HOGESCHOOL ROTTERDAM

Training Digital Signal Processing

ELETDS02

Introductie

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What is digital signal processing?

- A subject of mathematics and engineering that involves manipulation of digital signals.

- Applications:
  - Multimedia (MP3, MPEG-2 video, etc...)
  - Health (EEG, MRI scan, CT scan, hearing aid)
  - Telecom (Phones, modems, etc...)
  - Industry (PID controllers, smart sensors, sensor fusion, motor controllers)
  - Automotive (Radar, Lidar, Vision, motor management)

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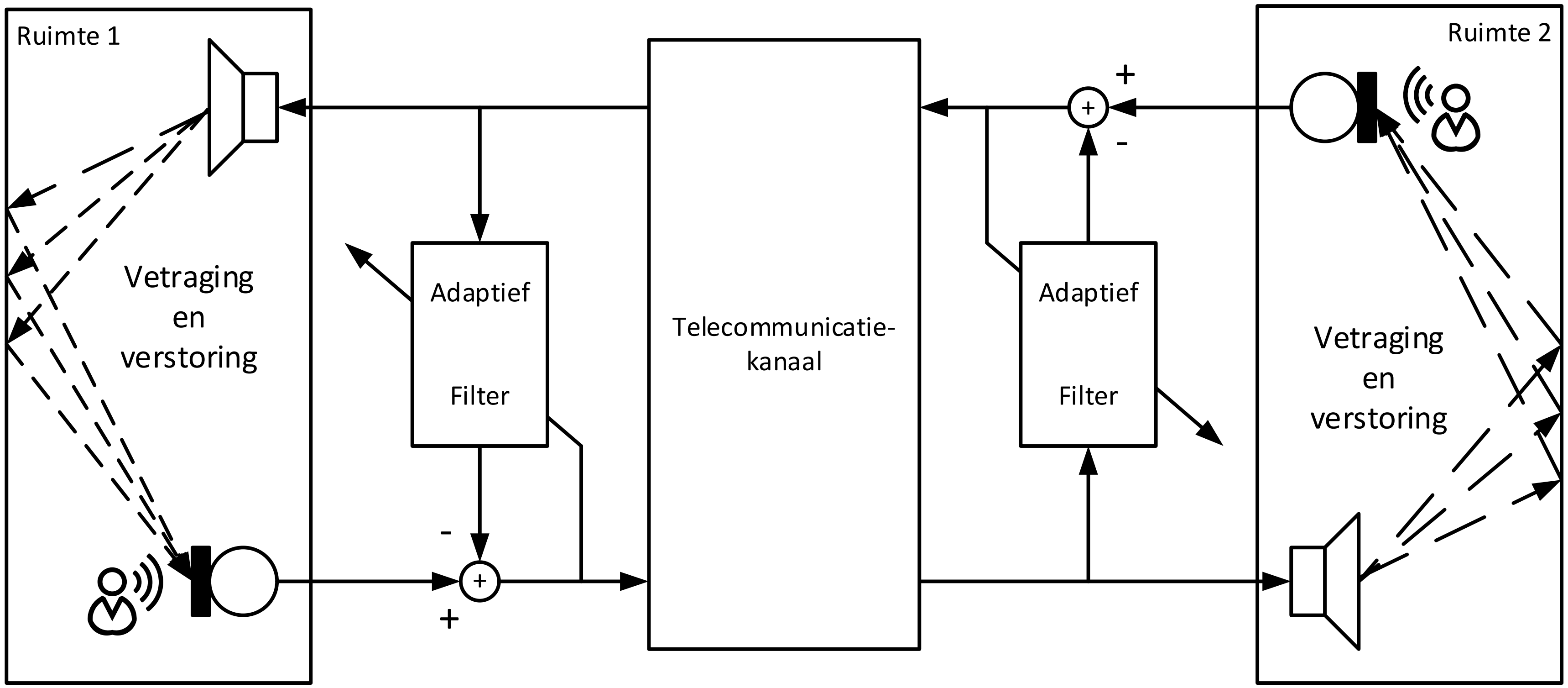
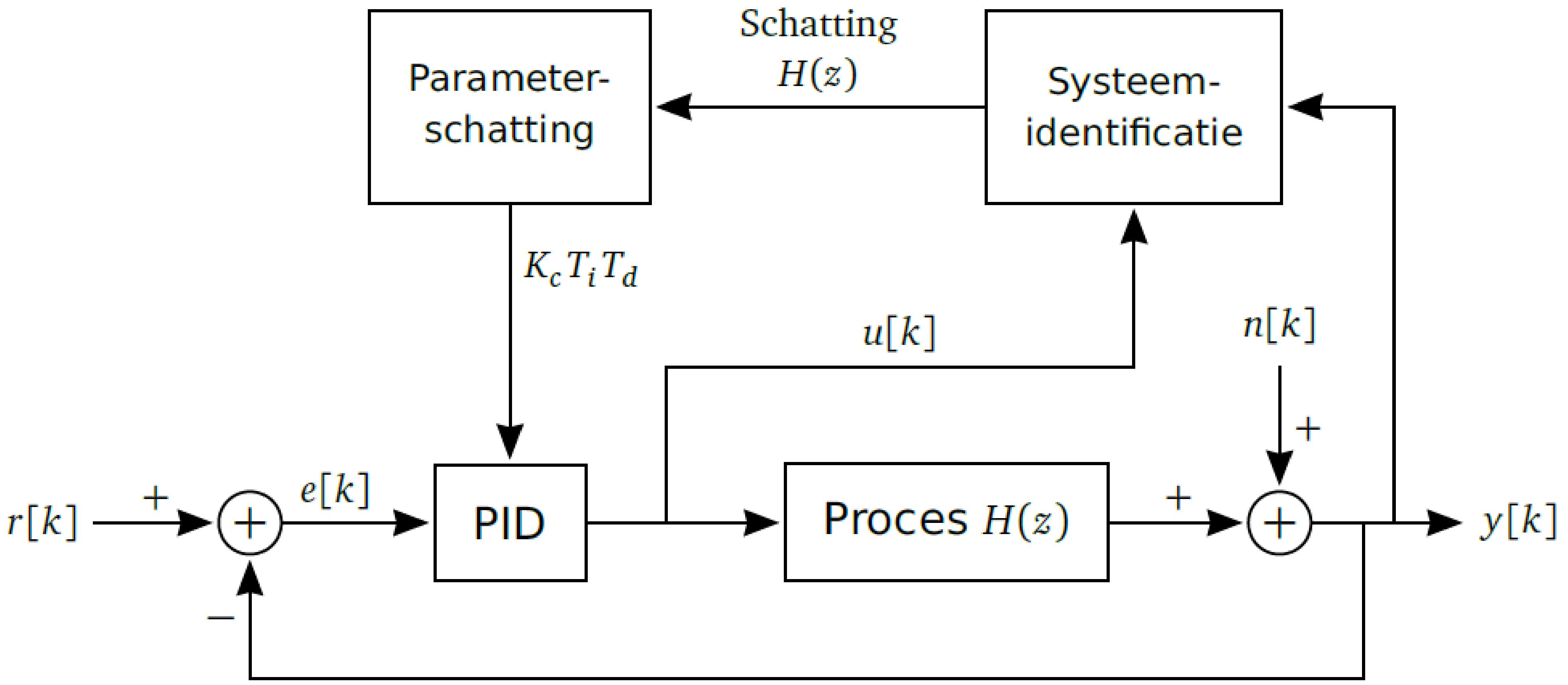
Telecommunication application: echo cancellation



