IN 221 (AUG) 3:0
Sensors and Transducers

Department of Instrumentation and Applied Physics (IAP)
and
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Bangalore 560012

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Welcome!

Course

IN 221 (AUG) 3:0
Sensors and Transducers

Introductory course on sensors and transducers

Class Hours

MWF 12:00 to 13:00
Lecture Hall 1, IAP

Instructors and Topics

- **Manish Arora**: Industrial applications of sensors and transducers, Ultrasonic sensors and transducers, Mechatronics
- **Asha Bhardwaj**: Microfabrication, Making micro and nano scale sensors and transducers
- **Chandni Usha**: Semiconductor sensors and transducers
- **Baladitya Suri**: SAW devices, signal processing and noise
- **Sai Siva Gorthi**: Optical characterization, sensing, measurement
- **G. R. Jayanth**: MEMS sensors and transducers, Scaling laws for miniaturization
- **Atanu Mohanty**: Electromagnetic sensors and transducers

What is a sensor?

- Device that can be used to detect or measure a given physical quantity.
- Almost always used with other electronics.

Examples of sensors

- Microphone
- Photodiode, LDR (Light Dependent Resistor)
- CCD array (imaging element in digital camera)
- Thermocouple, thermistor
- Search coil, Hall sensor
- Antenna
- Piezoelectric sensors
- Chemical and gas sensors

What is a transducer?

- Device that converts one form of energy to another.
- Usually the input is an electrical signal and the output is some other physical quantity.
- Actuator: Transducer whose output is mechanical motion.

Examples of transducers

- Loudspeaker
- LED (Light Emitting Diode)
- Heater
- Coil
- Antenna
- Motors of various kinds
- Piezoelectric actuators

Examples

Example 1: Smartphone

- Transducers: Speaker, display, buzzer motor
- Sensors: Microphone, camera, accelerometer

Example 2: Making Plastic Sheets from Molten Plastic

- Transducers: Motor, heater
- Sensors for sensing thickness, temperature, and chemicals

Example 3: Generic Closed Loop Control System

- The *plant* will have *transducers*.
- The *feedback* signals will come from *sensors*.

Functional view

- Sensor
  Physical quantity $\rightarrow$ Electrical signal
- Transducer
  Electrical signal $\rightarrow$ Physical quantity

Points to note

- Many applications: Industry, Household appliances, Agriculture, Traffic management, Security, Weather monitoring, Scientific research
- The same device can be used as a sensor or as a transducer.
  - Piezoelectric device
  - Antenna
  - Loudspeaker
- Response is not always linear, not even continuous.
- There are many different kinds sensors and transducers.
- Based on a very wide range of working principles

Types of Sensors

Packaged vs. Constructed

- Many types of sensors are available in packaged form.
- Still, in industrial work, engineers sometimes make their own sensors.

Types of Output

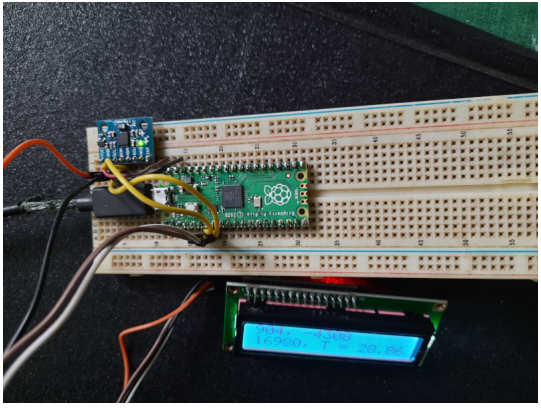
- Analogue output
  - Voltage proportional to the quantity
  - PWM (Pulse Width Modulation): Pulse width proportional to the quantity
  - Note: PWM is still considered analogue and NOT digital.
- Digital output
  - Parallel output
  - Serial output: One of several protocols
    - I^2C
    - SPI
    - ...

Two Examples of Sensor Modules

1. Accelerometer MPU6050
2. Pressure and temperature sensor BMP280

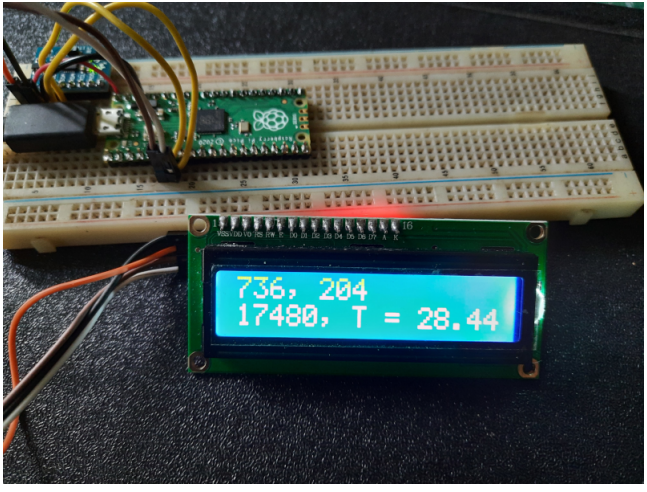
Other examples of readily available sensor and actuator modules will be discussed in the future.

