Actuators and Power Electronics

METE 3100

Notice

METE 3100 - Actuators and power electronics

Instructor

- **Dr. C. Rossa**

carlos.rossa@ontariotechu.net

Office hours

Tuesdays from 9:30 am to 11:30 pm

Any other time by appointment

Please avoid sending messages on Canvas. Contact me directly at carlos.rossa@ontariotechu.net for a fast reply.

METE 3100 - Actuators and power electronics

Lab Instructor

- Dr. **Masoud Farzam**

  Masoud.Farzam@ontariotechu.ca

- Office hours: Fridays 2:30-3:30 pm

Teaching Assistant

- **Ben DeBoer**

  benjamin.deboer1@ontariotechu.net

- Office hours: Wednesday 2-4 pm

METE 3100 - Actuators and power electronics

Lectures

- Tuesday, Thursday, 8:10 am to 9:30 am
- Online, synchronous

Labs

- Labs run biweekly - Friday from 15:30 to 17:30.
- Synchronous, online
- Labs will run remotely
- More information will follow shortly

METE 3100 - Actuators and power electronics

- Recommended textbook (not required)

  Principles of electric machines and power electronics
  P. Sen (any edition)

- Course notes are available via Canvas

  - Please print and use them to make notes
  - Annotated pdfs will be posted after each class

- Please review the student conduct policies

Course overview

The course comprises:

- 21 Lectures
- 5 Labs
- 1 Midterm exam
- 1 Final exam
- 1 Lab exam
- 1 Design project
- 4 Assignments (not marked)

Grading policy:

Final examination	40 %
Midterm examination	20 %
Lab reports	20 %
Design project report	15 %
Design project presentation	5 %
Assignments	0 %
	100 %

In-class participation marks - up to 5% (bonus - not required)

Attendance is mandatory for bonus marks

Grading policy

Midterm (20%)

→ Monday, February 22, 2021

→ **8:15 to 10:45 am** (online)

Final exam (40%) Comprehensive (all lectures)

→ Date and time TBD

→ Done during final exam

Design project (20%)

→ Report due March 31 by email

→ Presentation dates:

- April 1, 8:10 - 9:30 am
- April 6, **8:15** - **11:00 am**
- April 8, 8:10 - 9:30 am

Missed exams

Missed midterm exams for **legitimate reasons**: Final final will be reweighed accordingly provided that a formal request is accepted by FEAS

$\rightarrow$ Late design projects will not be accepted.

$\rightarrow$ Late lab reports will not be accepted.

Design project

The design project includes:

→ Desing and analysis of an electromagnetic system

→ Modelling and simulation of power circuits

→ 3 or 4 students per group

Design projects will be handed in the form of a report (15%)

→ Overall technical rigour and accuracy: 5%

→ Electromechanicalical modelling: 2.5%

→ Electromechanical simulation: 2.5%

→ Language and clarity: 1.25%

→ Presentation and graphics: 1.25%

→ Project economics and feasibility: 2.5

→ **Design report is due on March 31st**

Resources

Simulation

→ Matlab, Simulink, and Simscape

→ Multisim, Orcad, or LTspice

Drawing (suggested)

→ Inkscape: `https://inkscape.org/`

Text editing

→ LaTeX - A document preparation system

→ Step 1, install the engine: `https://miktex.org/`

→ Step 2, install the editor: `http://www.xm1math.net/texmaker/`

→ Step 3, use the provided template

Design project presentation

Design project presentation (5%)

→ Thursday April 1st, 8:10-9:30 am

→ Tuesday April 6th, **8:10-11:00 am**

→ Thursday April 8th, 8:10-9:30 am

→ 10 to 15 min per group depending on the number of groups

Grading:

