

Control Topic: Design Tasks 1-3

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 first 3 of 6 design tasks within this topic. The remaining design tasks will be released according to the schedule that appears on the course web-page at <http://subjects.ee.unsw.edu.au/~elec4123>.

Your performance in these design tasks will be assessed in the laboratory, although your participation in tutorial discussions will be separately assessed (worth a total of 20% over the duration of the course). The laboratory component of your assessment for the Control design tasks as a whole is worth 17% of the marks for the course. As indicated in the course overview, this is composed of 10% for design outcomes and 7% for understanding. To simplify the awarding of marks, these percentages are multiplied by a factor of 5. This means that there are a total of 50 marks for design outcomes in Control and 35 marks for design understanding in Control. An individual breakdown of the maximum marks available for each task is provided in the following. However, these individual figures may add up to more than a total of 85 marks. Where this happens, your overall mark in the Control design topic will be capped at 85.

The Control Rig

All of the Control design tasks are based on a custom control rig that allows a computer cooling fan to be driven in such a way as to raise or lower a “floater” within a slotted PVC pipe. The apparatus is illustrated roughly Figure 1, but additional illustrations and photos may be provided on the course web-site. Specifications for the computer cooling fan that powers the rig may be found on the course web-site. The following rules apply to your use of the control rig:

1. Marking, modifying or defacing any part of the rig is strictly forbidden. To mark positions along the PVC pipe you must use the masking tape provided in the laboratory.
2. You must avoid exceeding the rated motor supply voltage of 12V DC.
3. You may use the enameled wire (not the hookup wire) provided in the lab around the PVC pipe in order to create an inductive sensing element for the floater, securing it with masking tape, but you must leave at least a 5cm clear zone free from wire or masking tape at the base of the slot.
4. You must keep the control rig away from the bench edge to avoid risk of dropping it.
5. You may not take the control rig out of the laboratory and so you may wind up working with a different instance of the control rig in each week.

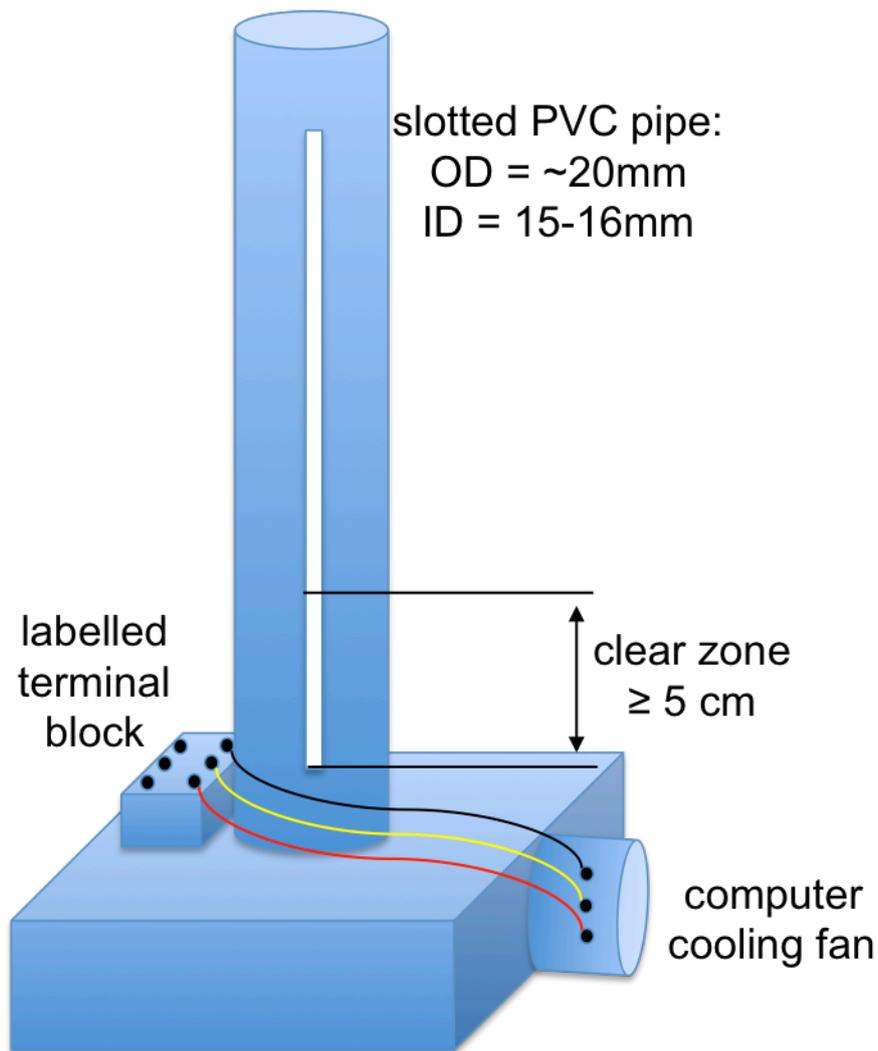


Figure 1: Control Rig

Other elements that either can or must be used as part of the control rig are as follows:

1. Small plastic “floater:” ~15mm diameter, ~8mm thick with drilled hole to fit bolt or ferrite rod. Initially, each student will receive one floater, but a second may be available later on.
2. Ferrite rod: 25mm long; ~3mm diameter
3. Small bolt: 38mm long; ~3mm diameter
4. Enameled winding wire: SWG 30 with OD (including enamel) of 0.32mm

Breadboard and Analog Circuit Rules

Some important aspects of the Control design tasks involve analog circuits, and hence require the use of a breadboard. Since the Control design tasks are cumulative, the breadboard that you bring into the laboratory in Weeks 7 and 8 **can be pre-populated** with the solutions for which you have already been **successfully assessed in a previous laboratory**. To do this, the following requirements must be met:

1. You must have the signed assessment label (or sticker) for the relevant task on the back of your breadboard – no exceptions.

2. You must present your breadboard to one of your lab demonstrators at the beginning of the laboratory session. The demonstrator will both verify that your task completion label matches her/his records and note that you cannot be re-assessed for that task.

Please remember to bring a breadboard with **sufficient size** to accommodate the solutions to multiple tasks at once, so as to take full advantage of these provisions.

Apart from the provisions mentioned above, you are expected to bring an unpopulated breadboard into the laboratory, but you may leave with a populated breadboard, exactly as in previous design topics.

Things to bring to the Lab

1. Your lab notebook – essential
2. A breadboard of sufficient size to accommodate at least two significant analog circuits (see Task 1 and Task 2)
3. A small screwdriver that can be used to change trimpot settings easily – this is not strictly necessary, but you will find that it helps.

Lab Notebook Rules

There will be no understanding marks awarded for design work that is not matched by appropriate **handwritten** descriptions, analysis and working in your lab notebook. This rule applies to both analog circuits and software. It is completely inappropriate to expect your laboratory demonstrator to assess your understanding of a task that involves software by reading your code. Instead, the principles behind your implementation, along with choices made, functions used, analytical working and recorded observations should all be found in your lab notebook.

The material in your lab notebook does not need to be neatly set out, and there may of course be many revisions as you work through design ideas and eliminate branches that did not work, but the demonstrator expects to see that your lab notebook reflects your thought processes.

Sharing Equipment and Computers in the Lab

As with earlier topics, the Control design task is to be performed individually, even though you are assigned to work in pairs with a lab partner. A separate physical instance of the control rig has been prepared for each student. However, the laboratory equipment and computers must generally be shared by a pair of students.

To do this, you must first ensure that your software resides on a personal USB stick, rather than relying upon storing your software on the computer's hard disk. Students whose software is not on a USB stick will not be marked.

You may bring your own laptop to the laboratory and use this to ensure greater access to a computer for developing solutions, but the USB stick rule still applies. In particular, you may be asked to demonstrate your solution on the standard laboratory computer at one of the assessment benches.

Communication in the Lab

As in previous design topics, you should communicate with your lab partner and establish a good working relationship for sharing the equipment and space available.

You can communicate freely with your lab partner regarding the design problem. There is no expectation that your partner should help you with the construction or preliminary testing of your design, but this is permitted so long as you both agree.

Apart from communication with your lab partner and the lab demonstrators, you should avoid any significant communication with other students in the lab. **Demonstrators have full authority to clamp down on unnecessary communication**, including by moving troublesome students to the end of the assessment list, which may delay assessment until a following week – this may then prevent you from bringing a populated breadboard to the next lab which may prove a significant impediment to your progress.

Assessment Procedure

Demonstrators will maintain an ordered assessment list. You may not add your name to the list until you have a solution you are prepared to have assessed. Students who have already been assessed for a task may have the opportunity to be re-assessed, during the same or a later laboratory session, but students who have not yet been assessed will be given priority over those seeking re-assessment.

Demonstrators may ask you to move to a separate area for assessment, so that your lab partner need not be disturbed. With this in mind, you should ensure that your implementation is as portable as possible, so that you can easily connect it to a separate power supply, signal generator, or oscilloscope, as appropriate. As mentioned, portability also requires that you keep all software components of your design work on a reliable personal USB stick.