- For example used with hands-free calling; the microphone also records the sound produced by the speaker.
- These signals can be suppressed by DSP techniques so that the echo is canceled.

Industrial application: Digital Control Systems



- Automatically tuning a PID controller in a process or plant.

What is this course about?

- Apply DSP theory in practice.
- DSP algorithms are widely used in embedded systems.
- Learn to use specific processors tailored for DSP.
- Implement some DSP algorithms on them.

What will we do

- First four weeks tiny lecture about theory
  - About one hour
- Rest of the time lab

Learning goals

Leerdoel	Niveau	Weging	De student is in staat om …
1	D	20%	… eenvoudige basisconcepten van DSP in de programmeertaal C te **realiseren**, zodanig dat de gecompileerde versie van deze realisatie op een bepaald platform correct wordt uitgevoerd.
2	D	20%	… een in frequentiedomein gespecificeerd filter met behulp van computersoftware te **ontwerpen** en te **realiseren** zodanig dat het geïmplementeerde filter voldoet aan de daaraan vooraf gestelde eisen.
3	D	60%	… een FIR- en een IIR-filter te **ontwerpen**, te **realiseren**, te **testen** en te **optimaliseren**. De student kan deze stappen en de hierbij gemaakte keuzes beschrijven in een consistent en taalkundig acceptabel verslag.

