University of Glasgow

Digital Control 4/M

ENG4042-ENG5022

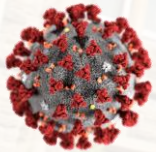
Matteo Ceriotti

WORLD CHANGERS WELCOME

University of Glasgow

Digital Control

- Welcome!
- Another (mostly) online academic year



What's your biggest concern for this semester (online learning)?

- Quality of online classes
- Technology issues (Zoom, internet connection not working, etc.)
- Lack of campus experience and social interactions
- Falling behind / Not keeping up with class pace
- Other: .....

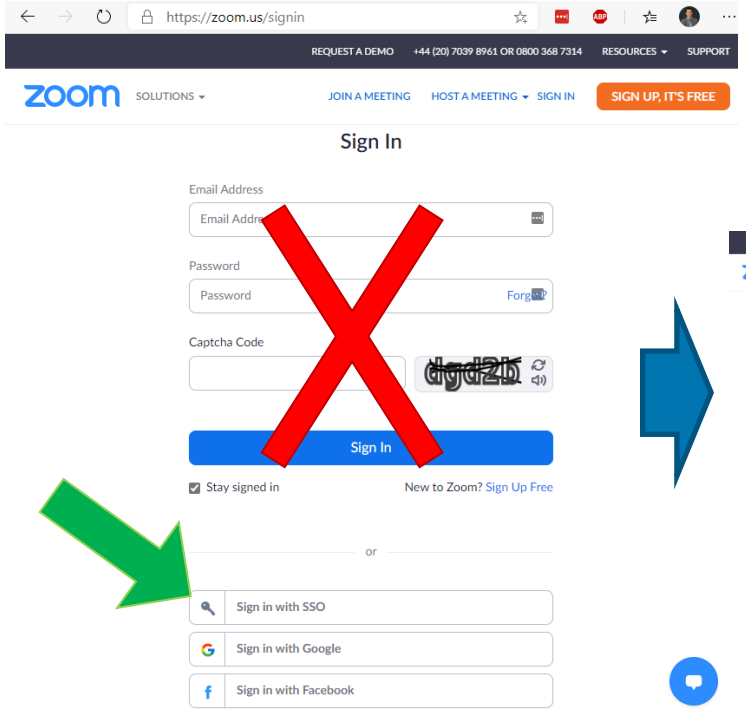
What's the biggest advantage/opportunity of online learning?

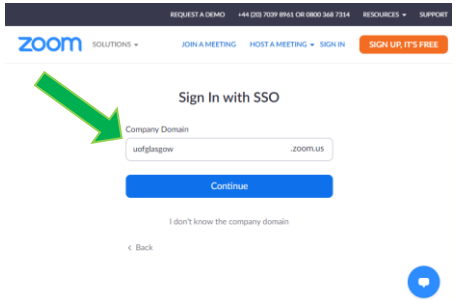
- Can do it from my home/where I am
- Can (re-)play recorded lectures/classes at my own pace
- Can use technology (online resources, electronic notes, etc.)
- Other: .....

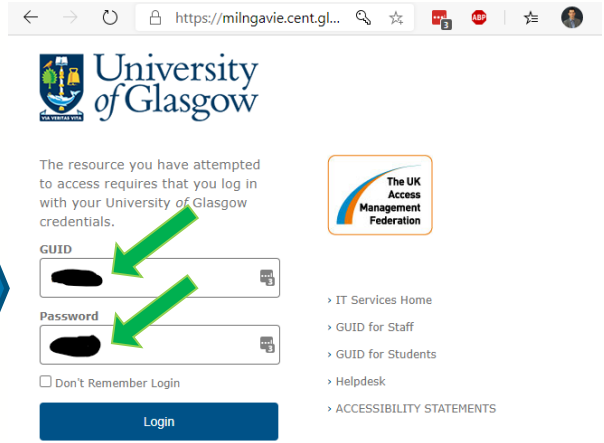
Zoom etiquette

- Mute yourself when not talking
  - Limit background noise
- Turn on your webcam if you have one
- Use the “raise your hand” function
- Use the chat for non-urgent questions and general discussion
  - Keep it in English and be polite: everyone can read

