uses I^2C must have a unique address that will be used to communicate with a device.
  - I^2C uses 10 bit addressing, supporting 2^{10} devices.
  - I^2C is a multi-master, half-duplex synchronous serial bus.

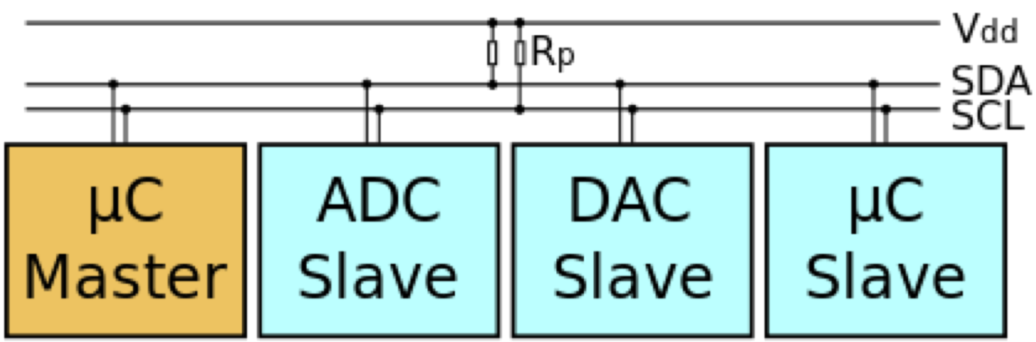
SPI vs I²C

SPI



SCLK - Serial Clock
MOSI - Master Output Slave Input
MISO - Master Input Slave Output
SS - Slave Select

I²C



SDA - Serial Data Line
SCL - Serial Clock Line

SPI vs I²C

SPI	I²C
4 lines enable full-duplex transmission	2 lines reduce space and simplify circuit layout; Lowers costs
No addressing is required due to CS	Addressing enables multi-master mode; Arbitration is required
Allowing only one master avoids conflicts	Multi-master mode is prone to conflicts
Hardware requirement support increases with an increasing number of connected devices -- costly	Hardware requirement is independent of the number of devices using the bus
The master's clock is configured according to the slave's speed but speed adaptation slows down the master.	Slower devices may stretch the clock -- latency but keeping other devices waiting
The absence of an official standard leads to application specific implementations	Official standard eases integration of devices since developers can rely on a certain implementation

Communication Interfaces - Summary

- Buses are essential highways to transfer data within a Smart Object
- Due to concerns about size, only serial buses are used.
- Serial buses demand high clock speeds to gain the same throughput as parallel buses
  - serial buses can also be bottlenecks
  - may not scale well with processor speed (e.g., I2C)

End