

EBU5375 Signals and systems: Applications in IoT Engineering

Dr Jesús Requena Carrión



Agenda

Quick review

A functional model of IoT device

Why is Signals & Systems important for IoT engineering?

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Why is Signals & Systems important for IoT engineering?

What does a typical IoT job look like?

IoT engineers spend most of their time...

- (a) Writing software.
- (b) Developing hardware.
- (c) Doing maths.

IoT Engineering: Technologies

Which, in your opinion, is the most important technology in IoT Engineering?

- (a) Cloud computing.
- (b) Hardware design.
- (c) Data Science.

IoT Engineering: Technologies

As an IoT student, which technology interests you the most?

- (a) Cloud computing.
- (b) Hardware design.
- (c) Data Science.

What are we learning this week?

1. **Applications of Signals and Systems to IoT Engineering: Overview.**
2. Sampling Theory and Interpolation.
3. Applications of Signal Theory to Telecommunication Systems.

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Why is Signals & Systems important for IoT engineering?

Internet of Things: Overview

According to wikipedia (Dec 2016), the Internet of Things (IoT)...

*... is the network of **physical objects** or things embedded with **electronics, software, sensors, and network connectivity**, which enables these objects to collect and exchange data.*

Hence, IoT devices consist of **hardware** and **software** components and at least must implement **sensing/actuating** and **communications** functionalities.

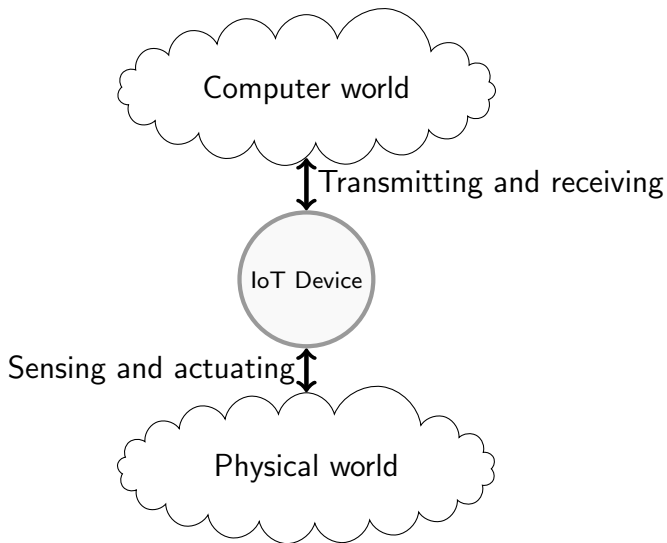
Internet of Things: Overview

Also according to wikipedia (Dec 2016), the Internet of Things (IoT)...

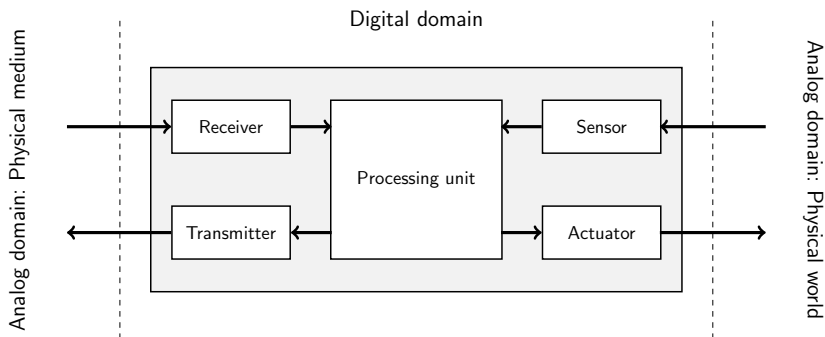
*... [create] opportunities for more direct integration between the **physical world** and **computer-based systems**.*

In other words, IoT devices connect the **physical world** with the **computer world**, moving **information** from one world to the other.

IoT devices



A basic functional model of IoT device



IoT devices must be able to interact with the physical world (sensing and actuating) and with the computer world (transmitting and receiving) via analogue interfaces.

The question arises, **why do IoT devices use digital technology?**

Dealing with varied information sources

Digital
Sources

Text

Analog
Sources

Image

Voltage

Temperature

Voice

Digitisation

Chemical

Digital
Processing

Digital
Transmission

Signal transmission: Amplification vs regeneration

When a signal travels through a channel, it suffers:

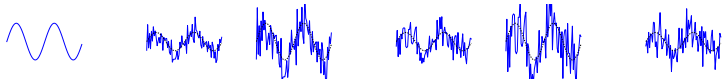
- **Attenuation.**
- **Distortion.**
- **Noise contamination.**

Special equipment called **repeaters** are inserted along the way to compensate these effects.

- In analog systems continuously-varying waveforms are transmitted. In order to preserve the transmitted waveforms, repeaters essentially **filter**, **equalise** and **amplify** the signal.
- In digital systems sequences predefined waveforms (symbols) are transmitted. In this case, repeaters **regenerate** such waveforms.