Grade

- Complete assignments
  - If **first six** assignments are signed off $P = 1$ else $P = 0$.
  - Assignments will only be signed off **during** the scheduled labs.
- Write a report of **last three** assignments (earn max 60 points V)

- Grade C is given by:

$$C = \left\lfloor \frac{P \times 40 + V}{10} + 0.5 \right\rfloor$$

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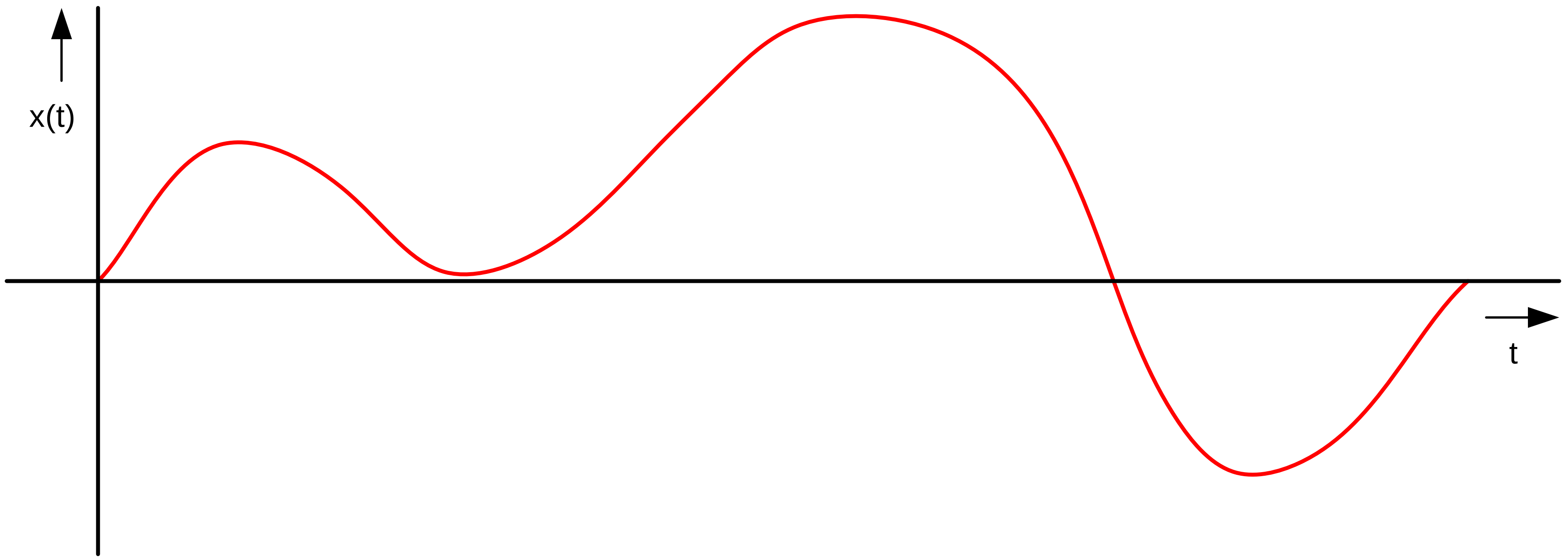
SIGNALS AND FREQUENCIES

Signals in time

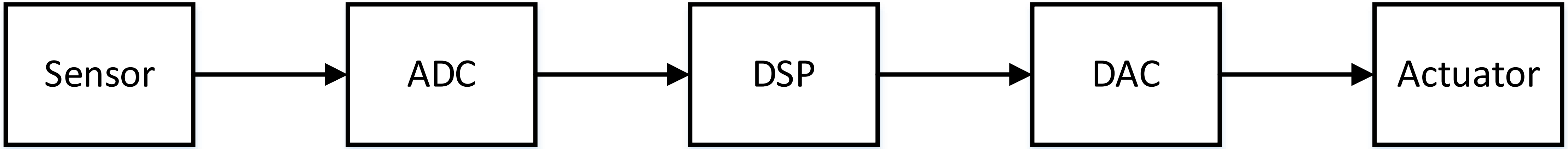
- We consider real world signals to be ***analog*** and of ***continuous-time***.
- At any point in time, the signal has an arbitrary value.



Discrete-time signals

- A digital processor works with limited numbers in discrete-time.
- Therefore we cannot manipulate analog, continuous-time signals.
- Need to sample and quantize.

