

332: 418 —Project 1 — Spring 2006

Assigned January 19, 2006. Part A is due February 2, 2006. Part B is due February 23, 2006.

PART A: SIMULATION

Design of a Stabilizing Controller for a Ship

Use the PD controller to stabilize a ship whose mathematical model is given in Section 8.6.1. For the obtained controller find the ship overshoot and the settling time due to a normalized average wave magnitude equal to 1. Experiment with three to four different PD controllers and suggest the one that has the best transient response specifications. Perform simulation using both MATLAB and SIMULINK. You will find that once the controller structure is defined, SIMULINK appears to be more efficient for simulation than MATLAB.

Every student must submit a technical report for Part A (typed in Word with MATLAB programs, SIMULINK block diagrams, figures, and obtained plots inserted). For Part B, **one technical report per team** is required.

Part B: CONTROLLER ELECTRONIC BOARD DESIGN

Design an electronic board for the controller obtained in Part A. Use operational amplifiers, resistors, and capacitors. Test the controller using the model for a ship. Note that you have to build an electronic simulator for these models using operational amplifiers, resistors and capacitors.

COMPONENTS NEEDED:

The ship controller design project will require the following components:

- 12 operational amplifiers
- 20 resistors of $1\text{ M}\Omega$;
- 1 resistor of $1.6\text{ M}\Omega$;
- 1 resistor of $840\text{ k}\Omega$ (use $820\text{ k}\Omega$);
- 1 resistor of $300\text{ k}\Omega$
- 1 resistor of $85\text{ k}\Omega$ (use $82\text{ k}\Omega$)
- 4 capacitors of $1\text{ }\mu\text{F}$
- 1 capacitor of 1 nF (for the approximate derivative)
- 1 capacitor of 10 nF (to filter out noise on the controller summing OpAmp)

RECOMMENDATION

Use the red wire for + (OpAmps' pin 7), green wire for – (OpAmps' pin 4), black wire for ground (OpAmps' pin 3), and blue wire for signals. Organize your board neatly. This will make the board testing easy.

TESTING STEPS:

1. Check the circuit once more to see that all components are present and properly connected.
2. Use the square wave of magnitude one and large period to imitate the step reference input.
3. Check the power supply voltages for OpAmps. Pin 4 should be -15 V and pin 7 should be $+15\text{ V}$.
4. Check that the amplifiers are not saturated (saturating voltage between pins 2 and 3 is less than 1 mV (for OpAmp 741 used in this design).
5. Be sure to use the amplifier with the approximative derivative (the output impedance is a parallel combination of a resistor and inductor with a large time constant (CR small)) instead of the pure derivative.
6. Break connection between the controller and the system model and check which one is not performing properly.
7. Test your controller by using a triangular wave input and observing performances of the integrator, differentiator, multiplier, and summing amplifiers. In that process open the feedback loop.
8. If necessary, run simulation in PSPICE.

REMARK 1:

Sometimes the pure integrators saturate (integrators sum the area between the signal and the horizontal axis). Small errors in the input signal are integrated into large errors in the output signal, which can cause amplifier saturation. To avoid this problem use the non-saturating integrator obtained by placing in parallel with the output capacitor a resistor such that the time constant is large (CR small)

REMARK 2:

Note that the resistors and capacitors used have accuracy of respectively 5% and 20%, and that their values are slightly off from the values used in the simulation phase. Despite to those inaccuracies, due to the feedback structure of your controller you will be able to achieve excellent results and the controlled system output will be very close to the one obtained in simulation.

REPORT PREPARATION

After the successful design of the electronic board observe on the oscilloscope the following signals: error, control, output signals. Plot these signals and include the plots in your report and comment on their values. Estimate the response overshoot and settling time and compare them to the corresponding values obtained in simulation. Your report should in addition contain the electronic scheme of the controller and system, discussion about the necessity to use the approximative derivative and the need to filter out noise to avoid amplifier saturation. Attach to the report one set of the MATLAB/Simulink simulation results.

The team project reports (prepared as technical reports) for Part B are due on Thursday , February 23, 2006.