Zoom UofG login





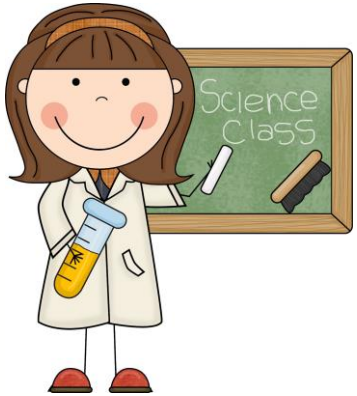


Sign in with SSO

Domain: uofglasgow

GUID & password

Format of teaching



- **Recorded lectures**
  - Cover all course, theoretical background, lecture notes

+

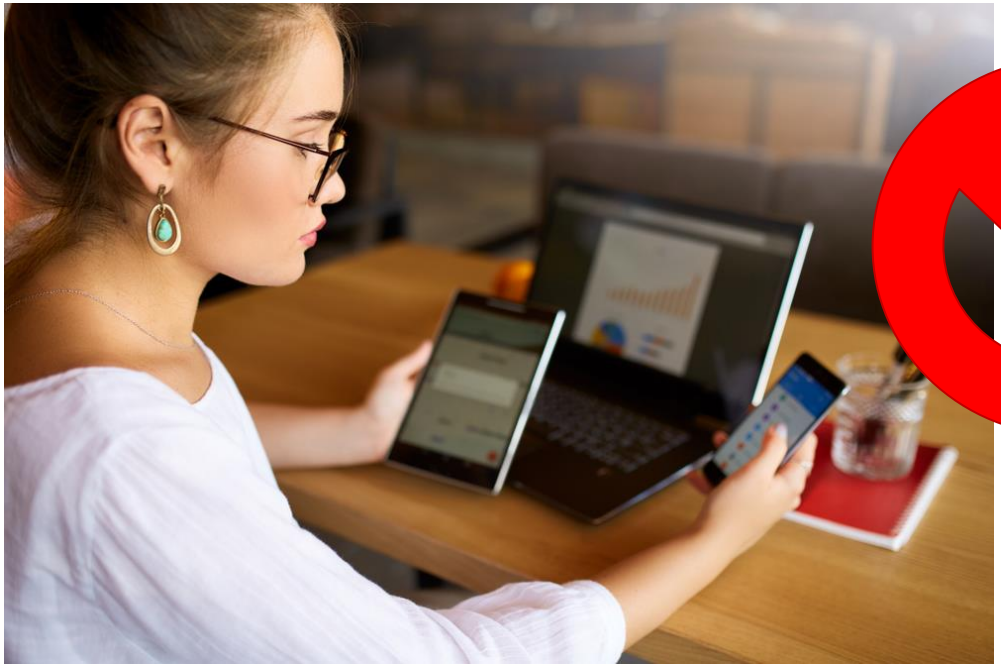
- **Live sessions (Zoom)**
  - Q&A, examples, numerical exercises, tutorials, past exam papers, etc.
  - Flexible

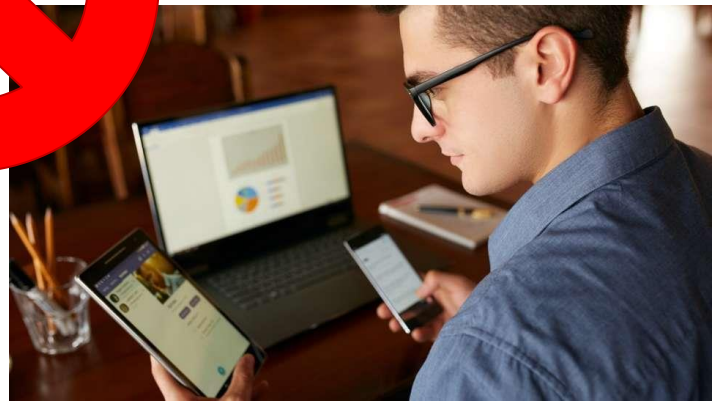
- **2 Live tutorial sessions (Zoom)**
  - Weeks 9~10
  - Past exam papers, Q&A, etc.