→ Technical rigour and accuracy: 2%

→ Clarity: 1%

→ Graphics: 1%

→ Questions and answers: 1%

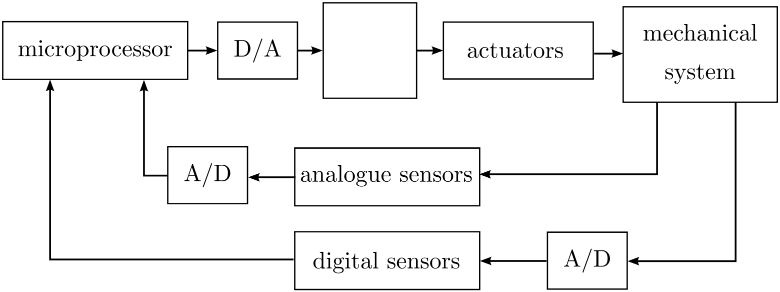
Course overview

- Notes will be available on the class website ahead of time
- Please download the notes and use them in class
- Some information may be missing; the missing information will be shown in class
- Annotated slides will be posted after each class
- You are strongly encourage to attend all lectures
- **Lecture notes are not self-contained**

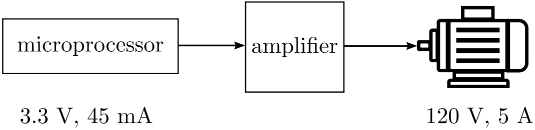
Topics

- Magnetic circuits
- Power electronics
- Electromagnetic energy conversion
- Electric machines
- Electric motors
- Modelling electric machines
- Speed and torque control of electric motors

Mechatronic control loop



Mechatronic control loop



→ Operational amplifiers

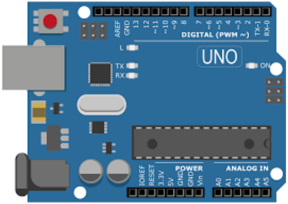
→ Transformers (?)

→ AC/DC converters

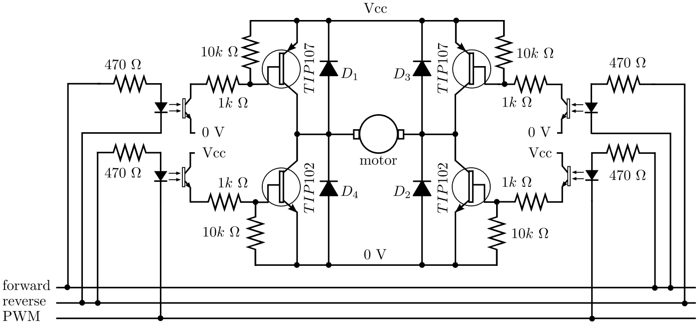
→ DC/DC converters

→ DC/AC converters

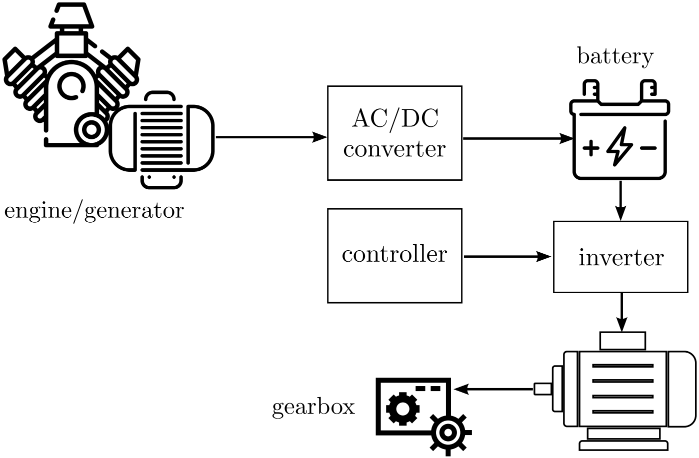
→ Pulse width modulation



Example of a power unit

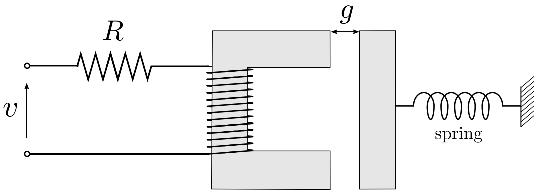


Electric cars



Electromechanical actuators

Lorentz actuator: A nearly perfect current to force converter



→ How does the current relate to the magnetic field?

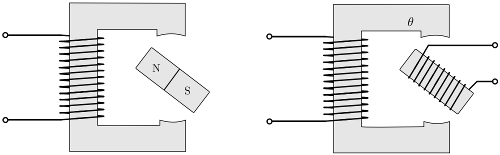
→ How does magnetic field relate to the force?