Signal transmission: Amplification vs regeneration

Analog Approach:
Amplification



Digital Approach:
Regeneration



Signal processing

Signal processing consists of operating with signals, i.e. perform mathematical operations on them. Examples of such mathematical operations are:

- Addition of two signals.
- Linear filtering.
- Modulation.

In order to apply signal processing techniques, it is necessary to **design a system** that implement the corresponding mathematical operations.

Signal processing

How do we implement a system for signal processing?

- Signals from the **analog world** are continuous-time signals and the systems that process them are **analog electronic circuits** (capacitors, resistances, etc).
- Signals from the **digital world** are discrete-time and the systems that process them are **digital electronic circuits** (such as microprocessors).

Digital systems offer many advantages over analog ones and hence, IoT devices internally represent the information in digital format, irrespective of the information source.

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Quick review

A functional model of IoT device

Why is Signals & Systems important for IoT engineering?

The BIG question: What is information?

IoT devices allow us to **move information** between the physical world and the computer world. But,

- What is information?
- How do we quantify information?
- How do we extract and represent information?
- How do we protect information?

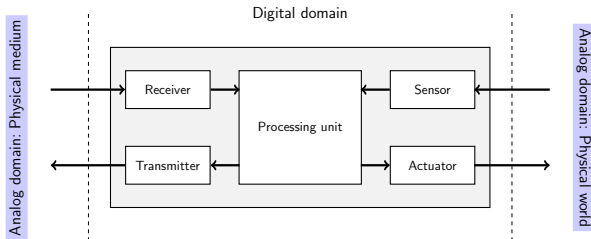
Signals are the entities that carry information. Therefore, **understanding the basics of Signals and Systems is the first step towards understanding information!**

In future courses, you will learn about Information Theory.

The physical world

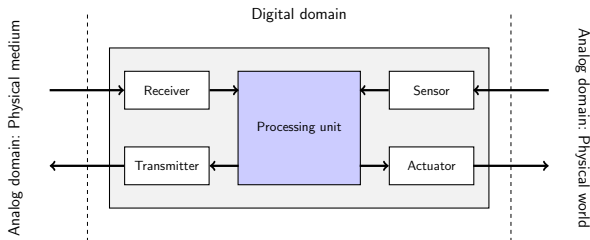
The nature of the physical world is analog and hence information is carried by **continuous-time signals**. Signals and Systems allows us to understand how to

- Extract information from signals from the physical world.
- Use signals to transmit and receive information through a physical medium.



IoT devices: Signal processing

IoT devices are internally digital and hence they process discrete-time signals. Signals and Systems allows us to understand how to process discrete-time signals to extract or transmit information.

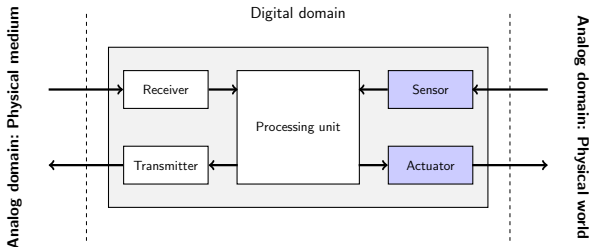


IoT devices: Sensing and actuating

IoT devices are digital, whereas the physical world is analog. Therefore:

- Sensors must convert the continuous-time signals from the physical world into discrete-time signals that can be used by the IoT device.
- Actuators must convert discrete-time signals from the IoT device into continuous-time signals for the physical world.

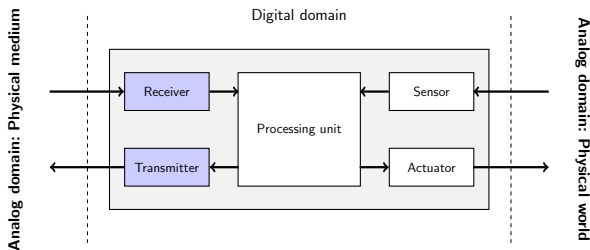
Signals and Systems shows us how to convert signals from one type to another without losing information. The first process is called **sampling** and the second process **interpolation**.



IoT devices: Transmitting and receiving

When information signals are transmitted through a physical medium, they are attenuated, distorted and contaminated by noise and other signals.

Signals and Systems helps us understanding how signals deteriorate during transmission and designing techniques for best transmitting and receiving information signals.



Electronic subsystems in IoT devices

IoT devices will contain different electronic subsystems to implement the functionalities that we have discussed, for instance:

- Microprocessors, digital signal processor (DSP).
- Analog to digital converters (ADC) and digital to analog converters (DAC).
- Sensors (temperature, chemical...) and actuators (servos).
- Wired or wireless communication units (USB, WiFi, Ethernet...).

Summary

We have studied:

- Continuous-time signals and systems. This is necessary to understand signals in the physical world.
- Discrete-time signals and systems. This is necessary to understand how signals are processed and transmitted by an IoT device and other computer-based systems.

This week we are going to learn about

- Sampling, interpolation and digital signal processing. This is necessary to understand conversion from continuous-time to discrete-time and vice-versa, and how information is treated in digital systems.
- Communications systems. This is important to understand how digital information is transmitted over a physical medium.