- \+ Experimental laboratory for ENG5022

- Feedback welcome

How should I watch pre-recorded lectures?





How should I watch pre-recorded lectures?

- Allocate time for watching lecture videos
- Focus on the lecture only, video in full-screen, notifications off
- Other online devices (phone) out of reach
- Take notes, as if you were in a lecture
- Take a break when you need to
  - Do not carry watching if you can’t focus
  - You do not have to watch a whole section at once
- Do it at a time that is convenient for you

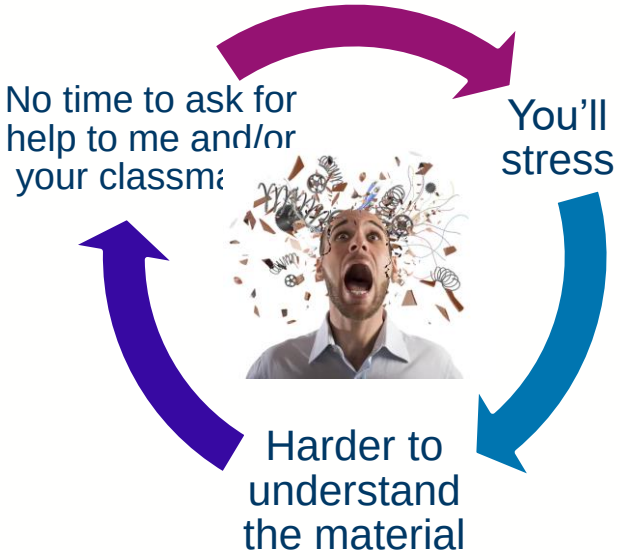
Why pre-recorded lectures?

- Fail-safe solution, in these uncertain times
  - Internet connection fail, illness, …
- Teaching via Zoom takes longer
- In my experience (8+ years), I have received very few questions while lecturing
  - Most questions were due to my own mistake explaining!
- You can (re-)watch & learn at a time convenient for **you**
- Frees live class time (Zoom) for Q&A, interactive activities, numerical examples, solutions of tutorial questions, past exam papers, …
- Cover entire lecture notes

The warning

- **Do not procrastinate**
- Pre-recorded video lectures will be available until the end of term but:
  - The interactive live classes will be meaningless if you have not followed the video lectures beforehand

  - If you cram during revision week:



Therefore, you should **promise to yourself now** that you'll watch the lectures week by week