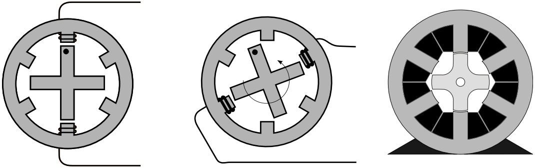
→ What is the influence of the material?

→ How can we model, power, and control the actuator?

Electromechanical actuators

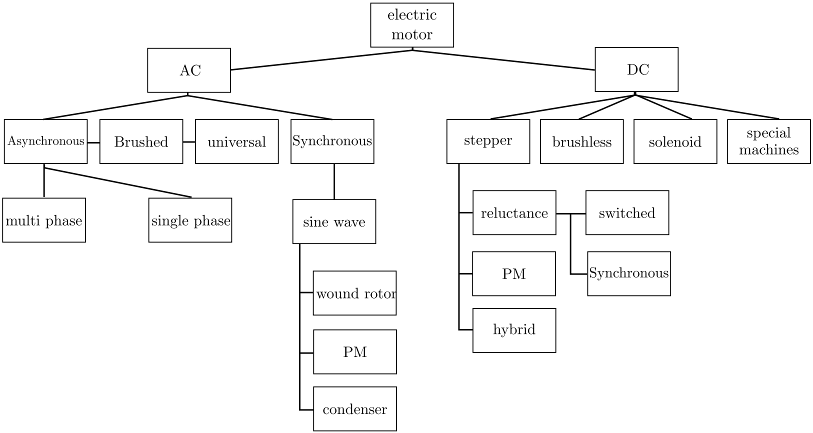
Rotary actuators: electric motors





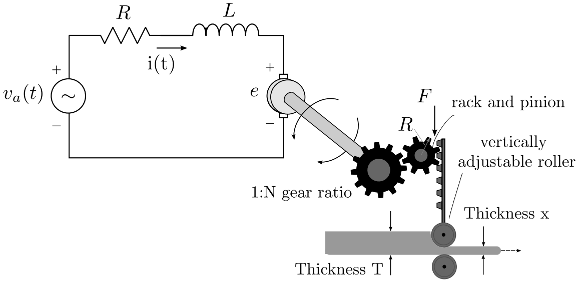
→ Operate based on the same principle as the linear actuator

Electric motors

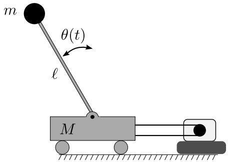


Closed-loop control

Force control



Velocity control



Example of design projects

P1 - Transducer for kinetic energy harvesting using full-wave rectification

P2 - Actuation system with analogue PID grasping force controller of a hand prosthetics

P3 - Linear induction motor for electromagnetic levitation and propulsion of a train

P4 - Sine pulse width modulation for a 3-phase alternating current motor

P5 - Design and control of a linear solenoid for high-precision positioning of a cable-driven laparoscopic endoscope

P6 - A bidirectional DC-DC converter fed DC motor for an electric vehicle

Example of design projects

P7 - Design and control of a 3D printed stepper motor

P8 - Speed control of brushless DC electric motor using a multilevel inverter for drones

P9 - Field-oriented control of a 3-phase permanent magnet motor

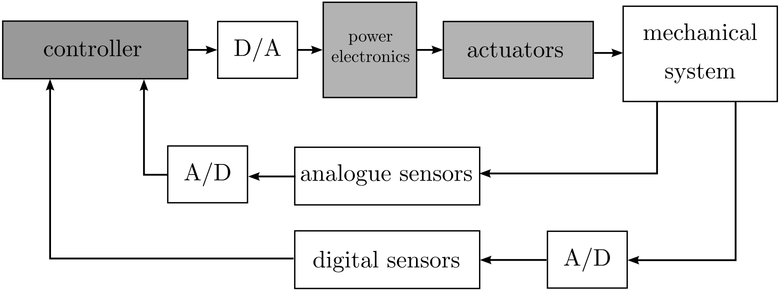
P10 - Electromechanical transducer for harvesting the energy from ocean waves using DC/DC converters