- Typical embedded system with DSP:



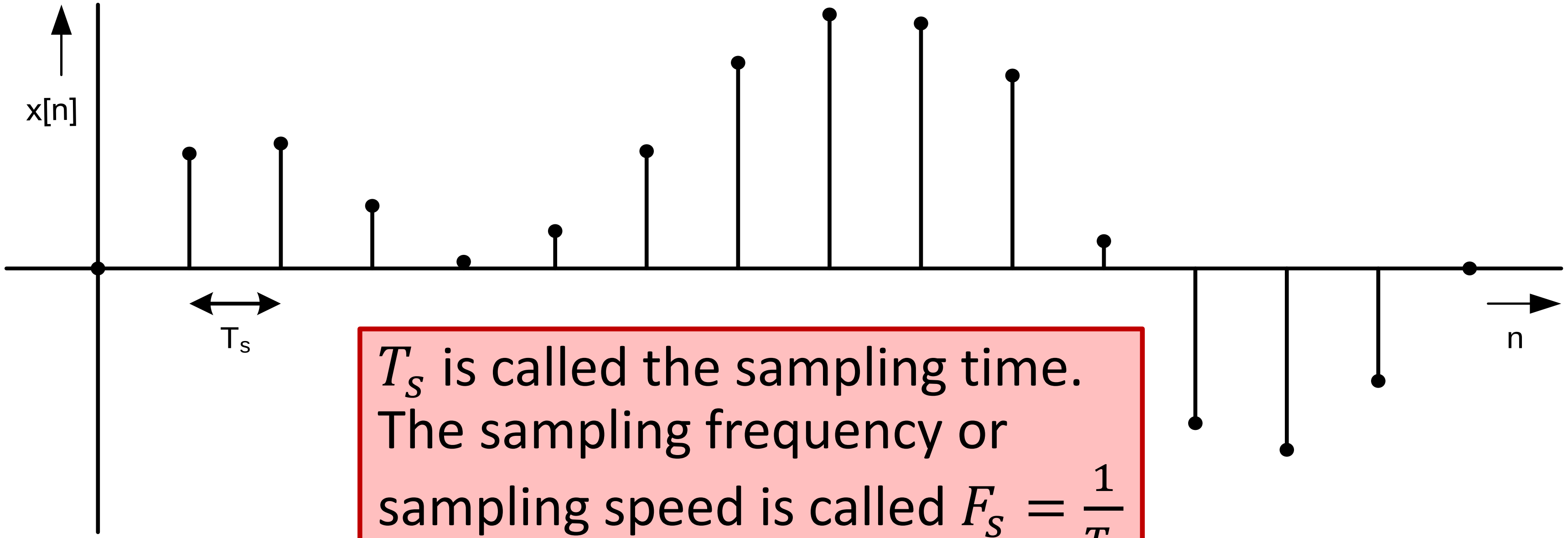
Digital Signal Processing versus Analog Signal Processing

- Advantages:
  - Flexibility
  - Reliability
  - Reproducibility
  - Complexity
  - Costs

- Disadvantages:
  - Bandwidth
  - Precision

Digital, Discrete-time signals

- When we *sample* a continuous-time analog signal at *regular* intervals of T_s we obtain an analog, ***discrete-time signal***.
- When we quantize an analog discrete-time signal we obtain a ***digital***, ***discrete-time signal***. We can for example quantize a signal using 16 bits.
- The signal only has a quantized value at discrete moments in time.