"Sign" here

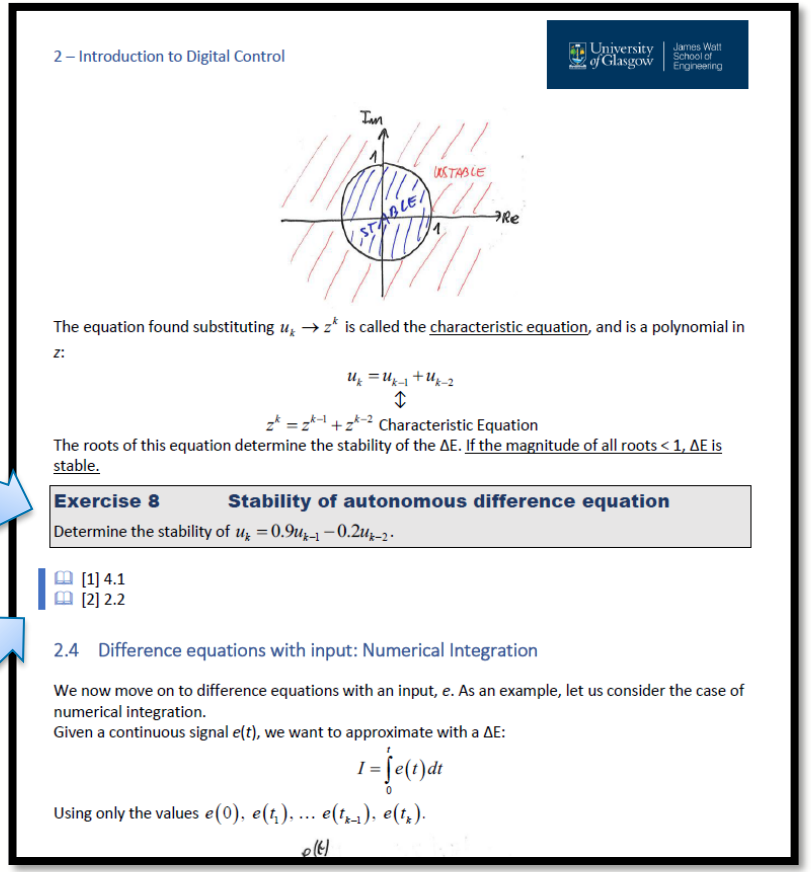
Resources: Moodle

https://moodle.gla.ac.uk/course/view.php?id=21118

- Full lecture notes
- Forum
  - Please use it for any course-related question – I will answer there
- Reading list (core textbook available in PDF through library)
- Practice exercises (will go live later)
- Past exam papers
- Feedback form: let me know anonymously

Lecture notes

- Available on Moodle in full right now
- Cover all theoretical material of the course
- Exercises showing applications to real-world problems and practice for exam
  - Do try them by yourself or with your mates (adhere to COVID restrictions)!
- References to related textbook sections



2 – Introduction to Digital Control

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The equation found substituting $u_k \to z^k$ is called the characteristic equation, and is a polynomial in z:

$$u_k = u_{k-1} + u_{k-2}$$
$$\updownarrow$$
$$z^k = z^{k-1} + z^{k-2} \quad \text{Characteristic Equation}$$

The roots of this equation determine the stability of the ΔE. If the magnitude of all roots < 1, ΔE is stable.

Exercise 8 Stability of autonomous difference equation

Determine the stability of $u_k = 0.9u_{k-1} - 0.2u_{k-2}$.

[1] 4.1
[2] 2.2

2.4 Difference equations with input: Numerical Integration

We now move on to difference equations with an input, *e*. As an example, let us consider the case of numerical integration.
Given a continuous signal *e*(*t*), we want to approximate with a ΔE:

$$I = \int_0^t e(t)\,dt$$

Using only the values $e(0),\ e(t_1),\ \ldots\ e(t_{k-1}),\ e(t_k)$.

e(t)

Assessment

ENG5022

- **Coursework (10%)**
  - •Design a controller for servo-motor
  - •Remote-controlled (TBC)
  - •Quiz on Moodle + Report
  - •3 groups with different timing, check your timetable/Moodle
- **Final (90%)**
  - •Online (timed (?) 2 hours)
  - •Theory + Numerical exercises

ENG4042

- **Final (100%):**
  - •Online (timed (?) 2 hours)
  - •Theory + Numerical exercises

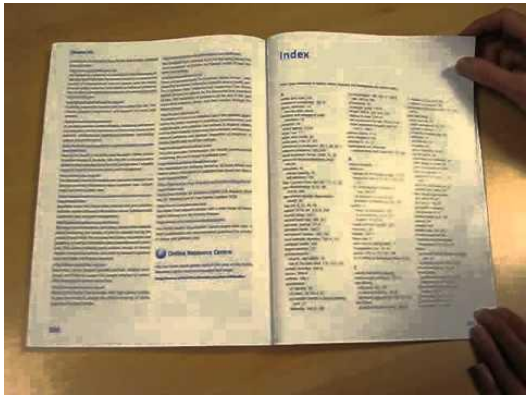
Prerequisites

- Basics of continuous-time dynamical systems
- Laplace transform, frequency domain
- Meaning of Transfer Function, Poles, Zeros, etc.
- Continuous-time control system theory
  - Basics of feedback control design: root locus, Nyquist plo

- Fundamentals of MATLAB/Simulink
  - Optional for ENG4042 (but highly advised)
  - Compulsory ENG5022 (due to experimental coursework)
    - “On ramp” courses with certificate