P11 - 3D printed axial brushless motor with a discrete autotransformer

P12 - Propose your own project

You are strongly encourage to meet with the course instructor and TA on a regular basis to get continuous feedback on your design project

Mechatronic control loop



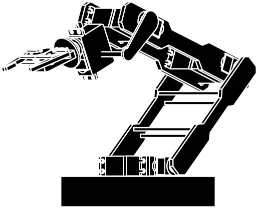
Suggested review topics

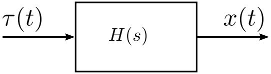
- → Fundamentals of electric circuit
- → Effective power, rms voltage, peak voltage, etc
- → Electromagnetism
- → Feedback control
- → Electromechanics
- → Arduino, C/C++
- → Solid state electronics
- → Transistors, diodes, operational amplifiers

Applications

What current must be applied to each of the robot joints so that end-effector applies an specific force to an object?

What voltage must be applied to each of the robot joints so that end-effector moves in a given direction with a constant speed?



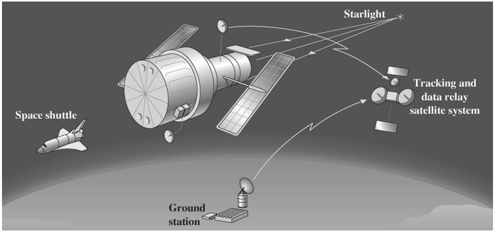


Applications

The levitation control system of the train must ensure that the train does not touches the guide. How can we design and control the levitation system?

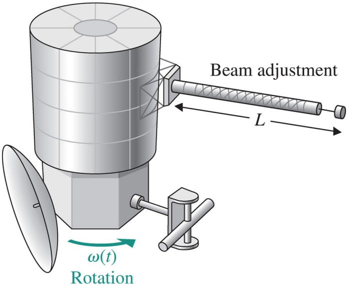
Applications

The pointing control system of a space telescope is desired to achieve an accuracy of 0.01 minute of arc. How can it be controlled?



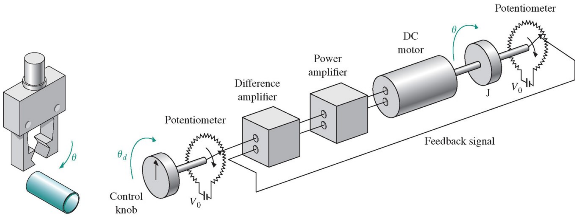
Applications

The rotational velocity of of the satellite is adjusted by changing the length of the beam. How can we control the position of the beam if it is actuated by a DC motor? Could a stepper motor be used instead?



Applications

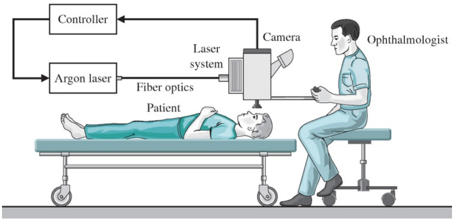
A robot gripper is to be controlled by a DC motor. How can we apply a controlled grasping force?



Applications

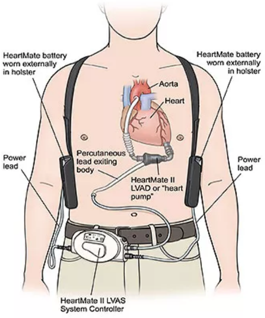
Automated control of the laser position during eye surgery enables the ophthalmologist to indicate to the controller where lesions should be inserted.

How can we design a controller that ensures accurate positioning? How do the motor characteristics influence performance?



Applications

A ventricular assist device is a mechanical pump used to support heart function and blood flow in people with weak or failing hearts.



The pump valve is controlled by a solenoid actuator. How can we relate the applied voltage to the mechanical displacement of the actuator?

Applications

Altitude control of the Osprey Tiltrotor requires precise velocity control of the electric motors. How do the motor characteristics influence the a PID gains?

How can DC power stored in a battery be converted in AC power?

Applications

A wind generator produces AC current. How can the power be injected to an existing AC grid?

$\rightarrow$ The AC current is first converted to DC, then back to AC. Why?

Next episode...

- Magnetic circuits