Control Topic: Design Tasks 4-6

Preliminary Notes

The Control Design topic in this subject is spread over 3 weeks, with laboratories in Weeks 7, 8 and 9. This handout introduces the final 3 design tasks within this topic.

For an introduction to the Control Design topic and all associated procedural and policy matters, please review the first 4 pages of the document "Control-Tasks1-3.pdf" that covers Control Design tasks 1-3.

Control Systems Design Task 4

The purpose of this design task is to characterize control rig itself. In particular, the goal is to characterise the system that transfers a control signal in Matlab (or possibly C/C++) that is delivered to the sound card (or possibly the NI-6009 USB DAQ device) to the position of the floater within the PVC rig of the control rig. This system involves the physical structure of the control rig, the fan and motor, the PWM driver that you developed for Task 1 and any delays incurred in the transfer of signals from your control program to the PWM circuit. Like Task 3, this task does not involve any actual design, but it represents a key step in the design of a control system.

To perform the characterisation, you need to observe the dynamics of the system as a step change is applied to the fan motor. Specifically, you need to adjust the PWM drive system first so that the floater is sitting within the sensitive region of your sensing system (Task 2). You will probably find it convenient to make this adjustment using the trimpot rather than by adjusting the signal delivered by the computer. You will then arrange for a step change in the motor drive signal to be delivered from the computer and observe the behaviour of the floater by recording the inductance-related signal received by the computer. By both controlling the motor and measuring the response in Matlab (or a C/C++ program), you will be able to identify any end-to-end delays that form part of the complete system.

You will need to think about how you can continuously issue motor voltage control signals via the sound card while continuously sampling the sound-card input. This is essentially automatic with Matlab, but you should check that you understand what is going on. If you are using the DAQ device with a C/C++ implementation, you may find that a multi-threaded solution, or one that employs callback functions, is required.

You should use the sensor characteristic that was measured for Task 3 to convert the inductance-related values received from your sensing system to a relative position for the floater, measured in centimetres. Of course, you should take care not to adjust the stimulus so that the floater is not driven beyond the sensitive region of your inductive sensing system.

Key system properties to be recovered in this task are as follows:

1. Gain, measured at steady state, representing the ratio between the ultimate change in position (cm) and change in the drive signal. The gain might not be constant over the sensitive range, so you should attempt to characterize any such non-linearity.
2. End-to-end delay, measured in milliseconds, between the point at which the stimulus is emitted and the point at which any response can be detected.
3. Velocity, in cm/s, as a function of time elapsed since the step change in drive signal. The velocity profile will help you to understand what is going on. You should have an idea of what you expect to happen and be prepared to explain this during assessment.

To obtain reliable results, you should average the outcomes from multiple experiments. Along the way, you should compute or estimate the variance in your measurements, so that you know how much averaging is required to get reliable information, especially for the velocity profile. The soft objective for this task is to maximize and evaluate the reliability of your measurements.

If Task 1 or Task 2 have not been completed successfully, you may still be able to obtain some of the marks for this task by driving the motor directly (not through the computer) and/or observing the floater position manually. To drive a step change in the motor drive signal directly, you may find it useful to manually introduce a resistor in parallel with the trimpot.

Be sure to record all relevant data in your lab notebook.

While this task itself only involves measurement, it imposes requirements on the sensing and drive systems from Task 2 and Task 1. You may find that you need to go back and improve your drive system, sensing system or floater configuration – i.e., improve the system – in order to get a meaningful system response function.

Assessment for this task:

Marks for this task are as follows:

- Measurement of gain: (____/3)
- Measurement of end-to-end delay (must be computer-based): (____/3)
- Measurement and recording of velocity profile: (____/3)
- Reliability of results: (___/3)
- Understanding (focus on velocity profile): (____/6)

Weeks in which this task may be completed:

You may complete this task in any of Weeks 8 or 9.

Control Systems Design Task 5

This is the first of two tasks in which you "close the loop." The purpose here, however, is to develop a closed loop system that can move the floater into the sensitive range of your inductive sensing system. There is no requirement on accuracy. Since the floater may start out either below or above the sensitive region, your control system will generally need to "hunt" for its position, adjusting the fan speed up and down according to some schedule, until the floater can be located by the sensing system.

The primary requirement for this task is to move the floater to a location that is between 0cm and 5cm above your inductive winding. Neither stable nor active positioning of the floater is required. Your solution should work when the floater is dropped into the PVC pipe from above; it should also work when the floater starts out at the bottom of the PVC pipe. Your solution should continue to "hunt" for the floater until it is detected within the sensitive range.

This task has a soft objective, which is to minimize the time taken to get the floater into the sensitive range. You will be awarded these marks if you can demonstrate that your design includes **effective** measures to minimize the hunting time.

Be sure to document your approach and observations in your lab notebook.

Assessment for this task:

Marks for this task are as follows:

- Achievement of requirements: (___/7)
- Minimizes hunting time: (___/3)
- Understanding: (____/6)

Weeks in which this task may be completed:

You may complete this task in any of Weeks 8 or 9.

Control Systems Design Task 6

The goal of this task is to design and build a closed loop control system which is able to control the control rig fan in such a way that the floater is positioned accurately. For this task, you will mark a control target location on the PVC pipe by drawing a thin line (or arrow) on masking tape. Do not mark the PVC pipe itself. Naturally, the target location should lie within the sensitive range of your inductive sensing system. You are allowed to adjust the initial set point of your control system in any way you like -- calibration. After that, however, your control system should work to restore the floater to the target location when disturbances occur.

Disturbances may be introduced in two ways. The trimpot associated with your PWM drive system may be adjusted to introduce a disturbance in the drive signal that your automatic control system should correct. The air flow in the control rig may be modified by partially covering the slot in the PVC pipe, or by partially obstructing the fan inlet. In response to all such changes, your control system should automatically restore the location of the floater to the marked target position.

Your control system is required to be stable, both with and without disturbances. Your control system is required to achieve a floater position that is within 2mm of the set point the introduction of any reasonable disturbance (one from which automatic control could be expected). You should be prepared to demonstrate, from a theoretical perspective, why this level of accuracy could be expected at steady state, ignoring non-idealities such as physical defects in the floater or PVC pipe.

For this design task, your soft objective is to design a solution which brings the floater to within 5mm of the target position as quickly as possible. To gain understanding marks for these soft objectives, you must be able to explain how you have theoretically modeled the control system and designed its parameters.

You should bear in mind that delay and inertial properties of the control rig may render a closed loop control system unstable. You should invest effort in understanding how delay can be modeled, discussing this, along with other modeling issues in your tutorial group.

While there is no specific requirement or objective related to undershoot or overshoot in this control task, you should bear in mind that overshoot/undershoot in your control system might move the floater outside the sensitive region of your inductive sensing system, even if the disturbance itself does not. This may dramatically impact the time taken to bring the floater back to the target location.

While you can be marked for this task even if you have not completed Task 5, good solutions to Task 6 should fall back to a hunting method (Task 5) if the floater moves outside the sensitive region.

Assessment for this task:

Marks for this task are as follows:

- Achievement of requirements: (___/6)
- Soft objective: (___/5)
- Understanding of delay and stability issues: (____/3)
- Understanding of steady state behaviour: (___/3)
- Understanding required to address soft objective: (___/3)

Weeks in which this task may be completed:

You may complete and be assessed for this task only in Week 9.