Contents of the course

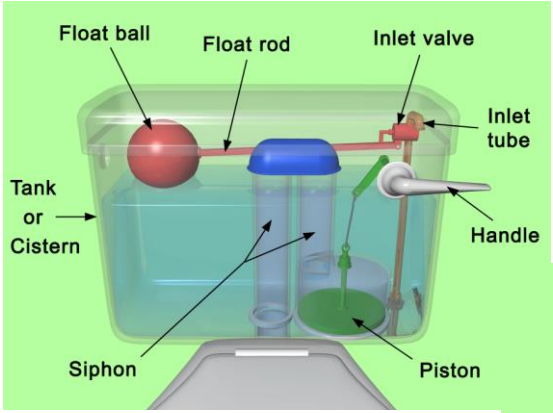
1. Review of Continuous/Analogue Systems and Control
2. Introduction to Digital Control
3. Z-transform and Discrete Transfer Function
4. Signal Analysis and Dynamic Response
5. Modelling of Systems with Digital Control
6. Stability
7. Design of digital controllers
8. Sampled-data systems

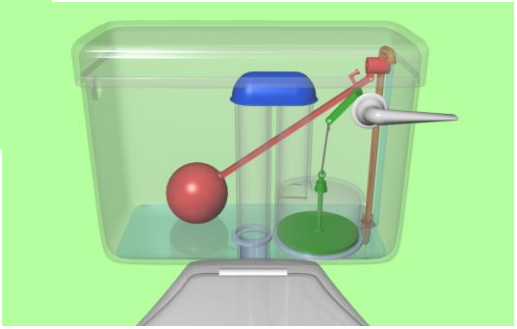


Analogue control systems

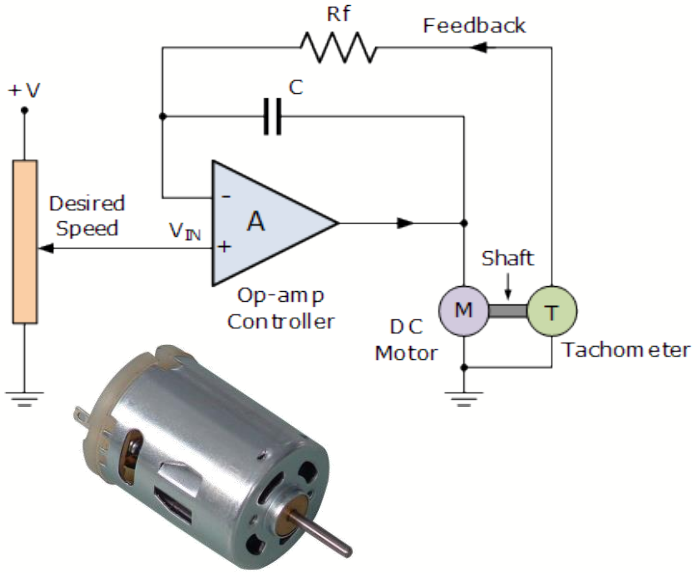
All signals are real-valued and continuous in time