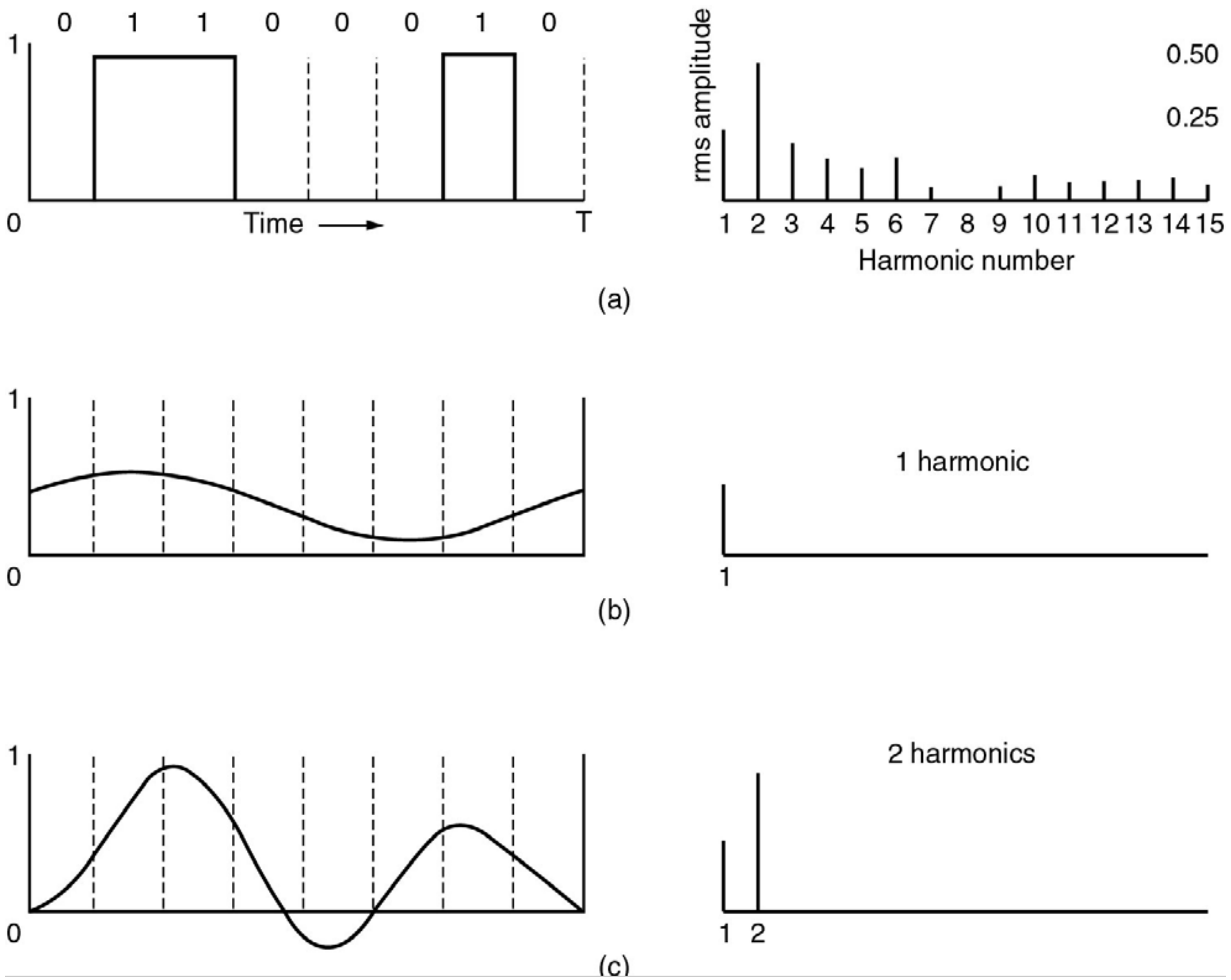
T_s is called the sampling time. The sampling frequency or sampling speed is called $F_s = \frac{1}{T_s}$

Fourier series

- In the beginning of the 19th century there was a mathematician called Jean-Baptiste Joseph **Fourier**.

- He noticed something interesting about periodic signals.