Control Systems Design Task 1

In this design task, you are to design and build a circuit for controlling the motor. The motor is designed to be controlled using pulse width modulation (PWM). Specifically, 12V DC should be applied to the RED (VCC = +12V) and BLACK (GND) wires, while a PWM control signal is applied between the YELLOW (PWM) and BLACK (GND) wires. Internally, a MOSFET transistor controls the power to the motor (ON/OFF), controlled via the PWM signal. You can drive the PWM signal at TTL voltage levels (0.8V or below means off, while 3V or above means on), but you can drive the input at voltages as high as VCC=12V if you like.

To control the motor, you should design and build a PWM control circuit with the following attributes:

1. Preferred operating frequency is up to 20kHz; lower frequencies may create audible switching noise.
2. Pulse width can be adjusted via a small trimpot – 10k Ω is recommended due to high availability in the labs. You are recommended to solder hook wire to the terminals of the trimpot to simplify the connection and adjustment of the trimpot.
3. Pulse width can be additionally modified via Matlab, using the output from the sound card of the lab computers.

Joint (additive) control via the trimpot and Matlab will prove very important to the Control Systems topic as a whole. You should think carefully about the computer control aspect, taking into account the fact that the sound card is AC coupled. This means that computer control of the fan motor via the sound card will need to be achieved via the frequency or amplitude of an oscillatory waveform. It is possible to use the NI-6809 Multifunction DAQ USB device that is available in the labs instead of the sound card. However, we do not have enough supply of these for each student to have their own, and support for the DAQ device via Matlab is not well supported, as explained in the lecture notes from Week 4 that are on the subject web-site.

Available Electronic Components (on hand with your lab demonstrator):

Diodes: 1n4148

Transistors: BC549, BC559

Analog IC's: LM324, LM348, LM741, LM555

Trimpot: 10k

Resistors and capacitors, as found in the laboratories

Assessment for this task:

Marks for this task are as follows:

- Full range control of the motor fan speed via trimpot: (___/5)
- Full range control of the motor fan speed via Matlab (or via C/C++): (___/5)
- Understanding: (___/7)

Weeks in which this task may be completed:

You may complete this task in any of Weeks 7, 8 or 9. Once all requirements have been met, you may bring your completed circuit into the laboratory in subsequent weeks.

Control Systems Design Task 2

This design task is concerned with the second major aspect of any control system: sensing. For this task, you will need to select a configuration for the floater, whose position within the PVC pipe is to be sensed. You will need to construct a sensing system and relevant circuit, and ultimately import the sensed position into Matlab via the sound card (or alternatively using the NI-6900 USB DAQ device). Together, these represent a significant amount of effort, for which you will be appropriately rewarded.

It is expected that you will sense the position of the floater by inductive means. To do this, an inductive coil should be created by winding a number (probably large) of turns of the enameled wire in the laboratories around the PVC pipe, at a location of your choosing. You must not use the hookup wire in the lab for this purpose, since it is much more expensive than the enameled wire and also relatively useless for this task!! You should secure your inductive coil via masking tape and you must avoid blocking the "clear zone" in the PVC pipe (see Figure 1).

You may take your inductive winding out of the lab and bring it back to the following lab, so you might want to consider using an inner paper foil with outward facing masking tape to facilitate extraction and re-introduction of the winding from/to the PVC pipe between lab sessions.

Typically, the floater would be expected to float just above the inductive winding, but in any case it must be possible to visually observe the location of the floater through the slot in the PVC pipe. Possible floater configurations that you could explore include:

1. Single floater, with ferrite rod (25mm) extending below the floater.
2. Single floater, with steel bolt (38mm) extending below the floater.
3. Two floaters, separated by a ferrite rod, with an additional ferrite rod extending below the lower floater. Note that in this case, it is the position of the upper floater that should ultimately be controlled.

By and large, the steel bolt leads to greater stability and hence less interaction between the floater and the walls of the PVC pipe. However, the steel bolt is heavier than the ferrite rod, will give you less inductive sensitivity and should be demagnetized – a demagnetizer is available for use within each laboratory, on hand with your lab demonstrator.

You will also be supplied with a small quantity of sandpaper (or emery paper) that you can use to remove any burrs or irregularities in the floater so that it moves unobstructed through the PVC pipe. You may take this sand paper and the floater arrangement that you construct out of the lab, but be sure to bring them back the next week.