Mechanical

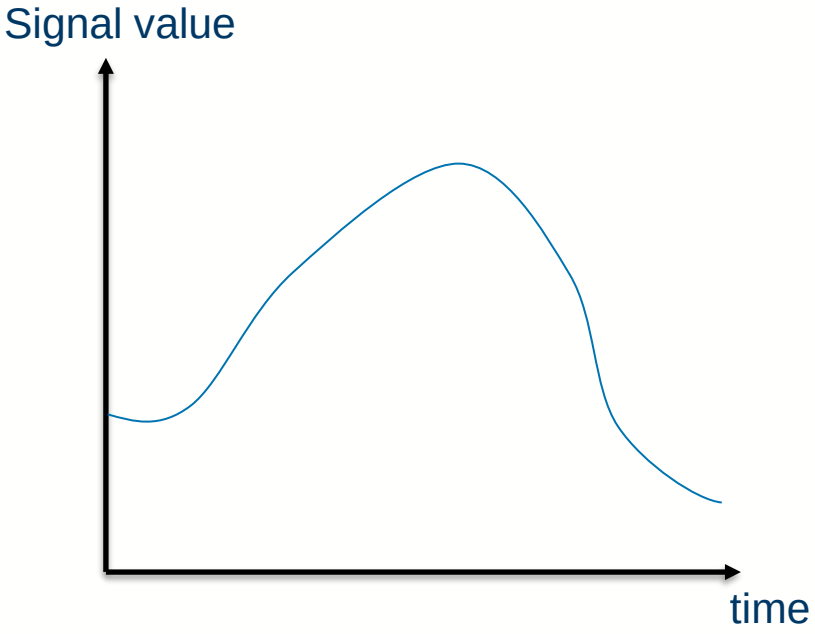




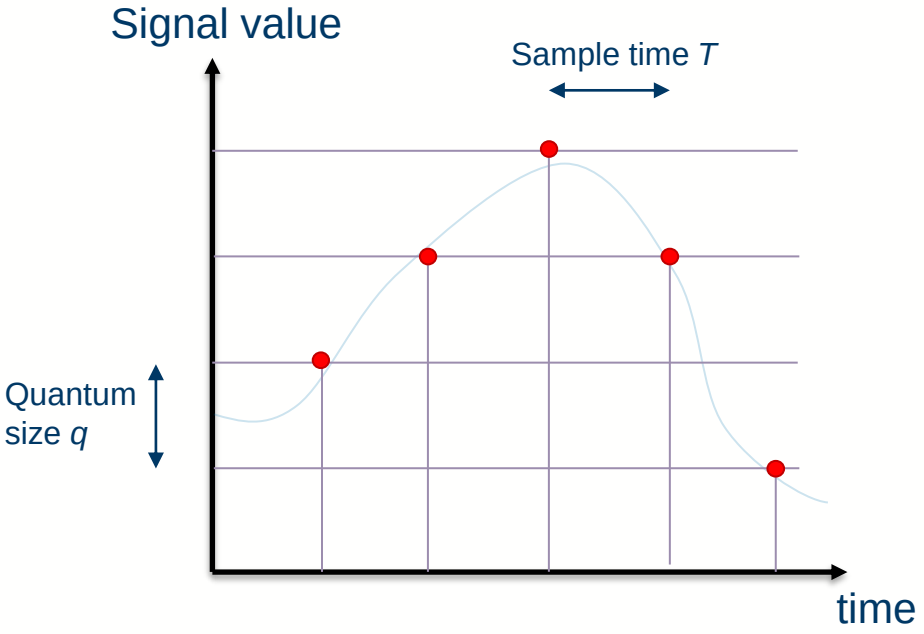
Electric/electronic



Continuous (analogue)



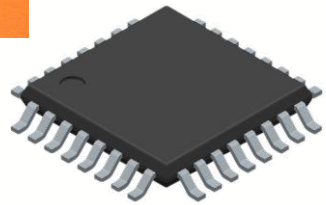
Digital (discrete and quantised)

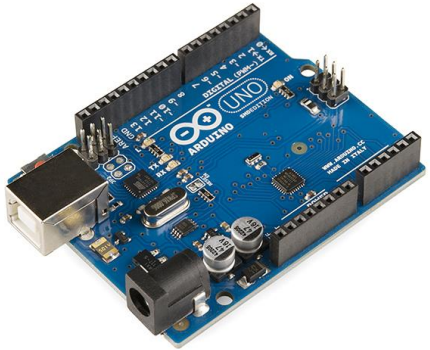


Why digital control (-lers)?

Advantages

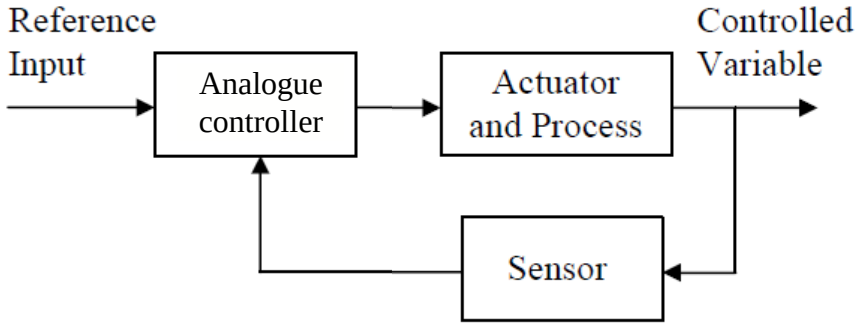
- Flexibility
- Multi-tasking
- Resilience to noise
- Cost
- Volume/Mass
- Depending on hardware:
  - Accuracy
  - Implementation errors
  - Speed