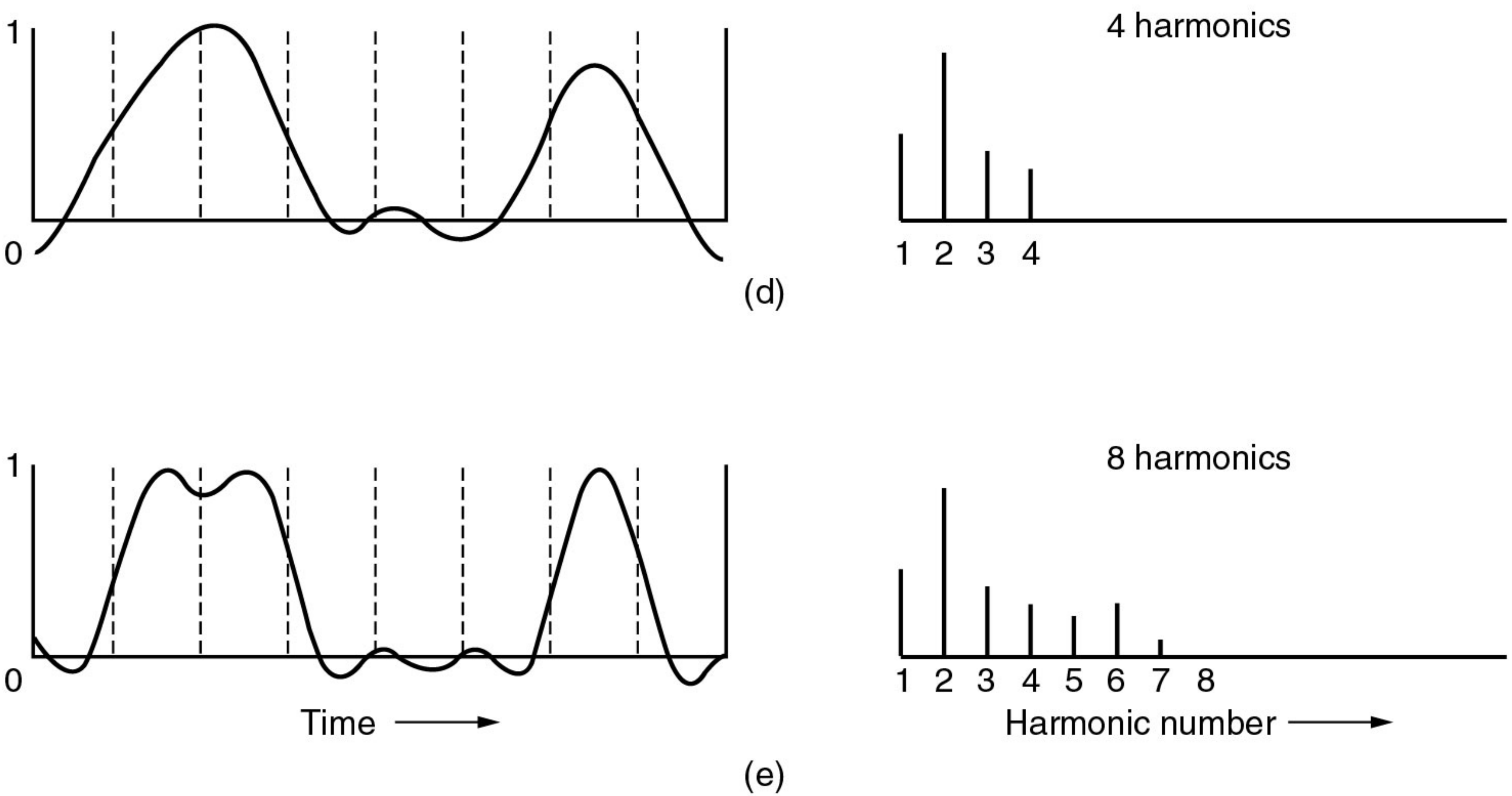
Fourier series example (1)



Binary Signal with Fourier harmonics amplitude

(b) – (c) Successive approximations to the original signal…

Fourier series example (2)



(d) – (e) Successive approximations to the original signal

Fourier series

Fourier figured out the mathematics:

$$f(t) = a_0 + \sum_{n=1}^{\infty} a_n \cos(n \cdot 2\pi f_0 \cdot t) + b_n \sin(n \cdot 2\pi f_0 \cdot t)$$