Example 1: Accelerometer MPU6050



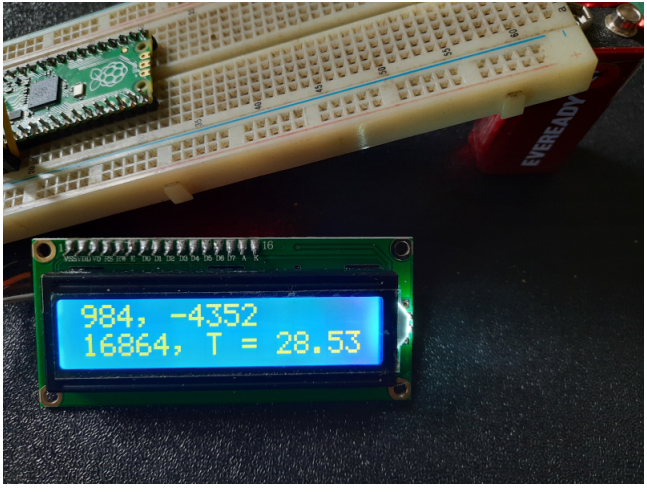
Small board: 16 mm $\times$ 20 mm, MPU6050 Accelerometer module ($\approx$ Rs. 115)
Big board: 22 mm $\times$ 53 mm, Raspberry Pi Pico
Powered from the USB Port

Example 1: Accelerometer MPU6050



First line: x and y components of acceleration in device units
Second line: z component of acceleration in device units, temperature
Horizontal Board: a_z: 17480 device units

Example 1: Accelerometer MPU6050



First line: x and y components of acceleration in device units
Second line: z component of acceleration in device units, temperature
Tilted Board: a_z: 16864 device units

Example 1: Calculations

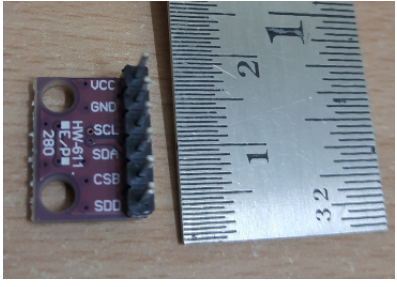
Length of breadboard: 16.5 cm
Height of battery: 4.3 cm

```
akm@akm:~/pico/pico-examples/i2c/lcd_1602_i2c$ lua
Lua 5.3.3  Copyright (C) 1994-2016 Lua.org, PUC-Rio
> math.deg(math.acos(16864/17480))
15.256010576751
> math.deg(math.asin(4.3/16.5))
15.106026666421
>
```

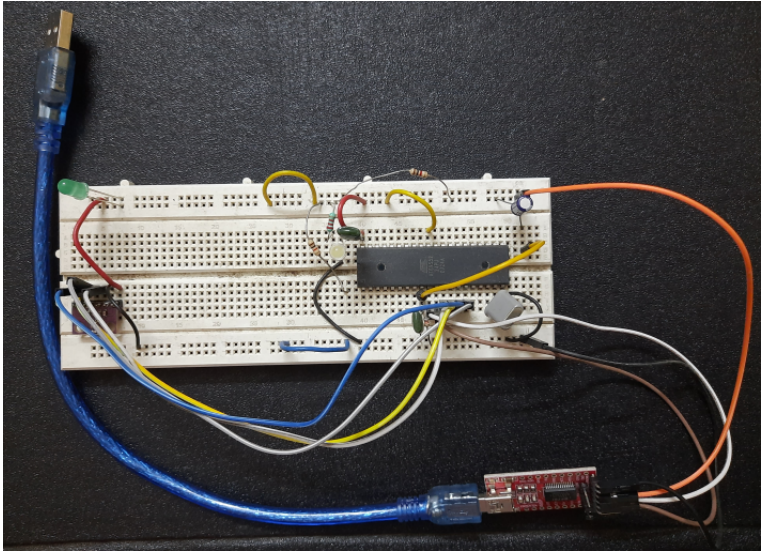
Tilt angle: $\approx$ 15 degrees

Example 2: BMP280

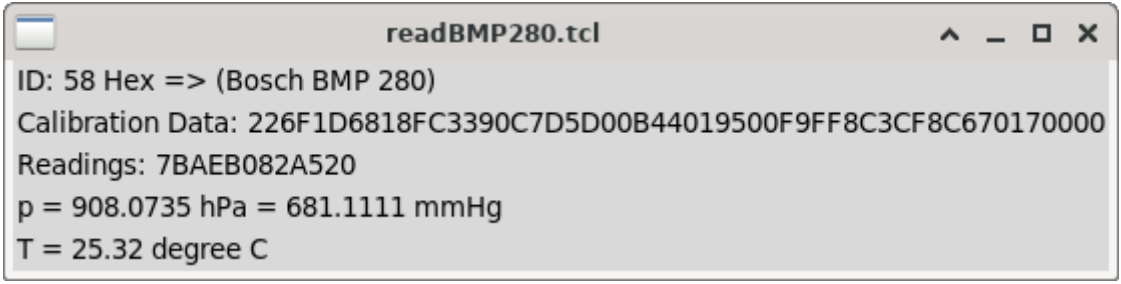
- Pressure and Temperature
- Inexpensive: $\approx$ Rs. 70
- Supports both SPI and $\mathrm{I^2C}$
- Another sensor BME280 can also measure humidity.



Example 2: System with BMP280



Example 2: BMP280 Output



Questions to ask about any sensor or transducer

- How does this sensor or transducer work?
- How is it fabricated?
- What kind of electronics is used in this sensor or transducer?
- How can we get readings from this sensor?
- How can we drive this transducer?
- What are its applications?
- How much does it cost?

Evaluation

- 7 instructors
- $\approx$ 6 lectures each
- $\approx$ 14 marks per instructor
  - Homework assignment
  - Examination in class
  - Take-home examination
- IISc Rules
  - Sessional: 50 marks
  - Final: 50 marks
- Attendance is important.
  - Low attendance $\Rightarrow$ INCOMPLETE grade
  - Penalties specific to this course