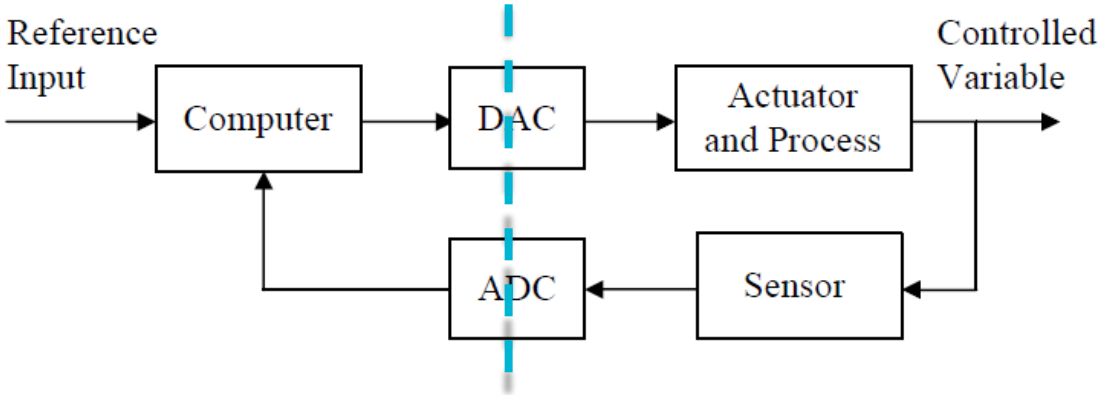


Feedback control systems

Analogue:

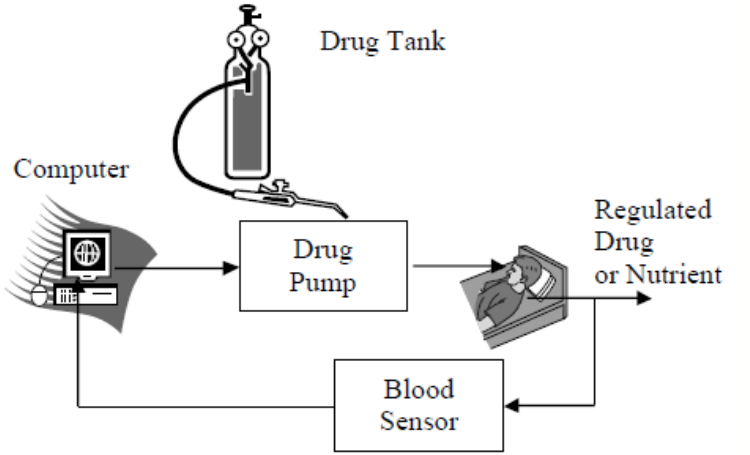


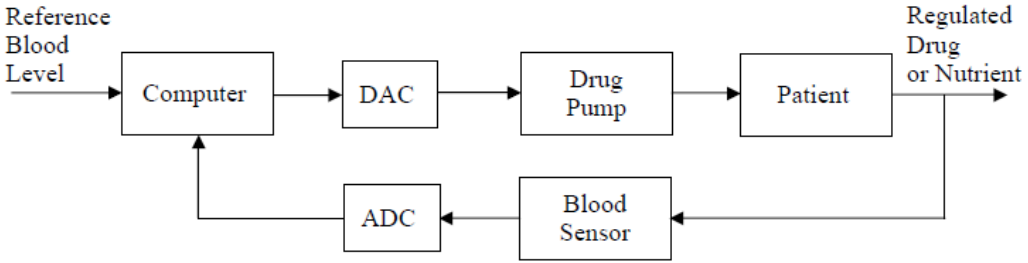
Digital:



Examples of digital controllers

Drug-delivery devices (e.g. insulin)