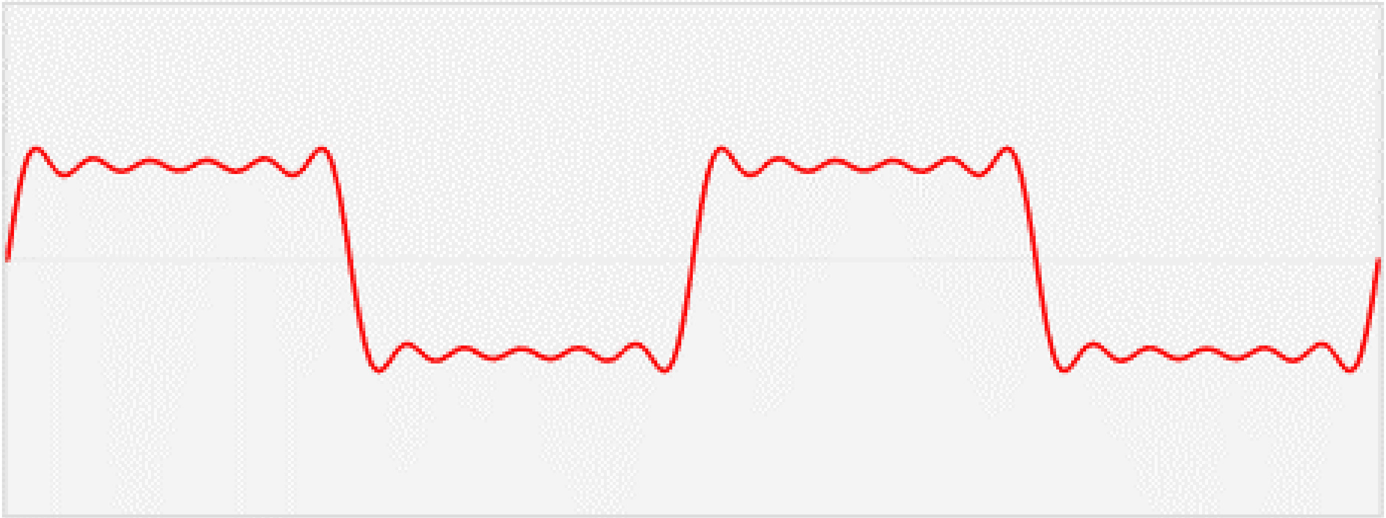
$$a_0 = 1/T \int_0^T f(t) \cdot dt$$

$$a_n = \frac{2}{T} \int_0^T f(t) \cos(n \cdot 2\pi f_0 \cdot t)\, dt$$

$$b_n = \frac{2}{T} \int_0^T f(t) \sin(n \cdot 2\pi f_0 \cdot t)\, dt$$

Fourier showed that **any periodic function can be written as an infinite sum of sine and cosine terms.**

Animation



Source: Lucas V. Barbosa

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Fourier transform (1)

(Warning: imperfect simplified description ahead.)

- The Fourier *series* shows the **amplitudes** of discrete **frequencies**.
- Suppose we apply the calculations on a signal that extends to infinity in time.

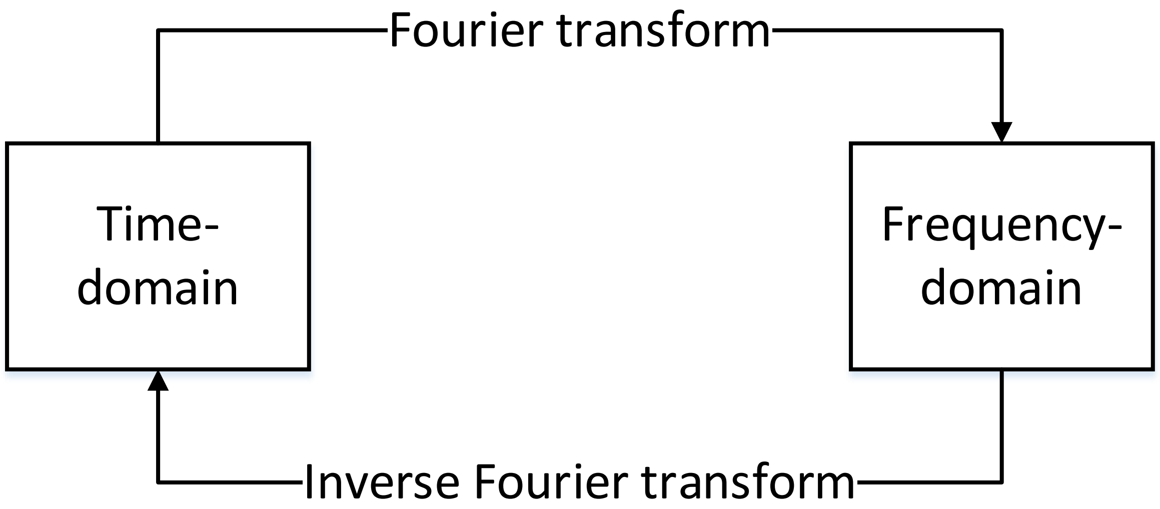
- The “period” of the signal approaches infinity,
- The “frequency” of the signal approaches zero,
- The number of frequencies becomes *infinite*
- In a way where the range of frequencies becomes *continuous*.

- We call this the ***Fourier Transform***.
- It shows us the signal **as a function of frequency instead of time**.
- This is called the ***frequency domain*** representation of the signal.

Fourier transform (2)

$$X(f) = \int_{-\infty}^{\infty} x(t)e^{-j2\pi f t}dt$$

- Some problems are **easier to solve,** or **specified**, in the **frequency domain**.
- No information is lost during transformation (in theory).
- We can reconstruct the signal with an inverse transform.



Discrete-time Fourier transform

- Fourier transform can also be done for discrete-time signals.
- We call this the Discrete-Time Fourier Transform (DTFT).

$$X(f) = \sum_{n=-\infty}^{\infty} x[n] e^{-j2\pi f n}$$

- The inverse transform is called the Inverse Discrete-Time Fourier Transform (IDTFT).

Do we have to fully understand and apply all these formulas?

- For this course at least try to *understand* the differences between time and frequency and the corresponding domain.
  - For complete understanding of the subject, you need to do the math.

- For this course we try to design and build discrete-time filters.

- To design filters: we can use MATLAB.