To sense the position of the floater, in the neighbourhood of your inductive coil, you will need to design and construct an analog circuit of some description. To connect the enameled winding wire to your breadboard, it is recommended that you strip the enamel from a 1cm length section at the end and solder lab hookup wire to the stripped section – if you cannot solder to the wire, you have not stripped enough enamel away.

The ultimate requirement of this task is to sense some quantity that is reliably related to the inductance in Matlab via the computer sound card (or using the NI-6900 USB DAQ

device), but you can gain many of the requirements marks for this task by providing a signal that can also be measured on the oscilloscope or voltmeter. For sensing via the sound card, you should bear in mind that the sound card is AC coupled. You are allowed to use both output and input channels of the sound card to complete the sensing system, but bear in mind that this could become cumbersome when you attempt to integrate your sensing system into a closed-loop control system.

There is a soft objective for this design task, which is to maximize the range of positions over which your inductive sensing system can reliably discriminate the location of the floater within the PVC pipe. To receive all 3 of the marks associated with this soft objective, you will need to be able to discriminate positions over a range of 5cm – throughout this whole range the floater (or top floater in duplex arrangement) should be visible through the slot in the PVC pipe. A range of 2cm or less will receive none of the 3 marks.

For sending signals to the sound card of the computer, you should use the same input protection circuit that you constructed for the Signal Processing design topic, consisting of 4 diodes and a resistor. If you are unsure of this, ask the demonstrator to check your work.

To test and demonstrate your solution, you will need to be able to control the position of the floater within the PVC pipe. The only easy way to do this is by controlling the fan motor speed, using your solution to Task 1 – trimpot-based control is sufficient here.

Available Electronic Components (on hand with your lab demonstrator):

Diodes: 1n4148

Transistors: BC549, BC559

Analog IC's: LM324, LM348, LM741, LM555

Resistors and capacitors, as found in the laboratories

Enameled winding wire: SWG 30 or similar

Assessment for this task:

Marks for this task are as follows:

- Repeatable sensing inductive change due to floater position: (___/6)
- Sensing of inductance-related quantities in Matlab (or C/C++): (___/6)
- Range of positions over which floater is sensed: (___/3)
- Understanding: (___/10)

Weeks in which this task may be completed:

You may complete this task in any of Weeks 7, 8 or 9. Once all requirements have been met, you may bring your completed circuit into the laboratory in subsequent weeks. You may, in any event, bring your inductive coil into the lab in any of weeks 8 and 9, so consider the advice above, concerning the creation of a winding that can easily be extracted from and re-inserted around the PVC pipe.

Control Systems Design Task 3

The purpose of this design task is to characterize the sensing system that you designed and constructed in Task 2. This is part of the third phase of any control system design, known as System Identification. In Task 4, you will complete the system identification phase by characterizing the motor-fan-floater actuation system, but this depends on the existence of a properly characterized sensing system.

To complete this task you will need to have met all the requirements for Task 2, with an inductive sensing system that is sensitive to floater positions ranging over at least 2cm.

Using annotated masking tape, mark off positions over which your sensing system is sensitive to the floater location, in multiple of 0.5cm or less. Do not write on the PVC pipe itself! Adjust the floater within the PVC pipe using the trimpot method of Task 1, moving it slowly through a range of positions and collecting the inductance-related measurements in Matlab (or a C/C++ program if you like). Do this multiple times, collecting the data and saving it to your USB stick. You need to be prepared to repeat a small part of this measurement process in the presence of your lab demonstrator. You also need to present a scatter plot of the measured relationship between position and inductance-related measurements to your demonstrator – most easily done in Matlab. You should also record key features of the position sensing system in your lab notebook. You will need these for the final phases of the Control Systems design topic.

While this task itself only involves measurement, it imposes requirements on the sensing system itself. If your measurements are not consistent with a reliable and repeatable sensing system for the position of the floater, over at least 2cm, you will need to go back and improve your sensing system and/or floater configuration. As with task 2, however, a good solution should offer sensing over a larger range of positions, so to obtain all requirements related marks, you need to achieve at least a 4cm sensing range.

Assessment for this task:

Marks for this task are as follows:

- Achievement of requirements over at least 2cm: (___/4)
- Achievement of requirements over at least 4cm: (___/2)
- Understanding and clear presentation and documentation of results: (___/4)

Weeks in which this task may be completed:

You may complete this task in any of Weeks 7, 8 or 9. Note, however, that if you do not carefully preserve your inductive winding arrangement between laboratories, you may need to repeat (or at least recheck) the characterization in order to use it in subsequent tasks.