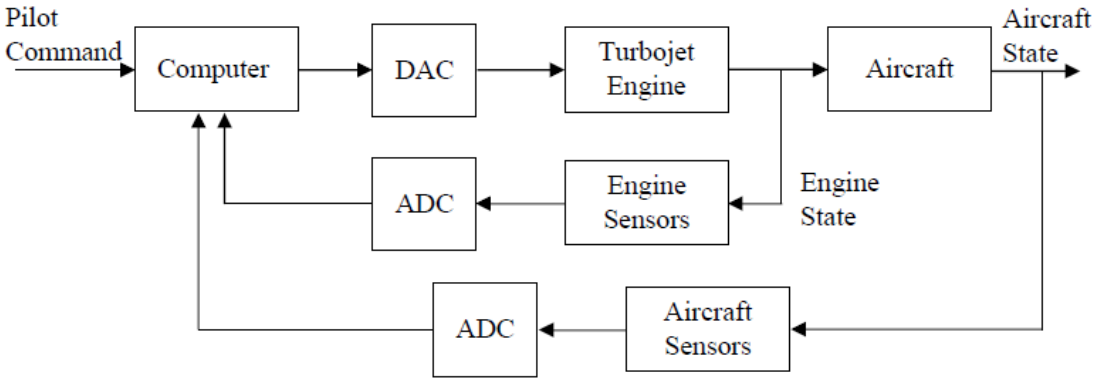




From: M. Sami Fadali, Antonio Visioli, “Digital control engineering: analysis and design”, 2019

Examples of digital controllers

Aircraft turbojet engine control system



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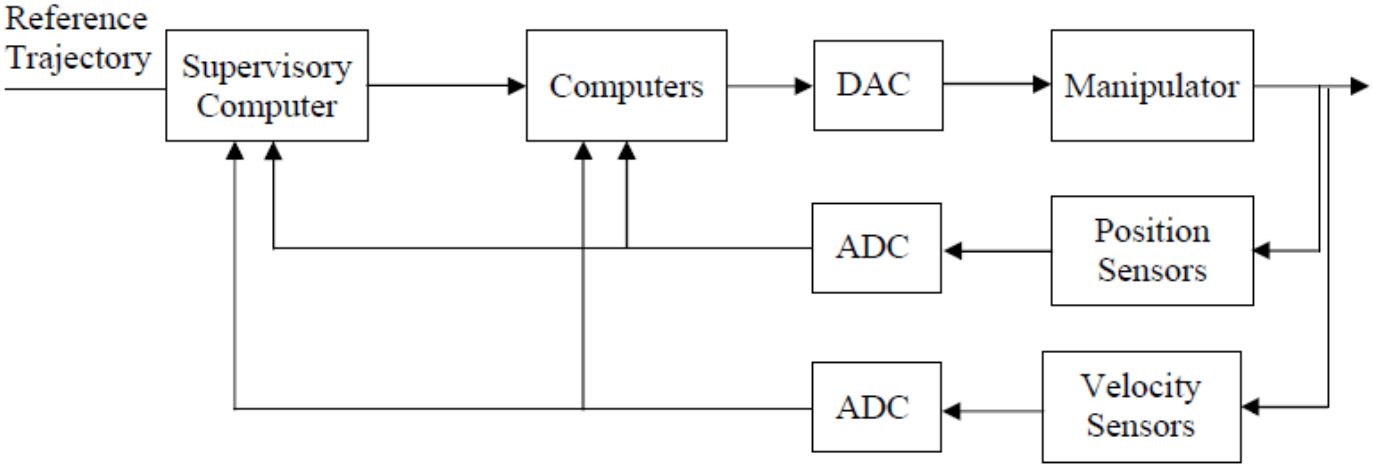
Examples of digital controllers

Robotic manipulator



From: M. Sami Fadali, Antonio Visioli, “Digital control engineering: analysis and design”, 2019

Homework

- Watch pre-recorded video lectures:

- **00 – Introduction**
- **01 – Review of continuous systems**
- **02 – Introduction to digital control**

- Take your own notes
- Write down questions/issues/sticky points
  - Discuss on these next week

Digital Control

- I have done our best for delivering the usual UofG teaching experience

- Feedback on online learning welcome

I hope that you'll enjoy this course and the rest of your studies!

STAY SAFE!


University of Glasgow
Thank you and good luck!
Matteo Ceriotti
matteo.ceriotti@glasgow.ac.uk
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