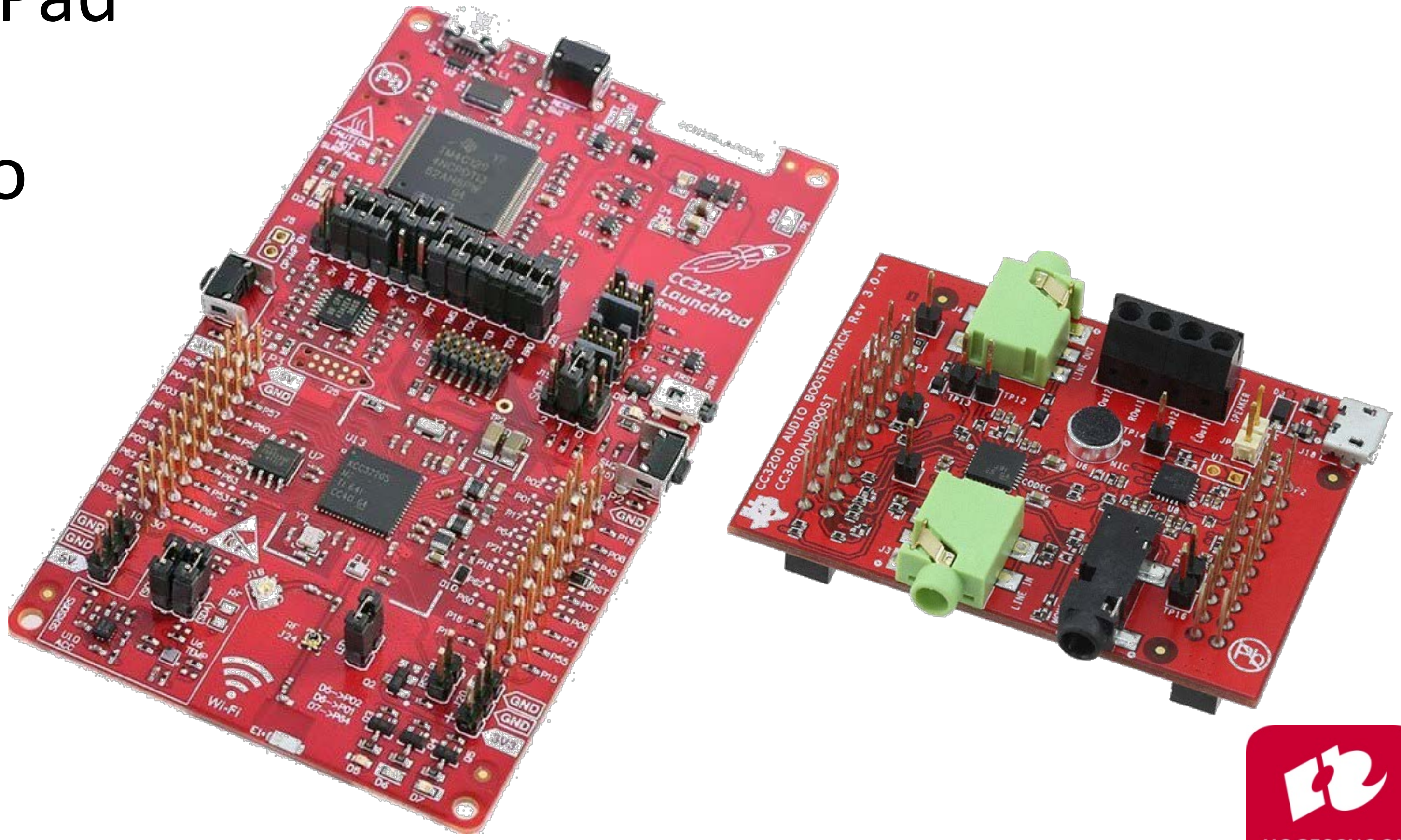
- More on filters next week.

Summary

- **Signals** in real life are **analog** and **continuous**.
- Need to **sample** and to **quantize** them to be able to process them digitally.
- They become **digital** and **discrete-time signals**.
- Signals can be represented as sines/cosines with certain **frequencies**.
- Many problems are specified or solved in the **Fourier frequency domain**.
- We can switch between time and frequency domain with the **Fourier Transform**.

TDS02

- Check who's your groupmember (List)
- Get the CC3220S LaunchPad (#17) for €47,50 and the CC3200AUDBOOST Audio BoosterPack (#12) for €17,50 from the shop (mailroom).
- Start with assignment 0 from the Lab Work Handbook.



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