Electronics Drive Circuit and Control System Design Summer 2021

NOTE: Class and tutorial hours will be combined for this part of the course.

The following will be the schedule of lecture/tutorial with possible minor changes:

- Electrical safety
- Electronics for DC motor control
- PWM motor drive circuit design
- Electromagnet drive circuit
- DC motor characteristics
- Motion control of a DC motor servo-system

Required:

- Matlab/Simulink (www.mathworks.com)

References:

- See lecture material

Electronics Project

Each group will design and simulate the power interface circuitry for driving a DC motor carrying an inertial load (e.g., a single link robotic arm). In a real system, a power electronics interface is necessary since the control/command signals from the microcontroller cannot provide enough power to drive the motor and the electromagnet.

Objectives

a) Design and simulate the power electronics drive circuitry using an H-bridge circuit, MOSFET driver, and/or other components.
b) Practice electronics design and simulation procedures to evaluate circuit operation.
c) Integrate the electronics circuit, feedback control, and mechanical system and evaluate performance of the complete system.

Requirements

a) The design should meet the DC motor ratings (and electromagnet if used) such as current, voltage, power, temperature (based on datasheets are posted on canvas).
b) The circuit is expected to work under normal room temperatures (20-25 degrees Celsius). Proper heat sink should be designed for the devices.
c) The circuit should be able to drive the motor back and forth and actuate an electromagnet for a pick and place operation.

The details about electronic design will be discussed in class. Students are required to attend the lectures to learn about these details and interact with the instructor.

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Control Project

You are required to design a feedback control positioning system using a DC motor by utilizing linear control system methods and integrate it with the electronics power drive circuit. Reasonable numerical values (e.g., based on motor datasheet- you can used a DC motor of your choice) should be selected for to perform design and simulation studies. The overall objective is to design an appropriate feedback controller for motion control of a robotic arm.

Objectives

- Apply concepts in control system design process such as transfer functions, root-locus, frequency response, transient analysis.
- Conduct simulations and analyze results to improve the design.
- Apply design and test procedures using computer analysis, design, and simulation tools.
- Each group is required to come up with a set of requirements based on the system they choose. Students are encouraged to come up with their own ideas in terms of what they want to incorporate into the design and how to simulate performance.

Requirements

Make reasonable assumptions about the requirements of the control system in terms of response time, bandwidth, and how the feedback system responds to parametric variations (e.g., changes in motor, arm, electronics drive parameters).

PROCEDURE

- Obtain the transfer functions between the input and output of interest. Alternatively, you may use more advanced control system modeling and design methods such as state-space control design (if you have taken more advanced control courses).
- Use the datasheet for the motor of your choice to obtain the necessary parameter values and use them in simulation studies (the datasheet for this motor is provided on canvas: GM8224S009)
- Use MATLAB/SIMULINK software tools in support of your controller design (e.g., using root-locus or frequency response method).
- Obtain the time domain response and evaluate performance of the system in the presence of nonlinearities such as power drive saturation (e.g., ±12V saturation limits), friction, and parametric uncertainties. Provide justification for any discrepancies.

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REPORT

The electronics/control report must contain the following sections:

i. Introduction
ii. Detailed analysis and design of the system (electronics/control) involved
iii. Simulation results and test procedure. The results should specify the performance of the system designed, how it met the design requirements, any problems encountered, and how they were addressed (or would be addressed if you had more time). The study should consider the effect of system parameter variations and inclusion of non-ideal effects such as nonlinearities and uncertainties (e.g., amplifier saturation, friction, parameter variations).
iv. Conclusions
v. Code and simulation files as attachments

Other information:

Overall, the report should look like a professional technical paper or industry white paper (do an internet search to see how they typically look like, e.g., IEEE/ASME Transactions on Mechatronics). The rubric provided in the following table may be used to organize your report

Report Component	**Points**
Design stages of the power electronics drive circuitry (e.g., motor/electromagnet for virtual projects), thermal design for PWM chip, MOSFET drive, etc	15%
Simulation results to evaluate the power drive circuit operation. Numerical results must be based on parameters obtained from real datasheets (DC motor, electromagnet, PWM chip, MOSFET)	15%
Determining control design criteria such as settling time and error performance	5%
Design stages of feedback motion control system by utilizing linear control system methods. Application of concepts in control system design such as transfer functions, root-locus, frequency response, and transient analysis.	10%
Study of simulation results to support the control design process such as the following: • Time domain and/or frequency domain response and evaluation of the system performance (e.g., root-locus, frequency response) • Transient analysis of closed-loop behavior • Comparison of performance and justification for using the proposed scheme	10%
Time domain response and performance evaluation of the system in the presence of nonlinearities such as power drive saturation (e.g., ±12V saturation limits), friction,	15%

mechanical load variations, and parametric uncertainties. Justification for any discrepancies and suggestions for improving performance	
Integration of the electronics circuit, feedback control, and mechanical system and performance evaluation of the complete system.	10%
Presentation: Quality graphs, formulas, flow of concepts, citations, discussion of results, conclusions, attachments	20%

Summary

- Lab report should be uploaded online at canvas.sfu.ca by the posted due date.
- All students in each group are expected to equally contribute to the completion of the project/report and will receive the same mark. If this is not the case, the students in each group should indicate the percentage contribution of each member. The individual marks will then be calculated based on the percentages indicated in the report.
- Each group will submit ONE report only.
- The report will have 40% of the final mark (~20% electronics/electrical + ~20% controls).
- Each group is required to write ONE report for the electronics and control project.

Contact information:

- Afagh Mohagheghi (email: amohaghe@sfu.ca)
- Instructor (electronics/control): Dr. M. Moallem (email: mmoallem@sfu.ca).
- Office hours by appointment through email. I will provide a zoom meeting room after setting the time/date.